Man and Resources of the Canadian Plains

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ABSTRACT. Whether any rock or mineral deposit constitutes a resource—that is whether it becomes of any use to mankind—depends on more than geological factors. Technological development, economics, and even cultural attitudes play a role in turning a deposit into a resource. Not all resources of the past are resources of the present.

The history of the use of mineral resources in the Canadian Plains shows a progression from accessible surface occurrences to deeper buried deposits, which could be developed only after increasingly sophisticated technology made their extraction possible. The earliest user group, the Paleo-Indians and Indians, relied solely on what could be obtained from the surface. The settlers extended their use of mineral deposits to moderate depth, as in the case of coal. Only with the coming of industrial use and modern technology did it become possible to extend exploitation to a depth of several thousand meters and thus to tap the energy and mineral resources in the rock column that underlies the Canadian Plains.

RESUME. Le fait qu'un dépôt rocheux ou minéral puisse constituer une ressource, c'est-à-dire qu'il devienne d'une certaine utilité pour l'homme, ne dépend pas uniquement de facteurs géologiques. La technologie, l'économie, la culture, même, sont autant de facteurs qui font en sorte qu'un dépôt puisse devenir une ressource. Les ressources du passé ne constituent pas toutes des ressources du présent.

L'histoire de l'utilisation des ressources minérales des Plaines canadiennes démontre une certaine progression, soit l'utilisation de ressources situées près de la surface et, par la suite, de ressources situées plus en profondeur, ressources que l'on n'a été en mesure de mettre en valeur qu'après la mise au point de techniques de plus en plus spécialisées. Les Paléo-indiens et les Indiens, premier groupe connu ayant fait usage de ces ressources, ne dépendaient que des ressources qui pouvaient être obtenues près de la surface. Par la suite, les pionniers ont poussé plus loin l'utilisation de dépôts minéraux en creusant à des profondeurs moyennes, comme cela a été le cas avec le charbon. Ce n'est qu'avec la venue de l'industrie et des techniques modernes qu'il est devenu possible d'exploiter les dépôts à une profondeur de plusieurs milliers de mètres et d'utiliser ainsi les ressources énergétiques et minérales de la colonne rocheuse située à la base des Plaines canadiennes.

Prologue

In the last half century or so the term mineral resources has become current in newspapers and magazines. Rarely is some kind of definition attempted. This is not surprising because the term is so broad as to be readily, albeit only vaguely, understood by anyone who has played the "animal, vegetable, and mineral" game and who regards resources as anything from this trinity which is valuable to mankind. Most commonly this value is economic, but it may also be scientific or even spiritual.

To earth scientists, however, such indefinite terminology is unsatisfactory. To them, the word mineral most commonly refers to a "naturally occurring element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties." Clearly, this is not the meaning of mineral in mineral resources. There the term has the common meaning of "any naturally formed inorganic material, *i.e.* a member of the mineral kingdom as opposed to the plant and animal kingdoms."

This broadening does not take care of everything, however. Scientists have to recognize that to the public oil and gas are "mineral," and not "animal" or "vegetable." All inanimate matter, as well as anything dead for some considerable time, appears to be regarded as "mineral."

Similarly, the vernacular sense of resources is used by experts and laity alike: "the mineral endowment, global, regional, or local, ultimately available for man's use." Mineral resources, then, are inorganic and some organic substances that are useful to people. This is where another problem begins.

One man's resource may well be another man's poison or nuisance. Field stones, so abundant in many parts of the glaciated Canadian Plains, provided material for tools to the aboriginal people of the region for millenia. Agriculture turned these stones from an asset into a liability.

Not infrequently a nuisance, or a deposit of only limited known usefulness, may turn into a mineral resource as a result of technological change. The western world has known about the bituminous sands near the confluence of the Clearwater and Athabasca Rivers since their mention in Alexander Mackenzie's book, published in 1802. The native people, who called Mackenzie's attention to the sands, knew about the deposits long before that time. They used the "tar" to make their birch bark canoes watertight. Only in the present century were the first attempts made to extract oil from the Athabasca Tar Sands on a large scale. Severe technological problems remain which must be overcome before extraction becomes efficient and economical.

Technology also has helped to discover mineral resources. The petroleum deposits of the Canadian Plains lie at considerable depth and there are few if any indications of their presence at the surface. In other places in the world, particularly in the dry, barren countries of the Middle East, large geological structures called anticlines, many of which are suitable traps for migrating fluid petroleum, can be seen from the air and even on small scale satellite images. They can be mapped at the surface and the presence of petroleum underground is suggested by seepages of gas and springs of oil which are very abundant in the Middle East.

In contrast, the systematic exploration for hydrocarbons in the rocks underlying the Canadian Plains had to wait for the development of prospecting tools that would make it possible to obtain a "picture" of underground structures. The most reliable and the most commonly used tool for deciphering masked geological structures is the seismometer. In seismic prospecting artificially generated (by explosion or vibration) earthquake waves penetrate layers below ground and are in part returned by being reflected upward. By repeating the creation of the earthquakes in many different places and by plotting the reflections of the shock waves, a plot showing the underground configuration of the layers can be obtained. With such plots, more reliable predictions can be made about the possible occurrence of oil and gas accumulations below the surface. In the last few years, the use of computer techniques, combined with a denser pattern of observations, has so enhanced the seismic method that small but highly productive oil fields—in particular the "pinnacle reefs" in Alberta—that previously escaped more cursory examinations can now be found.

Not only technical advances but economic forces also transform deposits of little value into mineral resources. The occurrence of glass sands along the Swan River, where it cuts through the Manitoba Escarpment, has been known for many years. No use of this sand was ever made. Other glass sands closer to a major market, such as Winnipeg, were used instead.

Some resources are discovered accidentally during searches for different mineral deposits. Exploration for hydrocarbons by drilling wells to obtain much needed stratigraphic information led to the discovery of both common and potash salt.

Commercial quantities of an inert gas, helium, were found when wells were drilled in the quest for natural gas. Some of this was accompanied by nitrogen gas. Carbon dioxide, too, was discovered when petroleum was wanted and, more often than not, was of little use in the absence of a market in which the natural substance had to compete with a purer, cheaper industrial product.

