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Introduction

To ask, "What are the Canadian Plains?" is to evoke answers as variable as day-to-day temperatures in February in the chinook belt of southern Alberta. You could be told that the Canadian Plains region is the grasslands, or the steppe, or the prairie and parkland, or the wheat-growing and ranching region of Interior Canada. You might even be informed that the Canadian Plains are more than that, and are, in fact, those lands in western Canada bounded on the east by the Canadian Shield, on the west by the Canadian Cordillera, and on the south by the Canada-United States boundary. Further probing might disclose that the region occupies an area exceeding one million square km and is some 1,300 km wide at its base along the 49th parallel, from where it extends north for over 2,600 km to the Mackenzie River Delta. However interesting these answers might be, they nevertheless only tell *where* the Canadian Plains are, not *what* they are!

What the Canadian Plains are is one concern of this Special Issue of Prairie Forum. The theme of this issue then can be expressed as one of demonstrating what the Canadian Plains are, relating the resources of the Canadian Plains to the people who depend on these resources, and reporting the ways in which man has wisely used, and conversely, directly and indirectly misused or abused these resources.

To establish what the Canadian Plains are, the first two articles in this issue consider and describe the geological forces and substrates that formed the Canadian Plains. The third and fourth articles deal with the climate and soils of the region. These are the major builders and components of the Canadian Plains environment, and ones that provide the physical and chemical properties needed to support the vegetation of the region, described in the fifth article. The remaining seven articles treat groups of animals which, directly and indirectly, depend upon the non-living and living elements of the ecosystem discussed in the first five articles.

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Geological History of the Interior Plains

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ABSTRACT. During the Archaean and Early Proterozoic Eras, the Interior Plains were the site of huge mountain systems. These were later worn to low, flat lands that formed the basement for the overlying mainly marine Phanerozoic sedimentary rocks. In places, these reach a thickness of over 3,000 m. Complex movements of seas resulted in a stratigraphically and geographically incomplete sedimentary record. The oldest rocks that rest on basement are Middle and Late Cambrian sandstones and shales. They are followed by Late Ordovician and Silurian carbonates, and these, in turn, by Middle and Late Devonian rocks. Devonian strata are lithologically very complex and important for their potash and rock salt deposits and oil-bearing reefs. The Mississippian is important for its hydrocarbon-bearing crinoidal limestones and others. Permian to Triassic uplift caused extensive erosion resulting in a major regional unconformity. The only Plains deposition, at this time, was in the Peace River area. The Triassic there is important for its petroleum content; the Permian is not.

Jurassic seas were widespread, with shale the main deposit. Near the end of this period the Columbian orogeny in British Columbia and southwestern Yukon resulted in clastic sediments being spread eastward across the Plains and adjacent areas during the succeeding Cretaceous. There was a complex interplay between land and sea resulting in deposition of continental and marine rock. The former contain coal; the latter oil and gas. Tertiary rocks are all continental and, as in the Cretaceous, derived mainly from the west. Deposition was interrupted during the Early and Middle Eocene by the Laramide orogeny which affected the entire Cordillera. The resulting Late Eocene to Miocene sediments are coarse grained due to this uplift. Most Tertiary sediments were removed by Pliocene erosion.

Between two and three million years ago, the Pleistocene Epoch or Ice Age followed, with much of western Canada being covered by glaciers. Eventually most of these melted bringing in the Present or Recent Epoch.

RESUME. Au cours de l'ère archéenne et du début de l'ère algonkienne, d'énormes chaînes de montagnes dominaient les Plaines intérieures actuelles. Par la suite, ces chaînes de montagnes ont été érodées jusqu'à ce qu'elles deviennent des terrains plats et de basse altitude, terrains qui ont constitué le socle des roches sédimentaires post-précambriennes formées en grande partie de roches marines. À certains endroits, ces roches sédimentaires atteignaient une épaisseur de plus de 3 000 mètres. Les mouvements complexes des eaux ont donné lieu à des enregistrements sédimentaires incomplets sur les plans statigraphique et géographique. Les roches les plus anciennes que l'on trouve sur le socle du Cambrien moyen et du Cambrien récent sont du grès et du schiste argileux. Les autres roches les plus anciennes que l'on trouve sur le grès et le schiste sont les carbonates ordoviciens et gothlandiens. Sur les carbonates, on trouve les roches du Dévonien moyen et du Dévonien récent. Les strates du Dévonian sont de composition très complexe sur le plan lithogique et elles sont importantes pour leurs dépôts en potasse et en sel gemme, ainsi que pour leurs filons métallifères contenant du pétrole. Pour sa part, le Mississipien est important pour ses calcaires à crinoïdes contenant des hydrocarbures. Les soulevèments permiens et triasiques ont engendré une érosion considérable et ont mené à une non-conformité régionale. À cette époque, les seuls dépôts que l'on trouvait sur les plaines étaient situés dans la région de Peace River. Le Trias a constitué une période importante en raison des gisements à teneur de pétrole auxquels elle a donné naissance, ce qui n'a pas été le cas du Permien.

Les eaux jurassiques étaient étendues et le schiste argileux constituait le principal dépôt de ces eaux. Vers la fin de cette période, la phase tectonique Columbia, qui s'est produite en Colombie-Britannique et au sud-ouest du Yukon, a donné naissance à des sédiments clastiques qui se sont étendus vers l'est des plaines et des régions adjacentes au cours de la période suivante, soit le Crétacé. Des interactions complexes entre la terre et les eaux ont donné lieu à des dépôts de roches continentales et marines. Les roches continentales contiennent du charbon tandis que les roches marines contiennent du pétrole et du gaz. Les roches de l'ère tertiaire sont toutes des roches continentales, et, comme pour la période du Crétacé, sont provenues en grande partie de l'Ouest. Au cours de l'Éocène supérieur ancien et de l'Éocène supérieur moyen, ces dépôts ont été interrompus par la phase tectonique Laramienne qui a touché la région de la Cordillère au grand complet. Les sédiments provenus de l'Éocène supérieur récent et du Miocène sont à gros grains en raison de ce soulèvement. La majorité des sédiments engendrés au cours de l'ère tertiaire ont été éliminés par l'érosion du Pliocène.

Il y a deux on trois millions d'années, est venu le Pléistocène on période glacière, qui a convert de glaciers une grande partie de l'Ouest du Canada. La plupart de ces glaciers se sont enfin fondus, annonçant l'époque actuelle.

ACKNOWLEDGMENTS

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Almost all rocks on continents form either plains or mountains: in plains, they are commonly sedimentary and, most important to a geologist, the layering or stratification they exhibit is near-horizontal. This results in the flat or subdued surface topography familiar to prairie people. Western Canada has two areas with these characteristics, here formally called Interior Plains and Hudson Bay Lowland (Figure 1). Stratification is generally not apparent on account of the general lack of outcrop, except along major rivers and lakes.

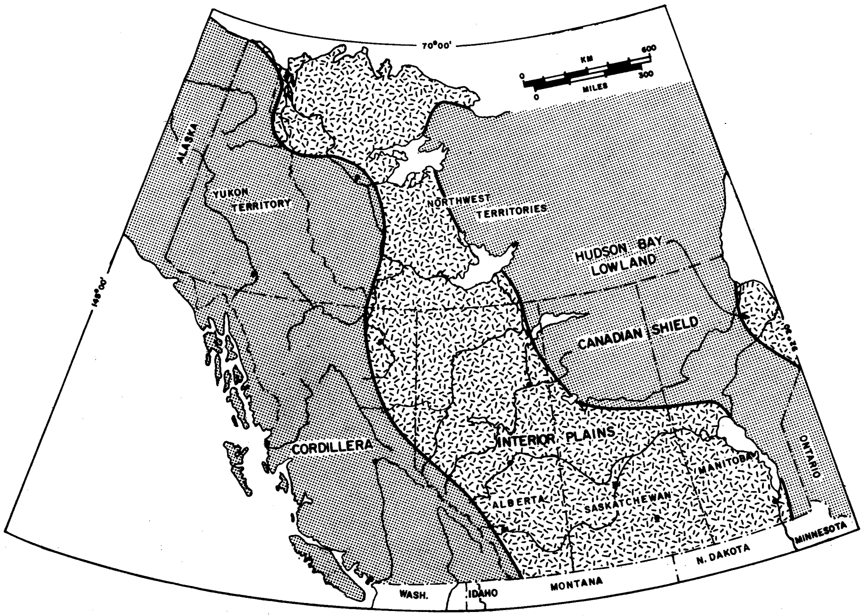

Figure 1. Geological Provinces of Western Canada. The Canadian and Alaskan area shown is that portrayed on the palaeogeographic maps of Figures 4 to 11. For simplicity, the Arctic Islands and shoreline of most of the Northwest Territories have been deleted.

To a geologist, mountains are only surface topographic features, the internal fabric or structure of which is more important. They may have stratified rocks of the kinds within plains but these have been deformed by mountain building, technically called orogeny. This results in the rocks being bent into folds, broken and moved by faults, and in many places intruded by molten rock or magma which later cools to form igneous rocks such as granite. Not uncommonly, the extreme heat and pressure associated with orogeny destroys all or nearly all trace of stratification, and results in the formation of metamorphic rocks. The Cordillera has all of these structures and rocks. Because it is, geologically speaking, a young set of mountains, formed between 150 and 50 million years ago, it is still topographically high. The sedimentary rocks of the Plains are very closely related to those in the eastern part of the Cordillera and it is difficult to discuss one without the other. Usually, they were deposited in the same seas, and events in the Cordillera often influenced the Plains.

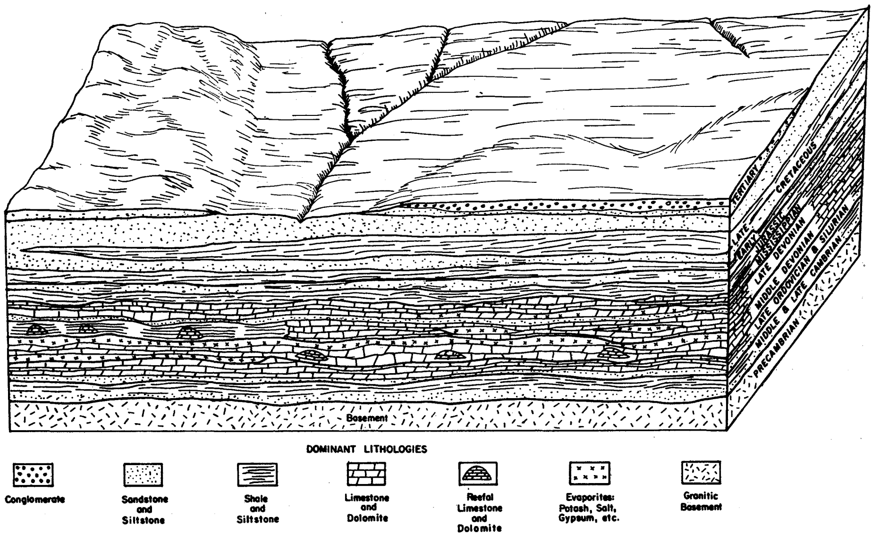

Figure 2. Diagrammatic sketch through the Interior Plains. This sketch shows the near-horizontal sedimentary rocks of the Plains resting on Precambrian basement. The sketch has a rough northwest - southeast orientation. The latter, on the right, is in Saskatchewan where the thickest succession occurs. The northwestern portion, toward the left, is toward central Alberta. Thickness of the rocks above basement approximates 3,000 m.

Figure 2 is a diagrammatic portrayal of the Interior Plains. Depending upon location, the underlying rocks are usually between 1,500 and 3,000 m thick and they are typically sandstone, shale, and limestone. In southern Saskatchewan the age of these underlying rocks ranges from Middle Cambrian at the base, to Tertiary near the top, representing a time span of nearly 500 million years (Figure 3). Because seas often covered the Interior Plains during the past, most rocks are of marine origin. The story of these seas is complex (Zeigler 1967, Nelson 1970). At times, they covered much of western Canada, resulting in widespread deposits of sedimentary rock. At other times they withdrew, subjecting the rocks to erosion and removal. The uppermost layers are commonly capped by loose sediments, most of which were deposited during the Pleistocene Epoch.

Eon	Era	Period	Epoch	Age
PHANEROZOIC EON	CENOZOIC ERA	QUATERNARY PERIOD	RECENT EPOCH	0 my
			PLEISTOCENE EPOCH	2-3 my
		TERTIARY PERIOD	PLIOCENE EPOCH	
			MIOCENE EPOCH	
			OLIGOCENE EPOCH	
			EOCENE EPOCH	
			PALEOCENE EPOCH	60 my
	MESOZOIC ERA	CRETACEOUS PERIOD		
		JURASSIC PERIOD		
		TRIASSIC PERIOD		200 my
	PALAEOZOIC ERA	PERMIAN PERIOD		
		PENNSYLVANIAN PERIOD		
		MISSISSIPPIAN PERIOD		
		DEVONIAN PERIOD		
		SILURIAN PERIOD		
		ORDOVICIAN PERIOD		
		CAMBRIAN PERIOD		600 my
PRECAMBRIAN EON	PROTEROZOIC ERA			2500 my
	ARCHAEAN ERA			4500 my

Figure 3. Geological Time-Table. Approximate ages, in millions of years, are indicated on the right.

The Plains rocks rest on ancient Precambrian granitic rocks, technically referred to as basement. This comes to the surface to form the low, flat Canadian Shield (Figure 1). Basement and Shield were once part of extensive Precambrian mountain systems that stretched across much of western Canada and, then, probably looked much like the Swiss Alps. And there was not just one mountain system! There is evidence that at least two sets of mountains were formed; one about 2,500 million years ago, and later another, about 1,700 million years ago. During the latter part of the Precambrian Eon, these suffered the effects of erosion by wind, water, and glaciers. By the middle of the Proterozoic Era they had been worn down to their granitic roots to form a low, lifeless land surface, now buried as basement under the Plains or exposed in the Shield.

At first glance, the Canadian Shield and its basement extension do not appear geologically impressive. But if one considers the time involved in their formation — thousands of millions of years — and the huge mountain systems of which they were once part, the succeeding later Proterozoic and Phanerozoic history of the Plains, with which this article is concerned, pales by comparison. The former spanned an interval of at least 3,000 million years, the latter only half that.

Modern western Canada could be said to have its beginnings during the middle of the Proterozoic Era, some 1,600 million years ago (Figure 4). At this time, the area of the Plains was a flat, lifeless desert probably covered, in places, by wind-blown sand dunes. There was no vegetation. Land plants were not to appear for another 1,200 million years, near the beginning of the Devonian Period. This deeply eroded land was all that remained of the once great Precambrian mountain systems. Bordering it on the west, over the area of the present Cordillera and beyond, was the ancestral Pacific Ocean. Although there was some shifting of land and sea, the shoreline was to remain approximately as shown on Figure 4 for over 1,000 million years, well into the Early Cambrian Epoch. Sediments such as gravel, sand, silt, clay, and lime-mud were deposited along its eastern fringes. These would later be hardened or lithified into conglomerate, sandstone, siltstone, shale, and limestone, respectively. There is considerable doubt about what

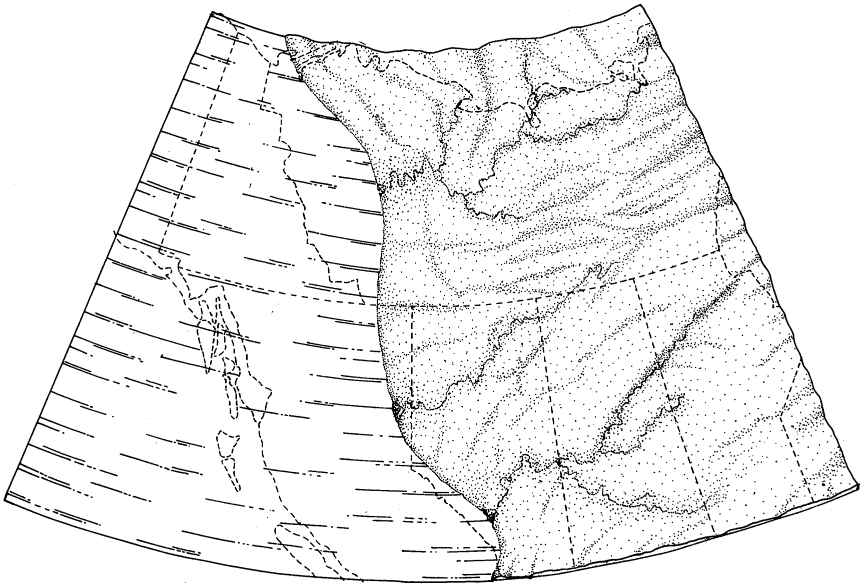

Figure 4. Middle Proterozoic to Early Cambrian palaeogeography. During this nearly 1,000 million-year interval the shoreline approximated the present Cordillera-Plains boundary (see Figure 1). To the east was rather low, wind-swept land devoid of vegetation. In the bordering sea, sedimentation took place for over 300 km from the shoreline (see text). Farther west was deep water, receiving little or no sedimentary deposits.

This interval is much more complex than shown. At least three distinct events of sedimentation occurred (Nelson, 1970). The only thing they have in common is the approximate correspondence of land and sea. The first event occurred with deposition of the fine-grained Middle Proterozoic sediments of the Purcell Group. The second, during the Late Proterozoic, saw a little understood period of mountain-building called the East Kootenay orogeny and attendant deposition of the Windermere Group. Tidal waves (see text) and glaciation (Eisbacher, 1981) may have accompanied sedimentation. The third interval, during the Early Cambrian, saw widespread deposition of sandstone *et al.* of the Gog Group and related rock units.

happened farther west. Present thinking among geologists is that much of central and western British Columbia, the southwestern Yukon, and beyond may have been deep water with little or no sedimentation on the ocean floor. It was to remain like that until well into the Jurassic Period. There are in fact two schools of thought regarding the origin of the Cordillera. One assumes that for much of the past, the area that is now the western part of the Cordillera was deep water, and its seafloor received little or no sediments. During Jurassic, two continents, here called "Terrane I" and "Terrane II," drifted eastward and collided with ancient North America (Figures 7 to 11). The force of collision formed the mountains of the Canadian Cordillera. This is the "Terrane Hypothesis" and is the explanation followed here. The other school thinks that most of the rocks in the Cordillera formed in place and were of geosynclinal origin. The western part was the site of subduction(s) resulting in sediments rich in volcanic material, the so-called eugeosyncline. The sediments of the inner or eastern part essentially lacked volcanics. This was the miogeosyncline. This explanation is detailed graphically in Chapter 8 of *The Face of Time* (Nelson 1970). It does not, however, show the subduction zones.

Proterozoic seas were probably teeming with life, and palaeontologists think that almost all invertebrate phyla were present—arthropods, molluscs, brachiopods, sponges, and the like. However, all the forms were soft-bodied, the animals had no shells or other hard parts. Consequently, upon death, their soft parts decomposed, leaving no trace. This means that Precambrian rocks are practically devoid of fossils owing to the lack of shells (Nelson 1970). About all we usually see are marine worm trails and impressions where jelly-fish settled on bottom sediments. The only hard parts commonly found are structures called stromatolites, thought to be calcareous secretions of marine plants.

At or near the beginning of the Cambrian a change occurred, causing animals to develop hard parts, such as shells, and hence these animals formed the first abundant fossils. This was a very significant biological event and, because of it, geological time is divided broadly into two eons: Precambrian and Phanerozoic ("evident life").

Numerous hypotheses have been advanced to explain the abrupt appearance of fossils at the beginning of the Cambrian. One of the more speculative explains it by tidal waves. This hypothesis assumes that Precambrian seas were tideless because there was no moon. Accordingly, the waters were quiet so animals had no need for protective shells. Toward the end of the Precambrian Eon the moon accidentally wandered into Earth's orbit and was captured there. For a time, this caused tremendous tidal waves. Animals that survived were forced to secrete protective shells. This occurred by the beginning of the Cambrian and hence rocks of this age contain the first fossils. "Far out?" It's hard to say. Readers who have driven along Toby Creek in southeastern British Columbia to ski at Panorama Resort may have noticed outcrops of a Late Precambrian conglomerate with very large and angular boulders. This is the Toby Formation. It has puzzled geologists since it was first described over 55 years ago. Proponents of the tidal-wave hypothesis claim that these huge boulders were ripped from pre-existing rocks by such waves.

Palaeozoic faunas are dominated by invertebrates, in particular archaic or now-extinct animals such as tetracorals, tabulate corals, stromatoporoids, diverse kinds of brachiopods, trilobites, crinoids, and graptolites (Nelson 1970). Of these, corals and brachiopods are the most common fossils.

The first widespread sedimentary deposition in the area of the present Plains took place in Middle Cambrian time. During this epoch, the sea began creeping eastward across southern Alberta and Saskatchewan, reaching Manitoba by the Late Cambrian. Sandstone, siltstone, and shale are the most common lithologies. These rocks rest with profound unconformity upon the old Precambrian granitic basement and now are buried at depths of up to 3,600 m below the surface.

After the Late Cambrian, during the Early and Middle Ordovician Epochs, the sea regressed to the area of the Cordillera, and once again a lifeless desert stretched across the area of the Plains. In the Late Ordovician, the sea again advanced. So widespread was its sweep that it can be said, with slight exaggeration, that the continent of North America ceased to exist for a short time. During this epoch and through much of the Silurian Period, the sea ebbed and flowed across western Canada developing in its warm, shallow bottom one of the world's most extensive blankets of limestone. In Manitoba, the Ordovician portion of this limestone is extensively quarried and sold under the trade name "Tyndall Stone." Many buildings in Canada use it either for construction or facing. The most familiar example is the interior of the Parliament buildings in Ottawa. The rock is distinguished by its mottled appearance. It also has the distinction of being one of the most fossiliferous rocks in Canada. The most apparent fossils are receptaculitids, solitary corals, compound tabulate corals of halysitid and favositid type, gastropods, and nautiloid cephalopods (Nelson 1970).

Petroleum—oil and natural gas—is thought to have been formed by the partial decay and sedimentary burial of water-dwelling microscopic animals and plants. After burial, gentle heat and pressure converted the organic remains into petroleum. This may later have migrated and accumulated in pore spaces of sedimentary rock to form a so-called "oil or gas pool," obviously not a pool at all. Many Ordovician and Silurian limestones exhibit good porosity but, so far, have been disappointing reservoirs for petroleum. Only very small fields have been found.

Biologically, the Devonian Period is very important. This was when the first land plants developed, and shortly afterward, and not without coincidence, the first land-dwelling insects and lung-breathing animals—primitive creatures we call amphibians. These closely resembled modern-day salamanders. Before the plants appeared, there was no incentive for animals to live on land because there was nothing to eat. Although vegetation was probably luxurious in other parts of the world, we have reason to believe that the western Canadian landscapes of the Devonian and succeeding periods, up to and including the Triassic, were rather barren. This is deduced from the relative lack of fossil pollen in rocks of these ages.

Devonian palaeogeography is complex, so much so that many more diagrams than Figures 5 and 6 are necessary for its portrayal. It was during the Devonian Period that potash and salt deposits formed in southern Saskatchewan and rich oil-bearing fossil reefs in central and northern Alberta. These deposits are now of immense economic importance.

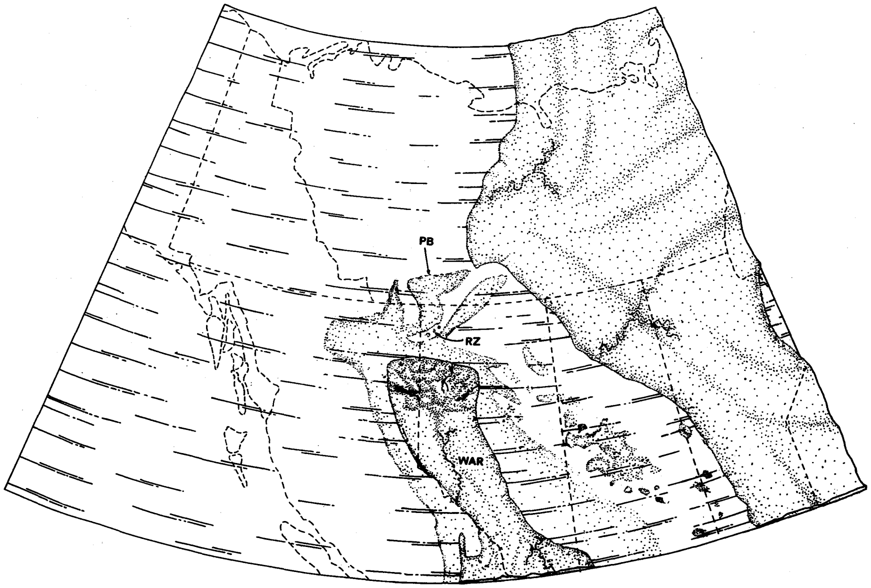

Figure 5. Middle Devonian palaeogeography. This sketch shows the part of this epoch when reef growth was predominant. The position of the eastern shoreline is very approximate. That on the southwest is well documented by drilling and forms the eastern side of a peninsular-like land called the West Alberta Ridge (WAR). A complex system of barrier reefs ringed most of the Ridge. Two large barriers ran northeasterly from the Ridge; the northernmost is called the Presqu'ile Barrier Reef (PB). Except in northwestern Alberta, neither barrier nor patch reefs have *yet* produced any significant amounts of petroleum. The most important producers are the Rainbow Lake and Zama patch reefs (RZ) which appear as small and insignificant specks on the diagram.

Later in Middle Devonian, the Presqu'ile Barrier Reef grew upward rapidly and restricted the flow of seawater causing the formation of evaporites like gypsum, rock salt and potash.

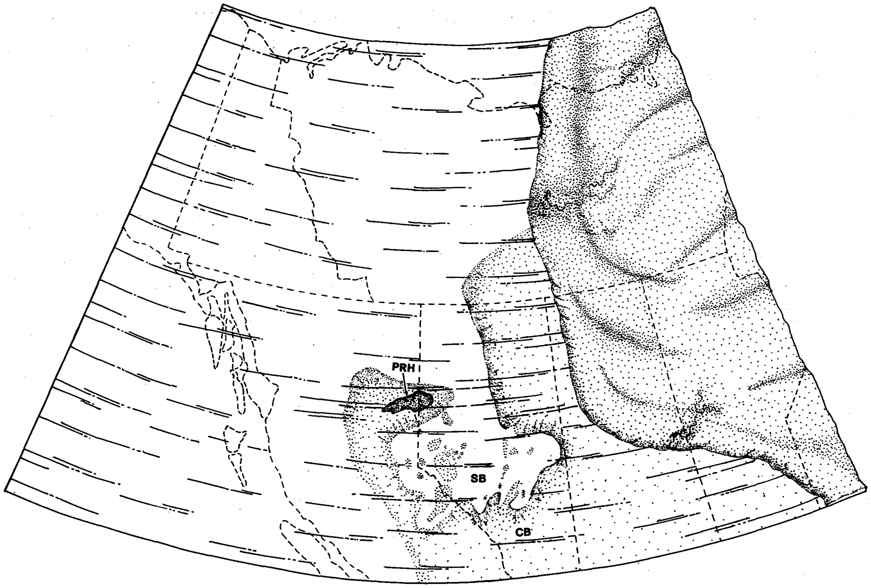

Figure 6. Late Devonian palaeogeography. The diagram shows only one part of this very complex epoch, when reef growth was extensive. Palaeogeographically, the main difference between Middle and Late Devonian is that, in the latter, the sea covered most of the West Alberta Ridge leaving only the northern part exposed—the so-called Peace River High (PRH).

From central Alberta northward the water was relatively deep, with shale being the main sedimentary deposit. This was the so-called Shale Basin (SB). South, west and east of this basin was the Carbonate Bank (CB) characterized by shallow water conditions with carbonates such as limestone and dolomite, along with evaporites. Reef growth may have been extensive in the Bank area occurring both as patch reefs and along its border facing the Shale Basin, as barrier reefs, indicated by darker stippling.

Essentially, three different kinds of palaeogeography occurred during the period, represented respectively by the Early, Middle and Late Devonian Epochs. During the Early Devonian, there was uplift causing the sea to recede from most of the Plains area. Once more a flat barren land was left like that in the Proterozoic to Early Cambrian interval. Geologically, however, the land was different in that the surface rock was not granitic but was limestone that had formed during the preceding Late Ordovician Epoch and Silurian Period. Erosion was extensive and by the end of the epoch most limestone had been stripped from the Plains area to expose basement. Remnants remain in the Northwest Territories and across southern Saskatchewan and adjacent parts of Alberta and Saskatchewan. These latter remnants form what is now referred to as the Williston Basin, so-called because the rocks extend across the border to Williston, North Dakota.

With the coming of Middle Devonian the sea once more crept across the Plains area flooding a basin in which the Elk Point Group of sediments were deposited. Rather than transgressing eastward, the sea moved in as a lobe from the northwest, covering the area shown on

Figure 5. It was not a rapid flooding. At first the sea moved southward to the Edmonton area. It then became very saline, and extensive salt deposits resulted in Alberta, which are now buried nearly 1,200 m below the surface. These are not economic at present. The southward advance then continued until the sea reached the northern United States.

As during Late Ordovician and Silurian time, the waters were warm and tropical, and extensive lime-mud deposition took place, later to form limestone. Two kinds accumulated. One was the normal sedimentary kind resulting from both chemical precipitation and movement and fragmentation of shells by water currents. The other was almost purely organic and was formed largely by enigmatic colonial animals called stromatoporoids. There is not enough space here adequately to define these long extinct animals—indeed some palaeontologists think that they were marine plants. Typically, they are fossils with vague outlines, although some have the shape and size of a cabbage head. Their internal structure of microscopic lamellae and pillars is diagnostic.

Stromatoporoids preferred to live in colonies covering large irregular areas on the old Devonian sea floor and their calcareous skeletons became cemented to each other. New generations grew upon remains of older generations so that a considerable thickness resulted, in some cases up to 300 m. This cementation process caused the formation of rigid structures that are called reefs or, more specifically, stromatoporoid reefs. Two main kinds are recognized. Patch reefs grew over areas a few meters to more than 30 km across. Usually, they have no definitive areal shape, other than subcircular or amoeboid. Barrier reefs may stretch for hundreds of kilometers and have definite lineation. The modern analogue, the Australian Great Barrier Reef, forms a barrier to navigation. Another important feature of these Devonian reefs is that a great deal of pore space exists due to the haphazard way stromatoporoid colonies became cemented together. This may be further increased by dolomitization. The normal composition of a reef is calcium carbonate—usually represented by the mineral calcite. By a process we do not fully understand, magnesium is commonly added to form calcium-magnesium carbonate or the mineral dolomite, which occupies a smaller volume and thus creates more spaces or pores.

On Figure 5, both barrier and patch reefs are shown in the Middle Devonian. Almost all of these might be tremendous reservoirs for oil—so porous and large are they. Yet, the only oil-bearing ones found so far are the tiny patch reefs in northwestern Alberta. These represent reservoirs of the very important Rainbow Lake and Zama oil fields. Saskatchewan and Manitoba have numerous reefs but these have not yet produced.

Toward the end of the Middle Devonian Epoch the northernmost reef, the Presqu'ile Barrier, grew upward so rapidly that it restricted seawater circulating from north to south. As a result, the water south of this reef started evaporating and became very saline. This caused precipitation of "evaporites," in particular potash and rock salt of the Prairie Formation, now the basis of a thriving mining industry in southern Saskatchewan.

At Pine Point Mine, on the south shore of Great Slave Lake, the pore spaces of the Presqu'ile reef contain one of the world's largest accumulations of lead and zinc sulphides. These minerals are thought to have migrated, in saline solution, eastward through the reef to their present position.

In the Late Devonian, the ocean was much more widespread. Figure 6 shows only one interval of this very complex epoch. Uplift in the north spread clay into relatively deep water in northern and central Alberta. This later formed shale and, accordingly, we refer to the area of deposition as the Shale Basin. To the east, west and south, more shallow conditions prevailed with evaporites, limestone, and dolomite being the main deposits. This was the Carbonate Bank. The first name is derived from the major chemical components of limestone and dolomite, calcium carbonate and calcium-magnesium carbonate, respectively. The second comes from the nature of the sea bottom, considered to be shallow and flat, like that of the present Grand Banks of Newfoundland. The Carbonate Bank is potentially an important petroleum reservoir area because it contains porous dolomite structures thought to be reefs. Surprisingly, relatively few wells have been drilled into it. The western part of the bank, in northern Alberta, is called the Grosmont Formation. It is dolomite with dried oil in the pore spaces, but, so far, the oil's dryness has prevented its extraction. The reserves are prodigious—estimates run near 250 billion barrels!

It is in the Shale Basin where the most important events occurred. Here patch reefs developed whose names—like Leduc or D_3, Redwater, Sturgeon Lake, Swan Hills—ring magically in the petroleum geologist's ears. Each of these little reefs, now buried about 1.5 km below the surface, may contain at least $1 billion worth of petroleum. Buried in shales of the Beaverhill Lake and Woodbend Formations, these patch reefs may occur like "plums-in-a-pudding" with no apparent explanation for their geographic position, or they may have linear trends such as those north and south of Edmonton. Indeed, they are so important to Alberta's economy that a large piece of stromatoporoidal reef forms a monument in front of the Institute of Sedimentary and Petroleum Geology in Calgary. A great deal of time and money has been spent in the search for these reefs in the Shale Basin. For no apparent reason almost all appear to be restricted to central Alberta.

During the succeeding Mississippian and Pennsylvanian Periods, seas once more remained over much of western Canada. We know a great deal about the former because the rocks are widespread and many are fossiliferous. The Pennsylvanian, however, is little understood. A great deal of it, in fact almost all of it, appears to have been removed from the Plains area by erosion.

During the Mississippian, marine conditions prevailed across the prairie provinces. A little understood uplift occurred in the northern part of the Canadian Shield. This was eroded to spread sand and silt southwestward into the sea. At first, these sediments reached only as far as northern British Columbia and Alberta but, by the end of the period, they had reached into the United States and pushed the sea out of most of the Plains area. Deposition, resulting in mainly sandstone and siltstone, continued on into the Pennsylvanian, but its record is largely lost from the Plains, except in the Peace River area and parts of the Northwest Territories.

Limestone is the main sedimentary rock type found in the Mississippian, and much of it is of a special type called crinoidal limestone. Stromatoporoids, so dominant in the Devonian, had disappeared. Elsewhere, they lived on until the Cretaceous but never again were they common. The seas were warm and tropical, as in the Devonian, and there is a considerable body of evidence that conditions may have been much like those in the Red Sea today. Stromatoporoids were replaced in importance by animals called crinoids which during this period underwent a population explosion across North America. Crinoids resemble plants and are popularly called "sea-lilies." But they are animals—distant cousins of starfish. Upon death, their skeletons usually disintegrate into small calcite plates to be wafted to-and-fro by water currents, and probably in those days, as today, by periodic typhoons. The result was that almost all trace of the original crinoid was destroyed, leaving only rather large broken fragments of shell which go to make crinoidal limestone. One of the formations in western Canada made of this limestone is about 300 m thick and occupies an area, about 130×500 km, extending from the Rocky Mountains out under the Plains. Assuming that three crushed crinoids make 50 cubic cm of crinoidal limestone, then a population of almost seven billion billion individuals was necessary to produce this limestone! And this formation is only a small part of the total Mississippian in North America made of this type of limestone.

In economic terms, crinoidal limestones are to the Mississippian as stromatoporoid reefs are to the Devonian. These rather coarsely-grained limestones, many associated with oolites and pellets, are commonly porous, showing promise as reservoir rock. Porosity may be further increased by dolomitization. The limestones occur in important fields in the Foothills, but only two areas on the Prairies have yielded significant amounts of Mississippian petroleum. One is the Sundre-Westward Ho! field north of Calgary; the other comprises a number of small fields straddling the southern Saskatchewan-Manitoba border. Among these are the Midale, Frobisher, and Virden fields. Yet, if one includes Foothills fields such as Turner Valley, the Mississippian ranks third in importance, economically, after Devonian and Cretaceous, particularly for natural gas.

For almost 100 million years, from Permian through Triassic, the sea again withdrew from most of the Plains area. And once again it left a flat, barren land, but one now underlain by Mississippian and Pennsylvanian rocks. During this long interval, almost all of the Pennsylvanian was removed by erosion and the Mississippian and Devonian stripped back, with the remnants now mainly confined to the Williston Basin and western Alberta.

The Peace River region of British Columbia and Alberta was the only part of the Plains area to remain covered by the sea. The rocks that accumulated there, particularly during the Triassic, are complexly interlensing and contain almost every sedimentary rock conceivable. Wherever porosity appears in these rocks, the potential for an oil field exists. Economically, the Permian has been very disappointing even though good porosity is present. The Triassic is the important producer, particularly in northeastern British Columbia where it contains most of that province's oil and gas reserves.

Although the distribution of land and sea in the Permian and in the Triassic Periods was similar, there was an extremely great biological difference between the periods. The change in fossil content is so great that the Triassic belongs to a new era, the Mesozoic—the era of "middle life." Familiar Palaeozoic animals, such as crinoids, brachiopods, and tetracorals were greatly reduced in numbers or became extinct. The new marine Mesozoic faunas were dominated by the ammonites and pelecypods (clams). The former are distant relatives of the Pearly Nautilus of today's seas.

On land the changes were less drastic. The rather humble cold-blooded reptiles survived and went on to become the dominant land animals of the Mesozoic. Indeed, this era is often called "the age of reptiles," the most spectacular representatives of which were the dinosaurs. Much more unassuming animals appeared in the Triassic—small, mouse-like, warm-blooded creatures called mammals. These were to occupy a humble ecological niche during the Mesozoic. At the end of the era, with the near-extinction of the reptiles, they went on to become the dominant animals of the Cenozoic.

A time-travelling astronaut would see a great difference in the landscape of the Jurassic Period. Whereas before the Jurassic, it was barren, it was now verdant. This statement is based upon the science of palynology, the study of fossil pollen. Pollen originates from land plants, but often it is blown seaward to settle and mix with marine sediments. In western Canada, sedimentary rocks older than Jurassic contain relatively little pollen, suggesting that lands bordering those ancient seas had little vegetation. Beginning with the Jurassic, and through to the Tertiary, however, the rocks possess abundant pollen, indicating that the land had abundant vegetation.

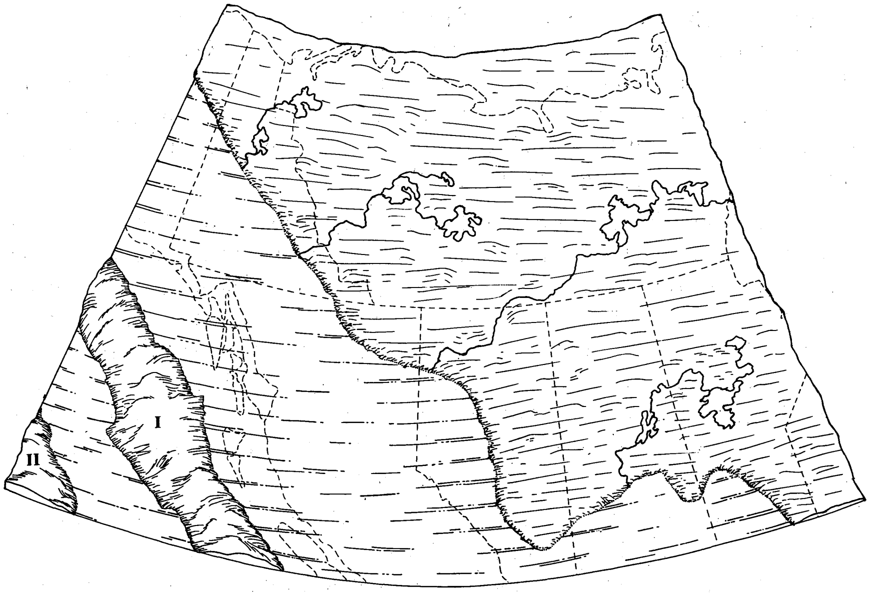

Figure 7. Jurassic palaeogeography. This illustration shows the distribution of land and sea for the later part of the period. On the land, the great difference from previous times was that there was now rather heavy vegetation, portrayed as near-horizontal lines on this and the following diagrams. Two continents, "Terrane I" (I) and "Terrane II" (II), were moving eastward by continental drift towards ancestral western Canada. Collision took place near the end of the period.

Jurassic palaeogeography is complex (Figure 7) and this is reflected in the rock record. Shale is by far the most common sedimentary rock but almost any other kind can be found interbedded and interlensing with it. At first, the seas covered the area of the present Cordillera and lapped across the Plains area of western Alberta to near Calgary and Lesser Slave Lake. During the Middle and Late Jurassic, much of western United States was covered by the Sundance Sea, so-called because the Sundance Formation, named from Sundance, Wyoming, was one of the rock units deposited in it. This sea spread northward into southern Saskatchewan, and almost as far as Saskatoon. It extended into southwestern Manitoba and joined with the western Alberta seaway on the west.

In terms of natural gas and oil deposits, the Jurassic has been disappointing. Because of the complex interlensing and generally porous sedimentary rocks, it might be expected that reservoirs in it would be common. For some inexplicable reason, only two main areas have yielded petroleum and neither produces large volumes. One straddles the southern Alberta-Saskatchewan border with numerous small oil fields, such as Conrad, Gull Lake, and Dollard. The other is about 160 km north of Calgary. Here fields like Gilby and Medicine River produce gas from porous shoreline sands.

The only Jurassic outcrops in the Plains are in southwestern Manitoba. The rocks are mainly gypsum and they are mined for their plaster-of-paris or calcium-sulphate content. Their age is in doubt—some geologists think that they are Triassic.

In order to understand the events that had a profound effect upon the Plains it is necessary to examine the ancestral Pacific Ocean. It has already been noted that geologists now think that much of western British Columbia was a deep-water sea floor receiving few sediments from Middle Proterozoic to Jurassic.

In the past 10 years a considerable body of evidence has accumulated to show that modern sea floors are sliding laterally and that continents may also move with them—the so-called continental drifting. It is believed that similar drifting may have happened in the past. This is the theory of plate-tectonics which regards sea floors like moving plates of rock, sliding over a plastic or liquid substratum.

During the Mesozoic, two continents that had been formed in the ancestral Pacific, began drifting eastward with the ocean floor towards western Canada. These are called "Terrane I" and "Terrane II," each with a very complicated geological history beyond the scope of this article. Instead of also moving eastward with the sliding sea floor, North America remained rigid so that the floor was forced to slide under the continent, down into what is known as a subduction zone.

Near the end of the Jurassic, Terrane I collided with the mass of sedimentary rock that had been accumulating since Middle Proterozoic in the eastern part of the ancestral Pacific (Figure 8). The rocks in the southwestern Yukon, and those in the areas of the present Columbia and Cassiar Mountains of British Columbia, were raised into mountains by this collision. As would be expected, the rocks of Terrane I were also deformed by the extreme forces. This episode of mountain-building, affecting both regions, is referred to as the Columbian orogeny, so named because much of British Columbia was affected by it. The collision and resulting orogeny appears to have occurred in different areas at different times. The main time was late in the Jurassic and continued into the Cretaceous Period.

With the collision of Terrane I the geological framework of modern-day western Canada began to appear. Much of what is now the

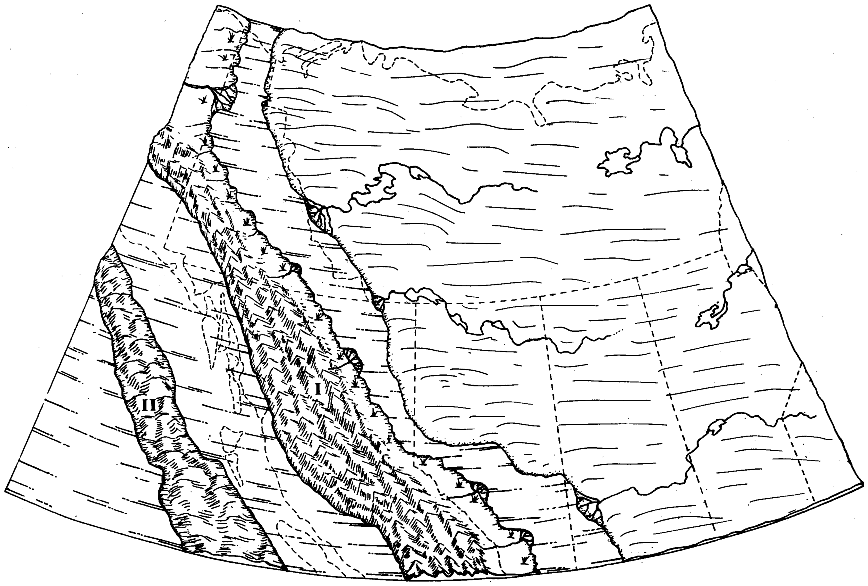

Figure 8. Late Jurassic and Early Cretaceous palaeogeography. This illustration shows two important events. First, Terrane I (I) has collided with ancestral western Canada. Both Terrane I and the western portion of sedimentary deposits that had accumulated along the fringes of the continent were welded together and made into mountains—the Columbian orogeny. Second, the sedimentary blanket derived by erosion of these mountains formed as a narrow coastal plain along the eastern side of the old Columbia Mountains. The rocks of the southern part of this plain now form the important coal-bearing Kootenay Formation.

southwestern Yukon, and much of mainland British Columbia, was mountainous from the Columbian orogeny, and undergoing erosion. The areas of Vancouver Island and Queen Charlotte Islands would not develop until Terrane II drifted into place later, closer to Cenozoic time. The old Columbian mountains had a profound effect on the Interior Plains because products of their erosion, particularly sediments such as sand and clay, were carried east by rivers and deposited as blankets over large areas.

Figures 8 to 10 show only the barest essentials of Cretaceous palaeogeography. Near the end of the Jurassic and continuing into very Early Cretaceous, conglomerate, sandstone, and shale formed on a narrow coastal plain over the site of the southern Rocky Mountains and Foothills (Figure 8). This was a complex of stream, lake, delta, and swamp deposits that now make up the Kootenay Formation. The swamps of Kootenay time were particularly important because they received layer after layer of partially decomposed vegetation that formed carbon-rich peat. After burial and compression by younger sediments, peat eventually became converted to coal to form the rich deposits in the southern Rocky Mountains near Blairmore in Alberta and Fernie in British Columbia.

