Guide to the Geology of

RIDING MOUNTAIN NATIONAL PARK

A. H. Lang

Cover—

Sunset over Clear Lake.
National Parks Service photo

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Guide to the Geology of

RIDING MOUNTAIN NATIONAL PARK

and its Vicinity

History of its Upland and other Scenery

A. H. Lang

MISCELLANEOUS REPORT 20

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ABOUT THIS BOOK

The main geological features of the park are described as non-technically as possible and the coverage is broadened to include interesting features that can be seen in the general region of the park, particularly when travelling to or from it.

Even if you have no knowledge of geology you can enjoy this book. A short explanation of the main geological principles involved is given near the beginning, and any additional technical words are explained as occasion arises.

The best method of using the book is to study it before leaving home, and perhaps also to obtain some of the maps or other literature mentioned at the end. Acquiring the book in advance would not only allow more thorough study at home or while travelling, but would also help you to recognize interesting geological conditions along the way. There is enough information on geological principles and the Plains region in general to interest any traveller or resident in the region, even if he never visits the park.

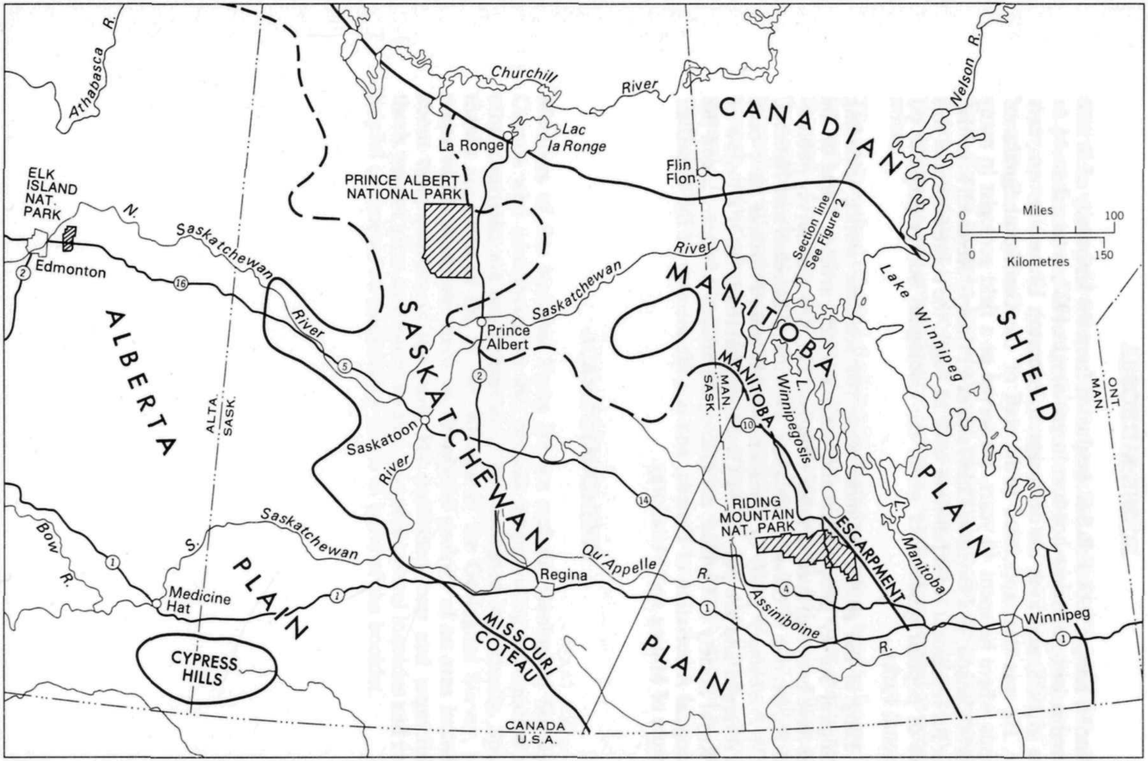
ACKNOWLEDGMENTS

Members of the National Parks Service and the Geological Survey of Canada who contributed to this booklet by providing information and other courtesies are too numerous to be mentioned individually. Special thanks are given to Dr. R. W. Klassen of the Geological Survey, who prepared his doctorate thesis on the glacial geology of an area including about three quarters of the park. His published map and unpublished thesis were of great assistance; he also answered several inquiries and made helpful comments on preliminary drafts of parts of the booklet.

THE AUTHOR

Arthur H. Lang, Ph.D. F.R.S.C. graduated from the University of British Columbia with first class honours in geology in 1927, received an M.A. there in 1928, and took his doctorate at Princeton University two years later. He was then appointed to the staff of the Geological Survey of Canada where he spent 40 years. He served as a field geologist in many parts of Canada, as a Division Chief, and as a Principal Research Scientist. After his retirement from full-time work he began the continuation of this series of popular guidebooks which the Geological Survey prepares on National Parks.