And then, there are purely imaginary mineral resources. The Department of Mineral Resources of Saskatchewan in the 1950s and 1960s offered courses in prospecting to inmates of the Prince Albert Penitentiary. On his release, one inmate staked some claims in sand-and-gravel deposits near Prince Albert with the intent of recovering the diamonds he believed would be there. This started a minor diamond rush which lasted only as long as it took some geologists familiar with diamond deposits to reach the scene.

Any discussion of mineral resources is based ordinarily on their spatial occurrence as shown on a map. In its simplest form, this is a geographic map that presents the location of the resource with respect to other natural features, such as rivers, or to the works of man, such as towns or highways. Geological maps showing occurrences of mineral deposits provide substantially more information to those familiar with the rules of association between rocks, their ages, and mineral deposits. Still more can be learned when the third dimension is taken into account by adding cross-sections to the map. Finally, geological reports that contain maps and sections synthesize the knowledge about mineral deposits by giving a verbal description of their origin and subsequent history.

Such scientific information is essential for those in search of new resource occurrences. In this essay, however, it appears to be more appropriate to abandon systematic scientific description and to follow a different course, one that is seldom taken by specialists. The mineral resources of the Canadian Plains will be looked at from the user's point of view. Moreover, because the potential and actual use of a mineral deposit does change in time, a historical user's approach will be followed. Only then is it possible to take into account the differences in cultural values, and the state of technological development, which are important factors that turn deposits into resources.

The users of mineral resources in the Canadian Plains can be grouped into three historic categories. First there were the earliest inhabitants, the Paleo-Indians and Indians. Their uses dominated the scene until about 1880, when settlers began making an increasing impact that lasted until about 1930; then modern industrial and agricultural users took over on a still larger scale.

Background

The definition of the boundaries of the Canadian Plains varies between scientific disciplines, each of which has a different way of looking at the natural environment. To geologists and physiographers the eastern boundary of the Canadian Plains is the Precambrian or Canadian Shield. To the west, the Foothills of the Cordilleran Orogen or, more precisely, the most easterly thrust fault of this mobile belt, form a natural line of division. To the north, these two boundaries come closer together but continue to the Arctic Ocean, making the Mackenzie River drainage basin a panhandle-shaped part of the Canadian Plains.

The southern boundary of the Canadian Plains, by its very name, is a political one and follows the boundary between Canada and the United States of America along the 49th parallel of north latitude. Geologically it would be more acceptable to extend the Canadian Plains southward to the limit of the maximum extent of the last glaciation—the overriding distinction between the Canadian Plains and the Interior Plains of the USA being the presence of glacial landforms in the former and their absence in the latter.

Whatever definition is given to the Canadian Plains, an understanding of the geological history of western Canada is needed before the region's landscape, and particularly its mineral resources, can be understood.

As early as 1851, the outline of the "Primitive District," or what is now called the Precambrian Shield, appeared on a map prepared by Sir John Richardson. On that map, the edge of the Shield in Manitoba, Saskatchewan, and northeastern Alberta is shown with fair accuracy. Modern geological maps differ from it only in detail where the position is obscured by a cover of glacial drift, or where access to the boundary was difficult before the days of air travel which made possible visits to exposures outside the traditional canoe routes.

The Precambrian or Canadian Shield is a land of much contorted hard rocks, such as light-coloured granites and gneisses and dark, metamorphosed schists of volcanic and sedimentary origin. Fringing these crystalline rocks are flat-lying, bedded limestones (composed of calcium carbonate) and dolomites (a variety of limestone rich in magnesium-calcium carbonate) of Paleozoic age. They are well-exposed in Manitoba and in east-central Saskatchewan but generally covered by younger Mesozoic bedrock farther west (Figure 1). Rocks of geological ages younger than Precambrian (for terminology see Table 1) lie in regular sequence on the Shield rocks in what is referred to as the Continental Platform, which is positioned between the Canadian Shield and the Western Cordillera. The Shield has been a stable block ever since it formed in Precambrian time. Periodically during the Phanerozoic, it was invaded by a shallow sea but no great thicknesses of sediments were then deposited. What had accumulated was soon removed by river erosion after the retreat of the seas.

The Interior Platform, the structural geological unit underlying

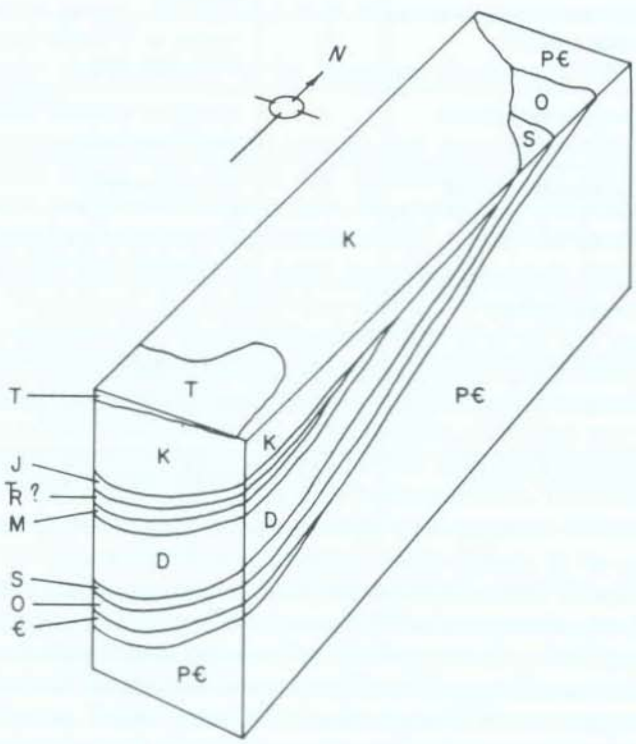

Figure 1. Schematic sections through Williston Basin.