It is thought that the old Kootenay coastal plain bordered a sea to

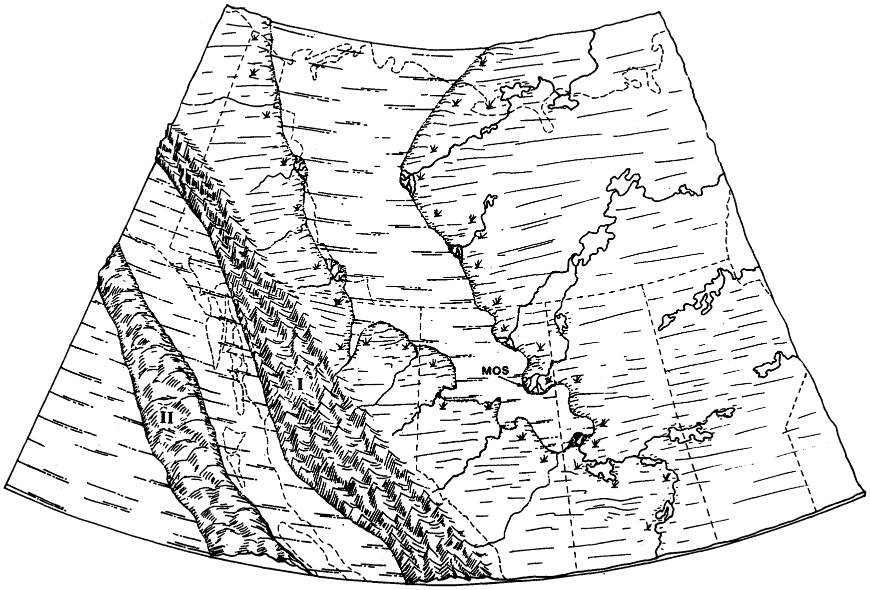

Figure 9. Early Cretaceous palaeogeography. The Columbia Mountains continued to be weathered and eroded. The resulting sediments were deposited as a broad blanket over much of what was later to become the Interior Plains and Rocky Mountains. These were a complexly interlensing series of river, lake and swamp sediments now forming the Mannville Formation. Among the sandstone deltas that developed along the developing sea shore was the reservoir for large quantities of oil, now called the McMurray Oil Sands (MOS).

During these intervals Terrane II (II) is presumed to have continued its eastward drift toward ancestral western Canada.

the east and north as shown on Figure 8. Except in northeastern British Columbia, almost all record of it has been removed by erosion.

The next interval of sedimentation spanned much of the Early Cretaceous Epoch and, geographically, it is completely different from that of the Kootenay. Sometimes it is referred to as Mannville time, so named after the widespread Mannville Formation resulting from this sedimentation. Then, much of the area of the present Rocky Mountains and Plains, and probably the Shield, was covered by a blanket of complexly interlensing sandstone and shale, originally deposited under continental conditions—stream, lake, swamp, and delta. Most sediments were derived from the mountains to the west.

Wherever porosity exists in these complexly interlensing rocks petroleum might be expected to occur. Alberta, south of Edmonton, has the lion's share of fields in the Mannville Formation, but most are small. The Lloydminster field, straddling the Alberta-Saskatchewan border, contains immense quantities of very thick oil, the so-called "heavy oil." It is difficult to extract because it flows so slowly. Someday, when technology is sufficiently advanced to extract it, the prairies will have a very rich resource.

In the north, during Mannville time, a sea began to move south-

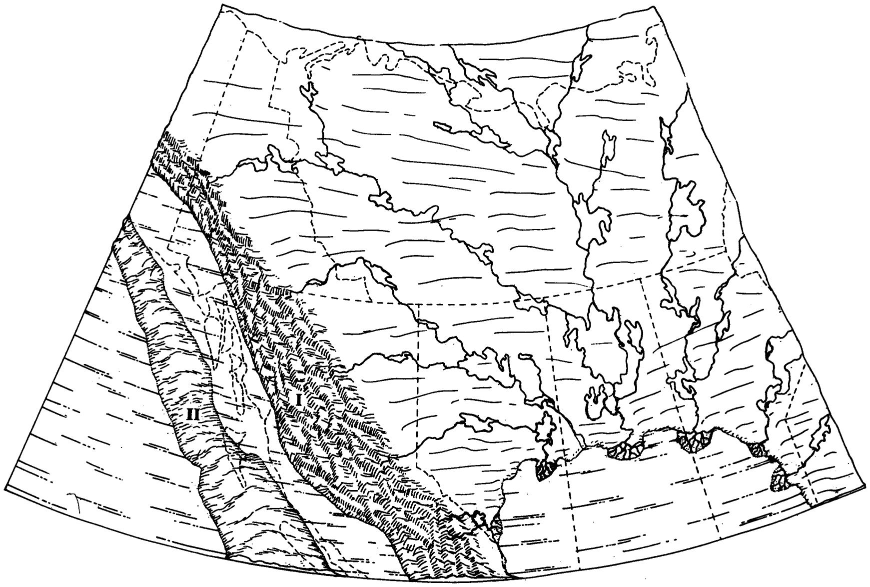

Figure 10. Late Cretaceous palaeogeography. During this time, Terrane II (II) continued to move closer to ancient western Canada. The old Columbia Mountains were gradually worn down resulting in sediments which subsequently shaped the Bearpaw, Edmonton and Paskapoo Formations.

Most dinosaur remains in western Canada date from Bearpaw time, e.g. Brooks and Drumheller areas.

eastward. Near present-day Fort McMurray, a large sandstone delta grew along its eastern shore. The pore spaces of this sandstone now contain huge reserves (some 660 billion barrels) of partially dried oil forming the "McMurray Oil Sands." The origin of this oil is uncertain. Most geologists think that it may have escaped from deeply buried Late Devonian reefs and then migrated laterally eastwards until coming to rest in the Sands.

While this sea advanced southward across Alberta and Saskatchewan, a similar one was moving northward across the interior of the United States. Both joined near the end of the Early Cretaceous and almost completely inundated the interior of western Canada. This was the Colorado Sea, so named from the Colorado Group (for simplicity, the overlying Lea Park Formation is included with the shales of the Colorado Group on Figure 2) because these widespread shale deposits in Canada are lateral extensions of similar shales in that State. For a time during the Early Cretaceous, coastal-plain deposition persisted southeastward from the Peace River area. Some of the old swamp deposits on this plain contain the rich Peace River coal deposits in British Columbia, and those near Nordegg in the Alberta Foothills. The Colorado Sea remained over western Canada during the time straddling the Early/Late Cretaceous boundary (unlike most other periods a Middle Cretaceous division is not recognized).

Locally, Colorado shales contain remnants of buried sandbars that, where porous, may be good reservoirs, particularly for natural gas. Most are in Alberta, south of Edmonton. These include the so-called "Viking fields" in the Early Cretaceous portion of the Colorado, and the Medicine Hat and nearby Hatton fields of Saskatchewan in the Late Cretaceous.

As noted earlier, most of the Colorado Group is shale. The fine-grained nature of this rock suggests that erosion had reduced the old Columbian mountains on the west to rather low hills. For a short time, however, during part of the Late Cretaceous, there was an uplift and sand was spread eastward into the Colorado Sea in the form of beaches and sandbars. The resulting sand bodies reached as far as Calgary and to within about 30 km southwest of Edmonton before pinching out. These sands are referred to as the Cardium Formation because they contain many fossil pelecypods belonging to the genus *Cardium*. About 80 km due west of Edmonton, near the pinch-out area, they become very porous and have yielded tremendous quantities of oil. This is the Pembina field. At the time of discovery in 1953 it was the largest oil field in North America.

At the end of Colorado time, the sea rather suddenly began withdrawing southward from western Canada leaving a coastal plain consisting of sandstone and shale of mixed river, estuarine, swamp, lake, and delta origin. The rocks of this plain are referred to as the Belly River Group. At the time of deposition they formed a widespread blanket across much of the interior of western Canada. Marine deposition, largely shale, continued in southern Saskatchewan and adjacent parts of Manitoba. Of the dominantly reptilian animals that lived along the margin of this plain, dinosaurs were the most spectacular. The Drumheller and Brooks areas of Alberta possess the most complete remains.

Before the sea withdrew from the interior of western Canada, one more northward transgression took place (Figure 10) reaching to the Edmonton area, and perhaps beyond, and westward into what are now the southern Rocky Mountains. Shales of the Bearpaw Formation were deposited in it. Accordingly, we refer to it as the Bearpaw Sea. Near the end of the Cretaceous it retreated southward and, by the beginning of the Tertiary Period, it had crossed the International Boundary and left Canada. During this retreat, widespread continental sedimentation prevailed on the lands bordering the sea, forming the sandstones and shales of the Edmonton Formation, youngest of Cretaceous rock formations. Deposition of the Edmonton continued without interruption into the Paleocene Epoch. Because there is a great biological break, going from the dominantly reptilian dinosaur fauna of the Edmonton into the mammalian one of the Paleocene, the rocks of the latter time interval are given a different name—the Paskapoo Formation.

For nearly 500 million years, from Middle Cambrian to Cretaceous, the Plains area had experienced marine advances and retreats. The retreat of the Cretaceous sea ended this. From now on, continental conditions would prevail.

The Paleocene landscape looked very much like that of the latest Cretaceous. Continental sandstones and shales, mostly derived from the west, blanketed the area occupied by the present Rocky Mountains, Foothills, and Plains: these did not yet exist. The orogeny that developed them was to occur very shortly in the Eocene Epoch. Coal seams, resulting from swamp environments, occur throughout, but the only economic one is in the Ravenscrag Formation near Estevan, Saskatchewan, where it is mined as fuel for the generation of electricity.

As the Paskapoo Formation was being deposited, Terrane II continued its eastward drift toward North America. Indeed, parts of it may have collided as early as the Cretaceous. The time of maximum impact appears to have been during the Eocene Epoch when all of the Cordillera was formed (Figure 11). In the west, the areas of Vancouver Island and Queen Charlotte Islands were created by additions from the Terrane. In the east, this collision resulted in relatively simple folding and faulting. This was when the Rocky Mountains and Foothills were

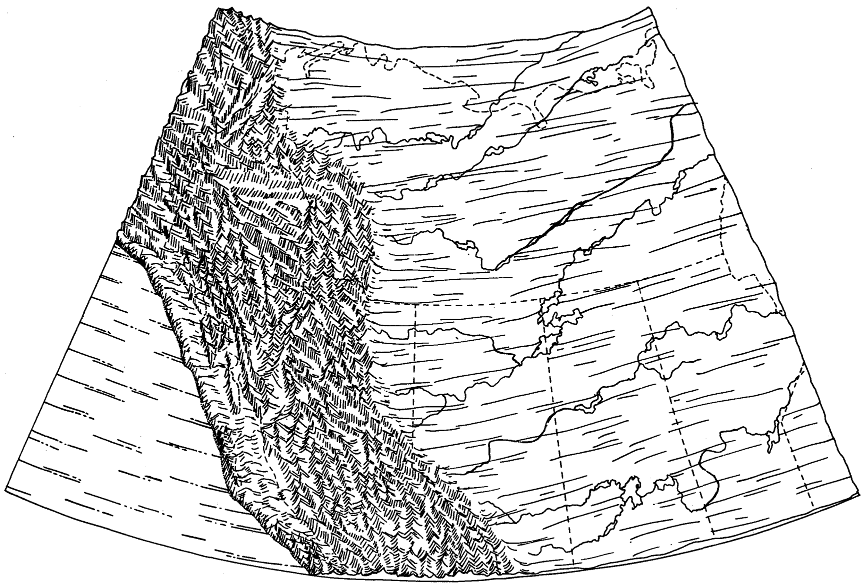

Figure 11. Eocene to Pliocene palaeogeography. Early in this interval, Terrane II collided with western Canada. The compressive forces, called the Laramide orogeny, resulted in the formation of the Cordillera as we now know it. After this orogeny, rivers flowed easterly from the newly-formed mountains and deposited broad blankets of continental sediments. During the Eocene to Pliocene Epochs erosion probably sculpted areas of the west coast of British Columbia, resulting in Vancouver Island and the Queen Charlotte Islands.

made and, in the north, mountain systems such as the Mackenzie and Franklin Mountains. We call this deformation the Rocky Mountain or Laramide orogeny. The latter term, derived from Fort Laramie, Wyoming, is now preferred.

By Eocene time, then, the whole Cordillera had been formed. The mountains of Vancouver Island and Queen Charlotte Islands are part of Terrane II. Most of mainland British Columbia, as far east as the Cassiar and Columbia Mountains, is formed by Terrane I. The sedimentary rocks of these mountains, as well as those of the Rocky Mountains and Foothills, were formed by deposition on the western edge of the old North American continent and are part of the same sedimentary package that exists under the Interior Plains.

With the formation of the Cordillera the stage was set for the final act of the geological drama. Rivers flowed eastward from the newly-formed Rocky Mountains and Foothills carrying sediments such as gravel and sand, and these were probably spread as surface sediments over much of the Interior Plains. Their coarse nature was a reflection of the high Cordilleran landmass to the west. Their ages range from Late Eocene to Miocene—so young as to be barely lithified. During the Pliocene Epoch, uplift replaced deposition and large areas of Tertiary sediments were removed by erosion.

Today, most Tertiary remnants are found in two areas of the Plains. One is in southwestern Alberta where only the Paskapoo Formation remains. Presumably, the younger and coarser Tertiary rocks were completely removed by erosion. The other is across southern Saskatchewan and adjacent parts of Alberta and Manitoba. Most rocks there are also Paleocene and equivalent to the Paskapoo, but go under different names. They make up almost all of Turtle Mountain in Manitoba and, accordingly, are called Turtle Mountain Formation. Across Saskatchewan, including the Cypress Hills straddling the Alberta-Saskatchewan border, they are called the Ravenscrag Formation. Only remnants of the overlying coarse Late Eocene to Miocene gravels and sands remain. Most are found in the upper part of the Cypress hills, and adjacent parts of Saskatchewan.

Towards the end of the Tertiary Period an event occurred that has never been explained satisfactorily—the climate of the earth began cooling, although by only a few degrees. This decrease in temperature was sufficient to cause the accumulation of permanent snow and, eventually, glaciers that moved across almost all of western Canada. This was the "Ice Age" or Pleistocene Epoch. The erosive effects were felt mostly in the Cordillera. During the Tertiary, the mountains were probably rounded as a result of the near-tropical climate. With the Pleistocene, they were scoured and abraded by glaciers, resulting in the common U-shaped valleys, sharp-crested peaks, and deep fiords. The Interior Plains and Canadian Shield, on the other hand, were subject to more of a plastering or subduing effect by deposition of glacial till and lake sediments.

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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

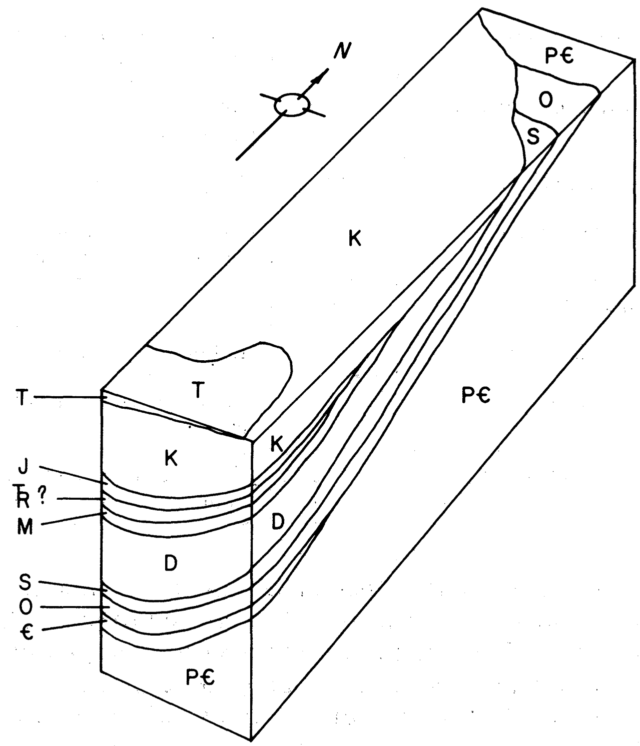

Figure 1. Schematic sections through Williston Basin.

TABLE 1

GEOLOGICAL COLUMN AND RELATED RESOURCES

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
			Pleistocene Epoch		Groundwater; fieldstones; sand and gravel; clay
		Tertiary Period		T	Groundwater; clay; coal; building stone (Alberta Sandstone)
	Mesozoic Era	Cretaceous Period		K	Groundwater; clay; coal; bentonite; volcanic ash; placer gold; oil, gas
		Jurassic Period		J	Oil, gas
		Triassic Period		TR	Except possibly for late Triassic, absent in Williston Basin, which was land
	Paleozoic Era	Permian Period		PM	Absent in Williston Basin, which was land
		Pennsylvanian Period		P	Absent in Williston Basin, which was land
		Mississippian Period		M	Oil, gas, sulphur
		Devonian Period		D	Oil, gas, sulphur; limestone; salt and potash in Prairie Evaporites
		Silurian Period		S	————
		Ordovician Period		O	Building stone (Tyndall stone)
		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,

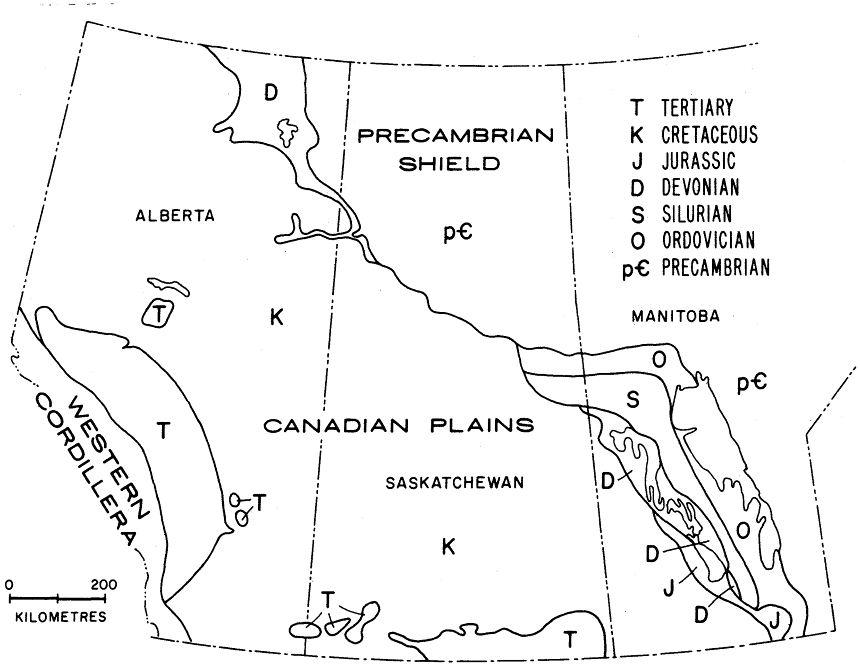

Figure 2. Bedrock geology of the Canadian Plains. Modified after GSC map 1250A.

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 south-eastern 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,

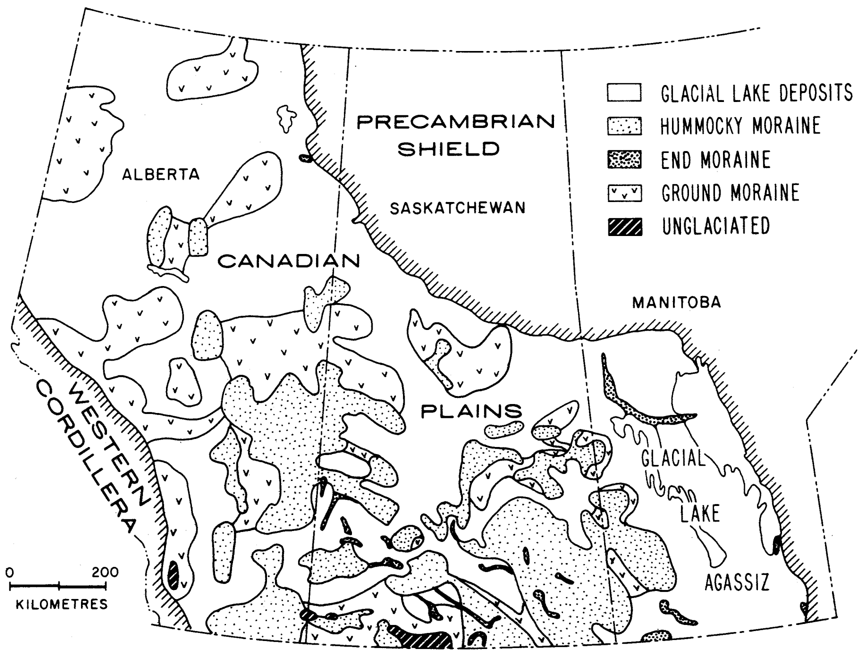

Figure 3. Surficial geology of the Canadian Plains. Modified after GSC map 1253A.

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 readvances, 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, nonfissile 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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Human Aspects of the Canadian Plains Climate

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ABSTRACT. This article discusses the climate of the Canadian Plains region as both resource and constraint. Adaptation to the prairie climate has been aided by improved weather information. This is especially true of agrometeorology. The impacts of weather and climate on non-agricultural activities have received less attention. Some climate-related issues of current concern include the hazard of severe thunderstorms and snowstorms, efficient energy use, air quality, and climatic change.

RESUME. On peut considérer le climat des Plaines canadiennes comme une ressource et comme une contrainte. Les progrès en météorologie ont facilité l'adaptation au climat de la région. L'agrométéorologie est particulièrement importante, ce qui fait qu'on a moins tenu compte des effets du temps et du climat sur les autres secteurs d'activité. On s'intéresse présentement à des questions connexes, telles que le danger d'orages et de tempêtes de neige, les économies d'énergie, la qualité de l'air et les changements climatiques.

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The climate of the Canadian Plains region may be viewed validly as an important natural resource, but it also imposes some significant constraints. The purpose here is to illustrate some of the interactions between climate and human activity on the Plains, interactions which emphasize the regional climate both as a useful resource and as a constraint or even a hazard.

The promotion of the Canadian Plains for agricultural settlement, which reached its peak with Clifford Sifton in the late 1890s and early 1900s, was based on the view of the regional climate as a valuable resource. Such a view was not universal. Forty years earlier, James Hector of the Palliser expedition had concluded—from flimsy evidence and without having visited the area—that a portion of the "American desert" extended into the Canadian Plains (Warkentin 1964). The report of the Palliser expedition concluded that agricultural settlement would be limited essentially to the "fertile belt" of the aspen parkland. Hector described the area south of the "fertile belt" as "arid country" and caused the term "Palliser's Triangle" to be applied to it. He wrote that "... the arid country is a triangular region, its apex reaching to the 52nd parallel, while its base, applied along the 49th, extends between long. 100° and 114° W", and that "... the arid district, although there are many fertile spots throughout its extent, can never be of much advantage to us as a possession" (Warkentin 1964). Henry Youle Hind, of the 1857-58 Canadian expedition, essentially agreed with this appraisal, describing that part of the Canadian Plains west of the Missouri Coteau "... from the character of its soil and the aridity of its climate ..." as "... permanently sterile and unfit for the abode of civilized man."

The shift towards a more favourable view of the climate of the Palliser's Triangle came largely as a result of the writings of John Macoun, the botanist who accompanied Sandford Fleming on his railway surveys of the plains in the 1870s. With as few weather observations as had been available to Hector and Hind, and without seeing the lands south of the South Saskatchewan, Macoun produced a much more favourable report in 1880. In 1879, he had visited the area southwest of Saskatoon which Palliser had reported to be arid in 1858, but it was wetter in the later year, and Macoun thought that the region was mostly suitable for agriculture. Macoun's report was optimistic, considering that he based his view partly on the excellent report by George Dawson of the 1873-74 49th Parallel survey, which took an intermediate position on the Palliser's Triangle (Warkentin 1964):

> ... it would appear at least doubtful, whether the rainfall over much of this region is sufficient for the maturing of crops.... At the same time... this country, formerly considered almost absolutely desert, is not—with the exception of a limited area—of this character;... a part of it may be of future importance agriculturally, and... a great area is well suited for pastoral occupation and stock farming.

This emphasizes the point that appraisal of a regional climate is crucial to human interaction with it. The first instrument observations of the climate of the Canadian Plains region were those of the Hudson's Bay Company (HBC), which began in the late eighteenth century (Catchpole 1980). These observations were intended by the Company to provide information useful to the conduct of the fur trade, while observations in the late twentieth century are designed to fulfill the needs of a much broader range of human activities. On the Canadian Plains, agriculture is the most important of these.

The early observations of the HBC in Rupert's Land were taken in northerly latitudes and in low-lying areas along major rivers and lakes, where the frost-free season might be expected to be short and where spring arrives late. In addition, the period from the seventeenth to the early nineteenth centuries, during which the HBC is almost our only source of direct information about the region's climate, is widely acknowledged to have been cold. Indeed, it has often been called the "Little Ice Age." It is not surprising, then, that the HBC for many years viewed Rupert's Land as being climatically unsuitable for agricultural purposes.

The impressions which American ranchers had of the Canadian Plains climate a century later appear to have been very different from those of the HBC. The ranchers ranged cattle north of the 49th parallel, in what is now southern Alberta and southwestern Saskatchewan, from the 1870s to the turn of the century (Evans 1979). Their use of the Canadian prairies differed significantly in time and space from that of the HBC. With its relatively frequent chinooks and generally thin snow cover, this southwestern region of the prairies was regarded as relatively benign until the disastrous winter of 1906-07. The heavy snowfall, severe cold and long duration of this winter decimated the cattle on the southwestern prairies and effectively ended American interest in the ranching industry there.

In more recent times, our knowledge of the Plains climate has increased rapidly, and a large proportion of the meteorological research on the Canadian Plains has been directed for the benefit of agricultural endeavours. This has allowed farming and ranching to adjust more appropriately to the nature of the regional climate. Much work remains to be done in the climate field, however, both in agriculture and in other areas. The development of appropriate building technology and measures to control atmospheric pollution on the prairies are two examples. This article considers a number of broad climatic themes in the human occupation of the Canadian prairies, but first a brief summary of the chief characteristics of the prairie climate is needed.

The Climate of the Canadian Plains

For a detailed discussion of the regional climate the reader is referred to Longley (1972). The prairies have a continental climate which grades from sub-humid to semi-arid and from warm summers and cold winters to cool summers and bitterly cold winters. In essence, the climate is that of the interior of North America—a climate of extremes, a climate which may present the farmer with a bountiful crop one year and next to nothing the year after, a climate which features both "normal" and "abnormal" years or seasons with about equal frequency, and a climate which encompasses the pleasures of low humidity, Indian summer, plentiful sunshine and timely rains along with occasional disasters by drought, flood, hail, blizzard and windstorm.

In terms of major climatic controls, continentality, latitude, and the presence of the Cordillera to the west must all be recognized. Nevertheless, the Pacific is the dominant source of moisture for the region's precipitation; only in southern Saskatchewan and southern Manitoba are incursions of humid Gulf of Mexico air of any real significance. The location of the region relative to North American "storm tracks," or low-pressure system passages, is crucial in this regard (Figure 1). In summer, these lows frequently move across the Canadian prairies, and thus summer is the wet season. In winter, they usually pass further to the south, across the American Great Plains, giving dominantly northerly winds and cold, dry air to the Canadian prairies. Clearly, southerly regions of the Canadian Plains will experience more frequent mild spells in winter and hot spells in summer.

The region's general location relative to mean frontal positions is a factor contributing to great seasonal and year-to-year variation.

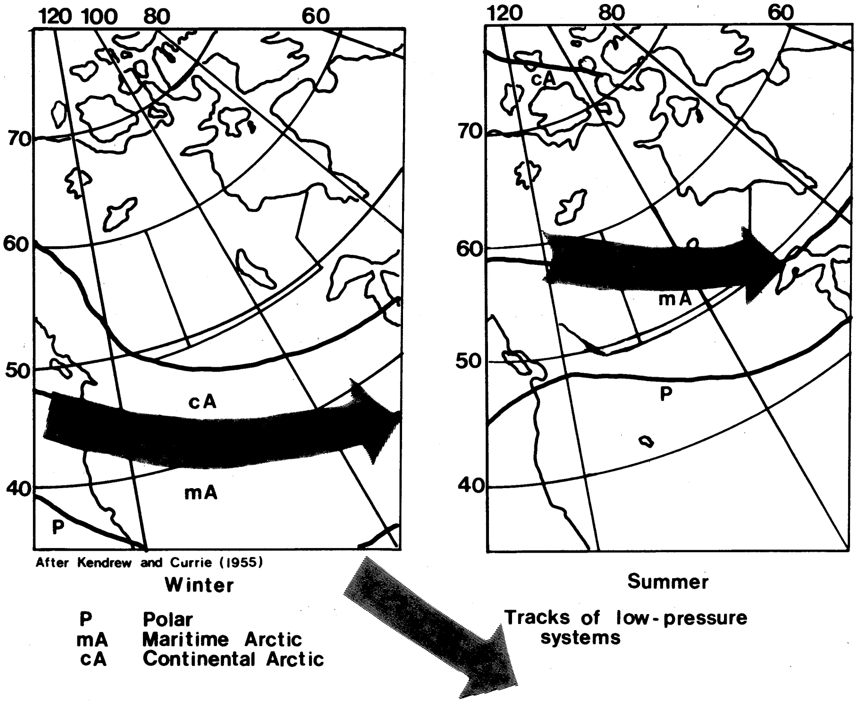

Figure 1. Mean positions of frontal zones and low-pressure system tracks

An extreme illustration of this is provided by comparing the winters of 1972-73 and 1973-74 on the southern prairies. At Regina, December 1972 was 5°C colder than the 30-year normal for 1941-70, while January and February 1973 were 7°C and 4°C warmer than their respective normals. By the end of January 1973, frequent thaws had reduced the depth of snow on the ground to 5 cm. In contrast, while December 1973 was a little warmer than a year earlier—although still 2°C colder than normal—January 1974 was 4°C colder than normal and had 38 cm of snow on the ground at the end of the month. Sales of snow-shovels were up considerably.

Climate as Resource and Constraint for Agriculture

In most years on the Canadian prairies, the light, heat and water requirements of a range of crops are met. Plant breeding for faster-maturing or drought-resistant varieties has made crop production increasingly more reliable. In a good year, timely rains in spring and early summer and a dry harvest period without early frost contribute to bumper crops of wheat and other grains. More complete climatic information and the findings of research into prairie agrometeorology have helped to increase the volume and stability of farm production.

Nevertheless, climatic hazards remain. Droughts, farmland flooding, hail, and frost can all cause serious damage. The 1980 drought in Manitoba and Saskatchewan caused a loss of agricultural income of about $1 billion (Fraser 1981). In 1974 excess water on the land from spring rains and late snowmelt delayed seeding on many parts of the prairies and in the fall significant damage was then done to the crop by frost. Hail damage is much more geographically scattered than drought or frost damage, but its total is less variable from year to year. It consistently reduces the prairie crop by 2 to 5 percent. Heavy snowstorms cause losses in the ranching industry, as happened in southern Alberta in 1967 (Janz and Treffry 1968).

Work continues on improving the response to these hazards. The demonstrations of 1976, 1977 and 1980 that drought is still a major threat on the prairies (McKay 1981) have led to a renewed thrust by the Prairie Farm Rehabilitation Administration (PFRA) on drought-related studies.

Drought conditions are very difficult to define. Witness the confusion wrought by the federal support programmes of 1980, which were to be limited to farmers who had received less than 60 percent of normal precipitation between 1 November 1979 and 31 May 1980. The "60 percent line" turned out to be difficult to draw on the map, and the administration of the programmes became a major headache. In any case, drought is a matter of degree; 62 percent and 58 percent are not much different. Even in a "normal" year, crop yields over most of the prairies fall below levels attainable were optimum amounts of water available.

This characteristic "moisture deficit" situation was recognized at an early stage in prairie settlement and led to the development of irrigation enterprises before the end of the nineteenth century. Even so, the extension of irrigation agriculture on the Canadian Plains has fallen short of many expectations. Only in southern Alberta has it grown to dominate the landscape of a large area of the Canadian Plains. This development took place because of readily available water supplies from rivers rising in the Rocky Mountains and their foothills, and because of the efforts of a number of irrigation pioneers. Much of southern Saskatchewan was just as dry, and its soils were broadly similar, but adequate supplies of water to irrigate large areas were unavailable. Also the first quarter of the twentieth century had generally favourable climatic conditions for grain farming. Even when moisture deficits turned into droughts in the 1930s, the depressed prices of farm products and the rapid improvement and implementation of dryland-farming techniques militated against rapid expansion of irrigated area, with its accompanying high capital costs.

The impact of drought on farmers and ranchers may reach far beyond the reduction of crop yields. Such problems as water-supply shortages and a greater susceptibility of pastures to lightning fires

(Rowe 1969) may also arise. These examples relate to drought but they illustrate the wide range of constraints that many elements of climate may place on the prairie agricultural sector.

Agrometeorology has been an important contributor to increased stability in farm production from year to year. New farming techniques and varieties of plants, improved knowledge of yield-weather relationships, the beginnings of specific farm weather forecasting, and increased awareness of the relations between weather and such farm operations as seeding, harvesting, and spraying have all helped. Weather-related crop losses are still significant, however, and crop insurance remains a vital input for most prairie farmers.

Climatic Impacts Outside Agriculture

The dominance of agriculture in the overall economy of the Canadian Plains region has been reduced considerably since the 1940s. Mineral resources and, to a lesser extent, those of the forest, have been increasingly utilized. A manufacturing sector of modest proportions has also emerged. The regional population has grown, and has become more urbanized. In the 1981 Census, the farm population represented only 10.6 percent of the total in the prairie provinces. Dramatic shifts in demands for energy production and distribution, transportation, water management, and recreational opportunities have accompanied these changes. The regional climate is a variable which has to be kept in mind in meeting these demands.

The long-distance transmission of electricity at very high voltages to supply the power needs of major towns and cities is now common practice. On the prairies, transmission facilities can be constructed without designing into them as much resistance to ice storms as in southern Ontario or southern Québec, where the ice-accumulation hazard is considerably greater (Chaîné *et al.* 1974). On the other hand, lightning strikes to the transmission facilities are a great burden to electrical utilities on the prairies (LaDochy and Annett 1983).

The two westernmost prairie provinces are rich in fossil fuels, and the majority of their electricity generation equipment uses these sources; Manitoba relies more on hydro-electricity. The heating of buildings, at least in the villages, towns, and cities, is largely accomplished by burning natural gas, most of which comes from Alberta and western Saskatchewan. In this region of continental climate, both the electrical and natural-gas distribution systems must be capable of meeting occasional massive peak demands resulting from extreme cold accompanied by strong winds. This requires the provision of an energy capacity in the systems which is utilized only rarely. This is especially true of the natural-gas system; extreme electrical demands may often be met through judicious use of the prairie supply by tie-in of the distribution grid with those of neighbouring provinces or states. Manitoba experienced serious losses of revenue from diminished hydropower generation resulting from low streamflow in the 1980-81 drought (Fraser 1981). Normally the province exports electrical power, but in this case the situation was reversed.

Transportation on the Canadian Plains is a beneficiary of the relatively dry climate. Heavy fog and severe snowstorms, both of which cause serious problems for air and road transport, are infrequent. Spring break-up is perhaps the most difficult time in terms of climate, as many highways and rural roads are subject to load limitations for a number of weeks. In a wet spring following a winter of exceptionally heavy snowfall, washouts of road and railway grades may be very common, as was the case in April 1974. Heavy summer rains may have the same effect. On the southern prairies the winters of 1964-65 and 1973-74 were unusually snowy and resulted in haphazard, irregular service along many of the railway branchlines.

Water supply takes on a special significance in a sub-humid area such as the Canadian prairies. Its importance in an agricultural context has already been mentioned. But large quantities of water—of differing degrees of quality—are also required for oil extraction, power generation, industries, and municipalities. Indeed, some observers have gone so far as to say that in southern Alberta and southern Saskatchewan water shortages for these purposes loom ominously in the near future, and that the only real solution is the long-distance diversion of water from the northern basins of the prairie provinces.

In 1950 came a dramatic reminder that the Plains climate produces water excesses as well as shortages. The Red River Valley flood of that year did damage estimated at $100 million (in 1950 dollars) and took two lives (Boughner 1950). The ultimate response to that episode was a major investment in flood-protection works. Winnipeg is the only one of the five large prairie cities to be located entirely on floodplain land and merits the application of such expensive protective measures. However, the nature of the regional climate coupled with the affinity of prairie dwellers for flood plains produces a considerable flood potential. Carman, Weyburn, Moose Jaw, Lumsden, Swift Current, Vegreville, Whitecourt, Peace River and Fort McMurray are a few of the smaller cities and towns that have experienced serious flooding in recent years.

As in other parts of inland Canada, much outdoor recreation in the prairie provinces is based on lakes. Climatic fluctuations produce great variations in lake levels, variations which may be ecologically desirable but which are unpopular with most recreational users. Along the lakes of the Qu'Appelle chain in 1974-75, high water levels and accompanying ice eroded cottage lawns and destroyed boathouses. At numerous lakes in central Alberta, the problem in the 1960s and 1970s was one of declining water levels. In semi-arid western Saskatchewan, even bodies of water no bigger than large ponds may be used for summer cottages. Small and large reservoirs are often used for recreation, but in a region of hot summers and scarce surface water, problems of quality, and of water-level fluctuations associated with draw-down for irrigation and municipal supply, arise.

Elements of the Plains climate have an important impact on wildlife. Fish, deer and waterfowl populations are significant components of the recreational experience for many prairie residents. Very hot weather in southern Manitoba in July and August 1983 produced a large fish kill on Lake Winnipeg in mid-August which was very detrimental to lake recreation. Deer populations in the southern prairies were greatly reduced in the long cold winters of 1973-74 and 1978-79. Waterfowl habitat is strongly affected in amount and quality by precipitation over the previous 18 months. Breeding success is much greater when water levels in sloughs are at above-normal levels. Important losses of ducks and upland game birds may result from severe hailstorms, as in two Alberta storms of July 1953. These storms were estimated by Smith and Webster (1955) to have killed between 64,000 and 148,000 waterfowl.

As elsewhere, climate is a force to which man has had to adapt, perhaps more carefully in the Plains than in many other parts of the world. The desirability of continued improvement in this adaptation is evident in some of the climate-related issues which have come to the forefront in the past decade.

Current Concerns

Some present-day concerns relating to the climate of the Canadian prairies include severe storms, increasing energy efficiency and air pollution. The southern Manitoba blizzard of February 1984 stimulated memories of the epic blizzard of January 1975 (Babin 1975), providing a grim reminder that even in mild winters such as that of 1983-84, the weather of the Plains can be unforgiving of carelessness. Blizzards are severe weather phenomena that are usually synoptic in scale, but sub-synoptic summer storms on the prairies can be devastating also. The extension by the Atmospheric Environment Service (AES) of its Severe Weather Watch programme to Saskatchewan in 1980 coincided with an increasing awareness on the part of the Saskatchewan media and public that summer storms can be dangerous. Table 1 illustrates a sampling of severe thunderstorm events from 1979-83 and verifies that there is cause for concern. The establishment of weather radar by the AES at Broadview and Elbow in the early 1980s has already enhanced the forecasting of thunderstorms in Saskatchewan. As can be seen from Figure 2, these radars, coupled with the American radar at Williston, N.D., provide coverage to several of Saskatchewan's larger cities. A level of service that was already present

TABLE 1

SELECTED SEVERE THUNDERSTORM EVENTS ON THE PRAIRIES, 1979–83

Date	Event	Location	Damage and Casualties
8 August 1979	Hailstorms	Saskatchewan	$25-30 million; worst single-day crop-hail loss in 1970s
	Two tornadoes	Regina	$8 million; many minor injuries
25 May 1980	Thunderstorm winds, 2 or 3 tornadoes	S Saskatchewan SE Alberta	Power lines, roofs damaged; ice rink and barns destroyed
14 July 1981	Heavy rain	Edmonton	Four deaths in flooded sewer system
28 July 1981	Golfball-size hail, lightning	Calgary	$125 million; 2 lightning deaths
1 July 1982	Heavy rain, hail	Lethbridge and area	Flooding, $5 million crop loss
16 July 1982	Tornado	nr. Portage la Prairie	Damaged buildings, downed trees
	Hailstorms	S Manitoba	Severe crop damage in many areas
23 July 1982	Heavy rain	Emerson	81 mm in 75 minutes; flooded basements, damaged crops
24 June 1983	Heavy rain, hail	Edmonton, Saskatoon	Severe flooding; two drownings
	Tornado	nr. Lloydminster, Alberta	Heavy damage to several farmsteads
8-9 July 1983	Heavy rain	Regina	Severe flooding; $10 million est.

Sources: Blair 1983; newspapers; *Canadian Weather Review*.

in Alberta and Manitoba is now available in all three prairie provinces. However, the disastrous urban flooding that resulted from thunderstorms in 1983 indicates that weather radar alone cannot prevent multi-million dollar storm damages. The deaths that resulted from thunderstorm floods in Edmonton and Saskatoon on 24 June 1983 demonstrate that good forecasts by themselves are not enough. Public awareness of the very real dangers posed by flash floods needs to be increased. The design capacities of urban drainage systems may also need to be re-evaluated.

The tornado hazard on the prairies has received a lot of attention in recent years. The Aubigny disaster in the Red River Valley in June

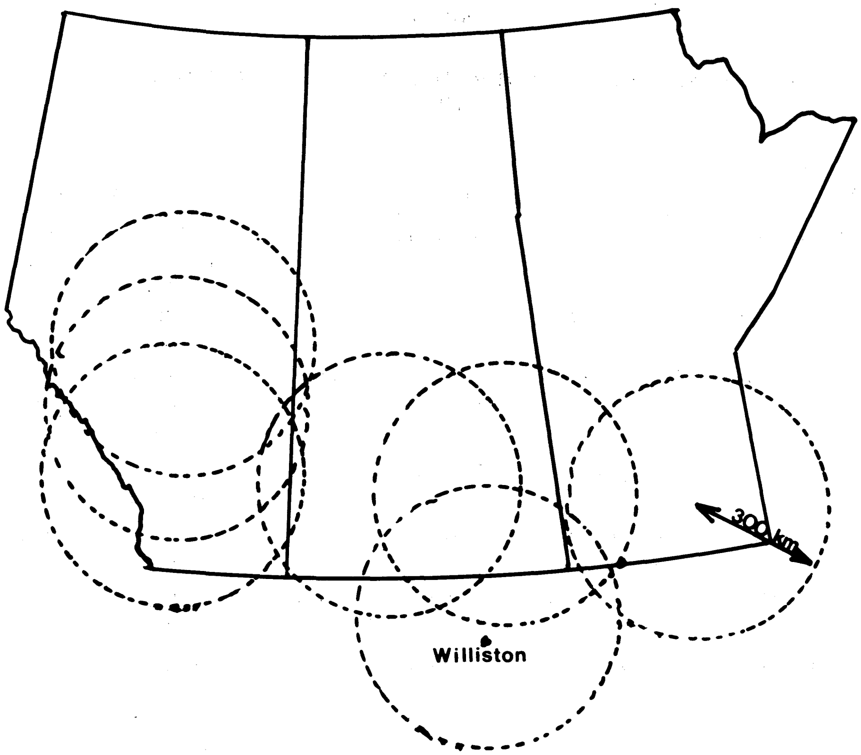

Figure 2. Current weather radar coverage on the prairies

1978 (two deaths, thirty houses destroyed or severely damaged) and the near miss of 8 August 1979 in Regina ($8 million damage, miraculously no serious injuries), following so closely on the heels of the Woodstock, Ontario tornado tragedy of two days earlier, put the message over. The Canadian Plains are overwhelmingly areas of sparse population in which tornadoes usually touch down on open fields and trees. But as our population has grown more urbanized, the chance of a major disaster may have increased. The strong tornado near Blackfoot and Lloydminster, Alberta, on 8 July 1983 undoubtedly would have produced casualties in an urban area. In June 1912 Regina experienced the greatest single-tornado death toll, 30, recorded anywhere north of Nebraska. From Manitoba to Alberta, the tornado is an infrequent but very real threat.

The greatest dollar losses in prairie thunderstorms result from hail. Large urban centres on the prairies are few and far between, but grain crops are widespread. Major hailstorms in cities hit the headlines (Table 2), but it is in the farm fields that they do the most damage. Fully 3 to 4 percent of the prairie grain crop, worth more than $100 million, is lost to hail in an average year. Small wonder, then, that hail insurance is regarded as a necessity by many farmers, and that hail sup-

TABLE 2

SELECTED MAJOR HAILSTORMS IN LARGE PRAIRIE CITIES

Date	Location	Damage
4 August 1969	Edmonton	Many million dollars, south and northeast Edmonton
11 July 1978	Yorkton	$1 million, to roofs, siding, windows, windshields
28 July 1981	Calgary	$125 million; most costly hailstorm ever on prairies
11 August 1982	Saskatoon	$6 million, eastern Saskatoon
14 August 1982	Prince Albert	Two hailstorms in one day. Baseball-size stones, total damage including local crops $10 million

Sources: Blair 1983; newspapers.

pression has been a long-pursued goal in central Alberta, where damaging hailstorms are as frequent as anywhere in the world. Here a major hail-research project, begun in the mid 1950s (Douglas and Hitschfeld 1959), evolved into an important cloud-seeding operation in the 1970s (Alberta Research Council 1979), and continues to the present day.

The topic of cloud seeding leads to thoughts about water shortages on the prairies. Adequate water supply is a recurrent concern, particularly in the drier grassland areas. Homeowners like their lots to look as green and well-watered as those in Vancouver or Ottawa, and almost everyone likes green parks. High summer temperatures cause water-quality problems in small surface reservoirs, and often result in water rationing in small urban communities (Gerhart 1982). Even Regina and Moose Jaw are dependent upon a shallow lake for most of their municipal water, a situation which often results in taste and odour problems in late summer.