TABLE 1

GEOLOGICAL COLUMN AND RELATED RESOURCES

Eon	Era	Period	Geological time-rock units	Symbols in Fig. 1	Mineral Resources
PHANEROZOIC EON	Cenozoic Era	Quaternary Period	Postglacial or Holocene Epoch	Q	Surface water; sodium sulphate Shallow groundwater
PHANEROZOIC EON	Cenozoic Era	Quaternary Period	Pleistocene Epoch	Q	Groundwater; fieldstones; sand and gravel; clay
PHANEROZOIC EON	Cenozoic Era	Tertiary Period		T	Groundwater; clay; coal; building stone (Alberta Sandstone)
PHANEROZOIC EON	Mesozoic Era	Cretaceous Period		K	Groundwater; clay; coal; bentonite; volcanic ash; placer gold; oil, gas
PHANEROZOIC EON	Mesozoic Era	Jurassic Period		J	Oil, gas
PHANEROZOIC EON	Mesozoic Era	Triassic Period		TR	Except possibly for late Triassic, absent in Williston Basin, which was land
PHANEROZOIC EON	Paleozoic Era	Permian Period		PM	Absent in Williston Basin, which was land
PHANEROZOIC EON	Paleozoic Era	Pennsylvanian Period		P	Absent in Williston Basin, which was land
PHANEROZOIC EON	Paleozoic Era	Mississippian Period		M	Oil, gas, sulphur
PHANEROZOIC EON	Paleozoic Era	Devonian Period		D	Oil, gas, sulphur; limestone; salt and potash in Prairie Evaporites
PHANEROZOIC EON	Paleozoic Era	Silurian Period		S	————
PHANEROZOIC EON	Paleozoic Era	Ordovician Period		O	Building stone (Tyndall stone)
PHANEROZOIC EON	Paleozoic Era	Cambrian Period		Є	Helium, nitrogen; geothermal heat
PRECAMBRIAN EON				pЄ	Metals: gold, copper, zinc, uranium

the Canadian Plains, on the other hand, experienced a series of gentle up and down movements that caused the region to have a history of alternating land and sea conditions. Some parts of the platform tended to subside more than others. This is most noticeable in the Williston Basin, centred on Williston, North Dakota, which occupies southwestern Manitoba and adjacent southeastern Saskatchewan. Here, seas tended to persist longer than in other parts of the platform and,

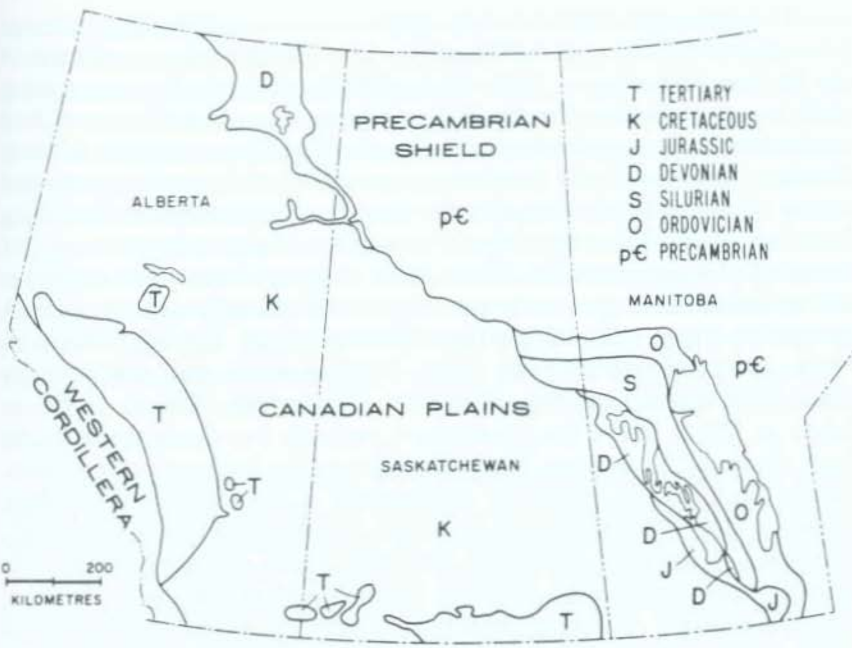

Figure 2. Bedrock geology of the Canadian Plains. Modified after GSC map 1250A.

consequently, the sediments in the basin are thicker and the sequence more complete.

The cross-section (Figure 1) shows that moving southerly across the Williston Basin, the top of the Precambrian lies at increasing depths below the present land surface. That is to say, in a well in southeastern Saskatchewan the Precambrian top would be at a depth of 3,160 m below the surface, or 2,600 m below sea level. On this Precambrian "basement" lie sedimentary rocks in the sequence in which they were deposited in the ancient seas that covered the interior of North America so many times in the past (Figure 1 and Table 1). This sequence is most complete near the centre of the sedimentary basin. At the surface of the Canadian Plains, Ordovician, Silurian, and Devonian rocks are exposed in Manitoba (Figure 2). The Cambrian is covered by younger Paleozoic rocks, as it is in Saskatchewan. Devonian rocks can be seen in outcrop in Saskatchewan and adjacent Alberta in the valley of the Clearwater River. Jurassic rocks appear at the surface in the Interior Platform region only in western Manitoba. Elsewhere they are blanketed by extensive Cretaceous sedimentary rocks. In the south-central Canadian Plains patches of Tertiary strata overlie the Cretaceous sediments. In the western part of the Plains, in front of the Foothills in Alberta, Tertiary sandstones and gravel conceal much of the Cretaceous shales that are the dominant bedrock sediments of most of the Canadian Plains.

The Canadian Plains do not constitute one smooth planar surface between the Shield and the Foothills. Dr. James Hector, geologist to the Palliser Expedition, 1857–1860, should get credit for recognizing three topographic *levels* in the Plains region, now generally referred to as the Manitoba Lowlands, the Saskatchewan Plains, and the Alberta Plateau. The Manitoba Lowlands occupy all of Manitoba west and south of the Shield. As well, the extensive exposures of flat-lying Ordovician and Silurian rocks in east-central Saskatchewan south of Amisk Lake are included. They lie at a general elevation of about 300 m and are bordered in the west by the Manitoba Escarpment which comprises, from the south to the northwest, the Riding Mountain, Duck Mountain, Porcupine Hills, Pasquia Hills, and Wapawekka Hills. The eastward-facing Manitoba Escarpment rises in places as much as 500 m above the Manitoba Lowlands but drops down on its back slopes to the average 600 m elevation of the Saskatchewan Plains. At the base of the Manitoba Escarpment is the erosional boundary between older Paleozoic and Mesozoic rocks and the overlying west-, or rather, basin-ward dipping Cretaceous shales and sandstones. The escarpment then appears to have been caused probably by Tertiary lateral planation of streams at a general level of 300 m which stripped away Cretaceous strata that had previously covered older rocks in Manitoba, as they still do in most of Saskatchewan and Alberta.

The Missouri Coteau defines the eastern edge of the Alberta Plateau. Where most pronounced, this eastward-facing escarpment stands only about 100 m above the Saskatchewan Plains. The average elevation of the Alberta Plateau is about 700 m but it rises gently as one proceeds westward. Like the Manitoba Escarpment, the Missouri Coteau probably represents the edge of an erosional plain although there are some indications that locally its position may be fault-controlled.

Although the gross topography of the Canadian Plains, expressed in its three levels, is determined by the geological history of the bedrock surface in pre-Quaternary time, it is through the events of the last two million years of Pleistocene and postglacial time that the Plains acquired their locally most obvious characteristics.

Whereas the hard rocks of the Shield show mainly the effects of glacial erosion, the Canadian Plains, with their surface of soft, easily erodible sands and clays of Cretaceous and Tertiary age, are characterized by an abundance of glacial deposital features. Glacial drift is by no means absent on the Shield but it is relatively thin and does not obliterate the rather subdued bedrock topography. It is the polished, scratched, and streamlined rocks that dominate the Precambrian Shield and its fringe of Paleozoic deposits. There is an abundance of outcrops.

In contrast, the Canadian Plains have only few outcrops which, in general, are confined to the lower parts of the major, deep valleys formed by streams that have cut through the thick cover of Pleistocene deposits into the underlying Mesozoic and Cenozoic bedrock. In the southern and western parts of the Canadian Plains outcrops of Cretaceous, and particularly Tertiary, sediments are again abundant and form a significant aspect of a landscape only thinly covered by glacial deposits near the edge of the continental glacier. The gravels, sands, silts, and clays of Mesozoic and Cenozoic age are generally soft and easily eroded, particularly in a climate that allows but scant vegetation and which has a precipitation pattern of strong, short-lived downpours. Where this particular combination of soft rocks and violent periodic water erosion prevails, streams can etch deeply into the sediments to create badlands, the "terres mauvaises" of the French fur traders.

The sediments deposited by glaciers, their meltwaters, and other closely associated waters, are referred to collectively as glacial drift. Those laid down directly by the ice are characteristically ill-sorted and composed of unlayered deposits of variously sized stones embedded in a matrix of finer particles. Such an ice-deposited material is called till. Its topographic expression may vary from nearly level to hilly. Landforms composed predominantly of till are known as moraines. Stony land of morainal origin covers large parts of the Canadian Plains,

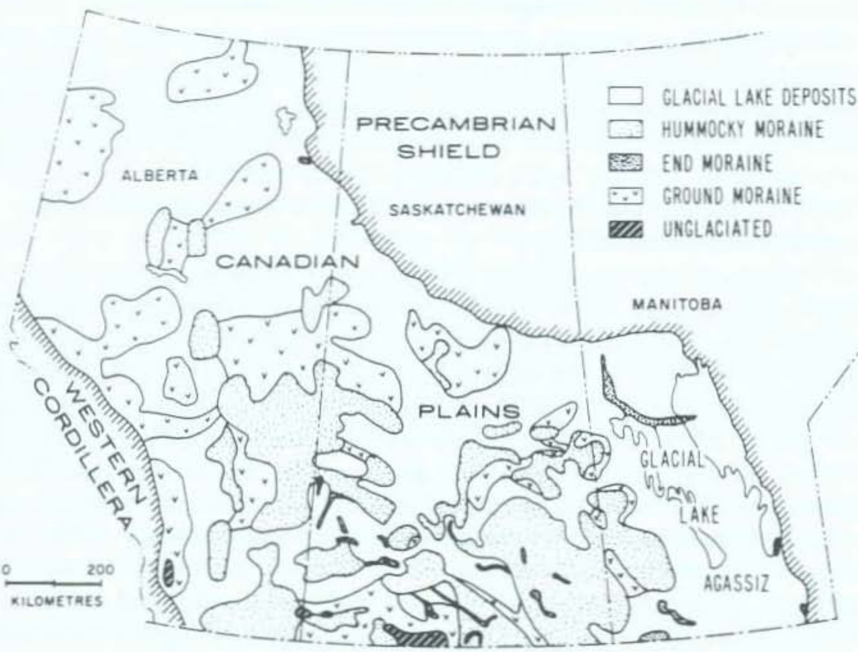

Figure 3. Surficial geology of the Canadian Plains. Modified after GSC map 1253A.

generally in irregularly shaped areas in which linear trends are not easily detected on the ground. When flying over the country, however, linear trends are better observable and can be seen in many places. The classical end or recessional moraine, a well-defined narrow and steep ridge, is rare on the Plains.

The most characteristic morainal deposits of the Canadian Plains are the stony, irregularly shaped hillocks or hummocks that cover underlying bedrock uplands (Figure 3). Such deposits resulted from the glacier stagnating and melting in place which caused a continuous shifting of the till in the ice during the melting process. Among the minor topographic features of dead-ice moraines are "circular depressions" already noted by Henry Y. Hind in 1858. These depressions were formed by the melting of a block of stagnant ice. Where the ice carried substantial amounts of debris, a rim of sloughed-off till surrounds the depression.

The water-laid sediments of glacial meltwater streams and those of glacial lakes are referred to as stratified drift. Most of these deposits were laid down in lakes, the bottoms of which now form the flat, stone-free land between the hummocky, stony land of the moraines. The Manitoba Lowlands are almost continuously covered by clays and silts of the largest-ever glacial lake in the world—Glacial Lake Agassiz. On the southern parts of the Saskatchewan Plains and the Alberta Plateau there is an approximately equal proportion of lake and morainal deposits; extensive lake deposits occur in their northern parts.