Future industrial development in some parts of the region, especially of coal and oil-shale resources, is expected to require more water than can presently be supplied. Whether the answer lies in long-distance water diversions, with accompanying ecological impacts and opposition in source regions, or in better conservation of existing supplies—or both—is a matter of controversy at present, especially in Alberta.

The "energy crisis" of 1973 contributed to a growing debate on the Plains, as elsewhere, over the adoption of more appropriate building technology and the wider use of alternative energy sources, such as solar and wind power. There is little doubt that residential energy consumption can be reduced by more effective application of existing knowledge of building climatology. Experimentation with solar and wind energy conversion has revealed many pitfalls as well as advantages, and it seems that widespread use of solar heating systems on the prairies is not likely in the near future.

Improvements are being made through the use of more and better forms of insulation. A house with a well-insulated attic is cooler in summer and warmer in winter. Building climatology suggests that other basic points such as the most energy-efficient orientations of standard house designs should be adopted. In a single subdivision there are often many houses of the same design but oriented in various directions, only one of which is optimal from an energy point of view. A house on the prairies with its large "picture" windows facing north loses the benefit of a considerable amount of solar radiation in winter, loses more heat in northerly wind situations, and uses more electricity for lighting also. Some house designs also appear to maximize the surface area of walls and roof, through which heat loss takes place, for a given floor area. I am not suggesting, of course, that everyone should live in a "box" or "square" house, in row housing, or apartments, but merely that these various climatological considerations should be taken into account more often than they seem to be.

Any part of the world with cold winters and a long period of snow cover is likely to have frequent ground-level temperature inversions which provide potential for air pollution. The Canadian prairies are certainly typical in this regard. Traditionally the region has been regarded as one with very clean air. But rapid urbanization and the large-scale exploitation of fossil fuels over the past 35 years have raised some concerns. LaDochy *et al.* (1976) pointed out that the air in Winnipeg is surprisingly dirty at certain times of the year. Shewchuk (1981) and Hammer (1980) noted that acid rain is falling in northern Saskatchewan. Calgary and Edmonton certainly have air-pollution potentials that must be regarded as incipient problems. Ice fogs have become more frequent in recent years. Voldner *et al.* (1980) show that there are major sources of sulphur dioxide at Thompson, Manitoba, at Fort McMurray and in the sour-gas processing plants of central Alberta and northeastern British Columbia. The detrimental impacts of emissions from sour-gas plants on the forests of the Whitecourt area have been documented by Legge (1980).

While air pollution may well be one of the "sleepers" as far as climatic problems in the prairie region are concerned, climatic change, a much more dubious feature and one very difficult to convincingly document, has been given far more play by scientists and by the media. The northern edge of prairie agriculture marks the limit of commercial grain production in North America. If the prairie climate should become a little warmer and drier, as some of the proponents of the "greenhouse effect" suggest may happen, then shortages of precipitation may become an even more limiting factor to crop growth in the region than they are now (Hare 1981). A few years ago, on the other hand, there was a speculation that a cooling trend was on the way and that the marginal climate of the Peace River district would invade the southern prairies. Crops would freeze rather than fry. Realistically, nobody knows the answer to these questions. What is "climatic change" and what is "fluctuation within the bounds of current climate"?

Conclusion

The Canadian Plains climate can be viewed validly as both a resource and a constraint. We should never lose sight of the necessary balance between these two opposing viewpoints. Nor should we forget that agricultural production, the mainstay of the prairie economy, depends on a lot more than just climate. The state of the Canadian economy, soils, water supply, government policies, and the unpredictable vagaries of international markets for farm products are all crucial components of making a living in our region. Climate provides a backdrop to all this; against this backdrop we make choices about our activities. Even if climate changes, the element of human choice will still remain. Viewed as a resource, our climate should not be a limiting factor in the foreseeable future as long as we respond and react rationally to it.

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The Soils of the Interior Plains of Western Canada

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ABSTRACT. Hundreds of different soils occur in the interior plains of Western Canada due to considerable variation in six soil forming factors. In their virgin state these soils varied greatly in their agricultural potential. Man's use of those soils has had some dramatic effects upon them.

RESUME. Dans les plaines intérieures de l'Ouest canadien, des variations importantes des six grands facteurs de formation des sols ont eu pour résultat la présence de centaines de sols différents. A l'état vierge, leur potentiel agricole variait considérablement, et leur exploitation a quelquefois eu des effets d'une très grande portée.

INTRODUCTION

Man's environment comprises several groups of natural objects, namely rock, water, air, organisms and soil. Few people would rank soil in a category equivalent to the others. Furthermore, there are many concepts of soil. Some view it simply as crushed rock, some think it is an organic layer on the earth's surface, some believe it is the surface layer which farmers cultivate and others define it as a plant-growth medium. Geologists and engineers describe soil as "... all the fragmentary material in the earth's crust overlying bedrock, with the possible exclusion of the thin layer of topsoil..." (Legget 1961). Not only are there several concepts, but the words dirt, earth, land and ground are frequently used synonymously with soil. To make the subject even more vague, soil is also used as a verb meaning "to make unclean," no matter what the defiling substance!

Part of the ambiguity is because soil exists as a continuum, not clearly distinguishable individuals. While the lateral boundaries between soil and not-soil (rock, water) are usually distinct, individual soils (called pedons and having minimal dimensions of length, width and depth) grade almost imperceptibly from one to the next. The lower boundary, separating soil from lithosphere, may be equally indistinct and very dependent upon definition.

Given this ambiguity, a clear, yet succinct, definition of soil has eluded soil scientists. Two North American glossaries (Soil Science Society of America 1971; McKeague 1976) each gives two definitions, paraphrased slightly as follows:

1. The unconsolidated material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.
2. The naturally occurring, unconsolidated material on the surface of the earth that has developed over a period of time under the influence of climate, organisms, relief and drainage, on geological material, and that differs from this parent material, from which it was derived, in a number of morphological, physical, chemical and biological characteristics.

The second definition implies that soil is a uniquely developed material. Indeed, it can be viewed as the object occurring at the interface of lithosphere, hydrosphere, atmosphere and biosphere (White 1979).

SOIL FORMATION AND OCCURRENCE

A number of authors (notably Jenny 1980) have written the second definition as a functional relationship:

$$s = f(c, o, p, r, d, t)$$

where s = soil (or a specific soil property), c = climate, o = organisms, p = parent material, r = relief, d = drainage, and t = time.

This relationship implies that a change in any one of the "independent" variables (the soil forming factors) will result in a different soil. While the relationship is not strictly valid because the variables on the right side are not truly independent, it is a useful framework within which to examine the genesis of soils in the Canadian Plains.

Parent Material

The rock material from which mineral soils formed is called the parent material. These underlying bedrocks and surficial deposits have a profound effect upon mineral soils. Since these materials were discussed earlier, only some important associations with soil properties are described here.

Bedrocks influenced Plains soils only indirectly because few soils developed directly on them. Soil texture (proportion of sand, silt and clay) was determined in part by the proximal bedrocks. Granites and sandstone usually resulted in coarser-textured parent materials while shales led to fine-textured ones.

Stoniness of soil can be associated with the nature and proximity of the contributing rock. Many soils in central Manitoba are relatively stony because of proximity of the hard Precambrian rocks and softer Paleozoic limestones. By contrast, more soils in northwestern Alberta, derived from soft Cretaceous shales, are relatively stone-free due to absence of stone source.

The calcium carbonate content of soil parent materials ranged from near zero to at least 60 percent depending largely upon the proximity of Paleozoic carbonates. Soil parent materials were commonly neutral to moderately alkaline but in some localities (for example, near Dauphin, Manitoba, and north of Fairview, Alberta) they were strongly acidic due to oxidation of pyrites contained in them (Dudas 1983).

Many soils, especially in the southern Plains region, are saline and/or high in exchangeable sodium because the underlying shales contain significant amounts of sodium sulphate and other salts (Bowser 1961). Other soils, however, are low in sulphur and selenium, partly because of the character of the source bedrock. Finally, the content of several micronutrients (boron, copper, iron, manganese and zinc) varies several fold in the parent materials of our soils because of their source bedrocks (Pawluk and Bayrock 1969).

These general trends are frequently masked by events occurring during and after the Pleistocene glaciation. Essentially the whole Plains region was covered by glacial ice which obliterated most pre-Pleistocene soils and scoured the underlying sediments and bedrock. When the ice melted it left an unsorted mixture of stones, sand, silt and clay known as glacial till. Tills were derived mainly from local bedrocks (Gravenor and Bayrock 1961) but some components came from distant sources. Glacial tills in the Plains region exhibit marked diversity because of the variations in underlying bedrocks.

Following deglaciation, water and wind caused considerable sorting of the glacial till. Water flowing from the ice carried suspended clay, silt and sand, leaving coarser fragments behind. As the water slowed, the suspended particles settled out sequentially, gravel first and clay last. A classical example of this sequence is found between Brandon and Portage la Prairie. The same processes left large sandy deposits near Whitecourt, Wainwright and Maple Creek, and fine-textured surficial deposits near Regina, Lethbridge, Drumheller and Edmonton. Some of the sandy areas were subsequently blown into dunes.

Thus, the surficial deposits, which became the parent materials of our soils, varied greatly depending upon the source bedrocks and the subsequent modes of deposition. It was upon these materials that soil forming (pedogenic) processes began to operate. Only a brief description of those processes is possible here:

a. Additions to the pedon. Some of the notable additions were water and dissolved carbon dioxide as precipitation, carbon and nitrogen in dead organisms, and, in some locales, salts carried in by rising ground water.
b. Removals from the pedon. The dominant loss from most Plains region soils was soluble salts (sulphates of sodium, magnesium and calcium). Some surface soil was lost through natural erosion.
c. Translocations within the pedon. Calcium and magnesium carbonates were moved from upper to lower horizons in most of our soils. Clay particles migrated from A to B horizons (for an explanation of soil horizon designations see Table 1) in Solonetzic and Luvisolic soils.
d. Transformations within the pedon. Organic materials from dead organisms were converted to humus and simple ions. The massive structure of the original surficial deposits was replaced by granular, blocky and prismatic structures. Some limited weathering of fine-

TABLE 1

EXPLANATION OF SOIL HORIZON DESIGNATIONS

Designation	Abbreviated Definition
L, F, H	Organic horizons, developed mainly from leaves, twigs and wood, in varying stages of decomposition. The forester's "duff."
A	Mineral horizon, at or near the soil surface. Often the "topsoil."
Ah	A horizon enriched with organic matter, brown or black, generally granular and friable.
Ae	A light-coloured mineral horizon, generally eluviated of clay, low in organic matter, often platy in structure.
Ahe	A horizon having characteristics intermediate between Ah and Ae.
AB	A horizon representing a gradual transition from the A horizon above and B horizon below.
B	Mineral horizon, normally underlying an A horizon, characterized by enrichment in material eluviated from above, by development of structure or by difference in colour.
Bm	A relatively soft, generally brownish horizon having prismatic structure.
Bt	A horizon that is enriched in clay eluviated from above, generally blocky in structure.
Bnt	A horizon that has strong columnar (or prismatic) primary structure that breaks into blocky secondary structure, an enrichment of clay from above, and a very hard consistency when dry.
BC	A horizon representing a gradual transition from the B horizon above to the C horizon below.
C	Mineral horizon that has been comparatively unaffected by pedogenic processes; it has changed little since it was deposited. The "subsoil."
Ck, Cca	Horizons showing the presence of potassium (k) or enrichment in calcium (ca) carbonates such as $CaCO_3$.
Cs, Csa	Horizons showing the presence of sulphur (s) or enrichment in (sa) "soluble" salts such as sodium sulphate Na_2SO_4. Often used jointly with symbols k, ca.

sized particles occurred; for example some micas have weathered to clays (Clayton *et al.* 1977) and potassium has been released from micas and feldspars (Dudas 1983).

The intensity of these soil forming processes was controlled by the remaining soil-forming factors which will now be discussed briefly.

Climate

Two important attributes of climate are temperature and moisture, and they have direct and indirect effects upon the intensity of pedogenic processes. Temperature controls the rates of chemical and biochemical reactions in soil. In western Canada it is related to the length of time that soils are thawed, and freeze-thaw cycles can affect weathering and decomposition rates. Moisture is involved directly through its effect on dissolution and eluviation of soil components, and on soil aeration. It is indirectly implicated through its effect on the quantity of plant remains added and on the rate of biological activities including decomposition.

Numerous ways have been designed to represent the climate of an area. For temperature, mean annual temperature, growing degree-days, length of the growing season, and hours of bright sun have been used (among others). Moisture has been expressed as mean annual precipitation, growing season precipitation, actual evapotranspiration and water deficit. Several climate classifications, such as Thornthwaite's and Köppen's (Fuchs 1973) have been designed. More recently a soil climatic classification was devised by soil survey and agrometeorological groups in Canada and the United States (Clayton *et al.* 1977). Very simplistically, soil climates are warmest and driest in the Medicine Hat - Swift Current area and they become cooler and moister radially in westerly, northerly and easterly directions.

Organisms

Many organisms, plant and animal, microscopic and macroscopic, influence soil development. The most obvious effect is the addition of organic materials, especially by higher plants. There are notable differences in amount of litter added annually by different plant communities. Above-ground litter varies from less than one tonne/ha for the Mixed Prairies of south-eastern Alberta to about three tonnes per hectare for the Boreal Forest. Conversely, the annual below-ground plant residues are higher in the Mixed Prairies than in the Boreal forest. Equally important are qualitative differences in the litter. For example, Lutwick and Dormaar (1976) found that grass-root lignins, recovered from Brown and Black Chernozemic soils, showed different resistance to thermal decomposition; and this pattern was similar to that for soil organic matter itself. Dormaar (1971) observed that an aqueous extract of aspen (*Populus tremuloides*) leaves lowered soil pH more than one from balsam (*P. balsamifera*) leaves, or distilled water. Other examples could be cited, but the point to be made is that various litters have different effects upon soil genesis.

Organisms exert other influences upon soil development. Roots permeate soil, opening channels, aiding in structural formation and moving nutrients upward (or downward). Roots provide favourable habitats for some microorganisms, and their respiration increases carbonic acid in soil solution. Soil fauna, though generally more unobstrusive, play significant roles. Larger animals, such as the Richardson's ground squirrel (*Spermophilus richardsonii*), produce channels in the soil and mix materials from various horizons. Mesofauna, such as mites, millipedes, earthworms and insects, collectively burrow in and mix soil materials, comminute litter, and induce structural formation. Their role has been largely ignored in the Plains region, but several recent studies (for example Sanborn 1981) have implicated mesofauna in reorganization of soil fabric. Contrary to popular opinion, however, it seems unlikely that earthworms were involved in soil genesis in the Plains region. There is considerable evidence that earthworms were not indigenous to that part of North America subjected to Pleistocene glaciation (Reynolds 1977).

Within the Plains region, several biomes, most readily identified as broad belts of vegetation, existed prior to settlement. Detailed discussion of these can be found in a later article. Note that, on the relatively well-drained uplands, the indigenous vegetation ranged from the Mixed Prairie (semi- and subarid portion) through the Fescue Prairie (subhumid portion) Associations of the Grasslands Region to the Boreal Region in the still cooler portions (Bailey 1981, Clayton *et al.* 1977). There is evidence that this general distribution of plant Associations has persisted for 2,000 - 4,000 years (Pettapiece 1969). There is considerable support for the hypothesis that prairie fires, perhaps set intentionally by the aboriginal inhabitants, helped to control the grassland - forest boundary (Bailey 1981, Macoun 1882, Pettapiece 1969).

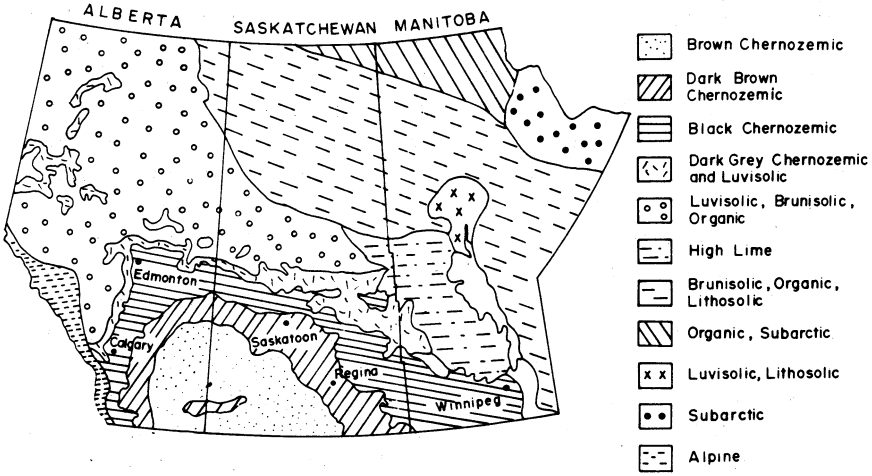

Figure 1. Major soil zones of the prairie provinces of Canada. (Courtesy of Dr. C. A. Campbell, Agriculture Canada, Swift Current).

The two factors, climate and organisms, occurring as broad belts across the Plains region, have evolved corresponding regions of soils, commonly called Soil Zones (Figure 1). In the semi- and subarid Mixed Prairies the dominant soils of the uplands are Brown and Dark Brown Chernozemics (Figure 2a). They have a brownish coloured,

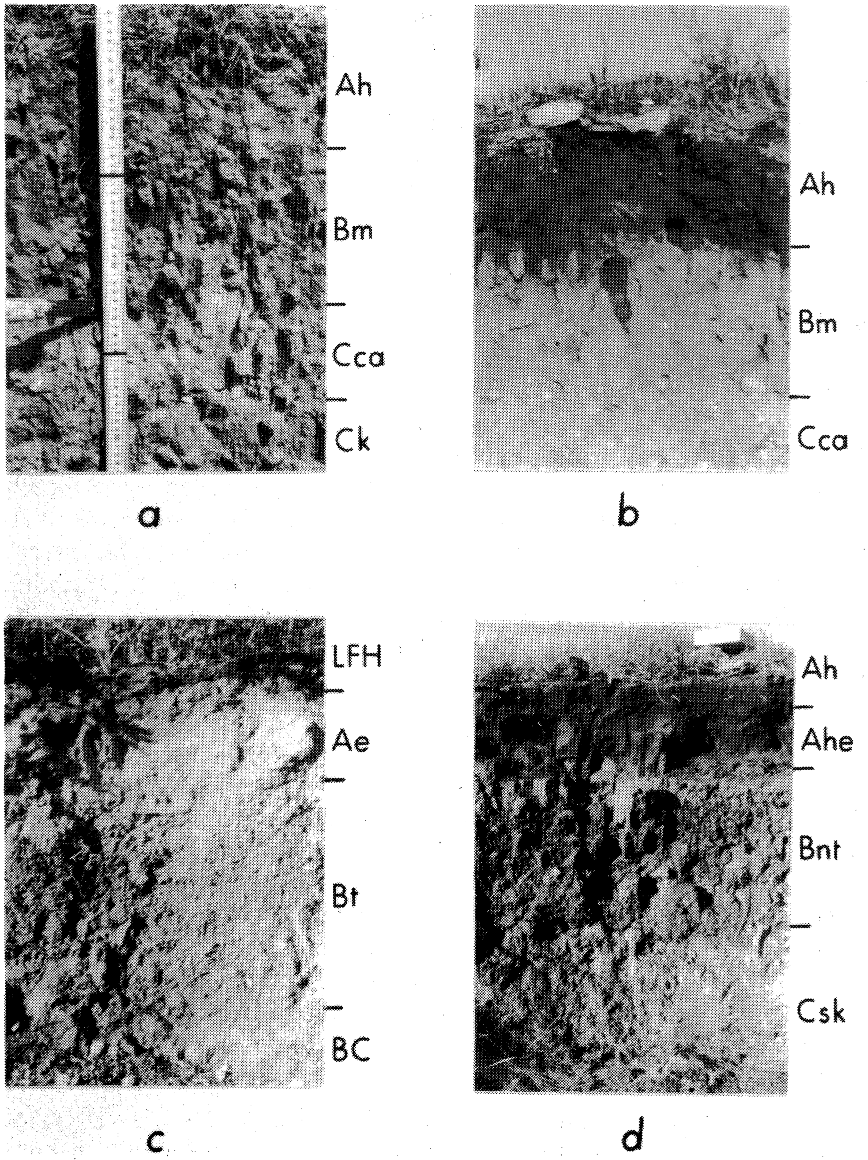

Figure 2. Profiles representing some of the major soil great groups of the Canadian Plains: (a) Brown Chernozemic (b) Black Chernozemic (c) Gray Luvisol (d) Black Solodized Solonetz.

friable, granular surface (Ah) horizon 100 - 200 mm thick. Underlying the Ah there is commonly a brownish coloured, fairly friable but prismatic Bm horizon 150 - 250 mm thick. A Cca and/ or Ck horizon, relatively unaffected by pedogenic processes and therefore little changed since its deposition, underlies the Bm horizon. The solum (A+B horizons) is, therefore, relatively thin and it has a neutral to slightly alkaline pH. Dark Brown Chernozemic soils tend to be darker in colour and thicker than Brown Chernozemics. Profiles often deviate from this typical description due to variations, such as texture and carbonate content, of the original parent material.

Black Chernozemic soils (Figure 2b) occur on the uplands of the subhumid Fescue Prairies. A typical profile has a black coloured, friable and granular surface (Ah) horizon ranging from 200 - 300 mm in thickness. It is underlain by a brownish, prismatic or blocky Bm horizon of similar thickness. The solum is, therefore, thicker than that of Brown Chernozemic soils and it is darker in colour because of a greater organic carbon content. Usually the Ah horizon is slightly acidic to neutral. Again, considerable variation arises from differences in parent material.

The typical soil occurring on the uplands in the Boreal Forest Region is the Gray Luvisol (Figure 2c). It is characterized by a sequence of organic horizons (L, F, H; the "duff" of the forester) which lies upon the mineral soil horizons. The upper mineral horizon (Ae), varying in thickness from 100 to 200 mm, is gray and has a platy structure. It has an ashy appearance and is usually moderately acidic. Underlying the Ae horizon is a dense, clayey, blocky-structured Bt horizon. It may be 400 to 700 mm thick and is often strongly acidic in the upper portion but mildly alkaline at the bottom. Typically the C horizon, usually separated from the Bt horizon by a transitional BC horizon, is encountered at 0.75 to 1.0 m.

Over extensive areas of the southern Plains region, especially in Alberta and Saskatchewan, a high content of water-soluble sodium salts tended to subordinate the effects of climate and organisms. In these areas Brown, Black or Gray Solonetzic soils (Figure 2d) developed. Such soils often have thin, moderately acidic Ah, Ahe and Ae horizons with a total thickness of 100 - 250 mm. These surface horizons are underlain by a very hard, columnar-structured Bnt horizon which is alkaline in reaction and is very impermeable to both roots and water. The Csk or Csak horizon, lying under the Bnt, is often sufficiently saline to prevent root growth.

Thus, broad bioclimatic influences, impinging upon a variety of parent materials, led to the development of broad regions of Chernozemic and Luvisolic soils. High soluble sodium content, derived directly or via groundwater discharge from saline bedrocks, frequently subordinated the bioclimatic effects resulting in genesis of Solonetzic soils. Still further diversity of soils arose from the effects of the other soil forming factors which will be discussed briefly.

Topography, Drainage, Time

These three remaining soil-forming factors serve to modify the effects of the broad, regional factors, or to define the duration of pedogenesis. Three attributes of topography are relevant. Elevation has the effect of modifying regional climate and hence vegetation. The result is a vertical, rather than latitudinal, zonation of soils which is exemplified on the Turtle Mountain of Manitoba, the Cypress Hills of Saskatchewan and Alberta, and the Cooking Lake moraine of Alberta. Luvisolic soils occur here at higher elevations as islands within extensive areas of Chernozemic soils. Relief, the shape of the land surface, controls the redistribution of precipitation, both rain and snow. On uneven ground, surface flow of rain and snowmelt results in locally arid and locally wet areas with attendant variations in vegetation and extent of leaching by percolating water. Relief also exerts some control on the distribution of snow, hill crests tending to be swept clean, lower slopes and depressions accumulating more than the watershed average (Nicholaichuk 1980). Aspect, the direction of slope, controls local climate and hence vegetation. In the Fescue Prairies it is common to find north-facing slopes treed while south-facing slopes are grassed. An excellent example is the hilly area between Stettler and Morrin in Alberta. Different soils may occur because of differences in bioclimatic influences associated with these variations in topography.

Drainage, as used here, refers to the internal water status of a soil; whether water moves rapidly and freely downward or whether the profile remains saturated for long periods of time. Drainage controls aeration of the soil. Poorly drained soils tend to be anaerobic much of the time and oxidative processes, whether chemical or biological, are greatly inhibited. Respiration by organisms (including roots) is lowered. Iron, manganese, nitrogen and sulphur are converted to reduced forms sometimes leading to metal toxicities, sometimes resulting in losses of plant-available nutrients. Poorly drained soils often receive ground-water which may carry soluble salts, leading to salinization of the profile.

It is generally accepted that the last continental glacier receded about 10,000 years ago. Since it receded from south to north, there is a progression in duration of pedogenesis from the southern to northern Plains region, but so far as this author knows the difference has not been implicated in soil variability across the Plains region. Some relatively small areas including parts of the Cypress and Porcupine hills of Alberta were unglaciated and in these locales soils are preglacial and much older. Other small areas have rather immature soils because pedogenesis has been of short duration. One example is the recently stabilized (or even unstabilized) sand dunes found in several places in the Plains region, including the Manitoba "desert" south of Carberry. Another example is the flood plains along many rivers and streams.

MAN'S USE OF THE SOILS

Pristine Use

The aboriginal people of the Canadian Plains apparently did not manipulate the soil to any extent, though they were certainly dependent upon its products. These tribes were hunters and gatherers. Unlike some eastern Canadian tribes, and others, including the Mandans of the Dakotas, they did not adopt agricultural practices (Strange 1954, MacEwan 1969b). They also made little use of soil material for construction, unlike south-western tribes in the United States who constructed adobe houses.

Very limited cultivation was done at some fur trading posts during the 1700s and 1800s and a few vegetables and small areas of cereal grains were grown. The fur companies were not anxious to see agricultural development which would lead to their demise. The first attempt at an agricultural colony was in 1812 when the Selkirk settlers arrived at Fort Garry. The settlers suffered numerous setbacks, not because of "the poverty of the soil" claimed by Sir George Simpson (MacEwan 1969a) but due to frosts, floods, grasshoppers and insurrections. The settlement grew slowly.

Scientific Explorations

In the mid 1800s considerable interest developed in Britain for settling the "great lone land." Thus, in 1857-59 the British government financed a "scientific" expedition, under John Palliser, to investigate the feasibility of settling what had come to be known as an extension of the great American desert. The Canadian government sent its own expedition, in 1857-58, under H. Y. Hind. Both expeditions concluded that the southern Plains were not suitable for agriculture. For example, Palliser wrote that "whenever we struck out on the broad prairie we generally found the soil worthless, except for here and there. . . ." (MacEwan undated). Later, Canadian botanist John Macoun spent several seasons crossing and recrossing the Plains. He concluded that the whole area was well suited to agriculture. Gray (1967) suggested that Palliser saw the Plains during dry years. If so, his conclusion was based on climatic constraints, not soil limitations. Similarly, Gray (1967) suggested that Macoun may have seen the area during wet years. With climatic constraints removed, Macoun would have been able to assess more reliably the soil productivity.

Land Survey

The decade 1865 - 1875 brought many significant events in Canada: 1867, confederation of four provinces; 1869, Rupert's Land purchased from Hudson's Bay Company by Canada; 1870, Manitoba joined Canada; 1871, British Columbia joined Canada; 1873, surveying began for the Canadian Pacific Railway. This flurry of activity encouraged settlement and a legal land survey became essential. The first legal land surveying began in 1869 south of Winnipeg and over the next three decades countless surveyors divided the Plains into a huge checkerboard. While the surveyors were supposed to classify the soil into one of four categories of agricultural suitability, criteria for doing so were not clearly defined. Besides, many surveyors, having diverse training and experience, were involved. Thus the surveyors' "township sheets" often provided unreliable, or little, information about the soil. Tyman (1972) was unable to find any correlation between the Dominion Lands Survey soil categories and subsequent soil survey ratings. In large measure, then, the original homesteaders were very much "on their own" in selecting their quarter sections. This lack of reliable information and the fact that many homesteaders had little farming experience, resulted in the opening, and early abandonment, of many areas of unsuitable land.

Inherent Soil Problems

Beginning in the early 1920s, long after much of the Plains had been settled, more thorough and scientific soil surveys were begun in the three prairie provinces. It was these surveys that recorded the presence of hundreds of different soils resulting from the interaction of the soil-forming factors discussed earlier. Obviously not all these soils would have equal agricultural potential but it is possible to present here only a brief discussion of their natural limitations, many of which remain or have become augmented since farming began. Detailed discussions can be found elsewhere (Eilers *et al.* 1974, McGill 1982, Moss 1967). Several physical problems occurred in various Plains soils. There were large areas of coarse-textured soils with low fertility and low water holding capacity. Luvisolic and Solonetzic soils, when cultivated, tended to form very dense, intractable surface crusts. Soils in these Orders also had dense subsurface horizons that restricted water movement and root growth. Some soils were so stony that tillage was difficult. Other soils occurred on rolling or hilly land where arable agriculture was ill-advised. Chemical problems were also found in soils of the Plains. Salinity, the presence of harmful levels of salts, occurred in many areas, some small, others extensive. Acidity was also a characteristic of many soils, particularly those in the Solonetzic and Luvisolic Orders. There were even some isolated areas in Manitoba and the Peace River area where few agricultural crops could be grown because of acidity. Fertility problems were also uncovered, sometimes soon after breaking the virgin land. While the nitrogen supply was generally adequate for several decades on the Chernozemic soils, Luvisolic soils became deficient very soon after agriculture began. Phosphorus was found to be in relatively low supply in most Plains soils and it was the first nutrient to be supplemented by commercial fertilizers. Sulphur supply was soon found to be inadequate in many Luvisolic soils of Alberta, while it was one of the components found in excess in saline soils. Potassium was apparently low in some relatively small soil areas. It would be quite incorrect to assume that all homesteaders obtained soils with unlimited agricultural potential!

Anthropogenic Soil Problems

Since settlement of the Plains about a century ago, man has had a profound effect upon the soil. Indeed, some soil scientists think that man should be listed, separately from all other organisms, as the seventh soil-forming factor! Man's effects have been both detrimental and beneficial. It is not possible to document all man-made changes in this article, but several extensive reports have been published recently (Advisory Committee to Canadian Wheat Board 1980, Alberta Soil Science Workshop 1981, McGill 1982, Prairie Farm Rehabilitation Administration 1982). A thumb-nail sketch must suffice here.

Soil organic matter level has declined drastically since settlement, especially in the prairie and parkland soils. In many cases the current level is about one-half the original level. It was inevitable that breaking the prairie sod would lead to such a reduction, because cultivating the soil permits much faster microbial oxidation (burning) of the organic matter, much as opening a furnace door and stirring the coals increases the burning rate. How great the organic matter loss has been depends upon the farmer's management; whether he has returned all straw and manure, and whether he has included forages in his crop rotation. Further, it is difficult to state the level at which organic matter ought to be maintained. What is reasonably safe to state is that most soils are now at the stage where all crop residues and manures ought to be returned and forage crops would be highly desirable.

Loss of organic matter has had several deleterious effects upon soil. First, the amount of nitrogen (and also sulphur) has declined proportionately since most of the soil's nitrogen exists in the organic form. Further, the rate at which nitrogen is released in plant-available form has declined even more, so that soils which for several decades could provide plants with sufficient nitrogen are now unable to do so. Secondly, organic matter serves as one of the "glues" in the soil, cementing the mineral particles into larger granules. Loss of organic matter, therefore, has led to poorer tilth of surface soils, and this, combined with frequent exposure of bare soil to rain and wind, has greatly accelerated erosion. In many fields much of the original "top soil" has been washed down slope or blown into fence rows, leaving farmers' crops to grow in generally less favourable "sub soil."

Another deleterious effect of farming Plains soils has been the expansion of saline (salty) soils. Whenever water, whether rain or irrigation, is added in excess of the soil's water-holding capacity, some of it escapes below the rooting depth. Eventually this water comes to the surface down slope, perhaps within a few meters, perhaps several kilometers from its source. If the water passed through saline soil horizons or geological strata en route to its eventual discharge area, salts will accumulate there. Improper irrigation development, including leaky canals, over-irrigation and unsuitable soils, has resulted in a large area of severely saline soil. Likewise, dryland farming practices, including summer-fallow and allowing snow to drift into fence rows and ditches instead of being retained uniformly over fields, have been responsible for much "dryland saline seep."

Another change wrought in soils by man's activities has been acidification. While "acid rain" is implicated to some extent, fallowing and use of ammonium-based fertilizers have also been responsible. Whenever the ammonium ion, coming from natural decomposition of soil organic matter, or from fertilizers, is converted to nitrate ion by soil bacteria there is a concomitant acidification of the soil. While not all soils have yet been made less productive due to acidification, some Luvisolic and Solonetzic soils, which were already moderately acidic, no doubt have. Fortunately the problem can be corrected by adding lime to the soil but this becomes another production cost for the farmer.

Management practices have evolved over the century of farming Plains soils and in many cases they have corrected some of the earlier man-made problems. Adoption of the practice of stubble mulching ("trash farming") has reduced wind erosion losses and decline of soil organic matter. It has, no doubt, reduced slightly the loss of the soil's nitrogen supply. Crop rotations including forages have been shown to be quite beneficial, but unfortunately are not widely adopted in most areas. Currently farmers and researchers are examining the possibility of "zero-till" farming to reduce the amount of tillage, and hence exposure, of the soil. Snow management is being tested as a means of storing more water over winter with the hope that fallowing can be reduced with a concomitant reduction of the salinity problem. Sprinkler irrigation and better methods of predicting water requirements help to reduce salinity problems in irrigated areas. Deep plowing or ripping of Solonetzic soils have been shown to be beneficial in many cases. The possibility that they may have long-term detrimental effects needs further examination. Recently, liming has been introduced in Alberta to combat soil acidification. Commercial fertilizers, especially those containing nitrogen, phosphorus and sulphur, have been used extensively to replace the soil nutrients exported from the region in the marketed products.

The kinds of agricultural enterprises which evolved in the Plains region were controlled to a large extent by the geographical and physical characteristics of the region. The relatively dry climate encouraged growing of cereal crops such as wheat, oats and barley. High initial fertility of many of those soils discouraged adoption of formal grain-forage rotations. Low population density and large distances from eastern Canadian and European markets dictated that the main products should be non-perishable and easily handled; cereal grains met these requirements admirably. The net effect of this export-oriented agriculture has been to ship many of our soil nutrients to distant places and to cause the previously noted marked reduction of soil organic matter. As in our forest and petroleum industries, agriculture on the Plains has been primarily an exporter of natural resources.

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Vegetation of the Canadian Plains

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ABSTRACT. The vegetation of the Great Plains from the 49th parallel to the lower Mackenzie River comprises, for descriptive purposes, seven broad zones or regions: Mixed Prairie, Fescue Prairie, Tall Grass Prairie, Aspen Parkland, Mixedwood Forest, Northwest Riverine Forest, and Subarctic Woodland. In the prairies and grovelands of the south, marshes are abundant; fens and bogs dominate wetlands in the north. Knowledge of the ecology of dominant species assists an understanding of the vegetation patterns which, to a greater or lesser extent, have been modified by fire and by direct human intervention. The history of agriculture and forestry on the Great Plains points up the rapidity with which stable ecosystems have been rendered unstable. Only the placing of high value on the native flora, fauna and terrain can effect their preservation.

RESUME. La végétation des grandes plaines, du 49e parallèle à la partie inférieure du fleuve Mackenzie, comprend, à des fins de description, sept vastes zones ou régions: la prairie mixte, la prairie fétuque, la prairie aux hautes herbes, le parc des trembles, la forêt mixte, la forêt fluviale du nord-ouest et la région boisée subarctique. Dans les prairies et les bosquets du Sud, on trouve un grand nombre de marais. Dans le Nord, les marécages et tourbières abondent. La connaissance de l'écologie des espèces dominantes aide à comprendre les modèles de végétation qui, à grande ou à petite échelle, sont modifiés par les incendies ou par l'intervention directe de l'homme. L'histoire de l'agriculture et de la foresterie des grandes plaines permet de démontrer à quelle vitesse des écosystèmes stables sont devenus instables. Afin de préserver ces écosystèmes, il faut accorder beaucoup de valeur à la flore, à la faune et aux terrains de la région visée.

ZONATION OF THE VEGETATION

Throughout the glaciated Great Plains of western Canada, from the 49th parallel to the Mackenzie River Delta, the surficial materials are sedimentary in origin; therefore, no major geological discontinuities interrupt the south-to-north climatic zonation of the vegetation. Thus a traverse from grassland to forest reflects the gradual change from a continental dry and warm regime to one that is moister and increasingly cooler. The far northwest receives less precipitation than the central forest area, and so beyond northern Alberta the climatic trend is toward a drier subarctic regime. To some extent moisture deficiencies in the northwest are counteracted by a lowering of net radiation and of potential evapotranspiration (Sanderson 1948) with the result that fine-textured soils—particularly in valleys—are watered sufficiently to support forests of good growth that contrast with the stunted woodlands on adjacent coarser upland materials.

Grasslands form a semi-circular belt from the border with the USA to about 55°N latitude in Alberta. Northward, in the predominantly forest matrix, islands of grassland continue to the Peace River country and beyond into the Yukon on sites unfavourable for tree growth. In the main grassland of the south the largest unit—the Mixed Prairie—occupies the semi-arid portions of southern Saskatchewan and southeastern Alberta (Coupland 1950). Here herbaceous life-forms (grasses, sedges, and forbs) abound, in the virtual absence of forest elements. Before settlement the dry-subhumid belt between

Mixed Prairie and the forest regions was also dominated by grasses; now the untilled remnants comprise a mosaic of aspen groves and grassland that is recognized as Fescue Prairie in Alberta and western Saskatchewan (Moss 1955, Coupland and Brayshaw 1953), changing eastward in Manitoba to Tall Grass Prairie.

Forests extend through 20 degrees of latitude from the east side of the nemoral Aspen Parkland in Manitoba, at the grassland transition, to coniferous outliers on the shores of the Beaufort Sea (Rowe 1972). Between these extremes lies the taiga, divided into three units. The boreal Mixedwood Forest is composed of closed-crown stands of both broadleaf and needleleaf trees and it dominates into the southern part of the Northwest Territories. The Northwest Riverine Forest characterizes the broad north-flowing river valleys down which tall stands advance to the Mackenzie delta. The Subarctic Woodland—open stands of small spruce—constitutes the sparse vegetation on uplands bordering the northernmost rivers and lakes. North of Great Bear Lake, a large area of treeless tundra marks the Great Plains extension to the Amundsen Gulf.

In the following descriptions, botanical names follow *Budd's Flora* by Looman and Best (1979).

HISTORY OF THE VEGETATION

Palaeobotanical studies suggest that with few exceptions the present zonation of the vegetation of the northern Great Plains has been stabilized for the last few thousand years. In the earlier post-glacial, major shifts in climate displaced the regional patterns (Ritchie 1976).

According to the pollen record, an early, cool post-glacial period prior to 10,000 years before present (BP) promoted groves of white spruce (*Picea glauca*) throughout the present area of grassland in the prairie provinces. As the late Wisconsinan glaciation ended, spruce spread from south of 49° N latitude on to the newly exposed landforms including moraines that mantelled decaying ice. A savanna biome formed, the openings between the spruce groves occupied by grasses, herbs of the goosefoot and ragweed families, sagebrush, juniper, and buffaloberry (*Shepherdia* sp.). A much warmer period (the altithermal) followed, during which trees receded northward and were replaced by grasses and herbs far beyond the present forest boundary. Beginning about 5000 BP a cooling trend was initiated, leading to the gradual stabilization of forest and grassland in the positions they occupy today. The long-past periods of climatic variation may explain the emplacement of islands of forest in grasslands (as in the Carberry Sandhills) and of islands of grassland in the forest (as in the Peace River country and even farther north).

An exception to the hypothesis of boundary stability since about 2500 BP may be the grassland-forest transition. Chernozemic black soils and grey black soils in the Aspen Parkland indicate a recent history of grassland rather than of tree cover. A reconstruction of the natural vegetation of Saskatchewan south of 52°N. latitude in the 1880s supports the thesis that woodland areas increased after settlement, particularly in the parkland belt (Archibold and Wilson 1980). Additional evidence (Houston and Bechard 1983) is the historically documented expansion of the range of the tree-nesting red-tailed hawk (*Buteo jamaicensis*). It is likely that intermittent drought and fire, plus the browsing of large herds of native ungulates, destabilized the grass-forest ecotone in pre-settlement times, allowing chernozemic soil development in association with depauperate aspen. On the other hand, some black soils such as those around Meadow Lake seem to have been formed in shallow marshes and were "wet prairies" in the sense implied by "Portage la Prairie," a portage through marshy lowlands between the Assiniboine River and Lake Manitoba. The presence of chernozemic dark soils, in such instances, need not imply what is commonly understood as a grassland environment. Furthermore, the chemical and physical nature of some soils, particularly the sodium-rich solonetzic, may have excluded trees and maintained the grassiness of certain areas within the forest environment (Wilkinson and Johnson 1983).

WETLANDS

Interspersed with grasslands and forests on the northern Great Plains are extensive lakes, ponds, and wetlands, the latter supporting marshes and saline meadows within the aspen groveland and grassland, and fen-bog complexes in the taiga.

Marshes characteristically occupy the margins of kettle holes or "sloughs"—fertile basins with fluctuating water levels where the regimes of temperature and nutrients are favourable to bacterial decay. Each year the biomass of the dominating coarse emergents and shallow marsh species such as common cattail (*Typha latifolia*), bulrushes (*Scirpus validus*, *S. acutus*), creeping spike-rush (*Eleocharis palustris*) and spangle top (*Scolochloa festucacea*) is decomposed and mineralized, producing a mucky substratum to whose high nutrient status intermittent draw-down and drying contributes.

In the grassland environment, where evaporation exceeds precipitation, all depressional areas naturally increase in content of salts unless ground-water movement removes them. Fresh water marshes remain fresh due to a net yearly loss of water by seepage that carries salts away. Thus they function as recharge areas, feeding into the groundwater system. By contrast, the groundwater flow is reversed in discharge areas, causing an increase in soluble salts. The result is a saline basin, characterized by such marsh halophytes as prairie bulrush (*Scirpus paludosus*), saltgrass (*Distichlis stricta*), Nuttall's salt-meadow grass (*Puccinellia nuttalliana*), red samphire (*Salicornia *rubra*) and, in the south, the greasewood (*Sarcobatus vermiculatus*).

In cooler climates northward, the decomposers are less efficient than in southern marshlands. The result is accumulation of peat deposits whose imprecise common name is "muskeg." Wherever water that has been in contact with mineral soil seeps through accumulating aquatic and semi-aquatic plant materials, neutralization of organic acids plus partial decomposition produces a humified fen peat. Fens are typically composed of the remains of sedges (*Carex* spp.) and brown mosses (*Drepanocladus* spp.). Conspicuous on their soggy surfaces are tamarack (*Larix laricina*), willows (*Salix* spp.) and dwarf birch (*Betula glandulosa*).

Bogs develop on top of fens, their surfaces raised by growth of *Sphagnum* mosses above the influence of circulating groundwater. Nourished by rain and snow-melt, they tend to be poorly decomposed, strongly acid, and low in nutrients. Bog peat is relatively firm and consolidated, hummocky at the surface due to the growth-form of *Sphagnum fuscum* and *S. nemoreum*, supporting stunted black spruce (*Picea mariana*) with Labrador tea (*Ledum groenlandicum*), cloudberry (*Rubus chamaemorus*), sheathed cotton-grass (*Eriophorum vaginatum*), and a few other acid-tolerant species. The northern bogs are perennially frozen.

In the south, marshes intergrade with fens wherever the peat decomposition process is tipped one way or the other by slight changes in the temperature-nutrient environment. Northward, fens and bogs intergrade in ways that reflect historical changes in water regime due to climatic fluctuations, flooding due to beaver activity, and fire. A common type of peatland consists of bog "strings" raised above wet fen hollows, forming ladder-like or chain-mail designs called "string bogs" or, better, "patterned peatlands."

ECOLOGY OF PRIMARY SPECIES

Regional changes in vegetation from south to north mirror adaptations to the climatic gradient of the dominant species of grassland and forest.

Near the United States boundary, western wheat grass (*Agropyron smithii*) is a prominent rhizomatous species adapted to dry warm sites and particularly abundant on disturbed and wind-eroded soils. Characteristically it is accompanied by the mid and low bunch grasses: spear grass (*Stipa comata*) and blue grama (*Bouteloua gracilis*). The latter, the major drought-resistant warm-season species in the south, has increased markedly in abundance wherever heavy grazing has occurred; it now dominates many areas formerly under the sole control of spear grasses and wheat grasses. Toward the Aspen Parkland along the gradient of declining temperature (shortening growing season) and increasing organic content of soils (marked by the colour change from brown to dark brown soils) the southern dominants are gradually replaced by northern wheat grass (*Agropyron dasystachyum*) and western porcupine grass (*Stipa spartea* var. *curtiseta*). Texture of soil is particularly important in controlling plant distribution. The spear grass is often the only dominant on sandy soils, while the wheat grasses exclude the spear grasses on clay soils where June grass (*Koeleria cristata*) tends to be abundant.

Toward the moister edge of the dark brown soil zone the climate is favourable to rough fescue (*Festuca scabrella*), particularly on fine-textured soils. This bunch mid-grass is probably given a competitive edge over shrubs by fire, although repeated annual burning seems to encourage its replacement by northern wheat grass and western porcupine grass (Wright and Bailey 1982).