Within these two large divisions in the glaciated terrain of the Canadian Plains smaller landforms provide certain characteristic mineral resources. Depressions in morainal areas are commonly filled with water, during at least part of the spring and summer. Poplar rings around these "sloughs" are a common sight in hummocky, stony land. The trees depend on the water that collects in these depressions, particularly after snow-melt.

Beaches, now abandoned, are abundant along the shores of Glacial Lake Agassiz. They also occur elsewhere surrounding smaller glacial lakes but nowhere in such profusion and so well developed as along the margins of the Manitoba Lowlands. They provide sources for sand and gravel. So do the deltas built up by streams that entered the glacial lakes. They, too, are particularly conspicuous in the area of former Glacial Lake Agassiz, the deltas of the Assiniboine and Saskatchewan Rivers being good examples. Again, however, they occur elsewhere having also developed in smaller glacial lakes. After the disappearance of the abundant water of early postglacial time, the surfaces of the deltas dried out and were then subjected to much modification by wind. Thus originated the large and small dune areas so common in the glaciated Plains.

River valleys in the Plains are remarkable in that they are surprisingly wide and in that they have the appearance of trenches cut into an essentially flat surface. Many travellers have remarked on their being unaware of a valley till they stood at the edge of its wall. Only then would they see a wide valley but one with a smaller than expected stream or even one without any water at all. The much greater amounts of water carried during the time when the glacier melted account for their large size.

Indians

The last Pleistocene glacier started to retreat from its maximum limit south of the 49th parallel, just outside the "Canadian" Plains, about 17,000 years ago. Throughout its complicated history of retreat, with its many standstills and occasional regional as well as local re-advances, the ice front maintained an east-southeast to west-northwest general orientation across the Plains. It is believed that about 13,500 years ago it stood along a line connecting Winnipeg, via a point south of Saskatoon, to Edmonton. By circa 11,000 years ago it was no longer covering the Canadian Plains but had retreated to the edge of the Shield.

Because most archaeologists agree that people had come to North America via the Bering Strait some 30,000 to 40,000 years ago, it is entirely possible that they came to the recently deglaciated Canadian Plains as soon as it was advantageous for them to do so. This means that they came after the establishment of vegetation and the large mammals, which were important sources of food. Paleo-Indian sites, about 12,000 years old, have been found in both southern Saskatchewan and southern Alberta. A 10,000 year-old site has been reported from near Edmonton.

The mineral resources available to these early people were those that occur at the surface, including the topography itself. The abandoned beaches of glacial lakes provided excellent camp sites, as did the sand dune expanses of former deltas. The quality of water in such areas of sand and gravel is much better than that of water on the heavy soils of the glacial lakes where, in places, it may be unfit to drink on account of its high salinity. Moreover, the scrub vegetation covering much of the beaches and most of the deltas provided a suitable habitat for small game.

Topography also aided the hunting of large game. In many places the valley walls of the deep-set glacial streams provided cliffs where buffalo (*Bison bison*) were killed by stampeding them over the edge.

The availability of water is of prime concern to inhabitants of the Canadian Plains. Although the area is not the desert it was believed to be in the middle of the nineteenth century, it has only scant quantities of water at the surface. Moreover, some of the largest prairie lakes, such as the Quill Lakes, are so saline during much of the year as to be useless for man.

The salt deposits at the surface of the Canadian Plains, which occur mainly in the central part of the Saskatchewan Plains, are predominantly sodium sulphate. In a few places there is also magnesium sulphate and some potassium salt. To both Indians and settlers these salts were probably nuisance deposits, although John Richardson, M.D., wrote in 1823 that the Indians used the substance medically, as a purgative.

Sodium chloride or common salt, on the other hand, is a desirable commodity. In places along the Manitoba Escarpment salt springs have provided this product for a long time, the best known being Monkman's Springs on the west shore of Lake Winnipegosis, Manitoba. There brine from porous limestone was crudely but effectively evaporated for years in the middle nineteenth century by a family-based enterprise. Richardson, who stayed the winter 1819-20 at Cumberland House, reported that he heard from visiting Indians about salt springs at the foot of the Pasquia Hills "... from which a considerable quantity of salt is annually extracted." He speculated that the water had circulated through salt deposits in Mesozoic rocks. Now that the stratigraphy of the subsurface is better known, it has become clear that the salt is derived from the Prairie Evaporites of Devonian age.

To the aboriginal peoples of the Plains, the Paleo-Indians and later, from the year A.D. 1 to the present, the Neo-Indians or Indians, the mineral resource of primary importance was stone for tools. Of the abundant erratics derived by the glaciers from the Precambrian Shield and deposited by them as part of the till that forms moraines, only some are suitable for cutting tools, such as stone knives or the points of spears and arrows. These tools need to be composed of hard, non-fissile minerals and to have a very finely grained rock texture. Only some metamorphosed volcanic rocks and sandstones or quartzites qualify in these respects. The sharpest edge is provided by microcrystalline (chert, flint) or glassy (obsidian) quartz-rich rock material. There is no source of obsidian in either drift or bedrock in the Canadian Plains. The closest exposures are in the area of Yellowstone Park in Wyoming. Some pieces of dark grey to black chert occur in the glacial drift but they are not of as good a quality as a flint extracted at least as early as some 4,000 - 5,000 years ago in what is now North Dakota. This distinctive, brownish Knife River flint became widespread among the Plains people. It provides an early example of trade in a mineral product in the region. The occurrence of copper and shells in some burial sites of the same period also indicates contact with other cultures.

Coarse-grained erratics, such as granites, gneisses, and schists, unsuitable for cutting tools, served for other purposes. Most noticeable still today are the tepee-rings of stones, a preponderance of which are sub-spherical gneisses and granites. Such stones were also used to lay out ceremonial or other configurations, as in the medicine-wheels.

Gneissic and granitic stones of suitable shape, and modified with a cup-shaped depression hollowed out in their tops, were used as mortars. Others, with a cut groove encircling their oblate shape, served as hammer heads.

Those stones of the drift that have a characteristically flat shape and are relatively soft, such as schists, were used by Indians for carving. Hand or face figures carved into disks of mica-schist have been found in several places.

Petroglyphs, rock carvings, are not confined to erratics. They were incised as well on the soft, easily worked, Tertiary sandstone outcrops of the southern Canadian Plains. Among those at St. Victor, Saskatchewan, are images of footprints of men and animals, hand prints, human faces, and outlines of animals. Their original significance or purpose is not known. They are believed to be several centuries old.

Bedrock exposures also provided Plains Indians with another resource of possibly religious or perhaps just curiosity value: fossils. In his description of Cretaceous fossils collected in 1858 from the elbow of the South Saskatchewan River, Hind included some specimens previously submitted by Indians to post managers of the Hudson's Bay Company.

Very large, prominent erratics may have had a religious significance to the Indian peoples of the Plains. This is held to have been the case with a 3 m high erratic in the Qu'Appelle River valley, near the elbow of the South Saskatchewan River in what was known as the Aiktow valley. In 1858 Hind noted that "the Indians place on it offerings to Manitou, and at the time of our visit it contained beads, bits of tobacco, fragments of cloth and other trifles." The site is at present flooded by the impounded waters of Diefenbaker Lake. Before flooding, part of the granite erratic was removed in a dynamite explosion and a fragment of it can now be found in the Provincial Rock Garden, Ottawa, where it represents the Province of Saskatchewan and its earliest people.

When the technique of making pottery penetrated the Canadian Plains some 1,900 years ago, clay deposits turned into a valuable resource needed for the manufacture of cooking pots. Whereas the stones occurred in abundance on the rough morainal land, it was the smooth glacial lake plains that provided the clay.

The Settlers

Like the Indians, the early settlers depended on the topography of the Canadian Plains. Because both regarded the wide expanse of flat lands as most desirable for obtaining food, either through the hunting of buffalo or through the development of agriculture, conflict was unavoidable in the long run. When it was resolved, through the combination of pressure and persuasion embodied in the Treaties, the Indians generally retained most of the morainal lands while the settlers occupied the stone-free clay land best suited to agriculture.

Whereas the Indians viewed the field stones as a resource (although many stones did not have the qualities regarded as desirable for their specific purpose), the settlers most likely despised them as a nuisance. The one use to which stones were put was as building materials and then only when better alternatives, particularly quarried stones, were unavailable or too costly. Several small buildings of field stones survive, including the Victoria School House, now re-located on the Campus of the University of Saskatchewan, Saskatoon.

One type of field stone for which the Indians had no use—the Ordovician dolomites derived from the northwestern corner of the Manitoba Lowlands and from there spread out by the glacier over the central part of the Saskatchewan Plains—served well as a building material on the University of Saskatchewan Campus from 1910 to the present. However, most of the dimension stone for public buildings on the Plains was quarried. The typical mottled brownish-grey dolomite from the Tyndall area, Manitoba, was used in the legislative buildings in Winnipeg and Regina. In Edmonton, "Alberta Sandstone" from the Glenbow Quarry near Calgary served the same purpose.

Limestone boulders, present but not abundant in the central part of the Canadian Plains, were used locally by fur traders and early immigrants for the production of lime by dead-burning in lime-kilns. In 1895 John Smith's lime kiln became Yorkton's first industry.

Clay for the manufacture of bricks also was an important mineral resource. Local production, however, did not meet demand and before World War I most of the brick used on the Plains was imported from the United States.

With the beginning of permanent year-round settlement, first at isolated fur-trade posts, the water resource was extended from the surface into the ground by the digging of wells. Later, simple spring-pole techniques were employed to drill wells, most commonly in places where seepages and springs at the surface indicated the presence of groundwater. Names of settlements such as Clearwater, located in front of the Manitoba Escarpment in the southern part of Manitoba, or Goodwater, Springvalley, Drinkwater, and Springwater, which in this order line up from the southeast to the northwest along the

Missouri Coteau in Saskatchewan, bear testimony to the vital importance of groundwater to the settlers.

Exploratory drilling for resources in the Canadian Plains started under a programme initiated by the Geological Survey of Canada soon after the jurisdiction of that organization had been extended to cover Rupert's Land and the North-Western Territory, acquired by Canada in 1870. In October 1874 a well located at Fort Pelly was abandoned at a depth of 30 m. The driller was a Mr. Fairbank of Petrolia, Ontario, centre of Canada's thriving petroleum industry since the late 1850s.

Edward Umfreville, a fur trader who established himself on the banks of the North Saskatchewan River, mentioned the occurrence of coal in the sands of the river's bank in his book published in 1790. Some seventy years later, in 1862, Mr. Thomas McMicking of Queenston, Canada West, elected leader of the largest single group of people (the Overlanders) ever to cross the Canadian Plains before the building of the railway, wrote in the New Westminster *British Columbian* about having had "... an opportunity here of examining one of the natural resources of this region that will no doubt some day prove of incalculable value to the whole of this region. I refer to the vast beds of coal which crop out of the banks of the [North] Saskatchewan at Edmonton, and extend for several hundred miles in a north-western direction. It appears in the face of the bank in several parallel beds or layers, varying from two to six feet in thickness, and interstratified with a kind of red clay that has the appearance of having been burnt. It is very easily obtained, lying, as it does, upon the surface."

The serious search for coal deposits had already started in 1857 with the Palliser Expedition whose geologist, Dr. James Hector, showed the presence of several seams in his cross section of the Souris River valley, the first stratigraphic section measured on the Plains. Towards the end of the nineteenth century Tertiary lignite was used locally in several places, including a camp of the North West Mounted Police at Short Creek in the Souris district during their trek westward in 1874. Soon afterwards a load of coal obtained from the surface, was barged to Winnipeg via the Souris and Assiniboine Rivers. The first underground mining companies were organized in the 1890s. By 1906 the Souris District had six large underground mines, employed 550 miners, and produced 1,500 tons per day. Upgrading of the low thermal lignite started in 1921 when briquettes were first produced at Bienfait, Saskatchewan.

The suggestion that lignite coal be used to produce electricity and that a publicly owned, integrated power system be built was made in a Royal Commission report on the Souris coal in 1912. Many years passed before this idea was put in practice, but at present lignite near Estevan and other places in the Souris District is used almost exclusively for generating power.