Eastward toward the Red River Valley, tall grass migrants from the Central Lowland to the south reflect a still moister climate and deep black soils. Big bluestem (*Andropogon gerardi*), little bluestem (*A. scoparius*) and porcupine grass (*Stipa spartea*) are the characteristic suite of species.

Considering next the woody dominants of the forested regions, aspen poplar (*Populus tremuloides*) attains its best growth in the southern Mixedwoods. Once established by seed, it reproduces and spreads from root sprouts to form dense clones (genetically equivalent populations) that may be one hectare or more in size. The aspen declines in size and vigour both southward toward the parkland and beyond northern Alberta, an apparent response to drought and to cold soil temperatures, respectively. Balsam poplar (*Populus balsamifera*) is frequent in the moister parts of the parkland belt. Preferring imperfectly drained soils, it attains its largest size on the active floodplains of northern rivers. Like aspen, it perpetuates itself vegetatively by root suckers. The white birch (*Betula papyrifera*) includes many genetic varieties that adapt it to a wide range of sites from dry sandy soils to wet peatlands. An abundance of small winged seeds make it an aggressive invader wherever the ground is disturbed, and once established it can maintain itself by stump sprouts. In the Mixedwoods, birch is locally common on moist eroding slopes, while northward it frequently dominates after fire on both upland and lowland sites. White spruce is prominent on deep moist soils throughout the taiga, but it also appears in the Cypress Hills and in the Carberry Sandhills. A companion of balsam poplar on floodplains, it also attains its largest size on alluvium. In the far northwest, cold soils and permafrost seem to deter the white spruce, although surprisingly it is a conspicuous species near treeline. Balsam fir (*Abies balsamea*), an occasional associate of white spruce, is unknown in the Northwest Territories. South and east of the Peace-Athabasca delta it is occasionally encountered in moist environments, especially those affording protection from fire by water or topography. Deciduous cone scales that put the seed on the ground soon after ripening, plus thin bark and resinous foliage, make fir the poorest fire-survivor of all the taiga trees. By contrast, jack pine (*Pinus banksiana*) is the fire tree *par excellence*, widely distributed wherever sandy surface materials favour rapid drying and frequent burning. A precocious tree, it fruits at an early age and produces cones in which seed is stored until the heat from a passing fire releases them. A close relative, the lodgepole pine (*Pinus contorta* var. *latifolia*) is dominant on the western margin of the Great Plains. Ecologically it is very similar to the jack pine. Black spruce seldom occurs on any but peatland sites in the southern part of the Mixedwoods. Northward on cold soils as well as in bogs it is the most prominent conifer, well adapted with a shallow root system and with low nutrient requirements to stressful environments. Its semi-closed seed-retaining cones confer an excellent post-fire regeneration potential. Tamarack or larch accompanies black spruce on peatlands, where it is usually confined as a poor competitor to the wetter, better lighted edges.

UPLAND VEGETATION

Vegetation can be described, classified and mapped in various ways according to scale and purpose (see, for example, the different approaches to Saskatchewan vegetation by Coupland and Rowe 1969, Looman 1979, Harris *et al.* 1983). The three types of grassland and four of forest on the Great Plains of western Canada as hereafter described merge gradually with one another. They are parts of a continuum, and their boundaries are not sharp—except on the map (Figure 1). Furthermore, wide variations in topography and soils within this glaciated landscape create numerous local habitats where communities that are more "at home" northward or southward perpetuate themselves. Thus lowlands and depressions with their typical sedge-reed vegetation also support tall shrubs and trees though surrounded by dry grassland, while uplands with variable relief and variable insolation on slopes of differing aspects allow grasses to flourish within a forest matrix, or vice versa. Within the grassland zone sandhills create soil moisture conditions that favour taller growing species than those on soils of finer texture nearby. This permits the white spruce, for example, to grow and reproduce itself naturally far south of the continuous forest belt.

Mixed Prairie

This grassland is so named because it is composed of both mid and short grasses. Except in the driest situations, the taller group of species contributes most to the vegetative cover: two species of *Stipa* —spear grass and western porcupine grass—and two species of *Agropyron*—western wheat grass and northern wheat grass. With these, the most common and ubiquitous associate is June grass. The short-grass layer is represented by low sedge (*Carex stenophylla* ssp. *eleocharis*) and blue grama grass, the latter brought to prominence by overgrazing. Grasses and sedges contribute 85 to 95 percent of the aboveground herbaceous biomass, the rest being forbs of which pasture sage (*Artemisia frigida*) is by far the most abundant species everywhere. Dwarf shrubs such as wild rose (*Rosa* spp.) are occasionally hidden

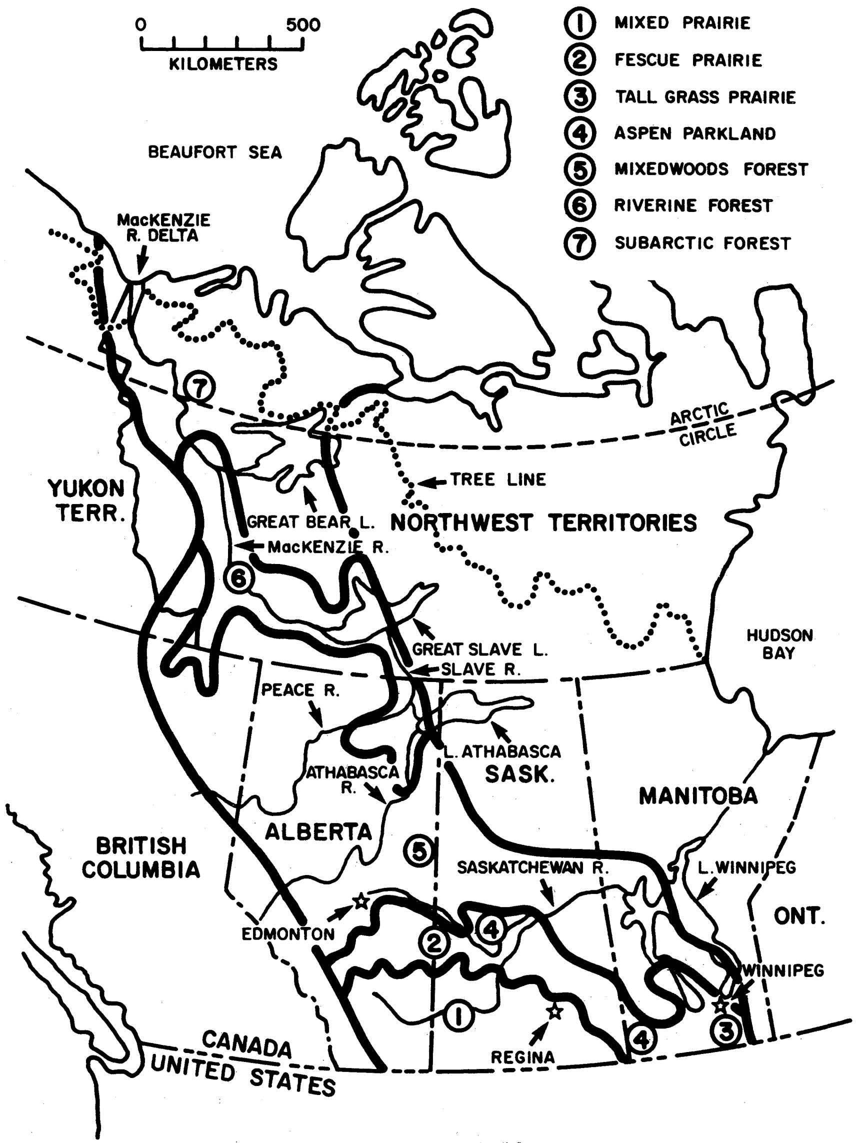

Figure 1. Vegetation zones of the Canadian Plains.

within the canopy of herbs. In some habitats shrubs outrank the herb cover in height, either scattered through the grass matrix as exemplified by hoary sagebrush (*Artemisia cana*) or locally dominating in dense stands as does western snowberry (*Symphoricarpos occidentalis*). The Mixed Prairie is the most extensive grassland region of North America, reaching southward from Canada to Texas in the United States. Some authors recognize the drier, western part of this grassland as the Short Grass Prairie, extending this interpretation northward to include the Canadian grasslands south of the Cypress Hills.

Fescue Prairie

In the foothills along the western edge of the Mixed Prairie and northward in east-central Alberta and west-central Saskatchewan the soils deepen toward the edge of the dark brown soil zone and Fescue Prairie becomes predominant. This grassland has a greater richness and abundance of grasses and forbs than the Mixed Prairie. In the moister, more favourable environment rough fescue is joined by Idaho fescue (*Festuca idahoensis*) and two oat grasses (*Danthonia parryi* and *D. intermedia*), the latter three prominent in the west but rare in Saskatchewan. Heavy grazing increases the proportions of Idaho fescue and Parry's oat grass at the expense of rough fescue. Occasional throughout are several grasses that are absent from the Mixed Prairie: Hooker's oatgrass (*Helictotrichon hookeri*) and awned wheat grass (*Agropyron trachycaulum* var. *unilaterale*). Characteristic forbs include geraniums, lupines, shooting stars, and many others that do not frequent the drier and warmer grasslands. The major conspicuous woody component scattered through the fescue community is shrubby cinquefoil (*Potentilla fruticosa*). Tongues and isolated areas of Fescue Prairie extend southward along the foothills of Montana and eastward into Mixed Prairie on such outlying uplands as the Milk River Ridge and the Cypress Hills. Well-developed examples of the type occur as relicts on the black soils of southeastern Saskatchewan and adjacent south-western Manitoba, but the former extent of Fescue Prairie in this eastern part of its range is difficult to reconstruct because much of the suitable habitat was converted to intensive agriculture before vegetation surveys were made.

Tall Grass Prairie

The belt of Fescue Prairie that coincides roughly with the black chernozemic and adjacent dark brown soils, merges in southern Manitoba with Tall Grass Prairie, the grassland type that formerly occupied the corn belt in west-central United States. Dominant grasses are a meter or more tall, the most conspicuous being big bluestem with needle grass and little bluestem. Reconstruction of the original range of the type is difficult as only a few relic prairies survive. Evidence suggests that under heavy grazing Kentucky blue grass (*Poa pratensis*) is a major increaser.

Aspen Parkland or Groveland

The aspen belt where grassland meets forest runs north along the foothills of the mountains, thence across central Alberta, and southeast in Saskatchewan to southwestern Manitoba. Willow scrub and balsam poplar are conspicuous associates of aspen in western and northern Alberta, respectively. Coincident with the gradient northward, from zonal dark brown to the black and dark grey soils in the three provinces, the character of Aspen Parkland changes from scattered groves in a grassland-and-marsh matrix to predominantly aspen with restricted grassy openings and then to continuous forest where boreal conifers first appear.

Associated with the groves of aspen on well-drained sites are grasses and broadleaf herbs tolerant of dappled shade, such as slender wheatgrass (*Agropyron trachycaulum*), purple oat grass (*Schizachne purpurascens*), baneberry (*Actaea rubra*), meadow rue (*Thalictrum venulosum*) plus a profusion of shrubs that includes red-fruited chokecherry (*Prunus virginiana*), pin cherry (*P. pensylvanica*), beaked hazelnut (*Corylus cornuta*), saskatoon (*Amelanchier alnifolia*), prickly rose (*Rosa acicularis*), wolfwillow (*Elaeagnus commutata*), and western snowberry. On imperfectly drained sites, balsam poplar accompanied by red-osier dogwood (*Cornus stolonifera*) and cranberries (*Viburnum edule*, *V. trilobum*) shows increased importance. It is joined by cottonwood (*Populus deltoides*), a variety of green ash (*Fraxinus pennsylvanica*), and box elder or Manitoba maple (*Acer negundo* var. *interius*) on the floodplains of streams in Saskatchewan and Manitoba. In the latter province, and fringing the Qu'Appelle Valley in Saskatchewan, bur oak (*Quercus macrocarpa*) mixes with aspen to form a distinctive nemoral type. The valley of the Red River is distinctive in its representation of species from the south and east, exemplified by basswood (*Tilia americana*) and riverbank grape (*Vitis riparia*).

Mixedwood Forest

Mixedwood Forest extends beyond the Aspen Parkland into the southern Northwest Territories between the Precambrian Shield on the east and the Cordillera on the west. Its southern edge is marked by the coincident appearance of white spruce, jack pine, black spruce, and tamarack. Zoltai (1975) mapped the ranges of these trees in detail, noting how often they reached their southern limits together. He proposed recognition of a narrow zone north of their common boundary, where balsam fir is absent, as transitional to the taiga proper. A similar "transitional" forest where boreal tree species are few is recognizable in the foothills of the mountains and in the Cypress Hills, although in both localities lodgepole pine takes the place of jack pine.

Mixedwood communities are most readily understood in relation to gradients of soil moisture and fire frequency. Dry areas are fire-prone and tend to be burned at short intervals. Such environments over the years have selected fast-growing species with high regenerative powers: jack pine with its seed stored in closed cones that open with heat, aspen that readily sprouts from the roots, and white birch that is both a prolific seeder and a stump-sprouter. Moist sites, less frequently visited by fire, are home to white spruce, balsam poplar, and balsam fir. Wet and organic terrains are dominated by tamarack and black spruce, the latter tree, like pine, is well adapted to regenerate after fires that release its cone-stored seed.

Typically then, pine forests dominate glaciofluvial outwash where rapidly drained sands are less favourable to the other pioneers, aspen and white birch. Low density on the driest sites allows the development of *Cladonia* lichens with bearberry (*Arctostaphylos uva-ursi*) and low grasses such as sheep's fescue (*Festuca ovina*) and northern rice grass (*Oryzopsis pungens*). On moister soils, blueberries (especially *Vaccinium myrtilloides*) form the pine understory. On the most productive sites where a water table is close to the surface, the shade from the vigorous trees eliminates all but a green carpet of feather mosses: *Pleurozium schreberi* and *Dicranum* spp.

Soils derived from glacial till and the loamy sediments of proglacial lakes have good water retention and, on upland sites, favourable drainage. Such growing conditions are conducive to mixed stands, commonly of aspen and white spruce (Kabzems *et al.* 1976). Aspen is particularly conspicuous following fire but natural mortality diminishes its importance after 70 to 90 years. Thus forests that escape fire for 100 years or more change from aspen-spruce to spruce, a process speeded near water by the industrious beaver (*Castor canadensis*). Should there be a seed source for balsam fir, this species will increase because of its unique ability to regenerate under a canopy of spruce-aspen. The succession from aspen to white spruce to balsam fir is paralleled by a gradual increase in shading of the forest floor that eliminates light-requiring shrubs and herbs while favouring the shade-tolerant evergreen half-shrubs and mosses. Early successional species associated with aspen-spruce are beaked willow (*Salix bebbiana*), fireweed (*Epilobium angustifolium*), northern bed-straw (*Galium boreale*), and wild peavines (*Lathyrus venosus*, *L. ochroleucus*). Late successional species with spruce-fir are the wintergreens (*Pyrola* spp.), northern starflower (*Trientalis borealis*), palmate-leaved colt's-foot (*Petasites palmatus*), stair-step moss (*Hylocomium splendens*), and Schreber's hypnum (*Pleurozium schreberi*).

In northern Alberta and the adjacent Northwest Territories, a colder and drier climate provides an environment less congenial to mixedwood forests. Just as on the fringe of the Precambrian Shield in Saskatchewan, the character of the vegetation changes as aspen and white spruce are replaced by black spruce, jack pine and white birch.

Poorly drained, fine-textured soils and depressional areas throughout the taiga accumulate peat cover. Fen peat communities on seepages are relatively rich in species. Although tamarack is the typical tree, the spruces sometimes colonize the drier, firmer fens. Bog peat that borders fens, typically raised above them a meter or so, is species-poor and supports only a simple acidophilous community of black spruce and evergreen dwarf shrubs.

Northwest Riverine Forest

A narrow but lengthy tract of forest occupies the Peace-Athabasca valley system in northern Alberta, joined via the Slave River and the lowlands at the west end of Great Slave Lake to the Fort Nelson, Liard and Mackenzie Rivers. On the active floodplains, two simple forest types exist side by side; balsam poplar on new point bars and recent alluvium, white spruce on the slightly higher, older depositional surfaces such as levees and filled backswamps.

Both balsam poplar and white spruce grow to a large size, the favourability of their sites indicated by the tall profuse understory of speckled alder (*Alnus rugosa*), willows (*Salix* spp.) and wild rose. Balsam fir reaches its northern limit on the Peace-Athabasca delta where, like the white birch, it is an occasional companion of white spruce. These trees, however, as well as aspen and pine, are relatively unimportant on floodplains. Toward the delta of the Mackenzie River a colder climate and soil stunts the white spruce and brings the black spruce into increased prominence.

Subarctic Woodland

Lichen woodlands and shallow peatlands occupy inactive floodplains in the northwest and dominate the glaciated upland plateaus that stretch away from the river valleys. In sharp contrast to the riverine forests the trees are scattered and low in stature, forming a savanna or woodland whose characteristic is a ground cover of handsome lichens. Prominent species, forming a mat 10 to 15 cm deep, are *Cladina mitis*, *C. rangiferina*, *C. amaurocraea*, *C. uncialis*, *C. stellaris*, and *Stereocaulon paschale*. Scattered through the white, grey and yellow carpet are the bright greens of dwarf-shrubs: black crowberry (*Empetrum nigrum*), dry-ground cranberry (*Vaccinium vitis-idaea*), northern blueberry (*Vaccinium uliginosum*), and northern Labrador tea (*Ledum palustre* var. *decumbens*). On certain stony or deep sedimentary soils, white spruce dominates the lichen woodlands, but the usual and most abundant tree is black spruce, accompanied by white birch and tamarack. Jack pine reaches its northern range limit at Norman Wells; it is not a constituent of lichen woodlands in the far northwest.

MODIFICATIONS OF THE VEGETATION BY MAN

From the time that humans first appeared on the Great Plains they have modified the vegetation, either indirectly through hunting pressure that reduced the numbers of large herbivores, or directly by the use of fire. If, as some believe, the sudden disappearance in the early post-glacial of the megafauna—mammoth, giant ground sloth, horse, camel, and giant bison—was due to over-efficient hunting by the Paleo-Indians, then from earliest times people must have initiated profound effects as woody plants and herbs responded to release from these major browsers and grazers. Just so in historic times the prairie bison were slaughtered, though replaced almost immediately by horses and cattle that restored a somewhat similar herbivore-grassland relationship. A one-way change, for which there was no redress by introduction of domestic animals to fill the same niche, resulted from decimation of beaver at the promptings of the fur-trading companies, drastically reducing the frequency of marshes and of peatlands in the southern boreal forest.

Burning must also have been a pervasive instrument of vegetation change from the earliest post-glacial until agricultural settlement, for the association of the large herbivores with early successional vegetation would not long have escaped the notice of observant people. Evidence is that the aboriginals purposefully used fires to drive and attract animals as well as to maintain open ground. Maintenance of the forest fringe as grassland by repeated burning was earlier mentioned as an explanation for the prevalence of black chernozemic soils in the aspen parkland.

Neither the forests nor the grasslands of the Canadian sector of the Great Plains were amenable to the kinds of Indian agriculture practiced in eastern and southern North America. Therefore the vegetation, though modified by the hunting-and-gathering cultures, was nevertheless maintained intact and ecologically stable. The picture changed drastically with the arrival of ranchers and farmers, the latter armed with the steel sod-bursting plough perfected by John Deere earlier in the century.

The establishment of a network of railways across the grasslands was initiated in the 1880s, and concurrently agricultural activities began to remake the landscape. Today the areas that have survived with least change are those unsuited for cultivation because of sandiness, stoniness, salinity, aridity, surface irregularities, or chemical condition of the soils. Relicts of the native vegetation are more abundant in the relatively arid brown soil zone where, over considerable tracts, more than half the landscape has escaped the plough.

Ranching

The first serious venture in livestock raising and crop culture was that of the Selkirk Settlers beginning in 1813. Extensive settlement and grazing of the lands in southern Manitoba awaited, however, the arrival of the railways, from the south in 1878 and from the east in 1881.

Westward, ranching began prior to construction of the rail lines, though not until the bison were well on their way to extermination, nor until the Northwest Mounted Police posts were established and treaties signed with the Indians (Johnston 1970). The first cattle were brought into southern Alberta in the late 1870s, after which ranching expanded rapidly with the granting of many large leases. Excessive optimism concerning productivity of the virgin grassland encouraged overstocking, particularly as government policy dictated that leased land be stocked by at least one animal for every 4.8 ha. Some decades later, grazing experiments were to disclose that while this gave an appropriate grazing intensity in the Fescue Prairie of the foothills, 12 ha per animal were required for sustained grazing in the drier parts of the Mixed Prairie. Some relief from range damage by overgrazing was gained the hard way—through heavy losses of animals in adverse winters—before experience was gained in balancing animal numbers to range area.

Today about 30 percent of the grassland region remains uncultivated, most of this being grazed by cattle. Persistent heavy grazing decreases the supply of soil moisture by reducing the amount of organic matter and vegetative protection at the soil surface. The rate of infiltration is reduced with the result that more moisture evaporates or runs off. Increased insolation at the unprotected soil surface during the warmest season further adds to evaporative loss. The results have been reduced plant vigour, in terms of both height and density, and changes in floristic composition. In the Mixed Prairie, the proportion of wheat grasses and spear grasses in the vegetation cover has decreased, while blue grama grass has become more abundant. In Fescue Prairie, rough fescue has decreased relative to its associated species while Mixed Prairie components have increased or invaded. These changes have reduced the capacity of the range to support livestock, and locally they have resulted in soil erosion by water and wind.

Farming

Until the end of the last century, settlement of land for farming west of Manitoba was restricted to a narrow belt along the main line of the railroad west to Calgary, and along branch lines that had been constructed to Lethbridge, Saskatoon, and Edmonton. In these areas, farming encroached on lands first occupied by ranchers. Then the intervening areas were settled and, by 1931, about 60 percent of the grassland region had been brought under cultivation.

The large population of draft animals required for farming increased the grazing pressure on a declining area of natural grassland in the early years, and serious overuse of the range was widespread. After 1920, increased use of tractors permitted a continuing reduction in grazing pressure for thirty years as the proportion of grazing load due to horses compared to cattle fell from one-half to one-tenth. Not until the 1970s was the former grazing intensity restored or exceeded, due to the increased population of beef cattle.

Prior to settlement for farming in the Great Plains grasslands, world agricultural experience in rain-fed crop culture was limited almost entirely to forest regions where soils required major and continuing inputs of lime and organic matter to sustain production. Here, however, the settlers found that the soil had such high reserves of nutrients and organic matter that excellent crops could be raised without any inputs except energy to plough and seed. The main limiting factor was low and erratic rainfall, a problem reduced by the discovery that summerfallowing stored moisture and controlled invading weeds. Nevertheless, by the 1930s experience indicated that certain cultivated areas could not sustain crop production. Many farms were abandoned in areas where wind erosion was particularly severe. Community pastures were established as a means of returning to grass areas submarginal for crop production.

Problems of soil deterioration on continuously farmed areas were early identified. Tillage breaks down soil aggregates whose cohesiveness is weakened by loss of cementing organic material. The resulting loss of tilth and granulosity makes soils susceptible to packing by machinery. The penetration of rainfall is impeded and sensitivity to erosion by wind and water is increased. Tillage of compacted soils requires significantly more power.

Furthermore, it became apparent in the 1970s that summerfallowing and other tillage practices that stirred and exposed the soil were conducive to rapid decomposition of organic matter, liberating more nutrients than the crops could use. Thus two-thirds of the nitrogen available for plant growth was lost yearly either to the atmosphere by volatilization or through soil leaching and erosion. Much of the remaining one-third was removed from farms in the exported grain. By the 1950s, fertility had declined to the point that chemical fertilizers were necessary to sustain crop production. Increase in their use was rapid, and by 1980 the amount of chemical nutrients applied to fields in Manitoba exceeded by 27 percent the net amount being removed in crops. Westward under less intensive agricultural management, nutrients exported as crop output still exceeded chemical inputs by 13 percent in Alberta and by 120 percent in Saskatchewan. The use of chemical fertilizers is increasing at an alarming rate to offset the declining capability of the soil to deliver available nutrients.

Concern for loss of fertility in croplands has caused a slowly developing trend toward reduction in frequency of tillage. Consideration is being given to the possibility that conservation of snow water and the use of herbicides can reduce the need for summerfallow and that crops can thrive under "zero tillage" where chemical weed control is effective. However, conservation of organic matter reduces the rate of release of nutrients for plants and requires greater artificial inputs to sustain a given level of production.

The use of herbicides was stimulated in the 1940s by the introduction of species-specific toxins that permitted control of weeds in growing crops. The great expanse of monocultural crops in the grassland zone so facilitated this approach to weed control that by 1950 herbicides were being used on a larger proportion of the cropland than in any other comparable region of the world. Despite widespread concerns for damage to the environment, herbicides continue to be used universally throughout the area.

Forestry

The first settlers came to Manitoba and the "Northwest Territories"—now Saskatchewan and Alberta—from milder forest climates of eastern North America and Europe. For them the grasslands seemed to lack an essential ingredient: trees. In his "Report of the Forestry Commissioner" to the Minister of the Department of the Interior in 1888, J. H. Morgan (1889) conjectured that the rich soils were treeless because of their "rank heavy growth" that encouraged fires. On the other hand he observed that "light soils scarcely furnish fuel enough to injure trees," and therefore "there is a great deal of sandy desert that might be rendered valuable by tree planting." He drew attention to Professor John Macoun's 1880 report of a "desert" at the 109th meridian and the 50th parallel (Saskatchewan's Great Sand Hills) where grew large cottonwoods and "a perfect oasis of nearly 700 acres surrounded by sandhills that kept out fire," remarking in an innocent *non sequitor* that in France more than 200,000 acres of sand had been successfully reforested. Further, he quoted an 1882 report by Dr. F. B. Hough to the effect that bringing the land under cultivation improved the climate, while the planting of trees would effect further amelioration of temperature and humidity. Morgan recommended establishment of Experimental Forest Stations to ascertain the tree species most suitable and valuable, following which "our next duty would be the reserving of large tracts of land for permanent forests."

Encouraging words such as these eventually led to the establishment of Forest Reserves at various sandhill sites within the grasslands, for example at Shilo, Manitoba, and Elbow and Dundurn, Saskatchewan. Although the federal government began an active farm tree-planting programme in 1901—the first planting stock being provided by the Indian Head Nursery—it was not until 1916 that plantations were started on the Forest Reserves. The afforestation effort, using native spruce and pines but also pinning hopes on the exotic Scots pine, continued until the end of the 1920s.

Results were not successful. The plantations were ravaged by droughts, by rabbits, and by fires that showed no respect for the theories of Macoun and Morgan. In the general transfer of resources in 1930, the federal government surrendered its sandhill forest reserves to the provinces, doubtless with a secret sigh of relief. Since then, attempts to transform the grassland into forest have largely been abandoned.

Although the grassland resisted afforestation, much of the southern forest proved susceptible to transformation to a "cultural grassland" when cleared and planted to annual cereals and oilseed crops. The dry years of the 1930s encouraged many farmers to leave the dusty south and begin again in the forest fringe. The trend toward clearing, breaking and farming forestland has continued to the present. For example, in the 23-year period from 1953 to 1975, forested land in the Mixedwood belt of Saskatchewan decreased by 53 percent according to Kabzems *et al.* (1976). These authors report a continuing rapid pace of deforestation, with attendant wind and water erosion of soils, plus silting and lowering of water levels in streams and rivers. Although most of the conversion is to cropland, some of the less suitable soils have been turned to grazing land either by clearing alone or by seeding to exotic species of grasses and legumes.

The first commercial utilization of the natural forests began about 1870 when the Hudson's Bay Company gave resource administration over to the federal government. Lumber was the chief commodity of value and the Mixedwood forests were combed for stands of large sawlog trees, particularly the white spruce. As small tree boles were of no value, a selection cutting system was used whereby only those 14 inches (35 cm) in diameter or larger at breast height were logged. This procedure, plus winter logging with horses when the ground was snow-covered, had minimal impact on the forest environment. Often natural regeneration followed the selection logging, though unfortunately the best sites where spruce reached heights in excess of 100 feet (31 m) and diameters up to 4 feet (1.2 m) were converted to low-grade brushy stands that still persist today.

With the arrival of wood-pulping mills, the forest economy changed drastically. No longer were scattered groves of large trees the prime target. Small spruce and pine are required in large quantities for the hundreds of tons of pulp produced daily by each mill, and clear cutting is the harvest method. Nor are spruce and pine the only valuable trees today. The broadleaf species that used to be considered "weed trees"—aspen, poplar, birch—are increasingly in demand for a variety of products. With all forest biomass targeted or potentially so, with harvesting mechanized and practiced year-around, and with clear cutting and surface disturbance by scarification the rule, major changes in the forestlands are underway. Forestry is moving toward agricultural techniques where the natural vegetation is replaced by selected fast-growing species that are planted, tended and harvested to secure high yields at short rotations. Despite the moves toward intensive forest management "... there is not a single province where acceptable regeneration is experienced on all the areas currently being cut" (Reed *et al.* 1978).

CONCLUSION

That people have drastically changed the natural vegetation of the Canadian Plains is a truism; that the rate of change continues to accelerate is frightening. The conventional philosophy of growth and of technological innovation apparently guarantees increasing use of resources, simplification of ecosystems, and continued environmental deterioration in the future.

These trends are evident everywhere in grassland, wetland and forest. The transitional Aspen Parkland, for example, that before settlement covered 20,255,000 ha in western Canada is now 80 percent agricultural. Competing for the remaining 20 percent are farmers, wildlifers, foresters, industrialists, recreationists. From the various viewpoints, aspen trees are seen as sources of cattle feed, biomass energy, farm shelter, wildlife habitat, wood pulp, chemicals, soil protection, snow saving, and aesthetic pleasure.

Depletion of aspen forests and the groveland impacts destructively on local climate, soil stability, surface and subsurface hydrology, as well as on the diverse native fauna and flora. Concerning the latter, Argus and White (1978), Maher *et al.* (1979), and White and Johnson (1980) have assessed the status of rare and endangered vascular plants in Alberta, Saskatchewan, and Manitoba, respectively, noting that to date only a small number of species has apparently been extirpated by human activity. The authors point to greater dangers in the future as uncontrolled developments continue.

The key to maintenance of native plants and animals is, first, that they be valued as parts of the earth's creation as well as for their uses, and second, that land-use planning and development be responsive to their ecological habitat needs. Without sensitive and far-sighted planning of land uses, employing ecological guidelines along with a system of rewards for observing and following them, a multitude of uncoordinated individual decisions to overgraze, plough, spray, cut, drain, and burn will incrementally destroy all native habitat. The greatest needs of the moment, therefore, are dedication to the preservation of flora, fauna, and their habitats, plus dedication to instituting long-term land use planning that recognizes the importance of natural wild areas.

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The Importance, Utilization, Management and Future of Wild Game Animals on the Canadian Plains

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ABSTRACT. The Canadian Plains region is endowed with more than 60 species of game animals and mammalian predators. Some 30 species of grouse, large mammalian herbivores, and carnivors historically played a role in the day-to-day sustenance, and the season-to-season survival of the nomadic and indigenous Indians in central Canada. However, the plains bison was the most sought-after faunal component on the Plains in primitive times, because of its abundance, size, herding behaviour, and its flesh and hide quality. This role as the major provider continued through the fur trade period in the nineteenth century.

The bison declined after 1830 and was essentially extinct on the Canadian Plains by the mid-1880s. So, too, were the plains wolf and grizzly—the major predators of the bison. Deer, moose, elk, and pronghorn populations were alarmingly low from 1900 until the 1930s. Protective legislation only partly curbed the decline of these animals resulting from the advent of severe winters and accompanying animal mortality, rapid human population growth, excessive use of game by the new settlers, and the concomitant loss of game habitat to settlement and agricultural activities.

Systematic studies of game populations in the early 1950s by wildlife biologists created a data base that permitted an improved and expanded approach to wildlife management on the Plains. The progressive loss of habitats since that time, coupled with greater demands for consumptive and non-consumptive uses of wildlife, and the increased occurrence of pollutants in and perturbations to the environment, have greatly increased the urgency and complexity of managing wildlife species.

RESUME. Plus de soixante espèces de gibier et de mammifères prédateurs habitent les Plaines canadiennes. Une trentaine d'espèces de gélinottes, de grands mammifères herbivores et de carnassiers jouaient autrefois un rôle dans l'alimentation et la survie des Autochtones nomades du centre du Canada. Le bison des plaines était alors l'animal le plus recherché, car il était à la fois abondant, de belle taille, grégaire, et sa viande ainsi que sa peau, de haute qualité. Le bison demeura l'élément de base de l'alimentation durant toute la période de la traite des fourrures au dix-neuvième siècle.

Le bison commença à disparaître après 1830 et fut virtuellement exterminé vers le milieu des années 1880, en même temps que ses principaux ennemis, le loup des plaines et le grizzly. Pendant les trois premières décennies de notre siècle, les populations de cerfs, d'orignaux, de wapitis et d'antilopes connurent un creux inquiétant. Les lois sur la protection de la faune ne réussirent qu'à ralentir le déclin, occasionné par la mortalité durant des hivers rigoureux, la croissance rapide de la population humaine, la chasse excessive par les pionniers et les pertes d'habitat dues à la colonisation et à l'agriculture.

Les biologistes entreprirent l'étude systématique des populations animales au début des années 1950, dans le but d'assembler les données nécessaires à une meilleure gestion générale de la faune des Prairies. La réduction des aires d'habitat depuis lors, conjugée à la pression croissante pour l'exploitation, destructive ou non, de la faune ainsi qu'à la multiplication des rejets polluants et des perturbations de l'environnement ont décuplé l'urgence et la complexité d'une saine gestion de la faune.

The Canadian Plains region, extending north from Canada's prairie steppe to the Mackenzie delta and adjacent barrens, is richly endowed with a wild animal resource of inestimable value. This is a renewable resource comprised of a wide array of invertebrate and vertebrate forms that have directly and indirectly, positively and negatively, interacted with the Plains-dwelling man, his interests and his endeavours.

Each of the more than 60 species of game animal and predator inhabitants of the Canadian Plains occupies a preferred habitat where, interacting with the other biological and physical elements in the environment, it assumes what is referred to as its niche, or role, or way of life within the community. Collectively these forms are called "wildlife," but each can be labelled more specifically as insects, fish, amphibians, and reptiles or, because of their size, conspicuousness, edibility and abundance, as avian and mammalian "game" animals. Such terms as waterfowl, upland game birds, furbearers, carnivores and big game, herbivores or ungulates are often applied to members of this latter group, better defining the roles, ecology, and taxonomic relationships of these species.

This chapter is concerned with these Plains "game" animals which were and are still important to man, and which have contributed meaningfully to man's welfare historically and currently. The furbearing animals so eagerly sought and bartered for by the Hudson's Bay and North West Companies and others in the eighteenth and nineteenth centuries, and the buffalo, waterfowl, fish, problem insects, and the wolf, will be treated specifically and in greater detail in subsequent chapters.

Many of the 30 or more species of upland game birds, ungulates, and mammalian predators resident on the Canadian Plains exhibit obvious anatomical and behavioural adaptations that permit them to exist in their chosen habitats. The distributional data for these species (Table 1) reveal that most of the native and introduced animals are highly adaptive and exist in habitats within two or more vegetative regions. Animals restricted currently and historically to the grasslands along the southern base of the Canadian Plains include the sage grouse, swift fox, pronghorn antelope and the introduced chukar partridge. The sage grouse, with its high dependence on the sagebrush-grassland habitat type of southwestern Saskatchewan and southeastern Alberta, is restricted to areas supporting sagebrush (*Artemisia cana* and *A. frigida*) and a variety of grasses and forbs.

Those occupying more diverse habitats in grassland and parkland, and grassland-parkland-boreal forest vegetation, include the blue grouse, mountain lion, and bighorn sheep (along the southwestern border of the Canadian Plains), the sharp-tailed grouse, coyote, red fox, bobcat, mule deer, white-tailed deer, and (historically) the greater prairie chicken (pinnated grouse), grizzly bear, gray wolf, elk and bison, plus the introduced gray (Hungarian) partridge, ring-necked pheasant, and wild turkey. Of the remainder, the ruffed grouse, black bear and moose are most common in parkland and boreal forest habitats, whereas the spruce grouse, lynx, woodland caribou, and the wood bison inhabit the boreal forest. The willow ptarmigan, rock ptarmigan, arctic fox, barren-ground caribou, and muskox inhabit the barrens at the northern extremity of the Canadian Plains panhandle near the Mackenzie River Delta and Arctic coast.

Estimates of wildlife abundance on the Canadian Plains for the mid-nineteenth century are generally lacking, but the distribution of some large mammals has been approximated. The plains bison was found throughout the Canadian Plains from southern Manitoba west to the Rocky Mountains, and north to the southern edge of the boreal forest. The plains wolf and grizzly, the two most important wild predators of the bison, co-occupied the habitats preferred by the bison. Elk were common on grassland habitats and islands of deciduous and coniferous forests in southern portions of Manitoba, Saskatchewan and Alberta. Bighorn sheep occupied habitats east of the Rockies along 49°N latitude as far east as the Sweetgrass Hills (Nelson 1973). Mule deer occurred throughout the southern plains, but they had been essentially replaced by the white-tailed deer in Manitoba by 1900. Pronghorns historically ranged over the prairie steppes from the vicinity of the Red River (Coues 1965) and other areas of southwestern Manitoba (McDonnell 1791, Palliser 1863) westward to the foothills of the Rocky Mountains (Richardson 1829). The journals of Alexander Henry the Younger (Coues 1965) record the pronghorn as far north as Edmonton, Alberta, in 1810. To the east in what is now the Province of Saskatchewan, the pronghorn was seasonally found as far north as 53°N latitude, in the vicinity of Carlton House (Richardson 1829, Woolsey 1863).

In primitive and historical times the bison was the major faunal element of the Canadian Plains in terms of numbers, biomass, and importance as a food source for native peoples. This abundance is confirmed by the diaries of travellers in the late eighteenth and nineteenth centuries which tell of impressive numbers of bison. Writing in his journal about a trip on the Saskatchewan River in 1793, John MacDonald of Garth reports "... the innumerable herds of Buffaloes & Deers & many grizle Bears on its banks feeding & crossing in such numbers that we often got our canoes amongst them & shot hundreds without need" (Morton 1938). An 1857 journal entry by Palliser (1863) reports "The whole region as far as the eye could reach was covered with buffalo in bands varying from hundreds to thousands. So vast were the herds that I began to have serious apprehension for my horses as the grass was eaten to the earth as if the plain had been devastated by locusts." A journal note by Thibodo (1940) on August 1859 at the "Q'Appelle River" states, "Buffalo too numerous to mention. They seem to number thousands as far as the eye can reach the prairie is dotted with them."

So abundant was this species that prior to the arrival of Europeans, man was clearly subordinate to the bison and other animals he hunted, and his effect on the Plains landscape was not significant (Nelson 1973). The tendency for bison to occupy prairie habitats and form large herds made them particularly conspicuous to hunters, and

TABLE 1

HISTORICAL AND RECENT DISTRIBUTION OF UPLAND GAME BIRDS, MAMMALIAN CARNIVORES AND UNGULATES ON THE CANADIAN PLAINS.[a]

SPECIES	Grassland	Parkland	Boreal Forest	Tundra
Blue grouse *Dendragapus obscurus*	SL[b]	SL		
Spruce grouse *Dendragapus canadensis*			C	
Sage grouse *Centrocercus urophasianus*	SL			
Willow ptarmigan *Lagopus lagopus*			SL	SL
Rock ptarmigan *Lagopus mutus*			SL	SL
Ruffed grouse *Bonasa umbellus*		CW	CL	
Greater prairie chicken *Tympanuchus cupido*	E	E		
Sharptailed grouse *Tympanuchus phasianellus*	CW	CW		
Gray partridge *Perdix perdix*	ICW	IFL		
Chukar partridge *Alectoris chukar*	ISL			
Ring-necked pheasant *Phasianus colchicus*	IFW	IFL		
Wild turkey *Meleagris gallopavo*		ISL		
Black bear *Ursus americanus*		SL	FW	
Grizzly bear *Ursus arctos*	CW	FL	SL	
Coyote *Canis latrans*	FW	FW	FL	
Gray wolf *Canis lupus*	CW	FL	SL	
Red fox *Vulpes vulpes*	CW	CW		

Swift fox *Vulpes velox*	E			
Arctic fox *Alopex lagopus*				SL
Mountain lion *Felis concolor*	SL		SL	
Lynx *Lynx canadensis*			CL	
Bobcat *Lynx rufus*	SW	CL		
Elk *Cervus elaphus*	SL	CL	CL	
Mule deer *Odocoileus hemionus*	CL	CL		
White-tailed deer *Odocoileus virginianus*	CL	CL		
Moose *Alces alces*		SL	CW	
Woodland Caribou *Rangifer tarandus caribou*			CW	
Barrenground Caribou *Rangifer tarandus groenlandicus*				CL
Pronghorn *Antilocapra americana*	CL			
Plains Bison *Bison bison bison*	E	E		
Wood Bison *B.b. athabascae*			S	
Muskox *Ovibos moschatus*				SL
Bighorn Sheep *Ovis canadensis*	CL		CL	

[a]vegetation regions after Rowe (1972).
[b]S = scarce
F = fairly common
C = common
L = local distribution within vegetation region
W= widespread distribution within vegetation region
E = extinct or near extinction
I = introduced

their often predictable response to organized hunting and coordinated harassment by Indians made them very vulnerable to large-scale, often non-selective, slaughter.

The importance to man of all other indigenous avian and mammalian species appears to have been minuscule and overshadowed by the importance of the bison. For example, the pronghorn antelope, present in North America in numbers equal to or exceeding those of the bison (40 million) in historical times (Seton 1953, Nelson 1925), was utilized to a much lesser degree than the bison.

The journals of travellers on the Canadian Plains prior to 1860 are replete with references to the great abundance and heavy utilization of the bison. Journal entries recording other wildlife species are far less numerous, and these usually note sightings of single or "several" animals. Even fewer entries deal with instances of these other species being shot and used for food. Nevertheless, statements such as "Red Deer plenty hereabouts . . . ," and ". . . Natives killed many Red Deer" appearing in the 1772 journal of Cocking (Burpee 1908), and "Flocks of antelopes pasture on the hillside . . ." recorded by G. Franchere in 1814 (Lamb 1969), and "wolves very numerous & very tame . . ." along the Saskatchewan River in 1859 (Thibodo 1940), and others, convey the impression that various game animals were abundant and utilized, at least locally, in this period.

Sometime after 1830 bison herds began to decline owing to a number of factors, among them an increased demand for bison robes, coupled with higher selling prices. The Métis increased their harvest of bison as they had a market for the robes among the Métis settlers in the Red River and Assiniboine Valleys, and the American whiskey traders, with their repeater rifles, encouraged Indians to increase their harvest of bison, rewarding them with alcohol and trade goods (Nelson 1973). By the 1870s, improved processing techniques resulted in the production of superior bison leather, which led to a further increase in the demand for bison, and the initiation of the era of the hide hunter. This was also the period when American military and political officials favoured a policy of bison reduction which would lead to a more complete control over Indians dependent upon that resource (Nelson 1973).

The remnants of the formerly vast bison herds on the Canadian Plains were eliminated in Manitoba by 1867 (Bird 1961) and were on the brink of extinction in the Cypress Hills, Saskatchewan, region by 1884 (Nelson 1973). The demise of the bison was accompanied and followed by the elimination of the plains-dwelling wolf and grizzly, and an increased utilization of elk, deer, pronghorns and other large mammals. Human Plains-dwellers suffered great hardships from the scarcity of herbivores and bison for food but this was partly alleviated by the native grouse on the Plains. Present year-round, the sharp-tailed, ruffed, spruce and sage grouse were of great value as human food locally because of their size, edibility and availability when other larger game animals were not present (Macoun 1882).

The formation of the Province of Manitoba in 1870 was a political event that formally closed the fur trade period and opened the land to agricultural development (Bird 1961). Manitoba then experienced a surge of settlers and entered an era of unregulated killing of wildlife for food that soon caused the populations of elk, moose and mule deer to reach unprecedented lows.

One of the earliest expressions of a consciousness of the need to expand legislation for the protection of game animals was evident in the newly-formed, diminutive, "postage-stamp" Province of Manitoba. Prior to 1900, Manitoba passed laws which banned Sunday hunting, prohibited the sale of grouse and venison, and established bag limit restrictions—a daily bag of 20 grouse and prairie chickens, and a season bag of 100 birds (Bossenmaier 1978). Notwithstanding these legislative restrictions, wildlife populations continued to decline. This spurred the Manitoba government to pass an Act for the Protection of Game in 1876 to legally terminate the unrestricted utilization of game animals (Bossenmaier 1978). The relative ineffectiveness of this legislation, the completion of the Canadian Pacific Railway in western Canada in the 1880s, and the subsequent expansion of ranching and settlement on the Plains continued to place demands on the game resource and further contributed to the decline of many wildlife species.

The critical status of many wild herbivore populations at the end of the nineteenth century is believed to have resulted from persistent over-utilization of the herds and, along the western edge of the Plains in particular, by excessive mortality resulting from a series of severe winters. The rapid expansion of settlement—the clearing of timbered lands for farming, and the use of local wildlife stocks for food at that time—reduced wildlife numbers and forced the withdrawal of some wildlife species because of habitat reduction. In southern Manitoba, this same alteration of vegetative cover created preferred habitats for the white-tailed deer which had arrived from Minnesota in the 1880s, and were attracted by new food sources from pioneer farm crops and regrowth from timber cutting (Goulden 1981). The pinnated grouse or prairie chicken extended its range into Manitoba from the south at about the same time. By 1890 in Saskatchewan, extensive cultivation with many interspersed islands of untilled, rocky, sandy-soil lands, created ideal habitat for the pinnated grouse. This bird began to appear in Saskatchewan and Alberta about 1900 and flourished until the 1920s (Pepper 1978, Mitchell 1959).