Coal and water were, of course, essential for the railroads which came to the Canadian Plains in 1882. The lignite, however, proved unsuitable for the fire-boxes of the time and the Canadian Pacific Railway instead used imported coal from the Appalachians in the USA. This coal was shipped to the Lakehead and distributed from there by train to depots on the Plains.

As early as 1861 Toronto's newspaper, *The Globe*, carried accounts of the discovery of gold in the North Saskatchewan River near Fort Edmonton. This gold was an added incentive to the Overlanders, who in 1862 trekked across the Canadian Plains on their ways to the Cariboo Mountains, in British Columbia, where gold discoveries were substantial enough to cause a gold rush. The value of gold recovered from the North Saskatchewan River amounted to only an estimated $700,000 between 1860 and 1940, but attempts to find it have lasted sporadically to the present. From 1905 until 1909 a gold dredge operated on the river near Prince Albert, Saskatchewan, but this operation failed on account of technical difficulties in separating the fine gold flakes from the river sand.

Industrial Society

No precise date separates the period when the use of mineral resources on the Canadian Plains was primarily local from the one when production was principally for the industrial, rather than the domestic market. This transition came at different times for different reasons.

As early as 1919 some 15 tons of sodium sulphate, or Glauber's salt, were shipped from Muskiki Lake, Saskatchewan. Surveys in the early 1920s by the Mines Branch, Canada Department of Mines, outlined several commercial deposits but most attempts at recovery ended in failure. Nevertheless, by 1930 production reached 31,500 tons.

The Canadian Plains, and particularly Saskatchewan, provide the country's sole commercial source of sodium sulphate, of which more than 99 percent is consumed by the kraft-paper industry to add strength to the finished product. The deposits occur in shallow lakes and extinct lake basins in a broad area about 160 to 480 km wide, extending 460 km from Alberta through Saskatchewan southeasterly into the United States. All the deposits are lacustrine and lie within areas of Pleistocene drift. Exploitation is currently undertaken at Palo, Alsask, Cabri, Chaplin, Ingebright, Bishopric, Ormiston, and Gladman in Saskatchewan, and at Metiskow in Alberta.

The origin of the sodium sulphate deposits is still a matter of controversy. There is agreement that the salt is deposited by groundwater emerging at the surface. The depth of circulation of that groundwater, and therefore the source of the elements that compose the salt, is no deeper than the Cretaceous rocks that underlie the glaciated Plains, according to some geologists. Others think that very deeply circulating water flowing from the Rocky Mountains easterly and penetrating through the Devonian Prairie Evaporites is responsible. The latter theory emphasizes a link between the geological characteristics of the deeply buried rocks in the Williston Basin and mineral resources at the surface.

The greatest technological change in the mining of the lignite coal in the Souris District came in 1930. It was to have important consequences, economically and socially, as well as environmentally. Late in that year surface strip mining was introduced from North Dakota. Before that time mining had been an underground and seasonal operation, with miners supplementing their income with farm work, but now fewer workers would be needed year-round. Underground working conditions were deplorable and dangerous but no improvements could be expected in what was becoming an obsolete technology. Yet change was slow and the last underground mine in Saskatchewan closed only in 1956.

Although the introduction of strip mining was inevitable because of its economic, social, health, and safety advantages, it was soon regarded by some as environmentally undesirable. This led to demands for the reclamation of land disturbed by strip mining.

Coal is now mined in Saskatchewan near Estevan and south of Willowbunch. In Alberta, mines on the Canadian Plains are concentrated near Edmonton, west and east of Stettler, and near Drumheller.

Without doubt, the petroleum industry has had the greatest impact on all aspects of life on the Canadian Plains, particularly on the Alberta Plateau region, to a lesser extent on the southeastern Saskatchewan Plains, and even less on the southwestern Manitoba Lowlands. The discovery of oil and gas at Turner Valley, Alberta, just outside and to the west of the Canadian Plains, in 1914, stimulated exploration for petroleum in the West and North. Reconnaissance mapping of surface structures in western Saskatchewan and adjacent Alberta in 1925 by G. S. Hume, Geological Survey of Canada, led to the discovery of the Ribstone-Blackfoot Anticline, where a well drilled in 1928 showed the presence of gas. On Good Friday, 1934, the Lloydminster Gas Company no. 1 or "Discovery" well, whose location was based on Hume's mapping, hit natural gas at 600 m depth from the Cretaceous Blairmore Sandstone. The gas was piped into Lloydminster, making it the first settlement on the Canadian Plains to be thus served. Heavy oil was discovered near Lloydminster in 1935, and the first producing well was drilled in April 1945 by the National Grant Company. Production was from the Cretaceous Sparky Sand at an average depth of 564 m. Because no Canadian refinery was designed to treat heavy oil, the product was shipped to the American Midwest for further processing. With the announcement on 23 August 1983 that agreement had been reached to built a heavy-oil "upgrader" in Regina, one can now look forward to the time that light refinery products, including gasoline, will be produced close to the source of the heavy oil.

During several years preceding 1926 Imperial Oil Company Ltd. drilled several exploratory deep test wells on the Plains using standard or cable-tool equipment, but no discoveries were made. In 1940 Imperial started an intensive search for petroleum using reflection seismograph surveys, experimental gravitymeter surveys, widespread surface geological mapping, and core hole drilling to provide samples for microfossil studies. This was followed in 1943-46 by 15 deep tests, most of the tests being located on seismically mapped anomalies. The drilling of wells several thousands of feet deep was possible only by using rotary drilling equipment. Cable-tool rigs are now no longer in use in the petroleum industry. As late as the early 1950s, however, the large wooden derrick of Palmer's cable-tool drill could still be seen in the Cypress Hills.