The period from 1900-1950 was one of crises, concerns, trial and error, and rapid human population growth. Alberta and Saskatchewan became provinces in 1905 with their own governmental responsibilities. These responsibilities were felt fully the following year during the infamous winter of 1906-07. Commencing in October 1906 and extending well into May 1907, the prevailing weather conditions were the most severe that had ever been recorded in western Canada (Davies and Vaughn 1960). Thousands of horses and cattle succumbed on the Canadian Plains, and stocks of pronghorns and deer were severely reduced. These events, coupled with the cognizance of the recent fate of the bison, seems to have had a salubrious after-effect, and protective laws were quickly formulated and enforced (Rowan 1952).

The gravity and after-shock of that catastrophic winter prompted the Dominion Government and the fledgling provincial governments to search out and set aside specific lands for the preservation of wildlife. The first bird sanctuary on the continent had been established in 1887 at Last Mountain Lake, Saskatchewan, and the first National Park in the Canadian Rockies had been established by the Dominion Government that same year. Commencing in 1907 additional National Parks were designated in the three prairie provinces. Certain Manitoba lands set aside as timber reservations by the Dominion Government in 1894 became four Game Preserves in 1911 (Bossenmaier 1978). Similarly, two Dominion Forest Reserves in Alberta became Game Reserves in 1918. By the 1940s many additional terrestrial and aquatic blocks for the protection of wildlife, or specifically for the protection of birds or pronghorn antelope, had been added to the system.

Major legislative events during this period were the signing of the Migratory Birds Treaty in 1916 by the United States and Great Britain, in the name of Canada, for the co-ordination, management and protection of the migratory bird resource in North America. The Natural Resources Transfer Agreement of 1930 placed the responsibility for the management of non-migratory wildlife on the doorstep of the provincial governments. The Canadian Wildlife Service was formed in 1947 for the purpose of managing migratory and other wildlife on provincial land, and all wildlife species in the Northwest Territories, the Yukon, and the National Parks. It was also charged with the overall administration of the migratory bird laws and was responsible for coordinating activities among provinces and between the provinces and the United States.

Concern over the welfare of wildlife after 1907 was related to the continued decline in numbers of game animals through exploitation by increasing numbers of settlers. Subsequent to the arrival of the mainline railroad in Manitoba in 1881 and in western Alberta in 1883, spur lines to communities in all three prairie provinces first resulted in corridors of agricultural settlement along the rail lines then, by 1910, an almost complete settlement on lands between these spur lines. During the period 1901-1931 the human population on the plains increased by nearly two million. As the acreages of cultivated "improved" land rose from 5.5 million acres in 1901 to almost 60 million acres in 1931 the natural landscape and wildlife habitat were severely modified (Coupland 1978). Anxiety over the wildlife in this period was also manifested in a number of provincial regulations designed to reduce or stop the harvesting of specific game populations. The provinces of Manitoba and Saskatchewan in 1917 and 1919, respectively, banned the hunting of elk in an effort to stem the progressive and dramatic decline in elk numbers within provincial boundaries (Hewitt 1921).

It appears that even though enforcement was only partly accomplished, these regulations did serve to prevent declines in some but not all local big game herds. The pronghorn antelope had disappeared from Manitoba by 1900 (Manitoba Department of Natural Resources 1983), and in Alberta and Saskatchewan the status of the pronghorn progressively worsened after 1910. That year Alberta closed the hunting season on pronghorns—a closure that remained in effect until 1935 (Mitchell 1980). By 1925, fewer than 3,000 pronghorns ranged over the prairies (Nelson 1925). In contrast, the populations of white-tailed deer showed a marked increase in Manitoba in this period and were extending their range into Saskatchewan. White-tails became abundant in Saskatchewan in the late 1920s and early 1930s (Saskatchewan Department of Tourism and Renewable Resources 1980).

Early in this century the wildlife management activities of governments centred around transplanting native animals into unoccupied habitats, establishing public shooting grounds, and protecting declining populations of game animals through restrictive hunting season legislation. Active groups of organized sportsmen embarked upon a programme of purchasing and releasing exotic upland game birds into what they considered suitable habitats. Commencing in 1908, the initial plantings of the ring-necked pheasant and gray (Hungarian) partridge were made in Alberta (Mitchell 1959). These two gallinaceous bird species were first released in select areas in Saskatchewan and Manitoba in the early 1920s and 1930s. Chukar partridge were released in Alberta and Manitoba in 1937. These plantings were followed by introductions of the wild turkey in Manitoba and Alberta in 1958 and 1961, respectively (Mitchell 1959, Bird 1961, Bossenmaier 1978).

After 1950, it became increasingly necessary to begin managing the Canadian Plains wildlife resource as more hunters took to the field. In the early 1950s, the three prairie provinces hired university-trained wildlife biologists who undertook basic inventory, habitat assessment and public relations programmes, and recommended hunting seasons designed to properly harvest the existing game animal stock. Little research was accomplished in these formative years while inventories were being accumulated, management units defined, and regulations formulated.

These difficult years of low-to-no budget appropriations for wildlife investigational work saw the beginnings of acceptance of wildlife management and research programmes. A body of wildlife biologists was developed which concerned itself with many aspects of wildlife status, biology, ecological research, and habitat capability. New approaches and improvements in census techniques were used to provide the data base necessary for justifying and establishing maximum harvest quotas, species-specific hunting regulations, wildlife management units, permit-by-area restrictions, and priorities in habitat development and manipulation for providing improved opportunities for harvesting game animals on a regular basis.

In response to demands by sportsmen and conservation groups in the late 1950s and early 1960s, the three prairie provinces embarked upon programmes of hunter training and firearm safety. These programmes were to acquaint outdoorsmen with some of the recreational options associated with wildlife, to provide instruction in their safe and enjoyable use, to teach safe and responsible handling of firearms at home and in the field, to instill in hunters a sense of responsibility and courtesy while hunting, to encourage a knowledge of the principles of conservation, to teach wildlife identification, and teach basic survival (Alberta Department of Recreation, Parks and Wildlife 1976).

Initial attempts at exchanging information and organizing management approaches for migratory and non-migratory game species were made in an *ad hoc* fashion in the late 1950s when provincial and federal biologists began meeting on a regular basis to discuss matters of species habitat and retention. At that same time a small group of biologists organized the Canadian Society of Wildlife and Fisheries Biologists, which later became the Canadian Society of Environmental Biologists. This was a period of mostly burgeoning upland bird and big game populations, improved dissemination of game animal information to administrators, naturalists, and hunters, a marked upswing in damage to crops by waterfowl, and a positive approach to preventing and compensating land owners for that damage.

In the late 1970s, a Wildlife Section of the Canadian Society of Zoologists was formed to provide a vehicle for the interchange of ideas and concerns between wildlife biologists and zoologists. In 1981 a new society called the Wildlife Society of Canada/Société de la Faune du Canada (WSC/SFC) was organized as an affiliate of The Wildlife Society (Washington, D.C.). This fledgling society, with chapters across Canada, is actively concerned with the perturbations to the environment and the welfare of wildlife and, through its position statements, it is a voice for wildlife and habitat conservation in Canada.

In the past two decades the management of wildlife species has become exceedingly complex. Increased demands for hunting opportunities have been made in the face of decreasing bird and mammal populations which have resulted from winter mortality and losses of habitat. More crown lands are being shared with domestic grazers, and more lands are being converted for crop production, or used for industrial development or hydro-electric power developments, thus making them unavailable to wildlife. The increased presence of environmental pollutants and perturbations is requiring an expanded monitoring and counter-action. The hunting rights of native Indians is a key issue to be addressed. There is a need to consider and plan for additional non-consumptive uses of the wildlife resource. Rare and endangered species must be identified and a lobby established to protect those which have not yet been exterminated. The on-going cooperative efforts to save the whooping crane (*Grus americana*), and the re-introduction of the swift fox onto the Canadian Plains in 1980 (Reynolds 1983) are but two examples of what can be done with sound planning and experimentation.

What of the future? We will continue to utilize the wildlife resources in both consumptive and non-consumptive ways, but we must carefully manage our resources. Munro (1979) suggests that the ecosystems and wildlife species within ecosystems can continue to benefit current and future generations of people. It will do so by maintaining life-support systems through the conservation of ecosystems, by preserving genetic diversity via the prevention of extinction of species and varieties, and by maintaining exploited ecosystems and stocks of plants and animals at sustainable levels. The question remains, "Will governments develop objectives that will ensure these benefits?" The answer will be related to some approximation of what wildlife is really worth. Bossenmaier (1979) points out that numerous economic, ecological and socio-cultural evaluations have been made to establish bench marks for wildlife management decisions and expenditures. To this end wildlife programmes have become increasingly identified with particular values such as sport hunting, viewing, trapping, sustenance, tourism, education, science, and environmental quality.

The "bottom line" on the importance and value of wildlife, and one which should ensure that governments will develop objectives to maintain wildlife and habitats for all time, is the recent national survey on the importance of wildlife to Canadians (Filion *et al.* 1983). A sample of almost 100,000 Canadians in 1981 revealed that wildlife-related activities are one of the most prevalent forms of recreation undertaken by Canadians who, in pursuing these activities, spend some $4.2 billion annually. The study also showed some 80 percent of Canadians feel that maintaining abundant wildlife was important to them. Eighty-two percent had similar feelings toward preserving endangered species.

Today's complexities in wildlife management, the keen competition for government funds, and the need to guarantee the viability of ecosystems and wildlife species in the future, necessitates formulation of long-range plans by governments and the development of a wildlife policy now. Such guidelines have been formulated and published (Government of Canada 1983). These guidelines reinforce the continuing importance of the precepts of wildlife management, including habitat maintenance and regulation of wildlife use. They also extend the concept of wildlife to include habitat, and thus reflect the interdependence of all living things.

Can wildlife habitat be saved? Can the degree of land alteration which results in the exclusion of wildlife be mitigated? One is encouraged to answer "yes" because of the recent (May 1984) announcement of the formation of "Wildlife Habitat Canada"—a crown corporation established to preserve natural habitats. The "up front" money of $1 million in 1984 and an additional $2 million in 1985 for this federal programme will be augmented beginning in 1985 by funds derived from an increase in the basic fee for the Migratory Game Bird Hunting Permit.

Can wildlife habitat be saved? One is again encouraged to answer "yes" because of the important bill recently (1984) passed by the Saskatchewan Government. "An Act Respecting the Protection and Management of Crown Lands Critical for the Maintenance of Wildlife Populations," known as "The Critical Wildlife Habitat Protection Act," protects crown lands that have been designated as critical to wildlife welfare and survival. These lands have a high priority wildlife use and may not be sold for conversion to other uses.

In retrospect, Canadian Plains residents have gained from the early trial and error approach and from the wildlife management and research attempts and findings. The need to understand and appreciate wildlife and its seasonal habitat requirements has never been more urgent. More and more demands are being made on the land and for the land. Industrial and agricultural interests are expanding and demanding, and an ever-increasing contingent of consumptive and non-consumptive users is looking to the wildlife resource as a provider of food and recreation. As Robert Herbst (1979) recently stated, "The fish and wildlife . . . represent our lifeline from the past, the strong rope of continuity between the great resources we found laid out for us on this continent and what we have made of them. The work we do here also is part of that rope, and it acknowledges the enormous area of interaction between the worlds we manage and world we manage from. The animals whose continued purchase on the planet depend on what we do will never send us a note of thanks, but a future human population may some day pause and honor the effort to which we contribute . . ."

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The Northern Great Plains: Pantry of the Northwestern Fur Trade, 1774-1885

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ABSTRACT. No other area of Canada rivalled the northern Great Plains as an environment ideally suited for the big game hunting economies of the native peoples. Indeed, only the marine environments of coastal British Columbia and the Gulf of St. Lawrence provided the nation's aboriginal inhabitants with a more abundant and reliable food supply. It was the meat surplus that could be harvested in the Plains area that proved to be crucial to the northwestward expansion of the fur trade and to the early development of the Red River colony of Manitoba. Although fur trading was also important, especially in the northern and northeastern fringes of the region, it is fair to say that throughout the heyday of the industry before Confederation, the trade in furs was of secondary importance. Put simply, without Plains provisions, it would have been difficult for traders to expand their operations to the extent that they did in the late eighteenth and early nineteenth centuries. For this reason, attention will be focussed on the Plains provision trade.

RESUME. Aucune autre région du Canada ne se prêtait aussi admirablement bien que le nord des grandes plaines à une vie économique fondée sur la chasse au gros gibier par les Autochtones. Seuls les milieux marins de la côte du Pacifique et du golfe du Saint-Laurent offraient à leurs habitants une source d'alimentation plus sûre et plus abondante. Ce sont les surplus de viande des plaines qui permirent l'expansion de la traite des fourrures vers le Nord-Ouest et le développement de la colonie de la Rivière-Rouge. Aux beaux jours de l'industrie des fourrures, avant la Confédération, l'échange des peaux était en lui-même une activité secondaire dans les plaines, bien qu'elle ait eu son importance au nord et au nord-est, en bordure des plaines. En bref, sans les provisions venues des plaines, les traiteurs auraient difficilement pu étendre leurs opérations aussi largement qu'ils l'ont fait à la fin du dix-huitième siècle et au début du siècle suivant. Il peut donc être utile d'examiner plus à fond le système de traite des provisions des plaines.

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The expansion of the fur trade into the Athabasca and Mackenzie River drainage basins in the late eighteenth century had major implications for the trading system that had already been established in the northern Great Plains. Operating a burgeoning network of posts posed serious logistical problems for the competing Hudson's Bay and North West companies. The boreal forests could not provide sufficient food to feed men stationed at the growing number of posts and those who manned the canoe and boat brigades plying the routes between them. European food was too costly to import in large quantities. Even more important, cargo space in canoes and York boats was limited. The proportion of that space devoted to provisions had to be kept to a minimum. Complicating this problem, the transportation season was too short to permit crews to hunt and fish along the way. For these reasons, food had to be obtained in the country and stockpiled at strategic locations along the transportation routes.

The European traders quickly realized that the parkland and prairie areas could serve as the pantry for the western fur trade. This

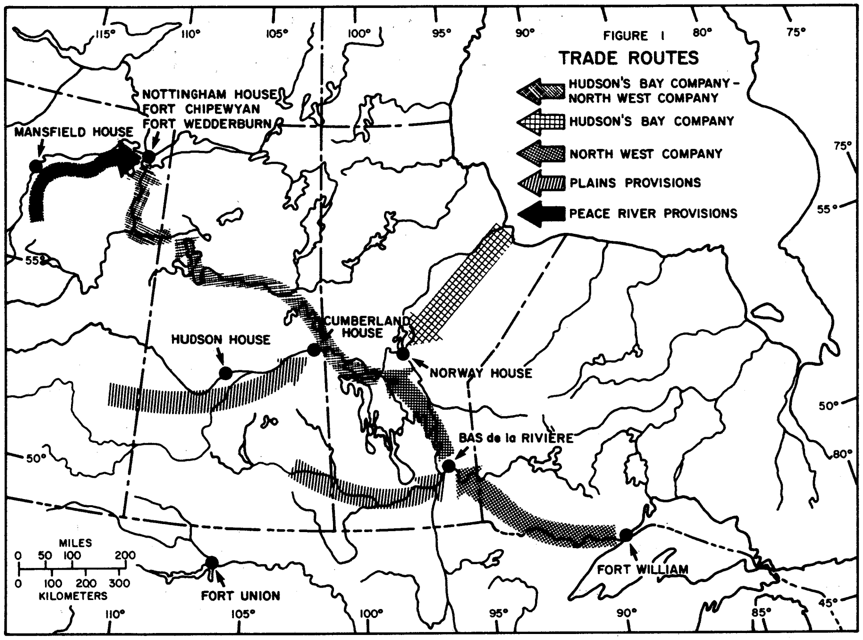

Figure 1. Trade routes

region could produce large food surpluses and it was strategically located beside the main supply line of the northwestern fur trade (Figure 1). In order to collect plains provisions, the Hudson's Bay Company and the North West Company built posts along the North Saskatchewan as well as the Red and Assiniboine rivers between 1779 and 1821. The provisions obtained from the Saskatchewan area were forwarded to Cumberland Lake for use by the Athabasca-bound brigades of the two companies. In the southern Manitoba area, the North West Company sent its foodstuffs to Fort Bas de la Rivière on the lower Winnipeg River for use by its canoe brigades as they travelled between Cumberland Lake and the Rainy Lake-Fort William area. The Hudson's Bay Company forwarded its provisions from southern Manitoba to Norway House, at the head of Lake Winnipeg, where they were picked up by inland brigades travelling to and from York Factory. Even with these new logistical arrangements a large proportion of cargo space continued to be taken up with provisions (Table 1).

Indians were quick to appreciate the opportunities the new provision market offered to them. For instance, in 1779 the Hudson's Bay Company built Hudson House on the North Saskatchewan River to obtain provisions for Cumberland House. Within a year, the local Indians were burning the surrounding prairies in the autumn to prevent the buffalo (*Bison bison*) herds from approaching the post. By making it impossible for the traders to hunt buffalo themselves, the

TABLE 1

PROPORTION OF NORTH WEST COMPANY CANOE SPACE DEVOTED TO PROVISIONS, 1814

Destination from Ft. William	% Provisions
Athabasca	34
Athabasca River	39
English River	38
Rat River	42
Upper Fort des Prairies	48
Lower Fort des Prairies	38
Upper Red River	25
Lower Red River	24
Fort Dauphin	28
Lake Winnipeg	37

Based on data in W. Wallace, *Documents Relating to the North West Company*, Toronto, 1934, pp. 277-79.

Indians hoped to increase the prices that they could demand for the provisions they brought to barter. This native practice became common place in the parklands.[1]

The foodstuffs that the Indians supplied consisted almost entirely of dried buffalo meat (jerk meat), pounded (powdered) meat, grease and pemmican. The butchering and processing was done by native women. Drying meat involved cutting it into long strips about 0.6 cm (0.25 inch) thick. The strips were then hung on wooden slats supported by tripods of sticks. It took two or three days for the meat to dry. The better quality dried meat was packed into bundles. The remainder was dried further over a hot fire until brittle. It was then laid out on a buffalo hide and pounded into a powder. This powdered meat was dumped into a kettle containing boiling fat or marrow. As it cooked the mixture turned into a paste. Crushed berries were often added at this time. While still boiling hot, the paste was poured into leather bags which were sealed as tightly as possible. The mixture was then allowed to cool until it was hard. This very nutritious food concentrate was known as pemmican.[2] It was highly stable and could be stored for long periods of time. For these reasons, pemmican was an ideal food for people on the move. It could be eaten right from the bag without any further preparation, roasted in its own fat, or boiled.[3]

The expanded market for buffalo meat products after 1780 had significant implications for the native suppliers. For example, it is reasonable to suppose that the prehistoric demand for dried provisions by parkland/grassland groups was limited because these groups hunted buffalo to some extent at all seasons of the year. Therefore, a large portion of their food consumption would have consisted of fresh or previously frozen (in winter) meat.[4] Dried provisions were used in emergencies when herds were not present locally, when travelling, or when engaged in raiding expeditions. Pemmican was especially important in the latter circumstances since it did not have to be cooked. Being able to avoid using fires while on the warpath was an important consideration in the open grasslands where smoke was visible for miles.

Besides domestic use, nomadic hunters probably also traded dried meat and pemmican with horticultural Indians who lived in the Missouri valley during the late prehistoric period.[5] In addition, some exchange undoubtedly took place when local food shortages were common in the forests. However, there is no reason to suppose that this trade was extensive.

In light of these considerations, it is clear that the fur trade provision market would have served to increase the importance of pemmican as an article of commerce. Whether or not this market stimulated the initial commercialization of the hunt is uncertain at this time because there is some archaeological evidence that suggests there may have been an increased output of dried provisions in the late prehistoric era.[6] On the basis of this evidence the archaeologist Thomas Kehoe has argued that the commercialization of the hunt began before European contact.[7] If Kehoe is correct, the development of a fur trade provision market may have simply served as a catalyst which accelerated a trend that had begun earlier. It is unclear why the process would have begun in the prehistoric/protohistoric periods. Possibly the incentive for increased pemmican production in the late precontact period was related to the increase in warfare that was associated with the northward spread of the horse. Acquisition of this animal may also have served to increase intertribal trade. Whatever the causes for the increased output may have been, it is clear that in the historic period the expanded output of provisions was aimed at serving a new external market.

While a changing economic climate provided the incentive, technological changes resulting from European contact made it easier for native groups to expand their production of traditional meat products and to transport them. For instance, historical accounts of pemmican-making indicate that buffalo fat was melted in copper or brass kettles.[8] It is uncertain how fat would have been melted down on a large scale in prehistoric times given the relatively poor quality ceramics that Indians possessed (judged by modern technical standards) and the fact that plains Indians used the buffalo paunch extensively as a cooking container. Being limited to this domestic equipment meant that most foods had to be either stone-boiled or roasted over an open fire. Indeed, when writing about the Métis (descendents of Indians and Europeans) buffalo hunts in the middle of the nineteenth century, Red

River settler Alexander Ross noted that a great deal of meat, fat, and bone marrow was wasted because the Métis hunters lacked a sufficient number of kettles to process it.[9] Ross's observation is of particular interest given the fact that the Métis undoubtedly were better equipped with kettles than their Plains Indian cousins. Thus, although kettles would have offered the prospect of improved efficiency of meat processing, the limited quantity of kettles available as late as the middle of the nineteenth century was a factor that set limits on the amount of pemmican that groups could make from their kill. In other words, food wastage may have been partly a function of the per capita distribution of kettles. It may be that prehistoric pemmican production occurred only on a relatively small scale owing to technological constraints.

Hunting efficiency and transportation capability was affected by the introduction northward of horses from the southern plains where they had been brought by the Spaniards. By the early 1700s horses were found in the southern Alberta region and by the 1740s they were being adopted by Indians in southern Manitoba. Horses altered summer hunting practices in that the animals enabled Indians, and later Métis, to "run" the herds. This involved having a group of men approach a herd as closely as possible before it took flight. Once the buffalo stampeded the Indian hunters chased after them on their horses. Being faster than the fleeing buffalo (a buffalo was said to run at two-thirds the pace of a horse), a good buffalo pony enabled Indian hunters to ride up along side of their prey and kill them at close range with arrows, lances or muskets. The chase usually continued until the horses were tired. As in the past, the Indian women and children followed, often on foot, to butcher the fallen prey. Although not without its hazards, this method of hunting was less risky and probably more efficient than the older walking surround or fire drive. Ross witnessed a Métis "buffalo run" that lasted two hours and yielded 1,375 animals. This is a kill rate of slightly more than 11 per minute. In terms of the 40 men involved, however, it is less impressive, giving each hunter an average of 3.5 animals.[10] Perhaps of greater importance, horses gave the plains hunters the potential of carrying larger loads at a faster pace than when dogs were the sole beasts of burden.[11] However, the potential was not fully realized because of limited availability. Many Indian groups in southern Manitoba and eastern Saskatchewan were "horse-poor." They did not have enough mounts for everyone. Therefore, the speed of these groups was limited to their slowest pedestrian members. In contrast, the Métis had a relative abundance of horses. They often travelled with riding horses, buffalo running ponies (which were used solely for that purpose), cart horses and pack horses.

As the fur traders pushed into the Athabasca and Mackenzie River country, they quickly realized it was necessary to have an advance food supply base to augment meat products obtained in the prairie region. The mainline of the fur trade skirted the edge of the Canadian Shield, where many large lakes (Great Bear Lake, Great Slave Lake, Lake Athabasca, Lake Winnipegosis and Lake Winnipeg) teemed with fish. The fisheries developed on these lakes supported a number of trading posts. However, even though fish could be smoked, dried or, in the case of sturgeon, processed into pemmican, it did not become an important voyaging food.[12] It is unclear why. Perhaps it was related to their food preferences. It is also likely that fish pemmican would have had a shorter "shelf life" than buffalo pemmican. The failure to exploit the great inland fisheries meant that alternative sources had to be developed. The Nor'Westers were the first to confront this problem and in the late 1870s they turned to the Beaver Indians living in the Peace River valley to supply them with the additional food. By the turn of the century the North West Company was relying on the Peace River area for all of its dried provisions in the region. This meat was sent from the Peace River valley to Fort Chipewyan where the Nor'Westers used it to outfit their canoes bound for Cumberland House from Peace River, Great Slave Lake, and Lake Athabasca.

In 1802 the Hudson's Bay Company moved into this area and built Nottingham House on Lake Athabasca, near Fort Chipewyan. It was hoped that the men at this post would be able to feed themselves on fish. Like the Nor'Westers, the Hudson's Bay Company men also realized that they would need to tap the Peace River country for more food. They launched this effort with the construction of Mansfield House on the Peace River in 1802. Realizing the strategic importance of the Peace River supply base and wanting to block the Hudson's Bay Company's push into Athabasca and Mackenzie river country, the Nor'Westers quickly moved to intimidate the Hudson's Bay Company on the Peace River. This venture was successful and the Hudson's Bay Company was forced to withdraw. Having failed to secure a supply base in the Peace River area, the Hudson's Bay Company also found it was necessary to close Nottingham House in 1809 and temporarily abandon the Athabasca country. They did not return again until 1815 when they built a new post, Fort Wedderburn, on Lake Athabasca. Once again the Hudson's Bay Company battled with the Nor'Westers for access to the provision trade of the Peace River country. This time they were successful and secured a toehold in the region by 1819.[13]

The battle for control of the provision trade at this time was not limited to the Peace River country. It erupted in the Red River area also. In 1812 the Hudson's Bay Company established the Selkirk agricultural colony on the banks of the Red River. This posed a strategic threat to the North West Company since the colony lay astride its provision supply line in that quarter. The seriousness of the danger was manifest in the winter of 1814. The colony was seriously short of provisions. In an effort to deal with the problem Miles Macdonell, the autocratic colonial governor, issued his "Pemmican Proclamation" on the 8 January 1814, forbidding the export from the area of any provisions that had been secured or grown there. All provisions were to be reserved for the colony's consumption.[14] Macdonell's action provoked the so-called "Pemmican War" in which the Nor'Westers, using the Métis as pawns, sought to destroy the colony.

The struggle for control of shares of the vital Plains provision trade continued in all quarters until the union of the two rival companies in 1821. Although this union temporarily reduced the overall labour force of the fur trade by as much as one-third, thereby temporarily diminishing the size of the provision market, this market rebounded a short while later. But after 1821 a new group emerged as one of the major suppliers—this group was comprised of French (the Métis) and English mixed-blood men. Most of these men were laid off by the Hudson's Bay Company in the early 1820s. Some simply quit. Previously most of them had been stationed at the parkland posts and had native wives of Parkland Indian ancestry. The mixed-bloods congregated near the Red River colony and around the present town of Pembina, North Dakota, until they abandoned the latter location in 1823. These men and their families combined the older Indian ways with the newer ones of the settlers. They established small farms but between sowing and harvest, they hunted buffalo for dried provisions and hides. From late August until early November many of them left for the plains a second time to secure fresh meat and buffalo robes for the winter. Their hunts were like those of their Plains Indian relatives, but there were also some differences. One was in the mode of transportation that the mixed-bloods used. The Métis employed two-wheeled carts fashioned of local materials (wood, leather and sinew) instead of the travois. These were the famed Red River carts. They were pulled by one horse, or an ox, and carried some 900 pounds of cargo—nearly double that of the travois. The carts gave the mixed-bloods great mobility, enabling them to extend their foraging range as far westward as was necessary to pursue the buffalo herds. Further, Indians tended to follow the herds, hunting them at all seasons. Since the mixed-bloods, who lived in fixed settlements, worked for the Hudson's Bay Company on a seasonal basis, and farmed on a part-time basis, they could not hunt all-year-round. Therefore, their buffalo hunting was confined largely to two hunts annually. These hunts were much like those organized by the Indians, except that Métis hunters skinned the slain buffalo and brought the carcasses back to camp rather than having their women and children follow in their wake. For both groups, the women did the butchering and meat processing.[15]

Recently it has been argued that the mixed economy of the Métis was better suited to the regional economic situation between 1821 and

1870 than was the way of life chosen by settlers who attempted farming on a full-time basis.[16] The farmers were frequently devastated by natural disasters. Colonial observer James Hargrave noted in 1870 that the Red River settlement had been completely flooded in 1808, 1826, 1852, and 1861, and had been plagued with locusts in 1818, 1819, 1857, 1858, and 1864 through 1868.[17] Besides these 13 major calamities in 60 years, droughts and early frosts were also a frequent problem. These recurring misfortunes kept the colony from producing a steady agricultural output sufficient to meet its own provision requirements. Poor storage and handling procedures frequently reduced the size of any surpluses produced.[18] Therefore, the developing colony remained partially dependent on the buffalo hunt to survive. This dependency extended the size of the provision market beyond that provided by the Hudson's Bay Company.

The Métis, as competitors of the Parkland Indians for the provision market, were most successful in southern Manitoba. One can assume that they satisfied nearly all of the colony's needs and a significant portion of the Hudson's Bay Company's requirements in that quarter. Posts situated along the middle and upper reaches of the Assiniboine River and North and South Saskatchewan Rivers and their tributaries supplemented the provisions that the mixed-bloods brought to Red River. Most of these western posts conducted the bulk of their provision trade with Indian groups. As in earlier years, these provisions were transported to Cumberland House and Norway House.

The dimensions of the provision market created by the fur trade can be pieced together by employing scattered bits of information that are available. For example, in the first decade of the nineteenth century the North West Company was obtaining an average of 12,600 lb. of pemmican from its Red River department and 27,000 to 45,000 lb. from the Saskatchewan area.[19] This gives an average annual total of between 39,600 to 57,600 lb. of pemmican for the North West Company from the prairie/parkland area. Historical accounts provide somewhat contradictory statements about the amounts of fresh meat that were needed to produce a bag of pemmican. James Hargrave stated that the meat of one bull made a 100-lb. bag of pemmican, while Father G. A. Belcourt claimed it took two buffalo cows to produce a 90-lb. bag of pemmican (one cow yielded 45 lb. of pemmican). But he added that experienced hunters reckoned it took eight to 10 cows' meat to fill one cart with pemmican (one cow = 90 to 112.5 lb. of pemmican).[20] There is a discrepancy in these figures of over 100 percent. Guillaume Charette, a Métis, observed that it took 4,000 cows to fill 500 carts with pemmican, or eight per cart.[21] This suggests that Belcourt's second figure is the more accurate estimate. Data obtained from the North West Company post of Fort Pembina reveal that the mean dressed weight of 35 bulls killed during the winter was 514 lb. while that of 112 cows was 402 lb.[22] In light of these various sets of figures, it would have taken approximately 350-440 lb. of fresh meat to produce 90-100 lb. of pemmican. This represents a weight loss of between 72 to 80 percent using cows and bulls. Using cows exclusively the range is 72-77.5 percent.

All historical sources agree that cow's meat was preferable for all types of consumption. F. G. Roe concluded that this preference was on the order of 10 to one.[23] More bulls would be taken only if there were not enough cows. Given the very strong historical preference for cows, and assuming a 75 percent weight loss in processing, it is possible to estimate the number of buffalo required to meet the pemmican demands of the fur trade as well as Métis and Indian subsistence requirements. For this reason, the estimates for slaughter will be expressed in "cow equivalents." On this basis it would have taken between 158,400 and 230,000 lb. of fresh meat to yield the quantity of pemmican the North West Company needed annually in the early nineteenth century. This represented roughly 400 to 575 buffalo cows. If we assume that the Hudson's Bay Company's requirements were the same during this period, the combined demand could have been met by killing fewer than 1,200 animals.

TABLE 2

PROVISION DEMAND OF THE HUDSON'S BAY COMPANY

Commodity	1840	1850	1860	1870
Pemmican (lb.)*	90,900	120,375	137,610	202,680
Dried Meat (lb.)**	20,000	16,600	11,000	9,000
Total	110,000	136,975	148,610	211,680
Price (sterling)/ lb.****	£ *s. d.*	£ *s. d.*	£ *s. d.*	£ *s. d.*
Pemmican	3	3	4	6
Dried Meat	2	2	3	4
Inventory value**** (sterling)				
Pemmican	1,136 5	1,504 14	2,293 10	5,067
Dried Meat	166 13	138 7	137 10	150
Total	1,302 18	1,643 1	2,431	5,217
Equivalent in Red River Cart Loads***	122	152	165	315
Equivalent in fresh meat (lb.)	482,000	579,870	615,625	864,053
Equivalent number of buffalo cows	1,205	1,450	1,539	2,160

*Ray, *Indians in the Fur Trade*, pp. 209-10.
**According to Belcourt, 1 cow = 67.50 lb. dried meat.
***Cart load = 900 lb.
****British Columbia Provincial Archives, Add MS, 220, "Standing Rules and Regulations, Northern Department, Rupert's Land, 1847-67," Public Archives of British Columbia, Add MSS 220.

Table 2 gives the provision demand of the Hudson's Bay Company at 10-year intervals between 1830 and 1870. These figures have been translated into equivalents. These data reveal that the size of the company's pemmican and dried meat market increased over two and one-half times between 1840 and 1870. But the numbers of animals needed for slaughter remained relatively low, suggesting that the provision market accounted for only a small percentage of the total output of provisions in the northern plains region.

This conclusion is based on an estimation of the magnitude of the demand for buffalo meat products by the Red River Colony and the native population. This estimation takes into account census figures for the colony, approximations of the native population in the mid-nineteenth century, scattered data dealing with food consumption at the beginning of that century, the ration rates employed by the Hudson's Bay Company and transportation capabilities of the mixed-blood population. During the winter of 1807-08, 41 men stationed at the North West Company post of Fort Pembina consumed 63,000 lb. of fresh buffalo meat over a 213-day period (1 September - 31 March). This represents an average of 7.2 lb./man/day or about 5,360 calories. In addition, during the same period the men consumed three red deer (*Cervus elaphus*), five black bear (*Ursus americanus*), four beaver (*Castor canadensis*), three swans (*Cygnus* sp.), one white crane (*Grus americana*), 12 outards, 36 ducks, and 1,150 fish of various kinds.[24] This level of consumption was only slightly below the rations that the Hudson's Bay Company provided for its boat brigades. Company boatmen were given eight lb. of fresh meat per day, their wives four, and their children two. Allowances for employees and their families stationed at trading posts was one-half that of the brigades. A variety of other foods was consumed also. Applying the Hudson's Bay Company rates to the population censuses of Red River suggests that the buffalo meat consumption of the colony would have ranged between approximately 2,200,000 lb. to 4,400,000 lb./year in 1831 potentially rising to between 7,500,000 lb. and 15,000,000 lb./year in 1870.[25]

This simple prediction must be modified, however, to account for additional factors besides human population growth. The colony was making slow, if erratic, progress in its agricultural output. Also, transportation capacity did not expand sufficiently to carry the quantity of meat projected by the 1870 estimate. In 1870 Hargrave wrote that an average of 1,200 carts took part in the two annual hunts—roughly the same number as in the late 1840s despite the population increase. This indicates that the Métis hunters could have supplied a maximum of 1,080,000 lb. of pemmican (the equivalent of 4,320,000 lb. of fresh meat) from the August hunt and 1,080,000 lb. of fresh meat in the autumn if all of their cargo space was devoted to provision supplies. Of course, this was not the case given that they also carried hides and robes. Thus, the annual buffalo consumption by the Red River colony in 1870 would have had to be less than the equivalent of 5,400,000 lb. of fresh buffalo meat per year. This indicates a daily ration of meat of less than three pounds of fresh buffalo meat per adult male or one-quarter less than the post allowance rate of the Hudson's Bay Company.

These calculations indicate that provision demands of the colony in 1831 would have generated a slaughter on the order of between 5,500 and 11,000 buffalo cows, while that of 1870 would have been under 13,500. This suggests that the maximum probable increase would have been less than two and one-half times between 1831 and 1870.

In 1856 Governor George Simpson of the Hudson's Bay Company calculated that the Plains Indians numbered just under 30,000.[26] Using this figure and applying the ration rates of the trading companies, the potential buffalo meat requirements of the Indians would have necessitated the slaughter of between 54,000 and almost 110,000 cows/year. In this case, the mean figure of about 82,000 is more likely, given that this number would closely approximate the size of slaughter that would be generated by a population of nearly 30,000 having a diet very similar to that of the men stationed at Fort Pembina in 1807-08.

As large as it appears, it should be pointed out that a projected kill rate of 82,000 animals per year is probably a conservative estimate bearing in mind that hunts were wasteful. During the summer season Indians sometimes slaughtered herds just to obtain the tongues and bosses for feasts. The rest of the carcass was left to spoil. Even without such profligate behaviour the hunt was wasteful by its very nature. Being a herd animal that was easily spooked to stampede, it was difficult for the Indians or Métis to kill only the buffalo that were needed. The most obvious example would be a cliff drive where it would have been impossible to control the number of animals that stampeded over a precipice. When running buffalo, hunters could not predict how many animals they could successfully skin and butcher. A number of problems could arise that could abbreviate the butchering. These included raiding parties of hostile native groups, rainstorms which rendered exposed meat useless, and nightfall. Predators, most notably wolves (*Canis lupus*), were effective scavengers after dark and took a heavy toll. According to one Métis hunter, besides these problems, the blinding dust of a run often made it impossible to carefully pick out the choice fat cows and many undesirable quarry were killed.[27] For all these reasons a significant allowance has to be made for wastage. Alexander Ross claimed that 2,500 animals were slain in one hunt by Métis but the meat of only 750 buffalo was processed—scarcely one-third.[28] Given all of the factors that could influence the ability of a party to process the meat of its hunt, wastage rates would not have been constant. If we assume that Ross's experience represented extreme conditions, then presumably they ranged up to as much as 66 percent.

Taken together, it is clear that the combined food needs of the Hudson's Bay Company, the Red River Colony and the Indians would have necessitated a slaughter that amounted to the equivalent of just under 100,000 cows (2,160 + 13,500 + 82,000) per year. Considering wastage, a range of 100,000 to 300,000 is a possibility. Of this, just over two percent of the kill would have been generated by the fur trade.

Although a slaughter of this magnitude might appear to represent a serious threat to the survival of the wild buffalo herds, this apparently was not the case if Roe's estimation of the natural rate of increase of the species is correct. Based on data obtained from the captive animals in Wainwright Buffalo Park, Roe concluded the population increased 18 percent/year.[29] At that rate the combined provision hunt could have been sustained by a herd of between 555,555 (if 100,000 were killed) and 1,666,666 animals (if the slaughter equalled 300,000). Most calculations of the size of the northern herds exceed these figures by a wide margin. Therefore, it seems likely that other economic developments in the nineteenth century served to accelerate the slaughter beyond the level of a sustainable harvest and eventually destroyed this vital food resource. The first of these developments was the emergence of a strong market for robes. A few robes had been traded ever since the beginning of the fur trade in the area in the late seventeenth century. However, the volume of this traffic was limited since there were no sizeable markets in eastern North America or Europe. Also, these articles were bulky and heavy and, therefore, it was difficult to transport large quantities of them by canoe. But by the early nineteenth century the picture began to change. American traders pushed up the Missouri River and established Fort Union at the confluence of the Yellowstone and Missouri rivers. This post became an important hub of trade drawing Indians from a large surrounding area, including the prairies south of the Saskatchewan and Assiniboine rivers. Using bateaux and steamboats the American traders' transportation costs were substantially less than those of the Hudson's Bay Company which continued to depend heavily on the less efficient York boat and canoe. The Americans' cheaper transportation costs enabled them to cater to the growing market for buffalo robes in eastern North America. This market developed to the point where it triggered off a virtual flood of robes down the Missouri River toward St. Louis. It has been estimated that between 1815 and the early 1860s the trade of the Missouri River area fluctuated between 20,000 to 200,000 robes/year.[30] Probably 50 percent of this trade came from the Canadian prairies north of the upper Missouri.

In the early 1820s Governor George Simpson of the Hudson's Bay Company made a few exploratory efforts to see if the company could take part in this new market either by making overland shipments to Montreal, or by exporting robes via York Factory to London for

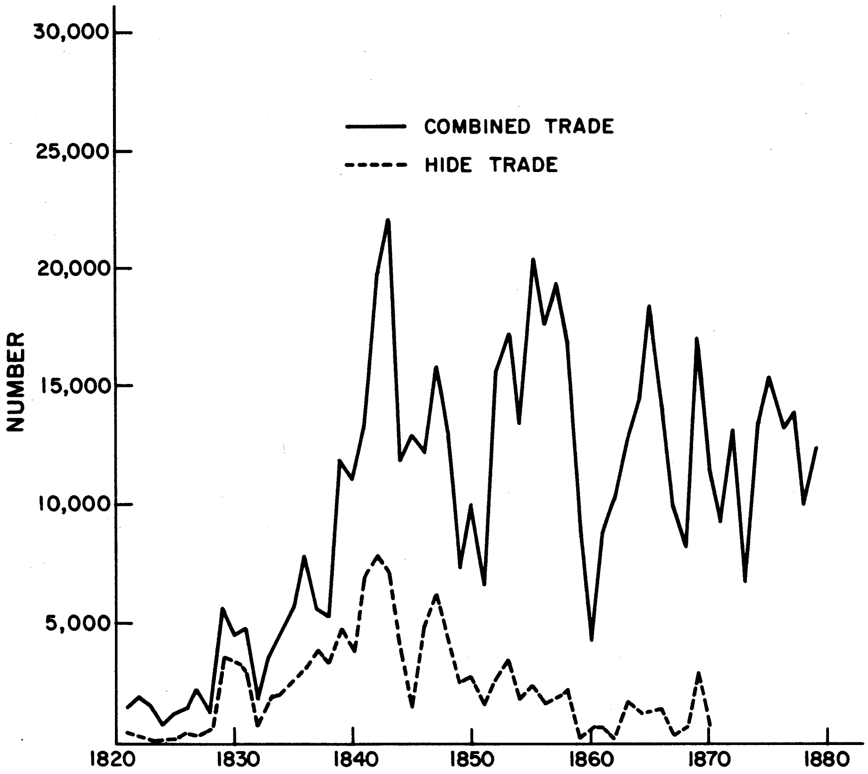

Figure 2. Hudson's Bay Company Northern Department hide and robe trade, 1821-1879.

reshipment from that city to New York. These initial efforts were failures.[31] Somewhat later the company became involved in the robe trade but its share of the enterprise remained very small (Figure 2). The Company's annual trade never reached 20,000. The Métis also became involved and in 1844 they began carting robes overland to the St. Paul area of Minnesota. Few data exist concerning the volume of traffic. However, in 1856 it amounted to more than 7,500 robes.[32] That year the Hudson's Bay Company traded almost 16,000 robes, suggesting that Métis trade comprised about 50 percent of that of the company's volume.

These sketchy data (in the case of the Métis) suggest that the combined robe trade of the Métis and Hudson's Bay Company ranged between 10,000 to 40,000/year between 1840 and 1879. Added to the 10,000 to 100,000 robes that probably flowed southward from the Canadian prairies to the Missouri River posts, an annual winter slaughter of 20,000 to 140,000 animals is indicated.

The robe hunt must be considered in relation to the provision hunt to understand the combined impact that it had on the native economy (Indian and Métis) and on the buffalo resource. Recall that the fur trade provision market consisted entirely of dried produce obtained from the summer hunts, therefore, no robes would have been taken as by-products of the 2,160 cows needed. Almost 11,000 of the 13,500 animals slaughtered for the colony's consumption were killed to produce dried meat products. Therefore, only about 2,500 (perhaps 7,500 if we allow for waste at the maximum rate) would have been killed for food during the robe season. There were about 6,000 Métis in Red River in 1870.[33] Allowing one robe for every man, woman and child per year for personal use, it is clear there would not have been any surplus left for trade. If, for the sake of discussion, we assume that the provision hunts of the Indians were spread out over the entire year, then 66 percent of the approximately 82,000 buffalo needed would have been slain at a time when robes could have been obtained as a by-product. This amounts to some 54,120 robes (perhaps 135,000 with a maximum wastage allowance). If we allocate two robes per Indian per year for clothing and bedding purposes (probably a conservative figure), it is necessary to subtract some 50,000 robes from the above figure to determine the number available for trading purposes. The result suggests that no by-product robes would have been available if Indian hunts were highly efficient and aimed primarily at meeting their food needs.

Adding together the median values of the estimated ranges of the volume of Canadian Indian robe trade to the Missouri River posts, the Hudson's Bay Company's robe trade, and the Métis traffic to Minnesota territory, it appears that the magnitude of the robe market for the region at mid-century was something on the order of 60,000 robes (40,000 + 13,000 + 6,000 = 59,000). This suggests that the development of the robe market could have had the effect of almost doubling the winter slaughter of buffalo (e.g., increasing it from just under some 56,600 to nearly 110,000). The problem is that we do not know if the Indians were able to take and process robes more efficiently than meat. If this was the case, then the robe trade may not have increased the Indians' winter kill at all if provision wastage was as high as 66 percent. If this was so, and all of the robes of the wasted animals were collected, then perhaps as many as 85,000 were available for trade. This seems unlikely, however, as robe processing, like meat preparation, was time-consuming although the rapid spoilage of the raw material was less critical.[34] Added to the summer hunt, conservatively estimated at just over 40,000 (27,060 + 2,160 + 11,000), the annual provision and robe slaughter probably ranged between 150,000 (assuming little wastage in the provision hunts) to as much as 354,000 (if two-thirds of the provision kill was wasted and no robes were obtained from the carcasses). The latter scenario is unlikely.

The magnitude of the difference in the economic importance of the provision and robe markets is not easy to gauge since we have good data only for the Hudson's Bay Company markets and, as noted earlier, the company took part in only a fraction of the robe trade. As Table 2 shows, the dried meat and pemmican that the Hudson's Bay Company purchased was valued in Sterling at £1,302 18*s.* in 1840, increasing to £5,217. Considering the number of Métis and Indians involved in the trade, these are very small figures. In contrast, the Company bought between 4,000 and 22,000 robes/year during this period (Figure 2). In 1843, at the height of the company's trade, it valued prime robes at 5*s.* and common at 2*s.*6*d.* Using an average price of 2*s.*9*d.* (the returns did not specify the quantities of prime and common) the 1843 trade was worth about £3,025 or nearly two and one-half times more than the provision market. In 1870 prime robes fetched 10*s.* and common 5*s.* for an average price of 7*s.*6*d.* At these prices the approximately 11,500 robes bought by the company were worth about £4,312 10*s.* to the Indians and Métis. In other words, the Hudson's Bay Company's robe market was of roughly the same value as its provision market. Since the company's prices for provisions and robes had doubled between 1840 and 1870, the shift in relative value of the markets represented the growing volume of the provision trade (it almost doubled between 1840 and 1870) whereas the volume of the robe trade showed an irregular decline. Thus, for Indians and Métis who traded solely with the Hudson's Bay Company, it would appear that the provision trade was of increasing relative importance. However, few traded exclusively with the company. Given the very large market for robes in the United States until the 1870s, one can speculate that before 1870 most Indian and Métis hunters derived the bulk of their hunting income from selling robes.

In the 1870s technological developments in the tanning industry made it possible to process buffalo hides. This had the effect of creating an extremely large market. Attention very quickly shifted from robes to hides to take advantage of this new economic opportunity. The development of this new trade served to accelerate the buffalo slaughter for a number of reasons. Hides could be prepared more quickly than robes and required less skilled labour. This meant that Euro-canadians could enter the field on a much larger scale than previously. The hide market was larger than that for robes, although the Hudson's Bay Company played a smaller role (Figure 2). Unlike the robe hunts, the kill was concentrated in a relatively short period. The dried provision needs of the Indians, Métis and the Hudson's Bay Company could have yielded something on the order of 40,560 hides. If the Indian and Métis population used two hides/year, probably a conservative number given the many uses hides served in their cultures, 60,000 hides would have been required for the native population annually. In short, there was no surplus. Indeed, the need for hides likely led the native population to slaughter more animals than their provision needs would have dictated, hence the "waste" noted earlier. If the estimates of food and hide needs are in the "ball park," one-third of the meat of the summer hunt could have been wasted as a result of the native demand for hides which necessitated a higher slaughter rate. In any event, it is clear that the hide trade probably increased the Indian and Métis level of hunting much more sharply simply because there was virtually no surplus available as a by-product of provision hunting. Thus, the robe and hide trade greatly increased the attack on the herds, hastening the day when they would vanish forever.

The tell-tale effects of overkill were manifest as early as the 1820s. By that time buffalo ceased to frequent the Red River valley near the colony. In the late 1850s their appearance in the southern Manitoba area was becoming irregular and this caused Alexander Ross to comment that the combined attack on the herds, from the north by Canadian groups and from the south by Americans, was forcing the herds to retreat westward.[35] He foresaw the day when they would be totally destroyed. By the 1860s the buffalo were in sharp decline north of the Qu'Appelle and South Saskatchewan rivers. By the late 1870s, the herds were largely confined to southwestern Saskatchewan and southern Alberta areas.

In the early 1880s the buffalo had declined to the point where native groups could no longer depend upon them for subsistence, much less produce a surplus of provisions, hides and robes for a commercial market. Thus, pemmican, once a staple of the fur trade, became very expensive (Table 2), rising from three cents/pound in the 1830s to between nine and one-half and ten cents/pound in the late 1870s. Also, the quality deteriorated. For these reasons, in 1880 the Hudson's Bay Company's chief factor at York Factory stated he was looking forward to the day when the company's dependence on this commodity would end entirely.[36] This came to pass a very short time later and brought a great deal of hardship and suffering to the Indians and many of the Métis. Alternative game supplies could not meet their subsistence needs and provide them with a sufficient quantity of marketable products to maintain their former lifestyle. The blow was severe. In the nineteenth century these groups had become the most economically independent and powerful groups in the west. But their economy and society had a fatal flaw. It was based on the exploitation of a single renewable resource at a rate that exceeded the level required for a sustained yield harvest. Thus the once proud Grassland Indians and many Métis were reduced to poverty levels by the 1880s and found themselves in a much worse socio-economic situation than their cousins in the wooded areas of the plains. The latter had never reached the same economic heights, but were spared reaching the same lows. The local provision market in the Peace River country led to the serious depletion of the wood buffalo population. But the market was organized very differently. Most of the meat was obtained by a relatively few Indians who were hired as post hunters. Therefore, income from this activity was not spread as broadly through the population. Also, since moose (*Alces alces*) was the preferred food animal for most of the local Indians, the assault on the buffalo in this area had very different implications for the native inhabitants.[37] As this resource declined, the Woodland Indian bands were able to continue to support themselves by hunting, fishing and trapping. Meanwhile their grassland counterparts were reduced to subsisting on ground squirrels ("gophers") (*Spermophilus* sp.), and prairie dogs (*Cynomys ludovicianus*), and relying increasingly on government assistance. The pantry of the prairie plains was bare and could never be stocked with natural surpluses again. There and then the era of the hunter yielded to that of the farmer and rancher.

NOTES

Bison have been referred to throughout this paper as buffalo in keeping with historical practices. The term mixed-blood is used for the same reasons.

1 Arthur J. Ray, *Indians in the Fur Trade.* Toronto, University of Toronto Press. 1974: 131-35.
2 Numerous accounts of this process exist. For a recently published observation see, G. Charette, *Vanishing Spaces: Memoirs of Louis Goulet.* Ed. and translated by R. Ellenwood, Winnipeg, Editions Bois-Brûlés 1980: 55.
3 *Ibid.*, 56.
4 Given this practise B. Gordon has cautioned against using the hunting schedule of the Métis as a model for the Indians. See, B. Gordon, *Of Men and Herds in Canadian Plains Prehistory.* Ottawa, National Museum of Canada 1979.
5 Ray, 1974: 87-9.
6 See, for example, Thomas Kehoe, *The Gull Lake Site.* Ottawa, National Museum of Man 1973: 22-50.
7 *Ibid.*, 195.
8 Charette, 55 and Alexander Ross, *The Red River Settlement.* (Reprint) Minneapolis, 1972: 257.
9 Ross, 257.
10 *Ibid.*, 256-57.
11 For a discussion of the spread of horses in this area see, Ray, 1974: 156-62.
12 A. J. Russell, *The Red River Country, Hudson's Bay & North-West Territories Considered in Relation to Canada*, Ottawa, G. E. Desbarats 1869: 194.
13 L. Ugarenko, "The Beaver Indians and the Peace River Fur Trade, 1700-1850," MA Thesis, York University, 1979: 80-7.
14 For a discussion of this episode see, A. S. Morton, *A History of the Canadian West to 1870-71.* 2nd ed. Toronto, Published in cooperation with University of Saskatchewan by University of Toronto Press 1973: 537-72.
15 J. J. Hargrave, *Red River.* Montreal, printed for the author by J. Lovell 1870: 168.
16 C. Sprenger, "The Metis Nation: The Buffalo Hunt vs. Agriculture in the Red River Settlement (Ca. 810-70," *Western Canadian Journal of Anthropology*, 3 (1), 1972: 159-78.
17 Hargrave, 1870: 175-76.
18 Ross, 1972: 113-14 and 120-24.
19 Ray, 1974: 132.
20 C. M. Judd, *Lower Fort Garry, The Fur Trade and the Settlement at Red River.* Ottawa, Parks Canada, MRS 202, 1976, Appendix E: 313.
21 Charette, 53.
22 Ray, 1974: 131.
23 F.G. Roe, *The North American Buffalo.* 2nd ed. Toronto, University of Toronto Press 1972: 373-76 and 860-61.
24 Ray, 1974: 131.
25 Hudson's Bay Company Ration schedules are contained in, "Standing Rules and Regulations, Northern Department, 1843-70," Public Archives of British Columbia, Add MSS 220. Red River census data are contained in *Censuses of Canada, 1665-1871.* Statistics Canada, Vol. 4, Ottawa, 1876.
26 Hudson's Bay Company Archives, Public Archives of Manitoba, E 18/8, folio 40.

[27] See, Ross, 1972: 258 and P. Erasmus, *Buffalo Days and Nights*. Ed. by I. Spry, Calgary, Glenbow-Alberta Institute, 1977: 31-33.
[28] Roe, 404-9.
[29] *Ibid.*, 503-5.
[30] Ray, 1974: 210-12.
[31] *Ibid.*
[32] *Ibid.*, 212.
[33] Hargrave, 1870: 174.
[34] Robes were processed by the women. The need for this skilled labour prevented large numbers of white hunters from entering into the trade.
[35] Ross, 267.
[36] A. J. Ray, "York Factory: The Crises of Transition, 1870-1880," *The Beaver*. Autumn, 1982: 28-9.
[37] Ugarenko, 117.

The North American Plains Bison: A Brief History

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ABSTRACT. The nineteenth century witnessed the movement of explorers, fur traders, and settlers onto the Great Plains. Settlement increased hunting pressure on the bison for food and for robes. However, the demand for furs lessened by the 1840s and the buffalo robe trade increased to meet a rising demand. Increased hunting eliminated the buffalo where settlement was greatest from the Red River country in Manitoba, south to eastern Kansas. The early 1870s brought forth a process for making commercial leather from bison hides. Hide hunters proceeded to eliminate bison on the southern and central Great Plains by 1878. Their attention then turned north and, by 1883, the free-roaming plains bison were nearly exterminated.

Efforts to save the bison rested on the efforts of a few Canadians and Americans. By 1900, efforts were successful to save the bison from extinction and their numbers continued to increase. The largest herd in North America was located near Wainwright, Alberta. The Wainwright bison population quickly increased to over 10,000. Approximately 6,000 buffalo were gradually moved to the newly-created Wood Buffalo National Park in northern Alberta. Today, there are over 50,000 bison in government and privately-owned herds.

RESUME. C'est au cours du dix-neuvième siècle que les explorateurs, les traiteurs de fourrures et les colons envahirent les Grandes Plaines de l'Amérique du Nord. La chasse au bison, pour sa viande et sa peau, s'intensifia sous la poussée du peuplement. Vers le début des années 1840, avec la fléchissement de l'ancien marché des fourrures, le commerce des peaux de bison prit rapidement de l'ampleur. On eut tôt fait d'exterminer le bison dans les zones plus densément colonisées, depuis la Rivière-Rouge jusqu'à l'est du Kansas. Au début des années 1870, on découvrit un procédé de transformation de la peau de bison en cuir industriel. Dès 1878, les chasseurs avaient exterminé le bison du sud et du centre des Grandes Plaines. Ils tournèrent leurs fusils vers le nord et, en 1883, le bison sauvage des plaines avait presque disparu.

Quelques rares Canadiens et Américains tentèrent d'éviter l'extinction. Ils y réussirent si bien qu'en 1900 le bison n'était plus menacé et la taille des troupeaux augmentait régulièrement. Le plus grand troupeau d'Amérique du Nord, près de Wainwright en Alberta, dépassa rapidement le cap des 10 000 têtes, dont 6 000 furent petit à petit menées vers le nouveau parc national de Wood Buffalo, au nord de la province. On compte aujourd'hui plus de 50 000 bisons dans des troupeaux sous la garde du gouvernement ou de particuliers.

Just 100 years ago, in the late fall of 1883, the buffalo hide hunters returned from the buffalo range with empty wagons. The success of their efforts over decades had brought this symbol of the old west to near extinction. Those empty wagons further signified the end of a way of life for the Plains Indians—of buffalo hunting that had persisted for 10,000 years.

The incredible numbers of bison—more commonly called "buffalo"—continually occasioned campfire discussions by prairie travellers after a long day on the trail. Robert M. Wright of Dodge City, who first entered Kansas in 1859, recalled, "I have indeed traveled through the buffaloes along the Arkansas River for 200 miles, almost one continuous herd as close together as it is customary to herd catttle. You might go north or south as you pleased and there would seem no dimunition of their numbers" (Wright 1902).

The most impressive estimate was also related by Wright (1902):

> General Sheridan and Major Inman were occupying my office at Fort Dodge one night, having just made the trip from Fort Supply, and called us in to consult

> as to how many buffaloes there were between Dodge and Supply. Taking a strip fifty miles east and fifty miles west, they had first made it 10,000,000,000. General Sheridan said "That won't do." They figured it again, and made it 1,000,000,000. Finally they reached the conclusion that there must be 100,000,000; but said they were afraid to give out these figures; nevertheless they believed them.

Perhaps a more accurate estimate was made by Ernest Thompson Seton, a Canadian naturalist, shortly after the turn of the century. Seton (1953) tackled the question more rationally by first determining the size of the original buffalo range (about three million square miles). He then determined from the 1900 census that the number of domestic cattle, sheep and horses on the Plains was 30 million but occupied only half the original buffalo range. Excluding the six million sheep, he argued that if half the plains area could support 24 million cattle and horses, then conservatively, it probably supported 40 million bison before the white man arrived.

Seton next considered the half-million square miles of prairie east of the plains. Using similar variables he arrived at an early prairie bison population of 30 million. He concluded with an estimate for the forest lands of five million bison or a total early population of 75 million (Seton 1953). Present estimates are more conservative and place the early bison numbers between 30 and 60 million.

To early explorers, buffalo were strange and ugly looking creatures. Today we consider them "majestic or noble animals," probably because of our guilt at having nearly exterminated the species. However, the buffalo probably hasn't changed appearance since the first descriptions were sent back to Spain in the early sixteenth century.

The buffalo bull has a large head and forequarters but small hindquarters that make him appear somewhat out of proportion. A full grown bull stands between 1.5 and 1.8 meters (5 and 6 feet) at the shoulder; may reach 3 meters (9.5 feet) in length and weigh over 910 kilograms (1 ton).

The buffalo cow is smaller, appears more gracile, has a smaller hump, and generally weighs between 275 and 410 kilograms (600 and 900 pounds).

A buffalo's hearing is reputedly keener than its vision, but its sense of smell is superb and odoriferous humans have reported themselves detectable at distances of nearly four miles.

Of their habits, there is nothing that bison find more enjoyable than "wallowing" on the ground. Wallowing or rollong on one side and then the other is not confined to season or sex. It increases during the rut or breeding season in July and August and in summer where a bit of moisture remained in some declivity wallowing offered relief from heat and insects. As George Catlin (1965) described:

> Finding in the low parts of the prairies a little stagnant water amongst the grass, and the ground underneath soft and saturated with moisture, an old bull lowers himself upon one knee, plunges his horns into the ground, throwing up the earth and soon making an excavation into which water trickles. It formes for him in a short time a cool and comfortable bath in which he wallows like a hog in the mire. Then he throws himself flat upon his side, and then, forcing himself violently around with his horns, his feet and his huge hump, he ploughs up the ground still more, thus enlarging his pool till he at length becomes nearly immersed. Besmeared with a coating of the pasty mixture, he at length rises, changed into "a monster of mud and ugliness," with the black mud dripping from his shaggy mane and thick woolly coat. The mud, soon drying upon his body, forms a covering that insures him immunity for hours from the attacks of insects.

Another enjoyable buffalo pastime was to rub against boulders strewn across the prairies by former glaciers. Rubbing was directed against trees, sod houses, and telegraph poles. In fact this great delight of buffalo was etched indelibly into the minds of early telegraph construction crews. Herds crossing an area of telegraph lines busied themselves rubbing down miles of poles and wire. Human ingenuity responded with the installation of sharp pointed spikes, or bradawls in thousands of telegraph poles to discourage such havoc. In March 1869, the Leavenworth, Kansas, *Daily Commercial* reported in favour of the buffalo.

> For the first time they came to scratch sure of a sensation in their thick hides that thrilled them from horn to tail. They would go fifteen miles to find a bradawl. They fought huge battles around the poles containing them, and the victor would proudly climb the mountaineous heap of rump and hump of the fallen, and scratch himself into bliss until the bradawl broke, or the pole came down. There has been no demand for bradawls from the Kansas region since the first invoice. (Dary 1974)

Benefits that buffalo rendered to prairie travellers far outweighed any harmful activities they showed. Ground depressions created by wallowing buffalo often provided the only water (bad as it might be) for survival within many miles. With little wood to be found across vast stretches of prairie, fuel for warmth and cooking availed the traveller in the lowly buffalo chip. Early experts considered them larger than those of domestic cattle and most serviceable after they had lain on the prairie for six to eight months. They burned with little flame but intense heat. In winter buffalo chips were unserviceable. However, at that season the bison were on their winter range in wooded valleys and timbered areas along with the Indians who had followed them there.

The buffalo was the staff-of-life for Plains Indian tribes. As Ewers (1966) pointed out:

> It has been said that in no other section of the world has the culture of a people been so strongly moulded by the presence of a single species of animal as in the Plains of North America. The buffalo not only furnished the Indians with food, clothing and shelter and many other articles in their material culture, it held a prominent place in the mythology, religion and ceremonial organization of the plains tribes.

Successful bison hunting took many forms. Singly or in small groups, Indians disguised as wolves "stalked" herds, mingling among the animals to silently kill one or more with well-placed arrows. Stalking is a universal hunting technique of great antiquity and basic to many other forms.

In the ancient "dog days" before the Indians acquired horses, another technique, "surrounding," incorporated stalking but involved every able-bodied member of the community or band. Buffalo were approached downwind with the Indians silently dividing into two groups to widely encircle the herd. The circle was gradually tightened, the frightened herd becoming increasingly dangerous to the wary hunters and their courageous families. The hunters hoped to start the herd milling in a tight circle within their human containment. In this way the entire herd could gradually be killed. Otherwise, they would break out at some point and endanger the Indians.

A variation of this technique permitted the buffalo an avenue of escape. After encirclement hunters lined on each side of the escape route fired their arrows killing and wounding many buffalo as they attempted to flee. The wounded animals were followed, dispatched, butchered, and the meat was taken to camp.

Introduction of the horse among the northern plains tribes (*ca.* A.D. 1730) made surrounding less dangerous. The horse gave maneuverability and speed unknown to a man on foot so that 50 hunters mounted on horseback could surround a herd of several hundred buffalo, force it to mill in a circle and despite the everpresent danger of being gored or trampled to death, quickly kill the entire herd.

In fall, the buffalo moved from the broad tablelands of their summer range into the parklands and river valleys of the winter range. The preferred hunting method at that season and throughout the winter was the spectacular "bison drive" over cliffs or into pounds constructed near their sheltered camps. Where cliffs were part of the landscape bison were driven over and killed or maimed in the fall. Not every cliff was suitable and where the selected cliff was low an enclosure would be incorporated at the base. Sometimes herds were driven over cutbanks. Further east on the more level plains pounds were necessary. Pounds were generally constructed in timbered coulees below the edge of more level grasslands. The pound consisted of a corral solidly made of logs, rocks and brush built high enough to keep the buffalo from leaping out and large enough to contain a small herd. Various kinds of entrances permitted the animals to enter the pound but foiled any attempts to escape.

Similar drive procedures applied to both pounds and jumps. A bison herd was lured to a position between V shaped drive lines that funneled the animals into the pound. Rock piles, brush or stacks of buffalo chips spaced a few feet apart formed the drive lines. The

Indians, hidden behind these piles closed in behind the herd, stampeding it into the pound.

If the drive went well the buffalo were killed inside the pound and butchered. The meat and hides were then distributed among band members according to custom.

After horses were introduced a new form of hunting developed—the chase on horseback. Bison could run nearly as fast as a good horse and had more endurance. The chase involved the fastest horses, well trained to run at full gallop alongside a buffalo so a rider could fire a fatal shot. Danger was ever present from a wounded buffalo turning quickly to gore the horse and rider. Equal danger resulted from stampeding animals raising great amounts of dust, thus preventing horse or rider from seeing gopher and badger holes. A horse at full gallop stepping into a badger hole could stumble and throw the rider, who could be killed in the fall or gored or trampled to death.

Cooking was done over an open fire or in locally manufactured earthenware pots or metal trade pots. When these weren't easily available food was boiled in buffalo hides. A receptacle was formed for the hide by digging a circular hole in the ground about one meter wide and one meter deep. The hide was placed in the hole, then filled with water and from a nearby fire hot stones were removed with wooden tongs and dropped in the water bringing it to a quick boil. Meat and vegetables were added and made into soup.

Extermination of the buffalo began soon after arrival of the first Europeans in the American colonies. According to Dary (1974)

> The near extermination of the American buffalo did not happen overnight, nor was one generation of human beings fully responsible for clearing the plains and prairies of this most noble animal.

In 1811, Lord Selkirk obtained a large tract of land that included the Red River Valley and other large areas of what is now southwestern Manitoba. Settlers were induced to come to the area with assignments of land and the colony prospered. Buffalo hunting soon became favoured over farming and large hunts were organized as buffalo became scarce near the settlement. These organized hunts began about 1820 and continued into the 1870s. Using the well-known Red River carts, the Red River hunters eventually extended their hunts westward into central Montana and later into the Cypress Hills of Alberta. Although the diminution of bison numbers does not rest alone with the Red River hunters, their hunts contributed to the gradual extermination of the buffalo on the northern plains.

Soon after the Louisiana Purchase in 1803 and the subsequent exploration of the northern part of this territory by Lewis and Clark between 1804 and 1806, American interest in the fur trade began with the establishment of Mañuel Lisa's fur trading post in 1807 on the Yellowstone River in present day Montana.

Although beaver and other furs were more important economically, the trade in buffalo robes and buffalo tongues (considered a great delicacy at the time) increased; Dary (1974) states:

> On the high plains east of the Rockies, the trade in buffalo robes and buffalo tongues began to increase, and during the 1820's about 200,000 buffalo were killed annually on the plains. But only about 5,000 of these were killed by white men.
>
> The trade in buffalo robes and tongues was particularly heavy along the Upper Missouri. There Indians were encouraged to kill the animals for robes and tongues and to trade these items at the growing numbers of trading posts. Buffalo were often killed for their tongues alone. This was particularly true during the summer months, when the buffalo's robe was poor. In 1804 Charles MacKenzie, after visiting some Mandan villages, reported, "Large parties who went daily in pursuit of the buffalo often killed whole herds, but returned only with the tongues." And George Catlin made a similar observation in the early 1830s. After he had arrived at Fort Pierre on the Missouri, he learned that only a few days earlier 500 or 600 Sioux had gone buffalo hunting. When the Indians returned, they had 1,400 fresh buffalo tongues, for which they were given a few gallons of whiskey.

By 1840, the fur trade had begun to change in Canada and the United States. Unrestricted trapping of beaver began to deplete the supply. Beaver hats went out of style and were replaced by hats made from silk imported from China. However, the buffalo robe trade continued to increase and 50,000 robes were shipped down the Missouri River from Fort Union in 1835 (Dary 1974).

Continued removal of such vast numbers of animals could lead only to extinction, a point that was almost attained during the last decade of free-roaming bison and buffalo-hunting Indians. A process for making quality commercial leather from buffalo hides was discovered in 1871-72. As the demand for buffalo hides sharply increased hunters from everywhere appeared on the Plains to make their fortunes.

The late 1870s culminated in the near extinction of bison on the southern plains and the hide hunters turned their attention to the northern herds in western Dakota, Montana and Wyoming. The fabled millions were gone by 1884 and the few remaining small herds in Montana and the Canadian west, not worth the time to hunt commercially, were soon killed for food by settlers and starving Indians.

Public outcry against the buffalo slaughter had begun years before the final curtain was drawn on the terrible drama. Concerned politicians had attempted to pass federal legislation to prevent the killing during the 1870s and had failed. "Too little too late" summed up both provincial and federal efforts.

The vast majority of buffalo alive today can trace their ancestry to those animals captured by James M. McKay, Charles Alloway, Charles Goodnight, Walking Coyote, Frederick Dupree and Charles J. Jones (Coder 1975).

The following material comes from an excellent summary by Coder (1975). The earliest efforts to capture buffalo were those of James McKay and Charles Alloway of Fort Garry, now Winnipeg. In 1873 they joined a brigade of Métis hunters and captured two little buffalo heifer calves and a husky little bull southwest of Battleford on the Battle River (Coder 1975). The calves did well and to increase their herd McKay and Alloway struck west again in 1874 with a hunting brigade comprised of nearly 2,000 Indians and Métis. On this trip they found buffalo half-way between Regina and Moose Jaw and near the international border. Again they captured two heifer calves and a little bull. However, the bull sickened and died. This was the foundation of the McKay-Alloway herd which was kept at Deer Lodge until 1880 when, after the death of McKay's wife and then McKay, the herd was auctioned and eight were purchased by Colonel Samuel L. Bedson, warden of the penitentiary at Stony Mountain, Manitoba.

To purchase the animals, Colonel Bedson is believed to have borrowed $1,000 from Donald A. Smith, later to become Lord Strathcona. Smith had a herd of buffalo on his estate at Silver Heights near Winnipeg, immediately adjacent to the McKay home at Deer Lodge. It is believed that he purchased the remainder of the McKay-Alloway herd.

In 1898, Lord Strathcona presented his animals to the Dominion Government. Five animals, which later died, were given to the City of Winnipeg; the remaining 13 were placed in Rocky Mountain Park at Banff, Alberta. The Bedson herd was sold in 1889 to Charles J. Jones of Garden City, Kansas.

Frederick Dupree, from Longueil, Québec, and of a distinguished family, moved west in 1838, worked in the fur trade, and later became a moderately wealthy cattle rancher and one of South Dakota's leading pioneers (Coder 1975). Dupree captured five buffalo calves in 1882. Several died, but in 1888 the herd had increased to nine (Hornaday 1889).

Dupree died in 1898 and his entire herd was bought by James "Scotty" Philip, a rancher north of Pierre, South Dakota, who also desired to save the buffalo.

Two others who figured prominently in saving the bison were Charles J. Jones of Garden City, Kansas, who captured 56 calves; Charles Goodnight, a famous pioneer cattleman from Texas, at the instigation of his wife, Mary Ann, captured several calves in 1878 and these became the nucleus of his herd. These were important contributions to the preservation of the buffalo.

What was called the Wainwright herd in Canada, and the Pablo herd in the United States, originated in the efforts of a humble, middle-aged, Pend d'Oreille Indian from western Montana named Samuel Walking Coyote.

In 1877, Sam, his wife and stepson joined a hunting party and travelled from the Flathead Valley east across the mountains to the Blackfoot country where buffalo were to be found.

In the Blackfoot country, buffalo hunting was excellent. Though married, Sam fell in love with a young Blackfoot woman and, rationalizing that extra help was needed in hunting and processing the hides, married her.

By spring the young Blackfoot wife had left and Sam began to fear the fate awaiting his return home at the hands of the tribal police.

A friend suggested that he capture some buffalo calves and take them home to demonstrate his penitence. He later arrived in the Flathead with four buffalo calves—two heifers and two bulls.

Stories vary as to Sam's fate when he arrived home. However, the small buffalo herd grew and two prospering ranchers, Michael Pablo and Charles Allard, purchased the animals from Sam. The herd thrived on the rich grasses in the Flathead and in 1890 represented the largest privately owned buffalo herd in the world.

In 1895, when Charles Allard died, the herd numbered about 300 and the animals were equally divided between Pablo and Allard's estate (Dary 1974). Most of Allard's buffalo were sold to Charles Conrad of Kalispell, Montana. Michael Pablo kept his herd until 1906. He had offered to sell them to the United States Government and President Theodore Roosevelt had urged Congress to purchase the herd, but Congress refused. The Canadian government made an offer of $200 per animal and the contract with the Canadian government was signed by Pablo in the fall of 1906.

Rounding up the buffalo, delivering them to the railhead, and then loading them onto railroad cars for shipment to Canada was no easy task. It took Pablo and his riders six years to complete the delivery which came to a surprising total of 748 buffalo (Coder 1975).

The buffalo were placed on a large range near Wainwright, Alberta. During the early 1920s the herd had grown to many thousands and beyond the grazing capacity of the range.

A regrettable decision by the Federal Government in Ottawa resulted in the transfer of over 6,000 bison north to Wood Buffalo National Park during the mid-1920s. This was unfortunate for two reasons. First, the Wainwright herd was afflicted with tuberculosis and second, the Wood bison which already resided in Wood Buffalo Park was regarded by most wildlife biologists as a distinct sub-species. The mixing of the two herds and production of the hybrid could eliminate the pure wood bison race.

During the 1950s and 1960s several herds of pure or nearly pure wood buffalo were located in Wood Buffalo National Park. Some were isolated from the mixed herds and moved to different parts of the nation to ensure their survival as a sub-species.

The mixed herd population, which is predominantly plains buffalo, has fluctuated in numbers to as many as 12,000 buffalo.

Today, the North American buffalo is no longer threatened with extinction. Private herds in Canada and the United States combined with government protected herds number well over 50,000.

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Status of Wolves in the Canadian Plains Region

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ABSTRACT. Wolves were present throughout the Great Plains Region prior to European settlement of the area. With the extirpation of bison in the nineteenth century, and as a result of the extension of agriculture in the region, the range of this carnivore was reduced. Numbers reached low levels around the turn of the century. Recent range extensions have been documented. For the time being, there is no reason to be alarmed about the survival of the species in the region. Currently, there are two areas of conflict with man. These pertain to depredation on livestock and competition with man for huntable populations of ungulates. A third area of conflict may develop if game farming and game ranching becomes established.

RESUME. Le loup habitait l'ensemble des Grandes Plaines avant leur peuplement. La disparition des troupeaux de bisons au dix-neuvième siècle et l'extension des zones agricoles déterminèrent un rétrécissement de son aire, et le loup se fit progressivement plus rare jusqu'au début de notre siècle. Toutefois, on a pu récemment constater un certain élargissement de son aire et, dans l'immédiat, il n'y a pas lieu de craindre pour sa survie dans la région. Il existe présentement deux sources potentielles de conflit avec l'homme: le pillage des troupeaux domestiques et la concurrence directe pour une des cibles du chasseur, le gibier ongulé. Si l'élevage commercial du gibier se répand, il risque de devenir une troisième source de conflit.

Introduction

I can recall observing bison grazing along an esker in Wood Buffalo National Park, when the shadow of a raven glided over the landscape. At that moment two grey wolves appeared out of dense cover, walked broadside to the bison and fully exposed themselves. For an instant I was reminded of a scene on the prairie landscape that existed before Europeans came to the west. These large predators then quietly disappeared as the bison continued to graze. Like the shadow of the raven, wolves on the prairie landscape are but a reflection of the past, and the presence of this carnivore in association with the bison on the prairies is only a matter of paintings and records in history books. Wolves, however, have not been exterminated and they are still present in substantial numbers in northern areas.

The wolf, whether by design or by accident, has always captured man's attention. To some the carnivore is a symbol of man's ability to protect wild places and wild creatures, while to others the wolf is a destructive animal that competes with man for livestock and game. Wherever wolves have disappeared, it has been largely as a result of man's activities. This paper briefly deals with the distribution (historical and current), economic status and conservation of wolves in the Plains (Figure 1).

Historical

The fate of wolves has been tied to the settlement of the prairie provinces by Europeans in the nineteenth century. Wolves disappeared wherever bison were eliminated and farming took over from the pristine hunting economy of the Plains Indians. The pattern followed that

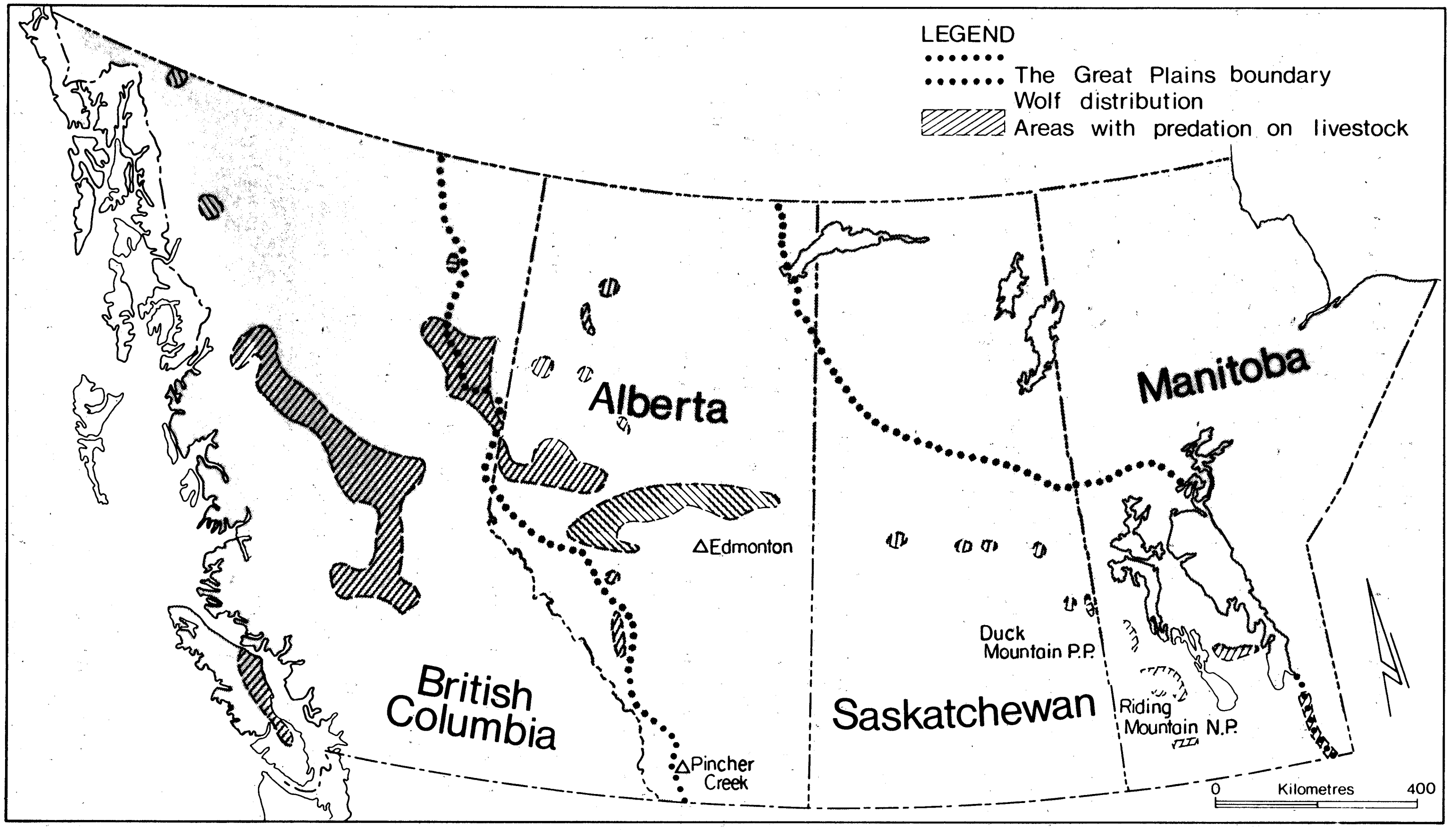

Figure 1. Overview of the 1981 generalized distribution of wolves in the Canadian Plains Region, showing areas of greatest incidence of wolf predation on livestock.

which occurred in the United States and elsewhere. Conflicts between humans and wolves inevitably followed wherever man had established intensive agriculture in former wolf ranges.

Records are available of wolf predation on cattle. For example, wolves were reported to have killed cattle at Fort Carlton in 1857 (Spry 1963). In southern Alberta, livestock depredation by wolves occurred in the 1870s (Rodney 1969) and in southern Manitoba around 1886 (Seton 1909). Therefore, survival of the species has been mostly in the Canadian portion of the Great Plains, in areas where agriculture is absent or not intensive.

Prior to European settlement, wolves appeared to be common throughout the region. Anthony Henday, probably the first white man to penetrate the region in 1754, wrote in his diary, "Wolves without numbers," and then goes on to say, "I cannot say whether them (wolves) or the buffalo are most numerous," (Burpee 1907). Later David Thompson observed wolves *ca.* 1810 along the eastern edge of the Rocky Mountains (along the Athabasca Valley in what is now Jasper National Park). Alexander Henry noted that wolves were common along the foothills *ca.* 1811 (Coues 1897), and Spry (1963) indicated that the Palliser expedition of 1857-1860 frequently encountered wolves throughout the prairies and foothills. In the north as well, wolves were common (Hearne 1795, MacFarlane 1908). Initial fur trade efforts probably had little effect on overall wolf numbers. Few traders ventured far from the fur trading posts and European demand for fur was centred mainly on beaver pelts. This general abundance of wolves probably lasted until about the mid-to late-1800s. At that time bison numbers decreased, while wolves were increasingly killed in retaliation for competing with man for meat supplies, both domestic and wild. Some early attempts at cattle ranching failed because of losses to wolf predation (Morton 1957), but how widespread this problem was is not certain. "Wolfing"—strychnine poisoning of bison, horse or other carcasses—became an effective means of taking wolves (Spry 1963, Rodney 1969), and this was followed by bounty payments (Williams 1946).

Increasing settlements by Europeans, the presence of improved guns and steel traps quickly reduced wolf numbers in southern areas of the Canadian Plains. After the turn of the century increased fur trapping in northern areas may have affected wolf reduction to some extent. During the 1920s and 1930s trappers moved northward, which resulted in keen competition. Establishment of a registered trapline system during the 1940s and 1950s reduced the trapping pressure on the fur resource. This, together with increased prey populations, studies on wolves and an evolving conservation ethic that looked upon predators as part of the total system, eventually resulted in protection and increases in wolf numbers in the north. Most of the southern areas were still devoid of wolves, but range extensions did take place in the central portions of the western Canadian provinces. Nowak (1983) called this "... one of the most remarkable wildlife comebacks in history." He goes on to say that, "In a sweeping arc from Alaska, ... to the Great Lakes ... the wolves spread. The greatest increases appear to have been in southwestern Canada, especially in Alberta, Saskatchewan and Manitoba, where the wolf reclaimed vast areas of its former range and was seen again in places where it could not be remembered by local people." As wolf numbers increased and the species extended its range, renewed conflicts with farming and with game populations occurred. Specific control programmes were established to reduce wolf/livestock conflicts. During the 1950s and early 1960s British Columbia, Alberta and Saskatchewan also controlled wolves for game management. Programmes were generally discontinued in 1961 (Tompa 1983a) and 1965 (Gunson 1983a, Stardom 1983) although in a few specific areas some forms of control were retained. Saskatchewan began wolf control for game populations in the mid-1930s and maintained it longer (to 1975) than did the other western provinces (Wiltse 1983). Concomitant with a reduction in wolf control was an increase in human hunting activities and a decline in ungulates. These general trends in western Canada have been documented for one species i.e. moose (*Alces alces*) (D. Eastman and J. Hatler, personal communication). As a result of declining numbers of ungulates, renewed calls for predator (wolf) control programmes have been made in British Columbia and Alberta. British Columbia responded in 1977 by implementing experimental wolf removal for game management purposes (Tompa 1983a). In the winter of 1983 Alberta encouraged greater wolf harvesting by promoting commercial wolf trapping. Both of these programmes sparked an outbreak of public concern and pitted the "non-consumptive" components of society (general non-hunting public) and the "consumptive" group (hunters) against each other.

Taxonomic Status

Designation of subspecies was important in the first half of the twentieth century. Wolves in North America were placed into 24 different subspecies (Hall 1981). Four of these fall within the Canadian portion of the Great Plains Region and of these *Canis lupus nubilus*, or buffalo wolf, is now extinct. This subspecies had a smaller skull (Skeel and Carbyn 1977), and probably was a smaller animal than the surviving three races. The subspecies *C. l. irremotus* in the western portion of the Plains region is now probably extinct. However, the designation of subspecific status of wolves can be questioned. This becomes particularly important when long distance movements of wolves are considered. Wolves within the region have been known to travel great distances (Van Camp and Gluckie 1979, Fritts 1983). It is possible that such movements are more common now, since man has created a patchwork of landscapes in which only small portions of original wilderness areas remain. These areas are interspersed in extensive areas of agricultural land; situations that are not favourable for the establishment of viable wolf populations.

Information on long distance movements further supports the need for a re-evaluation of the subspecies categories. Skeel and Carbyn (1977) and Novak (1983) questioned the validity of the current number of subspecies designations for the area.

A multivariate analysis of cranial characteristics indicated close affinities of wolf populations at the same latitude across an east/west gradient. The buffalo wolf differed from those populations now present in the central Plains region of Canada, but showed affinities with the eastern timber wolf (*C. l. lycaeon*). Wolves and bison are still associated together in the wild in Wood Buffalo National Park. However, the wolves there differ from the extinct buffalo wolf in that the subspecies is considerably larger (Skeel and Carbyn 1977). No satisfactory resolution to the taxonomic status is currently available.

Economic Implications

Economic impact of wolf predation pertaining to competition with human hunting has not been made, and in any case would be difficult to quantify. However, losses of livestock to wolf predation have been evaluated (Gunson 1983b). The problem exists in select areas where cattle production borders forested areas (Figure 1). The degree of depredation is variable from year to year and from one area to another. Predation on livestock is most pronounced in British Columbia, quite widespread in Alberta, and restricted to small areas in Saskatchewan and Manitoba (Gunson 1983b, Stardom 1983, Tompa 1983b). In all areas cattle losses occur most frequently in late summer (Gunson 1983b). Total dollar losses in 1981 were estimated at below $150,000 (Carbyn 1983, Gunson 1983b, Tompa 1983b).

Wolf fur production can offset economic disbenefits related to cattle depredation. Total value of fur in 1979-1980 for the four western provinces (including areas outside the geographic unit covered by the Canadian Plains) was about $160,000 (Tompa 1983a, Gunson 1983a, Wiltse 1983, Stardom 1983). This is a total of "new dollars" injected into the economy. A multiplier effect of from four to five times the above can be expected if overall economic benefits are considered (Stardom 1983). Not included in the above are losses of fur to trappers by raiding of traps and cost of wolf control. These cost factors, as with benefits, can vary considerably from year to year.

Current Status

As already mentioned, with few exceptions wolves have been completely eliminated in the southern half of the prairie provinces but are common in the northern half (Figure 1). A remnant southern distribution is occasionally recorded in southern Alberta and southern Manitoba. These are found either at the periphery of established populations (Alberta), or have extended their ranges into pockets of isolated wilderness areas (Manitoba). Within Alberta wolves are periodically reported within a region from southwest of Edmonton to Pincher Creek (probably sporadic movements from the Rocky Mountain area by nonresident stray animals). In southern Manitoba wolves occur in four areas, (1) Spruce Woods (occasional sightings), (2) Riding Mountain National Park, (3) Duck Mountain Provincial Park (resident populations) and (4) Inter Lake area (occasional stray animals or remnants of resident or displaced packs). It is doubtful that the species can ever become established in the Canadian Plains area where intensive farming predominates. Riding Mountain National Park, a wilderness enclave of 2,944 km^2, is an interesting exception. Other national parks—Elk Island and Grasslands National Park, for example—are too small to retain viable populations.

Future prospects

The species is still common in northern areas, and will not likely be systematically eliminated. Experience, however, has shown that the species is vulnerable to human activities. If extensive control programmes, particularly poisons, are widely used then the carnivore could be eliminated from a particular area within a short period of time. The existence of wilderness areas with adequate prey populations is not as important as man's activities within these areas. Wherever wolves prey on livestock it is a foregone conclusion that such economic losses will not be tolerated and site-specific control is always implemented. Several aspects, however, need to be considered. Proper land management schemes could reduce the problem. Livestock areas should not be interspersed with forest zones where the predation problem is accentuated. Secondly, carcasses of livestock should be removed quickly so that predators are not unduly attracted to livestock ranges, and thirdly, scaring devices which have been used on occasion (Fritts 1982) could be a method of reducing wolf predation on livestock in some areas.

The existing land use pattern defines the extent to which wolf predation on livestock prevails. Although widespread, the situation, viewed from the perspective of preservation of the species in the region, cannot be considered as a serious threat to the survival of the carnivore. Local extirpation will always be followed by reinvasions from neighbouring populations, as long as large tracts of land still contain wolf populations. However, market incentives for red meat production may result in other changes. Projections of demand for higher productivity will place renewed pressures for the expansion of the agricultural fringe with concomitant transformation of wildlife habitat to agricultural lands. This reduces wilderness areas and displaces the wilderness/ agricultural fringe. One argument put forth to counter this trend is that environmental values could be better safeguarded by developing an alternative system of meat production; namely, game ranching and game farming.

Game ranching and game farming differ in stocking rates and the degree of animal husbandry. In both cases all large carnivores will be unwanted since management is directed at a more restricted objective of increasing a single species' biomass production. It is questionable, therefore, that the objective of protecting all environmental values is fully served through these new types of proposed land uses. Current practices of red meat production through domestic cattle husbandry probably place greater restrictions on the total land areas that can be used. Under extreme conditions, game ranching, if developed fully, could affect regions currently containing wolf and other large carnivore populations. These regions would not normally be suitable for conventional agricultural practices. It is difficult to predict the long term consequences of current initiatives in game ranching. If the industry is accepted and grows in a slow, orderly fashion, overall impact may be less than initially perceived. Nevertheless, it is important to be aware of all the consequences. It is doubtful that romantic notions and esoteric values can ever win over economic forces, and this places the carnivore populations in some areas under renewed pressures of man's activities. Solutions to offset current trends may lie in the establishment of a broader network of legally recognized wilderness areas which are part and parcel of a nationwide wildlife conservation strategy.

The issue of wolf control for game management is controversial, and will remain so, as long as opposing views are held on the need for predator control to increase game for hunting. Ultimately a conservation strategy needs to be worked out which will secure the protection of a mammal that has been part of the Canadian landscape for a long time, and should remain as such in the future.

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The Waterfowl Resource of the Canadian Plains

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ABSTRACT. Waterfowl—ducks, geese, swans and cranes—comprise a major renewable resource of the Canadian Plains that is shared internationally. Many North American species occupy the Plains during the breeding season. The most productive habitats occur in the southern pothole region, so vital for duck production; the large southern lakes and marshes used mainly during the postbreeding molt and seasonal migrations; and the large northern deltas, important as breeding, postbreeding and migration habitat.

Aboriginal Plains Indians had minimal impact on waterfowl populations—their use of fire in the south helped maintain grassland ecosystems, thus modifying waterfowl habitats. Early European immigrant use of waterfowl for food and recreation did not harm the resource. Trade in trumpeter swan skins and whooping crane eggs reduced those species which apparently never were abundant.

The waterfowl habitat of the Plains has been subjected to increasing impacts in recent decades. Hydroelectric developments adversely affect habitat on northern deltas, but the main problem is the intensive farming practices in the south. Drainage of wetlands and conversion of natural upland to cultivated farmland have resulted in reduced duck populations. Protection of habitat has been difficult because of competition from other land uses and failure to recognize wildlife as an integral part of the ecosystem in land-use planning.