On 20 November 1946, after having drilled 133 dry holes on the Canadian Plains, Imperial Oil struck light oil at a depth of 1,544 m in the Devonian reef carbonate rocks of their Leduc no. 1 well, near Edmonton. Production of this well, starting in February 1947, marked the beginning of the modern large-scale exploitation of the petroleum resources of the Canadian Plains. It set off intensive exploration and was soon followed by discoveries of both oil and gas in Alberta, Saskatchewan, and southwestern Manitoba. At present there are numerous fields in Alberta on the Canadian Plains producing oil, natural gas, and sulphur. In Saskatchewan there are only two principal gas-producing fields, Coleville-Smiley and Steelman, the latter also being the province's sole sulphur producer. In Manitoba three fields produce only oil.

With the oil and gas industries, as with modern coal mining, came new environmental problems as well as economic prosperity and opportunity. Land-based oil spills, although they are not comparable in severity to those happening near-shore at sea, can nevertheless play havoc locally with groundwater supplies. Much wider-ranging effects are felt when, during drilling, there is a gas blowout, the well gets out of control, and a fire starts. Particularly with sour-gas wells (those rich in sulphur) such events may cause regional air pollution—with detrimental effects, not only on the environment but also on human health. The most severe such incident in the history of petroleum exploitation in western Canada happened in October 1982, when an Amoco Canada Petroleum Co. Ltd. gas well near Lodgepole, Alberta, about 130 km southwest of Edmonton, went out of control.

The search for oil and gas on the Canadian Plains by Imperial Oil during 1943-46 revealed the presence of an extensive Devonian evaporite basin. The Prairie Evaporites, as these salt beds are now known, yield two important resources: sodium-chloride, or ordinary salt, and various potash salts, the principal ones of which are potassium chloride, or sylvite, and potassium-magnesium chloride, or carnallite.

Solution mining of common salts commenced in May 1949 at Unity, Saskatchewan. The plant there is operated by Domtar Inc. Ltd. (Sifto Salt Division). Another salt plant, owned by The Canadian Salt Co. Ltd., is located at Lindbergh, Alberta. The same company also has a solution mining plant at Belle Plaine, between Regina and Moose Jaw.

Potash plants on the Canadian Plains are all located in Saskatchewan. One, at Belle Plaine (PPG Industries Canada, Ltd. Kalium Chemical Division) is a solution plant. The other eight mines now in operation extract the potassium salt by underground mining. The first of these, the Potash Company of America mine at Patience Lake, east of Saskatoon, was started in 1951 with the shaft reaching the salt beds in 1958. Soon after, it was necessary to close the shaft because of flooding by groundwater contained in the Cretaceous Blairmore Formation. Although during shaft sinking groundwater had been controlled by freezing, it became necessary to install a steel lining, so-called "tubbing," inside the shaft before mining could proceed. It was not until 1965 that extensive production could begin. Thus the Blairmore Formation, which in the Lloydminster area yielded desirable natural gas, turned out to be a reservoir of most undesirable pressurized and saline groundwater in the Saskatoon area—a liability, not a resource.

The principal use of potash is as a fertilizer. Saskatchewan's potash resource is located far from tidewater and cheap transportation to potential markets in California or Japan, but the relatively simple geological structure of vast deposits at a reasonable depth (which makes mechanized underground mining technically feasible and economically attractive) results in the province's pre-eminent position in the international potash market. However, there is some cost to be paid because common salt, an undesirable by-product which is discarded in tailing piles near the mines, may enter into the surface water and groundwater or be blown into the atmosphere. Measures have to be taken to keep these sources of pollution under control.

Besides the main mineral resources of the Canadian Plains—oil, gas, coal, potash, sodium sulphate, sulphur, and common salt—other minor resources are exploited. Some of these, sand and gravel in particular, can be called minor only in the sense that extraction occurs on a relatively small scale in any one place. But, because there are so many places where sand and gravel are taken to be used for highway building or other construction, the cumulative effect of this open pit mining may not be insignificant. Moreover, this extraction activity, having lasted ever since settlement began at an ever-increasing scale, now poses some supply problems. This is particularly evident in cities, towns, and villages located on glacial lake bottoms some distance away from the coarse-grained stratified drift that characterizes proglacial meltwater and ice-contact deposits.

Other minor mineral resources, on the other hand, are exploited only in one or two places and their effects on both the economy and the environment are therefore also only minor.

In Manitoba, gypsum is mined by Domtar Construction Materials Ltd. in an open pit at Gypsumville in rocks of Devonian age. Western Gypsum (1978) Ltd. operates at Harcus, Manitoba. Silica sand comes from Black Island at the very edge of the Canadian Plains, north of Winnipeg. At Morden, bentonite, a soft plastic clay used mainly to thicken oil-well drilling muds, is extracted.

In Saskatchewan, too, bentonite is produced at Avonlea near Wilcox, from Cretaceous rocks, the bentonite representing the weathered residue of volcanic ash falls.

In Alberta bentonite comes from Rosalind, to the southeast of Edmonton. Silica sand is mined from near Bruderheim to the northeast of Edmonton.

Epilogue

Throughout the time that man has occupied the Canadian Plains, use has been made of their mineral resources. At first this exploitation was confined to materials available at the surface. With time and more sophisticated technology mineral resources were tapped at ever-increasing depths.

The growth of population locally applied pressure to increase extraction of some resources. The demand to broaden exports in order to supply greater national and global populations was also felt. With the greater scale of extraction of mineral resources came greater pressures on the environment. Local underground mining of coal was followed by extensive open pit operations. The effects of petroleum extraction range from small spills to regional atmospheric disturbances, such as the emission of sulphur compounds caused by accidents at the well-head. The tailings of potash mines contribute their share to atmospheric and water pollution.

The Canadian Plains are known to have some mineral deposits which may never become resources for economic reasons. The Tertiary coals of the Cypress Hills contain small amounts of uranium which will remain not much more than a curiosity as long as the rich ore bodies of northern Saskatchewan can supply this energy source at a much lower cost. So will be the Precambrian iron-ore at Choiceland, Saskatchewan, because it is covered by Phanerozoic sedimentary rocks that prevent mining in open pits.

While some in the past have regarded the Canadian Plains as not much more than a "useless desert," in the twentieth century the pendulum of opinion swung toward the belief of a "storehouse of riches." Neither extreme opinion carries much weight. Only careful exploitation, tempered with conservation, can assure that the mineral resources are of long-lasting benefit to the people living on the Canadian Plains.

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