Continuing population declines of several species are probable unless the loss of waterfowl habitat on private farmlands in the southern Plains is curbed. Economic incentives for private landholders to produce wildlife may be the only practical way to protect this habitat. With careful management the waterfowl resource of the Canadian Plains will continue to flourish and provide enjoyment for generations to come.

RESUME. Le gibier aquatique—canards, oies, cygnes et grues—constitue une importante ressource renouvelable que les Plaines canadiennes partagent avec le reste du continent. Plusiers espèces nord-américaines viennent s'y reproduire, et trois types d'habitats sont les plus productifs: les étangs du sud, essentiels à la reproduction des canards, les grands lacs et les marais du sud, fréquentés surtout durant la mue et les migrations, et les vastes deltas du nord, lieux de prédilection durant la couvaison, l'élevage des oisillons et les migrations.

L'Indien des Plaines n'avait aucun effet appréciable sur les populations de gibier aquatique; ses feux contribuaient toutefois à préserver l'écosystème de la prairie et, ainsi, à modifier l'habitat propre aux oiseaux aquatiques. Les pionniers blancs chassaient également ce gibier pour leur alimentation et leur plaisir, sans entamer les populations. Le commerce des dépouilles de cygnes trompettes et des oeufs de grues blanches contribua pourtant à la réduction de ces espèces qui, peut-on croire, n'avaient jamais été bien abondantes. L'habitat des oiseaux aquatiques des Plaines a subi de plus en plus d'assauts au cours des dernières décennies. Les projets hydroélectriques ont un effet négatif sur les deltas du nord, mais le plus sérieux problème est relié à l'agriculture intensive pratiquée dans le sud. L'assèchement des marais et la mise en culture des terres mieux drainées se sont soldées par une diminution des populations de canards.

La règlementation de la chasse constitue le moyen privilégié de gestion des populations d'oiseaux aquatiques dans les Plaines. La chasses a généralement un effet beaucoup plus profond aux Etats-Unis qu'au Canada. La préservation de l'habitat s'avère difficile car on résiste mal aux pressions pour la mise en valeur du sol, et on se refuse à considérer la faune comme un élément intégral de l'écosystème lors de l'aménagement des zones en question. Le problème du pillage des récoltes a été partiellement résolu par les programmes de dédommagements aux fermiers et les projets de prévention faisant appel aux champs-buffets et aux stations de pâture.

Il est probable que le déclin des populations de plusieurs espèces suivra son cours actuel, à moins qu'on parvienne à stopper les pertes d'habitat sur les fermes du sud des Plaines. Le seul moyen pratique de protéger l'habitat consisterait vraisemblablement à stimuler financièrement la "production" de gibier aquatique par les fermiers et les ranchers. Grâce à une saine gestion, les oiseaux aquatiques continueront à fréquenter en grands nombres les Plaines canadiennes et ils feront la joie des générations à venir.

The avifauna of the Canadian Plains is one of the area's great natural resources, and no other group has commanded as much attention as the cranes, swans, geese and ducks collectively called waterfowl. Species in this group are found throughout the Plains and include some of our rarest as well as commonest birds. Many North American waterfowl breed in the Canadian Plains. This is a critical period in their annual life cycle; habitat conditions on the Plains have a profound effect on the well-being of these populations. All waterfowl are migratory and therefore represent a shared, international resource. High values are placed on this resource, not only for aesthetics, but also for recreational and subsistence hunting.

TABLE 1

DISTRIBUTION OF PRINCIPAL WATERFOWL SPECIES OF THE CANADIAN PLAINS BY VEGETATION REGION[a]

Species	**Grassland**	**Parkland**	**Boreal Forest**
Tundra swan *Cygnus columbianus*	M	M	fc[c]
Trumpeter swan *Cygnus buccinator*	s[b]	s	
White-fronted goose *Anser albifrons*	M	M	fc[c]
Snow goose *Chen caerulescens*	M	M	s[c]
Ross' goose *Chen rossii*	M	M	M
Canada goose *Branta canadensis* (large races)	C	C	FC
Canada goose *Branta canadensis* (small races)	M	M	fc
Wood duck *Aix sponsa*			fc
Green-winged teal *Anas crecca*	S	C	FC
Mallard *Anas platyrhynchos*	C	C	FC
Northern pintail *Anas acuta*	C	C	FC
Blue-winged teal *Anas discors*	C	C	S
Cinnamon teal *Anas cyanoptera*	s		
Northern shoveler *Anas clypeata*	C	C	S
Gadwall *Anas strepera*	C	FC	S
American wigeon *Anas americana*	S	C	FC
Canvasback *Aythya valisineria*	FC	C	FC
Redhead *Aythya americana*	C	C	S
Ring-necked duck *Aythya collaris*	S	FC	FC
Greater scaup *Aythya marila*			FC
Lesser scaup *Aythya affinis*	FC	C	C
Oldsquaw *Clangula hyemalis*			M
Surf scoter *Melanitta perspicillata*			FC
White-winged scoter *Melanitta fusca*	FC	FC	C
Common goldeneye *Bucephala clangula*	M	S	C
Bufflehead *Bucephala albeola*	M	S	C
Hooded merganser *Lophodytes cucullatus*		fc	fc
Common merganser *Mergus merganser*	M	FC	C
Red-breasted merganser *Mergus serrator*	M	FC	C
Ruddy duck *Oxyura jamaicensis*	FC	C	S
Sandhill crane *Grus canadensis*	M	S	FC
Whooping crane *Grus americana*	m	m	s

[a]Vegetation regions follow Rowe (1972); waterfowl distribution data are from Godfrey (1966), Bellrose (1976), and Palmer (1976).
[b]S = scarce, FC = fairly common, and C = common within a species' breeding range; M = migration only. Upper case indicates a relatively widespread distribution within vegetation region; lower case indicates local distribution.
[c]Breeding on treeless tundra.

Waterfowl Distribution and Habitat

Numerous waterfowl species inhabit the Canadian Plains, breeding from the southern grasslands to the wilderness of the Mackenzie River Delta on the Arctic coast (Table 1). Each species tends to occupy its preferred habitat or niche. The mallard is a highly adaptable species and exists in a wide range of habitat types. Canada geese, represented by several races, are also relatively successful throughout the Plains.

Fertile soils, rolling topography, and water, well distributed among diverse wetlands, provide excellent waterfowl habitat on the Plains. Waterfowl use the wetlands of the Plains during breeding, post-breeding and molting, and migration (spring and autumn). Large numbers gather at "staging" areas during migration where the birds acquire nutrient reserves to sustain them during spring breeding and winter. A few ducks and geese winter on southern rivers or reservoirs where power-generating projects keep the water from freezing.

Wetlands provide food, loafing sites and protective cover for broods, and serve as molting sites for adults. Some species also breed in wetlands. Canvasbacks, redheads and ruddy ducks build nests over water using emergent plants such as cattails (*Typha*), bulrushes (*Scirpus*) and whitetop (*Scolochloa*) for support and concealment. Trumpeter swans and Canada geese nest in marshes, often using old muskrat (*Ondatra zibethica*) houses for support. Both crane species build their nests in marshy areas, though not always surrounded by water.

Waterfowl nest in a variety of other locations. The goldeneyes, bufflehead, wood duck, and common and hooded mergansers usually lay their eggs in tree cavities, so their distribution is restricted to forested areas. The majority of waterfowl build their nests on the ground. Here, nesting cover can be a critical habitat component, protecting both the female and her eggs from inclement weather and predators. Distance of nests from water varies within and between species. Lesser scaup tend to nest closest to water, usually within 40 m. At the other extreme, mallards may nest 2 to 3 km from water, though the average is much less. Some species, for example, Canada geese, white-winged scoters and gadwalls, show a predilection for nesting on islands which are often free of mammalian predators.

Waterfowl habitat comprises a diverse array of wetland types and the surrounding uplands. Ecologically, the important waterfowl habitat of the Canadian Plains can be divided into three principal kinds: the "pothole" habitat of the parklands and grasslands, the large lakes and marshes of the southern Plains, and the large river deltas. These are the most productive areas and account for most of the waterfowl use that occurs in the Plains from spring to fall.

The pothole country of the Canadian Plains is the most important duck breeding area on the continent, producing close to 60 percent of

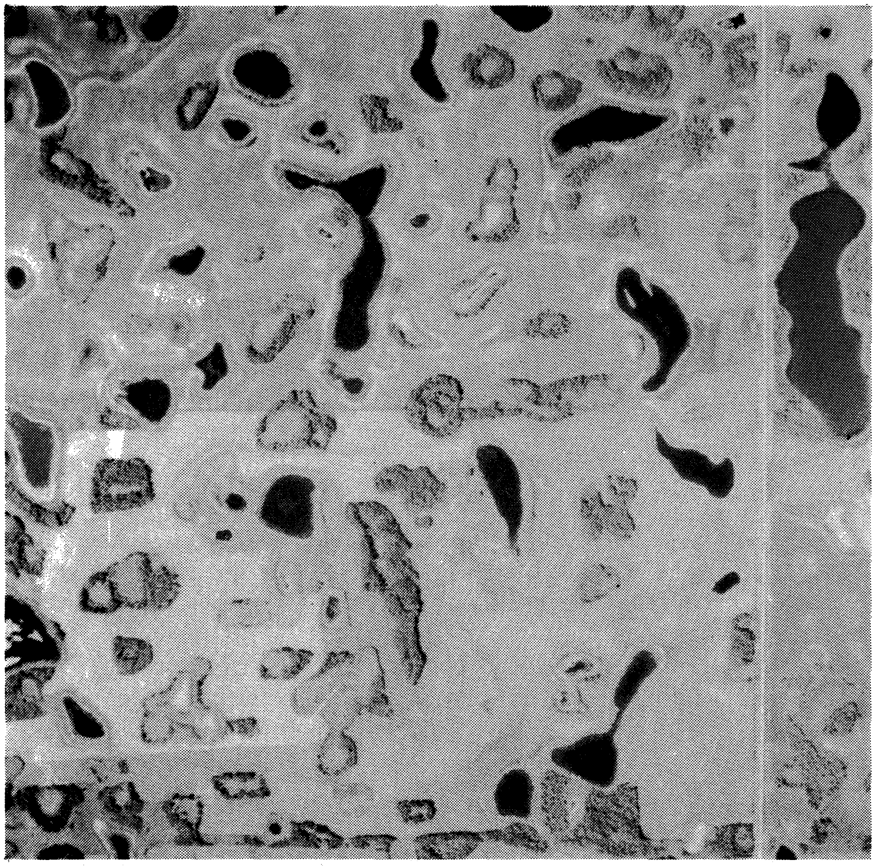

Figure 1. An aerial view of waterfowl breeding habitat in the Manitoba parklands.

the ducks shot by North American hunters (Pospahala *et al.* 1974), These birds are produced in the millions of depressions that we call sloughs, potholes, or lakes (Figure 1). The depressions, left by the receding glaciers, are subject to periodic drought. This results in a natural drawdown that enhances wetland fertility by recycling nutrients. Wetlands provide most of the requirements of breeding ducks, and for some species, all of their critical needs are found within the community of wetlands.

The density of wetlands holding water in the southern Canadian Plains varies greatly from year to year, depending on precipitation and runoff conditions. On a 583,605 km^2 area sampled each spring for waterfowl, wetland densities have varied from a high of 7.1 million to a low of 1.6 million (Pospahala *et al.* 1974). Water is usually most abundant during springs following high precipitation in the previous fall and winter. Wetlands tend to be more stable in the parklands than the grasslands because of higher precipitation and lower summer temperatures and evaporation rates (A. G. Smith *et al.* 1964).

Waterfowl pairs tend to spread throughout the habitat in spring. Spacing may serve as an anti-predator mechanism by effecting nest dispersion (McKinney 1965). It also may provide isolation needed to maintain the pair bond and to ensure that only the hen's mate fertilizes her ova (Hochbaum 1944). Perhaps of more importance, spacing may allow laying and incubating hens access to habitat resources without interference from other pairs (Dzubin 1969).

The variety of wetlands found in the pothole country of the Plains is an important feature that makes this habitat so productive. To illustrate, temporary ponds, ideal for use by breeding pairs, are often dry by brood-rearing time. Thus, good waterfowl habitat must include diverse wetland types to meet the needs of birds during the entire breeding season.

The large marshes and lakes of the southern Canadian Plains serve primarily as molting and staging areas for postbreeding diving ducks (*Aythya*, *Bucephala*, *Mergus*) and migrating waterfowl, respectively. The large lakes of the southern boreal forest, such as the remnants of glacial Lake Agassiz in southwestern Manitoba, are especially important as molting habitat for postbreeding diving ducks (Bergman 1973, Bailey 1983). These permanent wetlands provide abundant food and security during the flightless molt period. Drought-displaced ducks are also attracted to these areas (Bailey 1981a).

Numerous lakes of the southern Plains represent key staging habitat for many species of waterfowl. Particularly heavy use is made of these lakes by species that feed in harvested grain fields during autumn—mallards, pintails, and, to a limited extent, wigeon, blue-winged teal and green-winged teal, all goose species migrating through the Canadian Plains, and sandhill cranes. Perhaps the best known staging area is the north end of Last Mountain Lake, Saskatchewan.

River deltas constitute the third primary waterfowl habitat of the Canadian Plains. The Saskatchewan River Delta on the Saskatchewan-Manitoba border, the Peace-Athabasca Delta at the west end of Lake Athabasca, and the Mackenzie River Delta on the Beaufort Sea are most important. Originally, the waterfowl habitat of the Saskatchewan River Delta comprised about 9,000 km^2 (R. H. Smith *et al.* 1964); however, drainage, diking, and flooding for hydroelectric water storage has reduced this to about one-half. The Peace-Athabasca Delta occupies almost 4,400 km^2 including the large lakes, Claire, Mamawi and Richardson (Nieman and Dirschl 1973). Part of the delta lies within Wood Buffalo National Park. The Mackenzie River Delta is the largest of the three, occupying nearly 13,000 km^2 (R. H. Smith *et al.* 1964).

Deltas are formed where rivers slow as they enter oceans or large lakes, depositing enormous loads of suspended material carried from the uplands. They are dynamic systems, building, shifting, and alternately flooding and drying. These features make them valuable waterfowl habitat. The braided channels and numerous perched basins create vast shorelines, attractive for many waterfowl species. The rich sediments and periodic drawdowns maintain aquatic plant communities characteristic of prime waterfowl habitat.

Large numbers of waterfowl use the major deltas of the Canadian Plains during migration, breeding and molting. Biologists estimated that 163,000 breeding pairs of ducks on the Peace-Athabasca Delta produced 600,000 young in 1971 (Anon. 1972). In the same year, approximately 500,000 ducks used the delta during the molt, and 1,200,000 ducks and 165,000 geese and swans stopped there during the autumn migration. Densities of breeding dabbling ducks on the Canadian Arctic and subarctic deltas are second only to those of the grassland and parklands (Bellrose 1979). Some of the diving ducks breed in even greater densities on the deltas.

Northern deltas serve as valuable refuges for ducks displaced by drought conditions on the prairies. Some species, including, for example, the pintail and mallard, tend to "overfly" the prairies and parklands in response to drought, and settle in northern habitats (Smith 1970, Pospahala *et al.* 1974). These displaced birds apparently exhibit a low breeding effort, but increase their chances of survival so they can breed in future when habitat conditions improve.

River systems of the Plains are relatively unimportant as habitat for most waterfowl. Canada geese nest on cliff ledges and islands in some of the southern rivers. Some rivers serve as staging habitat for geese and are used mostly when drought reduces traditional staging areas. Common mergansers probably depend on riverine habitat during the breeding season more than any other species.

The boreal forest portion of the Plains contains a myriad of lakes, bogs and muskegs but most of these waters are unproductive, containing low levels of total dissolved solids. Waterfowl densities are sparse; breeding pairs of ducks often depend on small, isolated deltas formed by streams entering the lakes and rivers. Although comparatively unproductive, this waterfowl habitat is extremely stable; when duck production on the prairie fails, forest habitats continue to produce, albeit in low densities.

Most of the sandhill cranes and all of the whooping cranes that breed in the Canadian Plains, do so in boreal forest habitat. Whooping crane habitat in Wood Buffalo National Park has been described, in part, as "a marshy area interspersed with numerous potholes which are generally shallow and have soft marly bottoms" (Novakowski 1966).

Early Abundance

Paradoxically, there is scant information on the abundance of common waterfowl species of the Canadian Plains prior to settlement. Early travellers sometimes referred to large numbers of waterfowl, particularly ducks and geese seen during their journeys (e.g., Hind 1860, Macoun 1882, Coues 1897); but detailed accounts are scarce. In light of current knowledge of the population dynamics of waterfowl breeding on the prairies and parklands, it is probable that numbers fluctuated widely among years in response to climatic changes, not unlike they have in historic times (Crissey 1969).

Much of the historic information on the distribution and abundance of waterfowl concerns the less common species, particularly the large and conspicuous trumpeter swans and whooping cranes. The commercial value of their plumage and eggs also attracted attention. The trumpeter swan nested throughout much of the Canadian Plains, although apparently never in high numbers (Banko 1960). Whooping cranes also nested over much of the Canadian Plains, but were relatively scarce (McNulty 1966). Sandhill cranes were much more abundant than whooping cranes and bred on wetland habitats throughout most of the Canadian Plains from the grasslands to the Arctic coast (Walkinshaw 1949).

Waterfowl and the Indians

The Indians of the Plains had little opportunity to take waterfowl except during the nesting season as eggs and later as flightless young or molting adults. Bones found in middens of Plains Indians indicate that they did eat ducks on occasion. The explorer Alexander Henry saw Indians collecting eggs and flightless waterfowl on the Delta (Manitoba) marshes in July 1806 (Coues 1897). These practices were likely prevalent only on large marshes where waterfowl concentrated. Egg gathering may have been important locally during brief periods in the spring when waterfowl were nesting at high densities on islands. Traditionally, the southern Indians were bison (*Bison bison*) hunters. Their acquisition of horses and firearms made them efficient predators of the bison but had no impact on waterfowl. Even after the demise of the bison, the abundant waterfowl apparently did not interest the Indians despite their need for meat (Macoun 1882).

Fires probably had a greater impact on waterfowl than did the hunting and egg gathering by aboriginal Indians. Some fires were started by lightning strikes (Rowe 1969), but often Indians were responsible (Stewart 1956). Some prairie fires burned over many thousands of square miles (Hind 1860, Southesk 1875, Macoun 1882).

Fires occurred in the spring or autumn when there was ample dead, dry vegetation for fuel. These burns destroyed the residual plant cover, important to the early-nesting mallard and pintail. They also swept across dry marshes, burning dead cattail or bulrush, overwater nesting cover of the canvasback and redhead. On the other hand, marsh fires were often beneficial because they removed dense vegetation and helped to recycle nutrients (Yancey 1964).

Spring fires undoubtedly destroyed some nests, but renesting by ducks partially compensated for the loss. The direct effect of these vast fires on waterfowl populations and their habitat was dramatic but not lasting, since the event of fires was irregular in time and space. In fact periodic fires helped to maintain prairie ecosystems by checking the advance of aspens (*Populus tremuloides*) (Bird 1961, Archibold and Wilson 1980).

The Post-settlement Era

Waterfowl were an important source of food and recreation early in the post-settlement period of the southern Plains. Indeed, waterfowl hunting was promoted as an added attraction to entice prospective settlers to the west (Macoun 1882). As the Delta, Manitoba, marshes gained fame as prime waterfowl hunting grounds, a local tourist industry flourished in the early 1900s (Suggett 1981).

Early market-hunting of waterfowl for food was not significant in the Canadian Plains (Hewitt 1921). The Canadian Plains were far from potential markets, and lack of refrigeration made it impractical to ship fresh meat. Moreover, waterfowl were well dispersed most of the time, making it difficult to harvest them in numbers large enough to justify marketing. However, trade in swan skins was a brisk business throughout the Canadian Plains during the 1800s (Banko 1960). Fur traders like the Hudson's Bay Company annually shipped close to one thousand swan skins to European markets. Although both species were taken, trumpeter swans rather than tundra swans seem to have sustained most of the harvest.

Settlement by immigrants from Europe had a profound and lasting impact on waterfowl populations. Trade in skins and eggs (the latter especially prized by collectors), and encroachment upon their breeding grounds, eliminated the whooping crane and most trumpeter swans from the southern Plains. While the settlers on the Plains were modifying breeding habitat, most of the losses from hunting were occurring on the wintering grounds. Except for the two species just mentioned, hunting on the Canadian Plains probably had a negligible effect on populations. Even for those species, loss of habitat and human disturbance alone may have been enough to exterminate the southern populations.

With the arrival of the Canadian Pacific Railway in the late 1800s, settlement of the southern Plains was rapid (Thomas 1976). Grain fields soon dominated the landscape and an extensive road system gave access to the new prairie farms. Wildfires were all but eliminated, allowing aspen groves to increase (Archibold and Wilson 1980). The bison that had grazed the pristine prairie and wallowed in the sloughs had been exterminated. In the southern grasslands, domestic cattle grazed in their stead.

Waterfowl and Modern Man

Ducks of the Plains evolved in an environment subject to periodic drought, wildfires and overgrazing by bison (Tester and Marshall 1962). The adaptations and resilience needed to survive in their pristine environment enabled the species to continue to flourish with early agriculture. Over the decades, however, as farms became mechanized, and economic pressures to improve crop yields grew, habitat has become scarce as idle acres and pastures have been plowed and wetlands drained. Change has been accelerated by government subsidies. As a result, prairie duck populations are now much reduced from former periods.

Wetland drainage has been a major factor causing waterfowl populations to diminish and has often been facilitated by road construction. Improved technology has made drainage easier, and almost all wetlands are now susceptible to subsurface tile drainage or, more recently, the installation of plastic pipe. Drainage has been most prevalent in the parklands of central Alberta, central and southeastern Saskatchewan, and southwestern Manitoba. One estimate placed the loss of wetland habitat in the prairie provinces at 1.21 million hectares (Buckley *et al.* 1980).

The impact of wetland drainage on waterfowl has been compounded by a general intensification of farming practices during the past decade in the southern Plains (e.g., Kiel *et al.* 1972, Sellers 1973). In the absence of adequate nesting cover, foraging predators now find and destroy a high percentage of waterfowl clutches. Farming operations also add to the toll. Early-nesting species suffer most. Higgins (1977) suggested that upland nesting ducks could not perpetuate themselves where the land was more than 85 percent annually tilled.

Farming intensity in many parts of the Canadian parklands has left little natural upland habitat available for nesting ducks. By 1974, surveys on two Manitoba areas indicated 77 and 83 percent of the upland was under cultivation (Adams and Gentle 1978). A 1982 survey in central Saskatchewan showed similar trends. In a sample of 101 65-ha blocks of private farmland, about two-thirds were annually cultivated in excess of 85 percent (Sugden and Beyersbergen 1984). Breeding habitat is also being lost because much of the remaining idle land and pastures are being converted to crops each year.

Certain agricultural practices benefit waterfowl. In the grasslands where cattle ranching is the main land use, the development of reservoirs, stock dams and dugouts has likely stabilized and increased wetland habitat. Cereal grains are now a dietary staple of several waterfowl species in autumn. A few species such as the mallard also consume waste grain in spring and summer.

Some of the grain eaten in autumn comes from unharvested fields and this causes conflicts with farmers. Most of the damage is caused by mallards, pintails, several goose species, and sandhill cranes. By virtue of their wide distribution, relative abundance, and predilection for grain, mallards are the worst offenders. Wheat and barley are the crops most often damaged (Sugden 1976). Crop depredation became a significant problem in the 1940s after farmers started to windrow prior to combining (Bossenmaier and Marshall 1958). Chronic damage occurs near major staging lakes so a relatively small number of grain producers tend to sustain most of the loss. Costs of crop damage include the loss of farmers' income, loss of grain to the Gross National Product, and costs of compensation and damage prevention programmes. The threat of crop damage by waterfowl may also hinder habitat development programmes. Verified estimates for the value of grain lost to waterfowl are lacking. The average annual *reported* loss of wheat and barley in the three prairie provinces during 1972-81 was 0.7 and 1.4 million bushels, respectively (H. J. Poston, pers. com.).

Waterfowl habitat on the northern deltas is threatened by hydroelectric projects either through development of storage reservoirs or by altering the hydrological regime that created and maintained the deltas in a natural state (Anon. 1972). None of the major deltas of the Canadian Plains is immune from the effects of these projects.

Modern man has introduced numerous contaminants into the environment and many of these affect waterfowl of the Plains. Perhaps the best known is lead shot, deposited in the marshes from the guns of duck hunters. Waterfowl that ingest the pellets are poisoned, often fatally. Other heavy metals such as mercury, and herbicides, insecticides, industrial chemicals, and oil spills all contribute to the pollution hazards affecting waterfowl and other wildlife. Finally, diseases such as avian cholera and duck plague are a constant threat to waterfowl populations (Wobeser 1981).

Some impacts on waterfowl are less apparent. Human disturbance, for example, can cause waterfowl and cranes to shift their distribution even though habitat is available. Breeding cranes, in particular, seem intolerant to human intrusions. Recreational use of large wetlands on the southern Plains that serve as traditional habitat for broods or molting adults is also cause for concern.

Management of the Resource

A decline in wildlife populations prompted authorities in the United States and Canada to impose regulations affording some protection of this resource in the late 1800s. Special effort was made to halt market-hunting of waterfowl in the United States and spring hunting in both countries. Regulations restricting waterfowl harvests were made as early as 1876 in Manitoba (Day 1949). However, the most significant legislation affecting waterfowl resulted from the Migratory Birds Treaty signed by Great Britain (on Canada's behalf) and the United States of America in 1916. To implement the treaty, the Canadian parliament passed the Migratory Birds Convention Act (MBCA) in 1917.

This Act gave complete protection to endangered cranes and swans and provided a framework for regulating hunting and other activities affecting waterfowl throughout Canada. The MBCA also made possible the establishment of Migratory Bird Sanctuaries, some of which protect waterfowl in key areas during the breeding season. (The first sanctuary, at Last Mountain Lake, Saskatchewan, however, had been established in 1887, well before the MBCA.)

Waterfowl management in Canada is a responsibility shared between federal and provincial governments. The Canada Wildlife Act of 1973 enables the federal government to acquire and manage lands and to enter into agreements with provincial, municipal and private organizations for conservation, research and interpretation with respect to migratory birds.

Waterfowl populations that occupy the Canadian Plains are managed primarily through harvests both in Canada and the United States. As harvests increased during the post-World War II era, regulations became more restrictive, enforcement was intensified, and various surveys were instituted to monitor the status and distribution of hunted species (Crissey 1957). Breeding pair and production surveys are conducted on the Canadian prairies and parklands each spring and summer. Large-scale banding programmes yield information on waterfowl migrations, seasonal distribution, and survival rates. Other surveys provide information on hunter success, and species' age and sex composition of the harvest. Programmes to gain detailed information on habitat trends on the prairies are also underway.

By and large, regulations have been effective in controlling the consumptive use of waterfowl on the Canadian Plains. Hunting pressures in Canada have always been comparatively light and waterfowl populations are affected more by harvest regulations in the United States.

Protection and management of waterfowl habitat has been more difficult and less successful than management of waterfowl populations (Rounds 1981). Sanctuaries and game preserves protect a few key parcels of waterfowl habitat. Sanctuaries on Crown land have been useful for protecting colonial nesting sites used by waterfowl in the Arctic portion of the Plains.

Most wetland development has been undertaken by Ducks Unlimited (Canada), a private conservation organization supported largely by United States waterfowl hunters. Projects usually involve cooperative agreements with private landowners and the provincial government. Stabilization and control of wetland water levels and extension of shore lines in production habitat are the primary objectives.

Losses to farmers from waterfowl depredation have been addressed in two ways. Publicly funded programmes partially compensate grain producers for their losses caused by waterfowl. In addition, lure crops sponsored by wildlife agencies are grown or purchased for the sole purpose of keeping waterfowl from commercial crops. Bait stations provide threshed grain, usually on the shores of large lakes, for the same purpose. These programmes shift part of the burden from the grain farmer to the government agency and also to the waterfowl user who supports the abatement programmes through licence imposts (Sugden 1976).

The whooping crane has benefited from cooperative efforts of the Canadian and United States governments to restore its numbers and establish new breeding populations. Both the wintering area at Aransas National Wildlife Refuge, Texas, and the breeding grounds in Wood Buffalo National Park, Northwest Territories, are protected. Extensive publicity helps to protect the birds during migration. In recent years biologists have started to establish a second wild population by placing eggs of whoopers in nests of sandhill cranes (Kuyt 1981). The wild population of whooping cranes has increased from a low of 15 in 1941 to close to 100 in the early 1980s.

Research has aided management of the waterfowl resource. The Canadian Wildlife Service of the federal government has assumed a leading role for government-sponsored research, while the Delta Waterfowl Research Station (Manitoba), sponsored by the North American Wildlife Foundation, is the leader of non-government research.

Waterfowl represent a valuable renewable resource. No dollar value can be placed on these birds in terms of aesthetics and ecological diversity, but few would deny their rightful place in the world. On the other hand, benefits such as food, recreational hunting and birdwatching can be assigned tangible values. To illustrate, Fogarty *et al.* (1982) estimated that Canadians spend $157.8 million annually on sport hunting waterfowl.

The Future

The waterfowl of the Canadian Plains will continue to be a prominent renewable resource in coming decades. Demands for sport hunting as well as subsistence hunting will persist both in Canada and the United States, and waterfowl management goals will continue to reflect these demands. Non-consumptive uses such as birdwatching and photography will grow and wildlife agencies will spend more money providing places for such activities.

Resolution of the crop damage problem in the southern Plains remains an important challenge both for wildlife agencies and the agricultural community. Some gains may be anticipated as farmers shift to less susceptible crops or different cultural practices such as growing winter wheat. Control of the problem should become more effective as research provides greater insights into the biology of granivorous waterfowl.

Habitat destruction will be the foremost problem facing the waterfowl resource of the Plains. The most serious inroads into the waterfowl habitat base will continue to occur on the private farmlands of the southern Plains that are so important for waterfowl production. Development of more efficient farming techniques in the face of rising costs encourages farmers to convert ever more wetlands and idle upland to annual crops. Canadian Wheat Board quota rules as well as land taxing systems tend to penalize the farmer with idle land (Zittlau 1979, Ryder and Boag 1981). There is no incentive to maintain wildlife habitat on private lands.

Curbing the present trend of habitat destruction will be difficult but there is potential for improvement. Some form of incentive will be necessary if landowners are to consider the needs of waterfowl and other wildlife. In addition to preferential tax rates on "wildlife" lands and modifications of the grain quota system, now based on cultivated acreage, Ryder and Boag (1981) have suggested user fees as measures to reduce the problem. The adoption of new farming practices such as zero tillage (Cowan 1982) may also reduce the impact of intensive farming on upland nesting ducks. Of special interest is the increasing production of winter wheat which is seeded directly into stubble, thus eliminating mechanical operations harmful to duck nests as well as providing early nesting cover.

Land-use policies that recognize wildlife as an integral part of the environment will make it easier for wildlife managers to address the habitat problem, particularly on public lands. An enlightened public is no less important. Wildlife agencies must continue to publicize the values of a land ethic. An ecosystem approach that addresses all components both from short-term and long-term perspectives is preferred. Short-term benefits to an individual through draining a marsh, for example, may be more than offset by the problems associated with downstream flooding and impaired groundwater reserves.

Much has been learned about waterfowl in recent decades through research and investigation. Notwithstanding this extensive accumulation of information, there is a continued need for waterfowl research. As management of the resource must become more efficient, so must research. Answers to fundamental questions needed to manage the resource effectively will more likely be found through research based on the hypothesis-testing approach than research that focusses on a description of events (Sanderson *et al.* 1979). There is no substitute for sound ecological theory upon which to formulate research questions (Bailey 1981b).

Waterfowl are but one of many resources occupying the Plains, and their dependence on productive soils and wetlands will continue to put them in conflict with others. Preserving this heritage for the enjoyment of future generations is therefore a challenge that all must share. The task will be easier should more people develop an awareness of the ecological community in which they live, an issue eloquently discussed by Aldo Leopold (1949) in *A Sand County Almanac.* Such are the qualities needed to ensure that waterfowl of the Canadian Plains will continue to provide a source of lasting enjoyment to both present and future generations.

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Fish Resources and the Fisheries Industry of the Canadian Plains

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ABSTRACT. The Canadian Plains from the 49th parallel to the Mackenzie Delta have a substantial and regionally important fish resource capable of producing 40 million kilograms per year. Three categories of fishery—domestic, market and sport—involve about 750,000 people annually. Future problems of management will be generated from the sport fish section. There is potential for a larger resource yield in aquaculture as a cottage industry, enhancement of production in small lakes and imaginative management by the outfitter-angler cadre.

RESUME. Depuis le 49e parallèle jusqu'au delta du Mackenzie, les eaux des Plaines canadiennes possèdent des réserves de poissons substantielles et importantes dans l'économie de certaines régions, alors que les prises annuelles pourraient totaliser 40 million de kilos. A chaque année, environ 750 000 personnes s'adonnent à l'un ou l'autre de trois types de pêche: domestique, commerciale ou sportive. C'est dans ce dernier secteur que s'annoncent les grands problèmes de gestion. Des prises plus importantes seraient possibles grâce à la pisciculture artisanale, l'intensification de la production dans les lacs de petite étendue et l'adoption de mesures novatrices de gestion par les responsables des réseaux de camps de pêche.

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Explorers and fur traders experienced the great variation of aquatic resources on the Canadian Plains from their first contact with the country. When Peter Fidler spent all winter with the Piegans in southern Alberta in 1792, he travelled with horses and depended on bison (*Bison bison*) as a mainstay for meat. Fish were never mentioned. When the same surveyor spent 1810 at Ile-à-la-Crosse, he travelled entirely by canoe, and depended almost entirely on fish as sustenance for his party of at least 18 people (MacGregor 1966). The historical settlement pattern was based on agriculture and the distribution of population tended to keep people and fish apart. As a result, an understanding of the resource and experience in the fisheries industry has been restricted to limited and frequently isolated groups of people.

The resource base and changing status of fish need to be appreciated. The important consideration for the fisheries industry is the expected yield. The problems of management of the resource are complex; it is finely dissected in a topographic sense, has multiple species components, a variety of user groups, sometimes in conflict with each other, and about 750,000 people are directly involved in the harvest. This paper reviews the resource bases, examines the status of the resource in relation to the fisheries industry, and comments on potential, problems and predictions for the future.

This study utilizes the management records of Manitoba, Saskatchewan, Alberta and the Northwest Territories, as well as comments on fish from early journals, historical records and the scientific literature, to discuss Canadian Plains fish resource.

The Resource Base

Most of the Canadian Plains, with the exception of a few very minor areas in the Mackenzie Valley and the Cypress Hills, lay under a great ice sheet 15,000 years ago. As this ice melted and receded north and northeast, large pro-glacial lakes formed, generally draining to the south and the east (Prest 1976). These lakes, abutting the receding ice front, were up to 200 m deep (Klassen 1983) and over a period of several thousand years interconnected from northern Alberta to southern Manitoba. The best known is Glacial Lake Agassiz, which several times drained to the Mississippi and Great Lakes systems. Every larger water body on the Canadian Plains of Manitoba, Saskatchewan and Alberta originated from these glacial lakes, and their present-day remnants have names such as Winnipeg, La Ronge, Peter Pond and Lesser Slave.

Fish in waters farther to the south that survived the ice age had ample opportunity to migrate north as these water systems formed, evolved and receded to present day dimensions. Those species that preferred or could tolerate cold water, turbid or clear conditions and shallow to deep lakes moved in from the south, east and southwest. The arctic char and inconnu of the Mackenzie system came from the north. Some species seem to have come into plains waters from both the north and the south, *e.g.* arctic grayling, lake trout and burbot (McPhail and Lindsey 1970).

Lakes and rivers form the physical base of the fish resource of the Canadian Plains. The area, depth and quality of these waters determine the productivity of the fish populations in them. These characteristics are extremely variable, and much of the limnological and fisheries research of the past 40 years has been undertaken to understand the effects of these differences on the production of fish.

There are two great river systems—the Saskatchewan and the Mackenzie—that are mountain-fed so that neither their water supply nor the annual regime are derived from the plains through which they flow. Their dominant features are their early summer flood of mountain water and their very low flow in winter. The construction of large reservoirs in Saskatchewan, Alberta and British Columbia has effectively reversed the natural cycle in extensive reaches by storing water in summer and discharging large volumes in winter to generate hydroelectric power. The effect on the fish and the other biota of the riverine environment is subtle (Lehmkuhl 1972), extensive (Fredeen 1977) and it is certainly not well understood.

The Assiniboine-Red River system includes the Qu'Appelle and Souris Rivers. These are prairie rivers, high in nutrients, turbid, and generally having little water, except in early spring when the sudden snow melt of the prairies may produce a spectacular runoff. In many places, there is no perceptible flow in winter. The Milk and Frenchman Rivers, tributary streams of the Missouri system, are similar to the Assiniboine-Red River system, and drain a relatively small part of the southwestern prairies along the border with the United States. The headwaters of the Churchill system drain an area of the Plains, but at the northern end of Lac Ile-à-la-Crosse the Churchill becomes a Precambrian river. Because it drains from forest and lake country, the annual regime and water quality of this system are much moderated in comparison to the prairie rivers.

Although great rivers dominate the hydrography of the Canadian Plains, they produce a relatively small part of the fish yield. (Nevertheless, this harvest may be very significant locally, as in the Mackenzie Valley). More important, streams, large and small, feed nutrients to lakes of every size. These lakes are the culture vessels that produce fish, where water levels and growing conditions are relatively stable. In the presence of adequate nutrients, the factors that affect lake productivity are area and depth (Rawson 1952). The contribution of area is straightforward—more hectares produce more kilograms of fish, just as in wheat growing. The effect of depth is complex and is expressed in various ways. Shallow lakes are warm in summer, but fish may die in winter because of low oxygen concentrations (winterkill). Deeper lakes have better reservoirs of oxygen but are less productive because of lower water temperatures.

There are innumerable small water bodies throughout the Canadian Plains which are called ponds, sloughs, open muskeg and tundra lakes. These wetlands produce millions of waterfowl, but no harvestable fish because of winterkill. Many such waters are vital nursery areas in summer for walleye, pike, arctic grayling and forage species, all of which may migrate to more permanent waters to winter and mature. On the grasslands, some of these water bodies are highly saline and without fish. When planted with fry, the moderately saline lakes can produce large amounts per hectare, especially rainbow trout, walleye and whitefish. Redberry Lake is an example (Rawson 1946).

The riverine lakes of the Qu'Appelle and Churchill systems are generally larger than those above, permanent and quite fertile. The reservoirs of the Saskatchewan system are similar. All these waters produce fish consistently, although it is not clear whether reservoir use for power production adversely affects downstream areas such as Cumberland and Cedar Lakes.

The lakes of the boreal forest region produce by far the largest part of the fish resource harvested on the Canadian Plains. These non-riverine lakes are numerous, of every size, moderately fertile and generally cool—favourable conditions for whitefish, lake trout, walleye and pike. The series of very large lakes at the eastern and northern boundary of the Canadian Plains lies partly on the Precambrian, but their water is mostly from the sedimentary areas to the south and west. Lake Winnipeg, Manitoba, Winnipegosis, La Ronge, Ile-à-la-Crosse, Churchill, Peter Pond, Athabasca and Great Slave are the core of the Canadian Plains fish resource. Great Bear Lake is too infertile and too cold to produce much fish. Northward and westward, the lakes of the transition forest and tundra are small, infertile and cold so that fish grow very slowly.

The general correlation of productivity with the vegetation zones of the interior plains emphasizes the influence of edaphic (soil-related) and climatic factors. The highly fertile waters of the semi-arid grasslands region show the highest production of fish, up to 15 kg/ha. The northern plains, whether transition forest or tundra, are arid, infertile and cold, and are poorly productive of fish, up to 0.6 kg/ha. The great boreal forest region, moderately fertile and with a moderately long growing season, may yield 0.5-7.5 kg/ha (see also Rostlund 1952).

The biotic component of the resource is the species of fish which are harvested. Table 1 lists 22 species in a subjective arrangement that reflects the quantities harvested and the perceived desirability of the various groups. The list does not include such introductions as Pacific salmon, sunfish and others which, at present, enhance the resource base only in a political or exotic sense. The unique group of non-fish species is a product of some very saline lakes in the grasslands region of Saskatchewan; no true fish inhabit these waters. From 1961 to 1982, brine shrimp production varied widely from about 180,000 kg to a low of 1,000 kg in 1982. A minute red crustacean, cyclops, has been harvested also in small amounts for the tropical fish food industry (Hammer 1978). Several species of minnows (Cyprinidae) are harvested as fish bait, but there is no good indication of this component of the fish harvest in the region. In Saskatchewan, it has slowly increased from 20,000 to 30,000 kg/yr between 1976 and 1982.

The Status of the Resource

The "virgin" lake or stream is the dream and ideal of sportsmen and commercial fishermen alike—unfished, unpolluted and unknown (or as a substitute, isolated). The fish populations of such waters often have a similar structure. Compared to the exploited stock, there is a

TABLE 1

SPECIES OF FISH THAT ARE EXPLOITED
ON THE CANADIAN PLAINS AND THEIR MAIN CATEGORIES OF USE

Group	Scientific Name	Use[1]
Major species		
lake whitefish	*Coregonus clupeaformis*	C, D
lake trout	*Salvelinus namaycush*	C, D, S
northern pike	*Esox lucius*	C, D, S
walleye	*Stizostedion vitreum*	C, D, S
Restricted species		
sturgeon	*Acipenser fulvescens*	C, D, S
arctic char	*Salvelinus alpinus*	C, D, S
rainbow trout	*Salmo gairdneri*	C, D, S
cutthroat trout	*Salmo clarki*	S
arctic grayling	*Thymallus arcticus*	S
inconnu	*Stenodus leucichthys*	C, D
goldeye	*Hiodon alosoides*	C, S
sauger	*Stizostedion canadense*	C
Rough fish species		
cisco	*Coregonus* spp.	C, D
white sucker	*Catostomus commersoni*	C, D
longnose sucker	*Catostomus catostomus*	C, D
redhorse suckers	*Moxostoma* spp.	C
bigmouth buffalo	*Ictiobus cyprinellus*	C
carp	*Cyprinus carpio*	C
burbot	*Lota lota*	D
perch	*Perca flavescens*	S
Non-fish species		
brine shrimp	*Artemia salina*	
cyclops	*Diaptomus connexus*	

1 C - commercial; D - domestic (subsistence); S - sport.

disproportionate abundance of older larger specimens, a moderate number of small to medium specimens, sometimes stunted, and a smaller number of young fish than expected. The first catches of fishermen seem rewarding because the large fish provide good yields, but after some time these catches diminish. This is the "fishing up" process, and has often misled the industry and resource managers about the sustainable yield of the resource to be exploited. Population research and management studies are helpful to the manager, but the most direct experiment is to harvest the resource at increasing levels (annually) and to observe the yield which can be sustained. This will define the productivity of the system, the status of the resource. It is seen as an unsatisfactory method because it is slow, and unpredictable overfishing may occur. Also, uncontrolled economic input may influence the activity of the fishing industry, *e.g.* a high return from the fur harvest may reduce the number of fishermen who engage in the fishery.

TABLE 2

AVERAGE ANNUAL FISH PRODUCTION
OF THE CANADIAN PLAINS IN THE YEARS FISHED
IN MILLIONS OF KILOGRAMS

Period	Domestic	Commercial	Sport	Total
1882-1900	6.0	2.5[e]		8.5
1901-1920	5.2	7.3	+	12.5
1921-1930	5.0	13.1	+	18.1
1931-1940	6.0	15.3	2.0[e]	23.3
1941-1950	8.9	21.7	4.0[e]	34.6
1951-1960	10.4	22.1	6.0[e]	38.5
1961-1970	3.1	17.9	9.0[e]	30.0
1971-1980	1.7	14.9	12.6	29.2
1981-1982	1.3	15.3	13.0[e]	29.6
1941-1970		20.6 ± 2.3		34.4 ± 4.3

e - estimates based on various sources.
Note: The quantities are based on historical records and, since 1921, on the available management records of the various jurisdictions. In every case they are believed to be quite conservative estimates.

Table 2 presents an estimate of the average annual fish production of the Canadian Plains based on historical and management records. The domestic fishing includes all local use of fish for human consumption, dog food and fur farms. The quantities shown are extrapolated from information on various areas (Wynne-Edwards 1947, Miller 1947, Rawson 1947, Prince *et al.* 1912, Atton and Novakowski 1953, R. Orr and D. Walton, personal communication). In the late 1950s, there was a drastic reduction of domestic use of fish due to reduced dog and fur farm animal populations and increased availability of alternative foods for humans.

Commercial production records are the most reliable in Table 2 because they are based on the annual management reports of each jurisdiction, some published (Alberta 1976), others in-house documents. Information for 1882 to 1920 is to be found in part in Prince *et al.* (1912) and McIvor (1965). Bait fish production and the sales of fishermen peddlers are included in commercial production.

The catch of sport fish is frequently based on the number of license holders and an assumed average catch. In recent years, there have been two sport fishing surveys throughout the Canadian Plains area from which useful data have been derived (Table 3). In Saskatchewan, there is available a 25-year census on Lac la Ronge which provides additional information, e.g. the catch per angler from 1950 to 1974 averaged 17.7 kg/yr (Chen 1977). This is consistent with the 1975 and 1980 survey data in Table 3. Sport fish harvest can be expected to continue to increase to some degree as provinces attempt to develop the tourist industry in the plains.

TABLE 3

SPORT FISH PRODUCTION OF THE CANADIAN PLAINS
IN 1975 AND 1980

	Anglers	Total Catch millions kg	Catch per angler, kg
Manitoba			
1975	147 000	2.711	18.4
1980	169 730	2.079	12.3
Saskatchewan			
1975	213 881	4.000	18.7
1980	196 480	4.276	18.7
Alberta			
1975	278 941	2.985	10.7
1980	374 205	8.569	22.9
Northwest Territories			
1975	2 500[e]	0.215[e]	
1980	3 229	0.250[e]	
Total			
1975	642 322	9.911	15.4
1980	743 644	15.174	20.4

Sources: (Manitoba 1979, Brickley and Johnson 1978, Murray *et al.* 1984, Longmore *et al.* 1982, Devine 1982, D. Toews, personal communication).
e - estimates based on various sources.

In Table 2, it is notable that the decline of the domestic use of fish is balanced by the increase in sport use. The commercial production has declined in the last 12 years, mainly in response to the economic pressures of higher cost of production and poorer market demand.

Total production for the entire plains region in the period 1941-1970 averaged 34.4 ± 4.3 kg $\times 10^6$ (Table 2). This amount is probably a conservative estimate of potential sustained yield of the fish resource of the Canadian Plains. The fishing-up effect of Great Slave Lake from 1946 to 1950 may cause this estimate to be slightly high, but since in all entries there is a propensity to miss some records, I believe the real catch to be larger than shown. Rostlund (1952) estimated a total yield of 39.0 kg $\times 10^6$ for the same area of the Canadian Plains. His method used the area of water in each region and the estimated yield per unit area, based on the literature of that day. As more species are used, especially by anglers, it must be concluded that the potential sustained yield of the waters of the Canadian Plains is about 40 kg $\times 10^6$.

Other factors influencing the status of the fish resource seem to date to have had effects of minor magnitude. Pollution is of the nutrient variety, and it is most noticeable where water volume is reduced, as in the Qu'Appelle system. Oxygen values in winter indicate some similar stress from Winnipeg, Prince Albert, Edmonton and Calgary. Organic effluents from the Edmonton area caused extensive fish kills in a portion of the North Saskatchewan River in about 1954 but, generally, episodes of toxic pollution are short-lived, such as the occasional spill of chlorine from a Saskatoon chemical plant. The same site seems to have been the source of massive mercury pollution in the past, but is only one of the origins of this problem, which reduced fish harvest from Lake Winnipeg for a short time.

Reservoirs have so far increased commercial and sport fish production, though there are claims of detrimental downstream effects of the altered flow regime. Surface disturbance by shore development for recreation and by forestry activities may have adverse effects on spawning and nursery habitat in lakes and smaller streams.

People and the Fish Resource

The aboriginal peoples of the grasslands used fish mainly on a seasonal basis when a failure of the hunt brought on starvation. This was usually in early spring which, by coincidence, is when fish are more abundant in the open water of streams. Pike, walleye and suckers migrate to spawn at this time. In moderate-sized streams a boulder weir was constructed in the shallow water of a rapids. A basket of willow wands was woven and placed in the fast current in a small opening in the weir. Such a trap often produced a very good catch of pike and suckers after nightfall. Spears were also used. Gillnets were unknown to the residents of the grasslands and parklands regions (Rostlund 1952, Mandelbaum 1978) until they were introduced by the first traders to invade the country.

The tribes of the boreal forest and far north used gillnets in streams and shallow water. These were made of willow-root fibre. Hooks were used in jigging or trolling, and the gorge (a sharpened pencil of bone or wood, with the line attached at the middle) was used baited on a set line (Jenness 1932). Spears and weirs to trap fish were common. Always, there was an effort to take advantage of concentrations of fish during spring and fall movements of spawning fish. Drying and freezing were used to preserve mainly the autumn catch of whitefish. Freezing and thawing repeatedly of dressed fish in the open air is, of course, a very effective drying method, and this provided a staple food in the difficult freeze-up period of early winter (Jenness 1932). Preservation in spring and summer was not common because fresh catches were easily available. Fish was the single most important item of diet only in an area around Great Bear Lake (Rostlund 1952) where other animal populations are especially sparse (see also Driver 1961, Map 3).

Early historical use of fish by the explorers, fur traders and settlers was similar to the Indians' use—subsistence and emergency rations. About 1882, this so-called domestic use began to have competition on Lake Winnipeg from the market, generally called commercial fishing (McIvor 1965). By 1910, this activity had spread westward to Jackfish Lake near North Battleford (Prince *et al.* 1912). It reached Great Slave Lake in 1945 and today arctic char are canned next door to tourist outfitters on the arctic coast.

The size of the modern freshwater fisheries industry of the Canadian Plains has been outlined in the section on the status of the resource. Sport fishing was not important in 1912 (Prince *et al.* 1912), but grew gradually until 1950. Thereafter, expansion became more rapid. Today there may be 10,000 domestic users, 6,000 commercial fishermen (Ayles 1983) and up to 740,000 sport fishermen (Table 3). There will be changes in the future, such as aquaculture in small water bodies, and the back-to-the-land environmental philosophy, which will involve more people, but such changes will not likely alter the ratios of use significantly.

The effect of this industry on the fish resource has so far not been drastic. No species of our fish fauna has become extinct, but local populations (stocks) have been reduced. Sturgeon are now rarely caught in Manitoba (Ayles 1983); whitefish were seriously depleted in Peter Pond Lake. Farther north the risk of stock depletion may be greater. The threat of overfishing by sportsmen may be more serious and not as well recognized; it is also true that resource managers have not developed as effective strategies for controlling and allocating the activities of the sport sector. There has been a tendency for management bureaucracies to give traditional attention to the commercial sector with its organized market and, at the same time, to see the angler and tourist as a transient annoyance except in economic terms; the importance of the sport fishery has recently received some recognition in, e.g. the Alberta fisheries policy.

The fish resource provided relief supply for natives, explorers and traders who were suffering from starvation. In northern areas of the plains, it remains today a staple for some natives and trappers. Settlement developed first on waterways for reasons of transportation, but fish as a food supply and source of industry has contributed to the permanence of these population centres.

The Future

The fish resource will not generally deteriorate because it has characteristics that tend to protect it. It has many species components which are topographically widespread in innumerable waters. As a biological resource, it is ordinarily renewable. Individual species stocks will be here and there depleted, but they will recover if given even elementary population management. The challenge to managers is to distinguish between stock management and resource management. The former is concerned with individual species populations in individual lakes. The latter is really people management—how best can we organize and direct 740,000 anglers and the outfitting industry to harvest gamefish optimally. Both management modes are needed; up to the present, stock management in local situations has been largely ineffective.

The potential production of this resource in the Canadian Plains is about 40 million kg per year. New technology in aquaculture can certainly increase the use of small waters that are not now producing. Are there other avenues of development? As experienced from 1971 to the present, production will be more influenced by economic realities than by biotic and environmental capacities.

The problems of fish resource management and the fisheries industry arise both from the common property view of the resource and from characteristics of the industry. First, environmental degradation will remain a threat so long as communities and industry see the aquatic realm as a no-cost disposal site, and shore-land development does not recognize that gravity causes everything to run downhill to the nearest water. Second, the perception of a common property resource has permitted an excess of fishermen in relation to the available resource in the sport and commercial fishery sectors. Allocation, the proposed cure, has so far been ineffective.

Soft markets in the export sector of the fisheries industry are a continuing problem. In spite of effort at various times, local markets have not been effectively developed. It is a paradox that private peddlers, who have frequently been successful, have also experienced bureaucratic pressure to suppress their services. The final problem that plagues the economics of the export industry is the cost of transportation from the local fisherman to the processing and shipping centre. When this involves long distances and air transport, there is frequently no margin for wages to the fisherman, nor incentive to develop secondary processing plants such as fish meal or pet food production facilities.

The real domestic product of the prairie provinces more than doubled between 1961 and 1978. The percentage contribution of the fisheries industry has declined steadily in the same period: 1961 - 0.12%; 1970 - 0.06%; 1978 - 0.04% (Sahir and Seaborne 1982). This implies that the fish resource of the Canadian Plains is a more or less fixed quantity until there is some significant technological change.

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Insects on the Canadian Plains

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ABSTRACT. Insects, as herbivores, are indigenous to the Canadian Plains. They have always been serious natural contenders for available forage, initially to buffalo and latterly to man and his domestic animals. The Rocky Mountain locust destroyed the crops of the Selkirk settlers bringing poverty, starvation, and near collapse of the Red River Settlement. Three other field crop insect pests—cutworms, wireworms, and the wheat stem sawfly—decreased production of cereals in the short grass zone of the prairies by 5 to 25 percent from 1920 to 1950. Effective control was achieved through chemicals and genetic manipulation in plant breeding.

The rapid expansion of arable land after World War II allowed more rapeseed to be produced but it also saw the phenomenal and explosive outbreaks of the Bertha armyworm. The use of narrow-spectrum insecticides has permitted continued production of oilseed crops. Mosquitoes, an annual annoyance, also have caused periodic epidemics of western equine encephalitis since 1915. Incursion of man and livestock into the watershed of the Saskatchewan and Athabasca River systems has resulted in a confrontation with blackflies. More than 2,000 bovine animals have been killed by blackflies since 1915, many more crippled, and some ranchers forced out of the cattle business.

Animal parasites: fleas, ticks, lice, warbles, bots, and other maggots, have caused serious loss of flesh, leather, wool, and horse-power to early ranchers and settlers. Despite available modern chemical control agents, animal production continues to be seriously affected. Increased irrigation has expanded the detrimental ravages of aphids, beetles, and worms on specialty crops, limiting production, or even eliminating the growing of turnips and other root crops when effective chemicals were banned.

RESUME. Les insectes herbivores indigènes aux Plaines canadiennes ont toujours été des concurrents redoutables pour le bison et, plus récemment, pour l'homme et ses troupeaux domestiques. La sauterelle des Rocheuses ravagea les récoltes des colons de Lord Selkirk, causant la famine, la misère et l'écroulement presque complet de la colonie de la Rivière-Rouge. Trois autres insectes nuisibles—le ver gris des moissons, la larve du taupin et le cèphe—réduisirent la production céréalière de 5 à 25 pour cent entre 1920 et 1950 dans la prairie sèche. On a réussi à contrôler effectivement le problème par l'emploi d'insecticides et la manipulation génétique des plantes.

L'expansion rapide des surfaces cultivées après la Seconde Guerre mondiale a permis d'accroître la production du colza, mais elle a été marquée par des infestations phénoménales d'un agrotis communément appelé ver à Bertha. C'est grâce à des insecticides spécifiques qu'on a pu continuer à récolter les oléagineux. Les moustiques, une peste annuelle, ont causé des épidémies périodiques d'encéphalite équine depuis 1915. Dans les bassins de la Saskatchewan et de l'Athabasca, l'homme et ses troupeaux domestiques ont fait face à la mouche noire; toujours depuis 1915, plus de 2 000 bovins ont succombé à ses attaques, bon nombre d'autres ont été blessés et plusieurs éleveurs ont dû abandonner la partie.

Les parasites, tels que les puces, les poux, les tiques, les oestres et les autres larves ont causé des pertes importantes en viande, en cuir, en laine et en travail animal aux premiers agriculteurs et ranchers. Malgré les agents chimiques de contrôle présentement sur le marché, les pertes sont encore élevées. Le recours accru à l'irrigation s'est soldé par une augmentation des ravages causés par les aphidés, les coléoptères et les vers à certaines cultures spécialisées, réduisant ou, même, éliminant la production du navet et d'autres racines alimentaires suite à l'interdiction de la vente de produits chimiques effectifs.

INTRODUCTION

With the advent of discovery and exploration by man, the prairie land—with its attendant small shrubs, sloughs, and copses—was tilled, removing forever the stable condition of grass and soil and effacing the habitat of a multitude of soil-inhabiting insects. Man brought and introduced plants and animals that were exotic to the region. In cases where insects began using these introductions as food or as hosts, competition for food and an inevitable confrontation between man and insects ensued. This competition increased with the inexorable march of civilization and settlement of the west during the nineteenth century.

Pests of agricultural crops were many, but most notable and devastating were the grasshoppers, wheat stem sawfly, and the Bertha armyworm, as well as the many cutworms and wireworms that plagued the Canadian Plains. Blackflies and mosquitoes were a plague to man and a deterrent to livestock production. In addition, mosquitoes were later shown to transmit the virus causing sleeping sickness. The mere presence of the hordes of insects that greeted the new immigrants to the Canadian Plains had serious potential for disrupting socioeconomic development.

Although the pest status of insects in relation to agriculture, forestry, and human resources is always foremost in our minds, there were benefits derived from the industrious groups of pollinators and honey producers that have been domesticated to man's advantage. Even less often considered for their resource value in the ecological food chain are the vast groups of insects that are not pests. For those who are so inclined, these also provide a wonderful resource for study and pleasure. These various aspects of the impact of insects of the Canadian Plains in relation to our environment will be discussed in turn.

Locusts and Grasshoppers

The Great Northwest, the Great Plains, or the British North American Desert conjured up strange visions of an unknown land in the eighteenth and nineteenth centuries. Sandford Fleming and G. M. Grant, before they started their transcontinental trek in 1872, were a bit apprehensive because "Our former ideas had been that it was a barren desert; that there was only a horse-trail, and not always that, to travel by; that the mosquitoes were as big as grasshoppers and bit through everything... the North-West was to the average man of that day a sub-arctic region, the prey of hailstones, hostile Indians and grasshoppers, British Columbia a sea of mountains, New Ontario a barren wilderness effectively separating Eastern from Western Canada" (Innes 1956).

There was no doubt that insects, especially the biting flies and the locusts, would be encountered by any visitor, traveller, and settler in the Plains region. Lord Selkirk had great expectations for his colony on the Red River when he founded it in 1812. Limitations to successful settlement included "... bad seed, grubs, and faulty cultivation" (Morton 1957), but when clouds of grasshoppers, that darkened the sun, descended upon the colony in 1818, their crops vanished overnight and severely dampened their hopes (Ross 1856).

Although this was a severe setback, the settlers endured the plague even as they did in subsequent years. G. M. Dawson of the Canadian Geological Survey reported:

> ...1818, winged locusts; in 1819 the young appeared; from 1820 until 1857 none were noticed; in 1857 locusts arrived, but the source was not stated; in 1858 the progeny of the 1857 swarms were injurious. In 1864 fresh swarms arrived from the west, in July; their progeny were troublesome in 1865. In 1867 swarms appeared in August, and their progeny in 1868 ... in 1871 and 1872 the grasshoppers died in heaps and ridges at Fort Garry... In 1872 swarms appeared in August, and their progeny in 1873. In 1874 immense swarms arrived July 17th. In the summer of 1875 the progeny of the 1874 swarms hatched in great numbers over almost the entire area of Manitoba, and westward at least as far as Fort Ellice, on the Assiniboine River (Riley *et al.* 1877).

The locust outbreaks of 1864-1876 occurred at a time when colonization of the west was a top priority for governments. Immigrants were wooed and coerced to settle in the west, the richness and productivity of the land being offered as an inducement to settle there. However, the settlers coming north via the United States were warned not to go to a "... cold, locust-devoured, barren land where there was no market and no freedom, but to settle in Minnesota" (Grant 1967). In Winnipeg the American agents and sympathizers down-graded the merits of Manitoba and encouraged residency in the "superior" American west (Innes 1956). These warnings were heeded by many, resulting in the slowing down of colonization but not stopping it. Everywhere the settlers went, be it along the Qu'Appelle River or along the two branches of the Saskatchewan River, locusts were nearby.

Walter Traill at Fort Qu'Appelle in 1867 reported that "They came in clouds like smoke and for twelve days the air was alive with them," and concluded that "Farming here is all a delusion" (Atwood 1970). Grasshoppers prevailed as far west as Fort McLeod and south to Fort Benton, Montana, as observed by Bishop Grandin in 1876. The destruction wrought by the locusts caused him to conclude: "... that this fact constitutes the only obstacle to the colonization of this country" (Dempsey 1973).

By 1872 even the entomologists were worried about the successive locust invasions and the repetitive devastations caused by the Rocky Mountain locust and other indigenous species. C. J. S. Bethune, then President of the Entomological Society of Canada, however, was a bit more optimistic when he said, "... I expect to see the tide of immigration which for a few years past has been setting so strongly toward the plains of Kansas and Nebraska, toward our own more highly-favoured, even though more northern regions of Assiniboine and Saskatchewan" (Bethune 1874).

Not only were the locusts a deterrent to settlement, but when they struck they caused extreme hardship to the settlers, even starvation. Many homesteaders retained their homesteads and survived the effects of the locust onslaught of 1875 and 1876 by accepting relief from the Manitoba government. Some of these grasshopper mortgages, in which they offered their land as collateral for the food and seed that they received, may still be unpaid today (Riegert 1977).

By 1902 the Rocky Mountain locust, *Melanoplus spretus*, had disappeared from North America. Indigenous grasshoppers, principally six of the more than 100 species present on the Great Plains, have maintained the locust threat ever since. Outbreaks in the present century occurred in almost every decade (Riegert 1968). The most serious—indicated by the peak year of infestation, damage, and the amount of control required—occurred in 1921, 1935, 1939, 1942, 1950, 1963, 1967, and 1973. Crop production on more than three million acres of farm land was again being threatened by grasshoppers in 1983. Crop losses due to grasshoppers have soared to 25 percent of the annual crop production in some years (Saskatchewan Department of Agriculture 1944-58). Timely application of insecticides, using arsenicals in the pre-World War II years and a variety of synthetic organic compounds thereafter, have prevented large-scale crop losses. Weather, aided by naturally-occurring bio-agents, have been the ultimate suppressive weapons in the battle for control. Grasshoppers will never be eradicated from the Canadian Plains but control has been, and will continue to be possible, as long as man makes judicious use of the known natural, agronomic, and chemical means to suppress them.

Wheat Stem Sawfly (*Cephus cinctus*)

During a stop-over, and while collecting insects at Indian Head, Saskatchewan, on 5 July 1895, James Fletcher, the Dominion Entomologist, made a notable discovery. He collected small slender, adult wasps having yellow and black banded abdomens, insects that he predicted would become one of the greatest threats to wheat production on the Canadian Plains. In 1897 the first report of damage to wheat occurred in a field near Indian Head; damage that has continued in varying degrees of severity to the present day (Riegert 1980).

The wheat stem sawfly is an example of the transformation of a relatively harmless insect—one that had lived in the stems of grasses on the pristine prairies—into a noxious pest of cereal crops. The insect readily adopted the hollow stems of the cereals as its new home. Barley and oats were less susceptible to infestation, Durum wheats had a pithy core in their stems that blocked the insect's movement and feeding, while flax with its fibrous stems was quite immune from attack.

By 1917 the infested area extended from Portage la Prairie, Manitoba, to Moose Jaw, Saskatchewan. In 1920 the wheat fields at Brooks, Alberta, were infested and by 1925 the sawflies could be found at Gleichen, Strathmore, and Lethbridge. Federal entomologists in all three prairie provinces had worked diligently to find and perfect workable methods of control. Late seeding, mouldboard plowing to bury the larvae, the planting of coarse grains and Durum wheat as resistant crops, and the use of guard and trap strips to deter and capture the adult insects, were all proven agronomic practices available to the farmer. However, the increase in soil drifting forced farmers to abandon the plow and to use surface tillage equipment. This preserved the stubble as a trash cover to halt erosion by wind. Strip farming was also adopted as a second method of reducing soil drifting but this practice aggravated the wheat stem sawfly problem. The insects, being weak flyers, could now penetrate and readily infest the whole of the narrow fields whereas formerly only margins of the large fields had been infested.

An on-going intensive education and control campaign launched by the federal and provincial authorities in the late 1920s had convinced many farmers of the value of using the recommended agronomic control practices. Many adopted these procedures and some measure of success was achieved in reducing crop losses. Then the drought of the Dirty Thirties arrived augmented by heat, further soil drifting, and cereal rust. Nothing grew, farms were abandoned, and the livelihood of the remaining farmers was threatened by increased grasshopper infestations.

But the struggle against the wheat stem sawfly had not been abandoned. If agronomic practices were insufficient to hold the insects at bay then science and genetics could perhaps win the upper hand.

H. J. Kemp, a cerealist at the Dominion Experimental Farm, Swift Current, Saskatchewan, had included several semi-solid-stemmed bread wheats in his cereal breeding programme since 1929. Many hybrids showed remarkable resistance to sawfly infestation because of their pith-filled stems, the best being a variety, S-615. It was crossed with Apex, a rust resistant cultivar, producing a new wheat variety that was both rust and sawfly resistant. Unfortunately this hybrid line, when field tested in 1937, was wiped out by the heat and drought.

A renewed breeding programme was immediately initiated by A. W. Platt, a cerealist, aided by C. W. Farstad, an entomologist. By 1941 they had produced a very promising sawfly resistant line of wheat, No. 4188, which in five years of rigorous testing resulted in the licensing of a new wheat variety "Rescue" in 1946. Small amounts of this new wheat were available at first but by 1948 large acreages were seeded in the sawfly infested districts of Saskatchewan and Alberta.

Sawfly infestations dropped dramatically, as did the losses of wheat. In Saskatchewan alone the losses decreased from $23.6 million in 1944 to $3.3 million in 1958, despite a greatly expanded seeded acreage during the 14 years (Saskatchewan Department of Agriculture 1941-44). Science had won out; in this instance man's manipulation of genetic material had produced a means whereby the destructive power of an insect had been curbed.

Although the wheat stem sawfly has now been relegated to the position of a minor pest of cereal crops—it had occupied the number one position in the years 1941 to 1944—the struggle is not over. Agricultural and cereal production expanded rapidly into the Peace River district of Alberta after World War II. The wheat stem sawfly invaded the same territory beginning in 1956. The expansion of the infested area, and the subsequent damage to wheat, continues to demand constant vigilance by agriculturists and farmers alike. Although crop losses, due to the wheat stem sawfly, will not assume the proportions they once did, the use of "Rescue" and "Chinook" (the latter introduced in 1956) varieties of sawfly resistant wheats are still not the final answer. Farmers will have to rely upon, and use, conventional cultural and agronomic practices in their agricultural enterprises in order to maintain the upper hand in the struggle for survival against this, as well as other, insect pests.

Bertha Armyworm (*Mamestra configurata*)

Unlike the abundant grasshoppers that ruined agricultural crops as soon as settlement began on the Canadian Plains, the Bertha armyworm was relatively scarce. The first economic losses caused by the worms occurred at Moose Jaw, Saskatchewan, in 1922 (King 1925). Flax was the chief crop that was attacked. Small acreages were damaged in most years, including many vegetable gardens. In 1928 a large-scale infestation covered the prairie region and extended westward into central British Columbia. Vegetables, ornamentals, gardens, sweet clover forage, and flax fields were severely defoliated. Arsenicals were at hand to poison the worms but before much use could be made of them, the attack had subsided; the worms had disappeared after inflicting their damage.

The worms showed a very low profile for the next 20 years. Post-war expansion in agriculture had induced farmers to try oilseed crops as an alternative to the cereal monoculture, the former being a cash crop and not restricted by a bureaucratic, governmental quota system. More northerly regions of the prairies were well suited for rapeseed production, as the demand for oil was great. The new breed of farmers was more venturesome than the pioneering forefathers and, hence, was willing to gamble on a new crop. Rapeseed proved to be the Cinderella crop of the prairies. Yields were phenomenal, prices were high, and many farmers became debt-free almost overnight.

Then the spectre of insect trouble reared its foreboding head. The Bertha armyworm, which had been unobtrusive since 1929, became more numerous. Rapeseed (the term canola refers specifically to certain chemically-defined strains of rapeseed) was a favourite food of the worm and the farmers had placed it within easy reach. Infestations occurred in northern Saskatchewan in rapeseed fields in 1944. Damage to some fields made them not worth harvesting. Then the worms disappeared for several years, only to re-appear in economic numbers in 1947 in the northeastern districts. DDT promptly ended the outbreak.

Threatening infestations did not re-appear until 1955. The following year there was a population explosion of the worms; all rapeseed fields across northern Saskatchewan and part of Manitoba were infested. More than 15,000 acres were sprayed with DDT, application being made from the air. That ended the fight with Bertha for another 15 years.

By 1971 many more acres had been prepared for cultivation in the northern parts of all three prairie provinces. A gigantic outbreak of Bertha armyworm erupted in a 50-mile-wide band stretching across the prairie provinces from Swan River and Dauphin, Manitoba, to Edmonton, Alberta. About one million acres of infested rapeseed were sprayed with Lannate at a cost of $1.9 million for the chemical, and $1.5 million for the application by aircraft. Only 5.7 of the 104.6 million bushels of rapeseed were destroyed; a loss valued at $14.2 million (McDonald 1971). These were the statistics, but the Bertha armyworm story was much more than that. It was an event replete with emotionalism, deep concerns, at times near panic. The worms had been tough on resources, both financial and personnel, but as with all of man's encounters with insect hordes, it was a gigantic co-operative effort by whole communities, all levels of government, agri-business, and the news media. August of 1971, the "Month of Bertha," has not been celebrated in similar fashion since then.

There have been minor clashes and almost annual skirmishes. Pheromone traps and sex-lure chemicals have been used quite extensively in recent years to attract and capture the moths and thus forewarn growers of their impending presence. Prompt action by the growers, with appropriate insecticides, has kept the worms in check. There will be more confrontations in the future.

Cutworms and Wireworms

During the past millenia of time, the vast seas of grass on the Great Plains had acquired their own complement of sod- and soil-inhabiting insects. Included were the many species of cutworms, the worms being the larval stage of the dusky-coloured moths or "millers" usually found flying at dusk and attracted to lights. Also present were several species of "click" beetles whose larvae, the hard and shiny wireworms, fed below ground on the roots of the sod-forming plants.

When these virgin soils were tilled and planted to garden and cereal crops, the insect larvae turned to the new foods with relish. By 1900 the red-backed, variegated, and army cutworms had become a constant source of annoyance to growers. The first damage to cereal crops was reported in 1911 from Monarch, Alberta, where 520 acres of wheat were destroyed by the pale western cutworm (Hewitt 1912). The destruction soon increased to more than 30,000 acres of grain in southern Alberta in 1912 (Hewitt 1914). This precipitated action by the federal government in the appointment of an entomologist, E. H. Strickland, in 1913, to investigate and find remedies that would control the cutworm pests. These investigations were greatly expanded in subsequent years in western Canada and continued to the present time.

Wireworms had caused damage to gardens, especially to potatoes, and field crops in all parts of the Great Plains since the early 1900s. No attempt to alleviate the damage was made until the federal entomologist, K. M. King, was appointed in 1922 to initiate research and recommend control measures. This research has continued at Saskatoon up to the present time. Recommendations of late seeding, clean tillage, firm seed-bed, and crop rotation, alleviated the losses that had incurred. However, these measures gave no lasting control. Crop losses due to wireworms and cutworms continued to mount, from \$5.7 million annually in Saskatchewan for the period 1926 to 1935, to \$27 million in 1955 (McDonald 1965).

Having changed the environmental parameters of a grassland ecosystem, man has also had to alter traditional agricultural practices and create new deterrents to minimize the adverse economic effects of extant insect pest species. Organic, synthetic insecticides were introduced following World War II and the whole picture changed. Seed dressings, where used, virtually eliminated wireworm damage on the Plains. One treatment lasted for several years so that no damage was incurred to other environmental entities. Topical soil applications with these insecticides also curtailed the ravages of the cutworms. Currently, annual monitoring of adult moth populations, using pheromone traps, gives valuable assistance to the growers in gauging and limiting their needs for chemical, cultural, and biological control.

Blackflies

Blackflies and mosquitoes have been righteously damned and soundly cursed by all explorers, travellers, and settlers in the Canadian Plains, yet they have been accepted as a way of life. The annual visitations of these pesky creatures have been generally tolerated by man; their annoyance ameliorated by deterrent smudges, lotions, and ointments. Occasionally, as is the rule with and the nature of insect population densities, severe and damaging outbreaks occur. Blackflies fit this mould in classical form.

Fifty-five species of blackflies are known to infest streams and rivers on the Plains of western Canada. Most of them can be found in the eastern watershed of the Rocky Mountains in Alberta while 15 occur in Saskatchewan; five have no economic significance, two are pests of poultry, while eight cause annoyance to man and animals. All infest flowing waters and are particularly abundant in rocky rapids, falls, or in places where beds of weeds provide anchorage sites for the larvae. The most feared species, *Simulium arcticum*, automatically comes to mind when blackflies are mentioned. It is the only species capable of killing livestock on the Plains, causing death by direct toxemia and envenomization. It has been responsible for livestock deaths in Saskatchewan as early as 1886 when "... six cattle, two horses and an ox from farms 25 miles south of Saskatoon..." (Fredeen 1977a) were killed.

Outbreaks in 1913, 1917, 1919, and 1930 killed more than 600 animals. The most destructive outbreaks arose in 1944 to 1947, inclusive; more than 1,100 farm animals died including several high-priced herd bulls. Treatment of the Saskatchewan River and its two branches with the chemical larvicide DDT in 1948 and annually thereafter, prevented further extensive outbreaks and the attendant animal losses. Several other small rivers in northern and north-western Saskatchewan have also received treatment. Animals on about seven million acres of farm land subject to irregular infestation by blackflies in the past, have been freed of the danger from these vicious pests. When DDT was applied as a liquid having a specific gravity of 0.9 and the concentration of the insecticide was kept at 0.1 p.p.m., no harm came to the fish or to other aquatic invertebrates. Under these conditions DDT has been unexcelled and despite the hue and cry of environmentalists, and its ban in 1972, this insecticide merits reconsideration as a recommended means of controlling certain pest insects, including blackflies. Methoxychlor has been used as the larvicide of choice after the ban of DDT, giving satisfactory control of the blackflies since 1968.

Control of the water flow in the Saskatchewan River system has made some very significant changes to the species complex of blackflies in these waters. Dams in Alberta on the North Saskatchewan River, and the Gardiner Dam on the South branch, now exercise controlled water-flow of 50 and 100 percent, respectively, since 1968. The elimination of the flood crests has resulted in clear and slow-flowing water in the rivers. *Simulium arcticum*, abundant in turbulent fast-flowing and turbid waters has been almost entirely replaced by three other species of blackflies, viz. *S. luggeri*, *S. vittatum*, and *S. venustum*. In 1971 *Simulium luggeri* bred so abundantly that huge swarms of adults stampeded cattle and interrupted grazing. A similar outbreak occurred over 6,500 square miles of farmland in 1976 resulting in stampedes, broken bones, torn fences, and trampling of calves (Fredeen 1977b). In 1981 poultry losses were severe along the Souris River in Manitoba due to exsanguination by adults of *S. meridionale*. Precise economic losses are difficult to measure. However, Fredeen (1981) estimated that in 1978 alone, due to the summer-long, five-generation outbreak of *S. luggeri*, losses exceeded $1.4 million.

An on-going, perhaps annual, chemical treatment of the rivers and streams offers the only means of preventing outbreaks of blackflies and the resultant losses (Fredeen 1977c). Research is continuing and may provide alternative methods of equal effectiveness in the future.

It is only in recent years that the blackfly problem has expanded to cause economic losses and concern in Alberta. Populations of these flies have increased after World War II when irrigation systems were expanded in the southern districts of that province. Good control, however, first begun in 1953, was effected by the chemical larviciding of the system.

The livestock industry has gradually expanded northward into the upper reaches of the Canadian Plains in Alberta. This expansion predicted the increased economic importance of blackflies because the effects of the bites of the insects were always more virulent on "new" cattle that were brought in, such as purebred dams, herd sires, and young calves. Some cattle fatalities had occurred in the Vegreville area in 1956.

Outbreaks in 1961 and 1962, as well as surveys conducted by federal and provincial entomologists in 1963 to 1967, indicated that *Simulium arcticum* was also breeding in the Athabasca River. Severe attacks in 1971, and cattle fatalities in 1972, aroused so much concern that livestock owners demanded that control action be taken by the provincial government. Their written brief to the authorities indicated that up to 1971, in an area of 130,000 acres (203 square miles or 570 square km) containing 13,008 cows, 973 animals had been killed by blackflies and 38 bulls had been rendered sterile. In addition, animals had a reduced weight gain of 20 lbs (9 kg) per animal, valued at $390,000, and a loss in production due to unbred cows of about $90,000. "These losses, in addition to inefficiency of operation with interrupted calving schedules, sterile bulls, and dead animals, amounted to an immediate estimated annual monetary loss of about $600,000 for the survey area." (Haufe 1980).

By July 1973 a further 449 dead animals were reported, most of them being calves, and there were 588 unbred cows in the area. In 1974 the first of a three-year chemical control programme was begun by larviciding the Athabasca River. Populations of *Simulium arcticum* were reduced by 70 percent, as was the area of infestation (Depner *et al.* 1980). No larviciding was done in 1977, blackflies were back in full force, indicating that re-infestation of the river occurred annually.

However, the pesticide treatment of the Athabasca River did not affect the populations of three other species of blackflies, nor did it affect the fish, other aquatic invertebrates, mosquitoes, horse flies, deer flies, and culicoides (Shemanchuk 1980a).

Eradication of the biting flies in their breeding grounds is not possible in the Athabasca region. Strong objection by environmental groups to the use of larvicides in the river has complicated further direct control procedures. Alternative methods of protecting cattle from all biting flies, such as the use of repellents, are still being investigated; some show real promise (Shemanchuk 1980b, Khan 1980).

In the meantime some cattlemen have moved out of the area; others have reduced their herds, while some have relied on the seemingly blackfly-tolerant breed of cattle, the Charolais, to permit them to stay in business in blackfly country. Only human innovation, dogged determination, and continued technical and scientific advancement, will permit man to maintain a co-existing relationship with blackflies.

Mosquitoes

Mosquitoes have greeted everyone who has had the temerity to set foot on the central plains of Canada. Most people have regarded them as a necessary evil and grudgingly accepted their presence. They tried to live with them as best they could by keeping them at bay with smoke smudges, repellents, and sometimes with unsavoury, smelly lotions. Near the parkland where snows are more abundant and spring thaws provide myriad shallow, snow-melt pools, populations of mosquitoes can become exceedingly dense. Animals such as deer have been driven out of the bushes to escape the demonic onslaught, and have survived by seeking the higher ground or by immersion in convenient lakes or rivers. Along the northern edge of the Plains region man had to physically protect his face, hands, and body with protective clothing and veils. Working, eating, talking, and even breathing was often nearly impossible when such protection was ignored.

Exsanguination is a physical danger to man and beast; Hocking (1952) estimated that an unclothed individual could lose enough blood to mosquitoes in 1¾ hours to be fatal. The psychological effect of buzz-and-bite, and the allergic response to the bite, often caused complete debilitation of man. People were reluctant to settle in mosquito-infested regions and only the more hardy and dogged farmers—many driven out of southern regions by the drought and heat of the thirties—ventured into the northern districts such as the Peace River District of Alberta.

Although mosquitoes were regarded as important pests, the relationship between mosquitoes and human disease in Canada did not become apparent until the third decade of the twentieth century. It was then that several epidemics of sleeping sickness, or equine encephalitis (WEE), swept the prairies. It was in 1932 that the virus of WEE was found to be responsible for equine encephalomyelitis, a disease that had been killing horses since 1847. J. S. Fulton of the University of Saskatchewan was the first to isolate the virus in Canada in 1935, but he was not certain how the disease was transmitted (Fulton 1938). In 1937 and 1938 a much larger epidemic of horse encephalomyelitis occurred on the prairies, resulting in the loss of 15,000 of the 50,000 horses stricken with the disease (Fulton 1941, Dillenberg 1965). During those years 27 cases of human encephalitis were reported from Saskatchewan; six were fatal (Donovan and Bowman 1942). In Manitoba there were 29 cases and four deaths (Gareau 1941).

In 1939 Fulton isolated and identified the WEE virus as one that also caused human encephalitis. He prepared a chick-embryo vaccine to protect horses from the disease; 450,000 were vaccinated in 1939. This protected the animals but it left the human population vulnerable and unprotected. In 1941 the three prairie provinces suffered 1,094 human cases with 130 deaths (Brust 1982). The vectors and the reservoirs of the disease-causing virus were still unknown.

It wasn't until 1944 that the organism was isolated from a mosquito, *Culex restuans*, caught at Portage la Prairie in Manitoba (Norris 1946). In 1945 the virus was also isolated from another mosquito, *Culex tarsalis*, (McLintock 1947); a species now known to be the principal vector of WEE on the Great Plains. An extensive and intensive multidisciplinary study of mosquitoes and the ecology of WEE virus, launched in 1962, showed that the virus of WEE—as well as those of three other encephalitic diseases—was present in native populations of at least seven species of mosquito in Manitoba (Sekla and Stackiw 1982), nine in Saskatchewan and three in Alberta (McLintock and Iversen 1975). The vertebrate reservoirs of the virus included migrating birds, ground squirrels (*Spermophilus* sp.), snakes, frogs, reindeer, bison (*Bison bison*), and domestic fowl. It is now certain that wherever mosquitoes abound on the prairies, WEE is not far away.

Further epidemics of encephalitis on the Canadian prairies in 1963, 1975, 1977, and 1981 had increased the awareness of the dangers of mosquitoes and the disease to man. More intensive adulticiding of endemic centres were undertaken to lessen the degree of danger. The general population of humans is increasing on the Plains and more urban people are invading rural environments for recreational purposes during the summer when the threat from arboviruses is greatest. It is apparent that epidemics of WEE will occur in the future because people knowingly refuse to take proper precautions: minimal outdoor activity especially at the sunset hour; liberal use of repellents; wearing of protective clothing; extra precaution for young children who have not yet acquired immunity. Epidemics will occur in years of high mosquito populations, especially where a susceptible human population exists. Because mosquitoes cannot be eradicated they will continue to present an unfavourable and expanded health hazard to man and animals on the Plains. Mosquitoes have limited settlement and industrial expansion in some sectors during the past, and will exert a retardative effect in the future.

Pollinators

Since the early days of this century (1914-1922), the Dominion Apiarist, F. W. L. Sladen, was convinced of the importance of honey bees, bumble bees, and leafcutter bees, as pollinators of forage crops, especially alfalfa. His pioneering work in apiculture indicated that the honey bee was of little value but that alfalfa had to be specially visited by other bees, blossoms "tripped," and cross pollination effected. Although this was confirmed by H. E. Gray in the 1930s, not much was done to improve pollination strategies that would increase the production of alfalfa seed. It was only during and after World War II, when seed production became critical, and expanded forage crop programmes in the Plains region demanded a readily available and large seed supply, that a concerted effort was made to increase pollination by insects.

Initial work by federal entomologists (1930-1945) indicated that leafcutter bees were the insects that could best pollinate alfalfa. A full-scale forage improvement and increased alfalfa seed production programme was initiated by the federal Department of Agriculture after World War II. Colonization of bumblebees near alfalfa fields proved beneficial in northern Saskatchewan where these insects were active pollinators but they were not amenable to be housed in man-made domiciles. One species of leafcutter bee, *Megachile rotundata*, could be domiciled and proved to be as influential in the production of alfalfa seed as honey bees are to the production of honey.

This species, introduced into eastern United States in 1948 from Europe or Asia Minor, had spread to the semi-arid regions of the north-western United States in the 1950s, and imported into Canada in January 1962 (Hobbs 1972). It nests readily in soda straws or in holes bored in wood, in corrugated cardboard, or in multiple-structured grooved boards comprising up to 24 hives each having 3,000 tunnels to house 40,000 to 60,000 bees. The latter structures, when placed in alfalfa fields in hive shelters and near a source of food, will enhance pollination of the alfalfa; often doubling the amount of seed produced.

Today most of the alfalfa seed producers maintain stocks of bees from year to year. The industry has expanded, especially along the northern fringes of the Plains, so much so that more bees are produced annually than are required to pollinate alfalfa. At present the bees are also used in alfalfa fields in the Peace River region of Alberta. However, the short growing season and longer periods of reduced temperature that prevent bee activity, are drawbacks to a successful seed production industry. If a more hardy strain of bees can be produced—one that flies actively at lower temperature—then it will be possible to expand alfalfa seed production into regions farther north in the panhandle of the Canadian Plains.

In addition to the leafcutter bees many other insects abound whose activities also include pollination. Clovers, peas, beans, melons, and a complex array of trees and shrubs are visited by a succession of bees, flies, wasps, and moths; all contributing to successful and bounteous seed and fruit sets. Without the abundance of these insects on the Plains, horticultural produce and successful small fruit culture would be very restricted.

Beneficial Insects

Honey bees (*Apis mellifera*), in particular, supply honey that is a welcome and nutritious supplement to the diet of most Canadians. The honey industry, begun as a one-man operation on an individual settler's home, has today blossomed into an enterprise valued, in 1978, at $26.3 million in the prairie provinces (Canada Year Book 1980-1981). Many of the noxious insects can be and are controlled by other biological agents, notably the insect parasites and predators. For the past 60 years professional entomologists of the prairies have been engaged in promoting their usefulness. Success has been achieved on a limited scale: controlling the Klamath weed with a beetle, nodding thistle with a weevil, and aphids with ladybird beetles. A host of small wasps and flies help to keep many forest, garden, and field crop insects at low population levels. Others such as dung beetles, ground beetles, and flesh flies provide janitorial service in cleaning up detritus, offal, and the waste products of other creatures. Of greater importance are the many insect larvae, pupae, and adults that provide the food, both in water and on land, to other life forms. Aquatic vertebrates depend for much or most of their food on insects, as do birds, rodents, and amphibians. Without the insects the depleted food chain would soon be evidenced by a greatly reduced animal population generally.

Other Insects

The foregoing have been but a few of the vast number of encounters between insects and man on the Canadian Plains. In addition to the many species of annoying and dangerous biting flies mentioned, other species have been on hand to desecrate the body of man and his animals. Included here are the lice, fleas, and bed-bugs as unwanted guests of his person and in his home; the debilitating bots of horses, keds of sheep, and the lice of swine and poultry.

Cattle grubs, or warbles (*Hypoderma* sp.), have been among the most harmful parasites of livestock on the Canadian Plains. Since the earliest days of settlement the warble flies have enacted their toll in reduced monetary returns from sales of milk, flesh, and hides from every farm and ranch on the Plains. To minimize losses and maximize beef and milk production, the federal government launched vigorous warble-control campaigns during World War II. R. H. Painter of Lethbridge directed the campaign, in which more than a million animals received treatment annually to kill the grubs that were lodged in their backs. Applications of systemic insecticides today permit whole areas to be declared "warble free." The warble flies were one of the principal reasons for the expansion of livestock insect entomology into western Canada and, together with other major field crop pests, the establishment of entomological research facilities in each of the prairie provinces.

And when the crops were harvested, stored in bins, granaries, and elevators across the plains, the grains were subject to attack and destruction by a series of stored products insects. Grain beetles, mites, and moths often overran the conveniently stockpiled food stuffs, ruining an estimated 10 to 20 percent in some years. During World War II, when grain could not find its way to overseas markets because of the blockaded wartime shipping lanes, much of the western grain had to be stored for several years on the prairies. Losses due to insect manifestations and spoilage were phenomenal. The need for insect control and improved management of stored products prompted the establishment of a federal entomological laboratory in Winnipeg in 1941. Since then its scientists have given devoted service to farmers, millers, and grain companies, not only assisting and directing the fumigation of stored products, but also exploring new and improved avenues of control. Even though the transporting of agricultural products in and out of the plains region of Canada still remains a bottleneck to the full development and expanded potential productivity of the prairies, producers today are not limited by the occurrence of stored products insects. These insect pests may limit the net returns of production but do not deter productivity itself.

To add to the story of the hindrance to agricultural expansion and economic development in western Canada because of noxious insects, one should elaborate on the activity of the 200 or more species of aphids found there. Included here are the destructive pea aphid, the corn-leaf aphid as a destroyer of late-seeded barley, and the sugar beet root aphid.

The latter originally spent part of its life on the poplar tree and the remainder on native weeds. When sugar beets were introduced into areas where aphids abounded, especially in southern Manitoba and in the irrigated areas of Alberta, they were adopted as suitable hosts by the aphids. When beet acreages increased as a result of expanded irrigation facilities, so did the aphid populations. The damage to the beets, aided by the sugar beet maggot and the sugar beet webworm, became a significant factor in successfully growing beets. By diligent crop rotation, timely application of selective insecticides, and aided by the work of several insect parasites, producers maintained a viable commercial agricultural enterprise.

There are also hundreds of other insect pests of gardens and horticultural crops, ranging from worms in cabbages, to flea beetles on radishes, and maggots in raspberries. Some fly maggots parasitized livestock while others invaded the smoked-meat larder of the pioneer and devastated his root crops. Not only are carrots, onions, and beets attacked, many market gardeners today have given up the growing of turnips. DDT and heptachlor gave excellent protection against root maggot injury even when used at minimal and acceptable rates of application. Since their ban it has been extremely difficult and very costly to produce marketable root crops.

However, the struggle continues; the battles against insect pests are not all won.

Weather has been man's greatest ally in the fight against insects. Nearly all outbreaks are due to climatic conditions that favour insect survival and reproduction. Conversely, the opposite effect occurs when inclement weather persists. The Canadian Plains are renowned for the changing aspects of climate and weather. Insect pests will continue to thrive and harass man, or decline in numbers, as long as these changing environmental conditions persist. Progress, whether socio-economic, scientific, or humanistic, will depend on how well man can utilize the vagaries of nature in maintaining his tenuous supremacy over the insects that surround him.

The Bright Side

Insects have afforded pleasure to many people who have admired them as objects of Nature's art gallery. Collectors have assembled the showy coloured butterflies, irridescent beetles, graceful dragonflies, and delicate Mayflies. Many a pioneer whiled away the long, lonesome hours of isolation on the prairies by arranging, studying, and enjoying the collection of insects at hand. Others classified and described new species, sharing their new-found knowledge with fellow naturalists. Entomological scientists have used the insects as tools to help them solve problems of evolution, physiology, ecology, and heredity. Numbers of insect species on the Canadian Plains exceed those of all other animal species combined. Sheer numbers perhaps account for the attention that insects have received, apart from their beneficial or noxious attributes.

To all who have dealt with insects these creatures have been fascinating objects of life harbouring secrets of structure and behaviour that pique the inner conscience. The insects of the Great Plains have been particularly intriguing because their precarious existence and tenacious persistence in the face of change, places them in a category of endurance that man deserves to emulate.

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