Dr. Lang is the author of more than 100 scientific works, including Geological Survey publications and other scientific articles. Some of the latter have been reprinted in other countries. His principal Survey publications *Prospecting in Canada*, *Canadian Deposits of Uranium and Thorium*, and *A Preliminary Study of Canadian Metallogenic Provinces* have been well reviewed and are popular in Canada and abroad. He is a Fellow of the Royal Society of Canada, the Geological Society of America and the Geological Association of Canada, and is a life member of the Canadian Institute of Mining and Metallurgy.



Riding Mountain National Park and the two other National Parks in the southern part of the Interior Plains region, shown in relation to the Canadian Shield and the Alberta, Saskatchewan and Manitoba Plains.

INTRODUCTION

Riding Mountain is really a rolling plateau whose wooded slopes and numerous lakes form an environment very different from that of the lower plain and valleys of Manitoba.

When viewed from the flat Manitoba farmlands its summit, rising 1,500 feet, looks indeed like a low mountain. It is not surprising that the early fur traders called it so, probably adding the word 'riding' because in this general vicinity they changed from canoes to saddle horses to continue westward. There has been some suggestion that the Indians used an equivalent expression even earlier.

One of the questions most frequently asked of the Chief Park Naturalist is "how did the mountain get there?" When asked his own opinion, the visitor's reply is generally that it must be "just a huge pile of dirt." There is much more to it than that, as is explained later.

The park is not a unique area, so the geology of the park and the descriptions of examples in it are a help in understanding much of the so-called 'Prairie Provinces.' Geology is fundamental to ecology, or environment as a whole, which is now of increasing concern to many persons. The geological history of a place determines its height above sea level, which has much influence on scenery and climate. The flatness or irregularity of land surfaces, which affects suitability for farming, road-building and sports such as golf and skiing, is the result of geological processes. Geological conditions determine the kinds of soils, gravels and other overburden that cover the bedrock of most regions. Climate, kind of overburden, and to some extent, the type of bedrock combine to affect plants, forests and wildlife and to determine the suitability of an area for farming or other activities. Geology accounts for the distribution of the streams and lakes, features that add so much to the beauty of the park and provide various opportunities for recreation. The importance of geology in locating springs and wells, in deciding on good foundations, and in avoiding places that may be subject to landslides, is being recognized increasingly.

The taking of specimens from the park is not permitted. Leaving rocks, minerals and fossils so that they can be observed in their natural settings by other visitors is an important aspect of conservation.

Boundaries and Access

Riding Mountain National Park, with an area of 1,150 square miles, is in southwestern Manitoba about 60 miles north of Brandon. The west boundary is 18 miles east of the Saskatchewan border.

The park is very irregular in shape, the boundaries having many right-angled jogs because of the way in which blocks of land were obtained. From the west boundary it extends eastward about 65 miles, almost to Highway 5. The east and northeast boundaries were located to take in the Manitoba Escarpment, described later. Instead of curving, the boundary jogs to follow the escarpment at land corners until it reaches the north boundary, which lies 8 miles south of Dauphin. The north boundary, which is fairly straight except for a few jogs and a

stretch where it follows the bank of Vermilion River, is 10 miles south of Grandview and 9 miles south of Gilbert Plains. The south boundary is especially joggy, to avoid blocks of farmland. The western part of the park is the narrowest, being only about 9 miles from north to south. The greatest north to south dimension is 26 miles, from the north Park Entrance to the south end of Clear Lake.

Wasagaming, a townsite administered by the National Parks Service and the only community in the park, is on Highway 10 close to the south boundary.

Most visitors arrive by way of the south Park Entrance at Wasagaming. From it three paved roads—Highway 10, Ta-wapit Drive, and Wasagaming Drive—lead to the east end of Clear Lake; from there Highway 10 extends north to the north Park Entrance and on to Dauphin. Near the east end of Clear Lake, Highway 19, which is paved, leads to the east Park Entrance and then goes a short distance to Highway 5. A paved road follows the north shore of Clear Lake, then becomes a gravelled road to Lake Audy. These are the main roads within the park that are open to the public. Other roads that lead to the park boundaries, or a short distance into the park, connect with some of the many miles of wardens' roads and trails that may be used to hike to more remote parts of it, but are not open to private vehicles.

Examples of most of the geological features to be seen in or near the park can be visited by motor roads. Only a few examples in more remote parts are, therefore, mentioned in the booklet or shown on the accompanying maps.

SOME GEOLOGICAL FUNDAMENTALS

Geology is based on a few main principles whose truth has been shown again and again. They must be grasped before the story behind any landscape can be appreciated properly. The basic facts are that the earth is almost inconceivably old and geological processes have changed little since the original crust and atmosphere of the earth were formed. These processes are going on now, and some important ones can be observed at suitable places on the earth's surface. In exposures of layered rocks—those formed from sediments or lavas—older layers are at the bottom and the overlying ones were formed successively later. An exception occurs where layers have been overturned, as sometimes happens when rocks have been much disturbed, but this does not apply in the Plains region. Much of what we see at the surface of the earth resulted from processes that are still going on, and there has been ample time for them to have produced these results.

The bedrock and unconsolidated material such as gravel, sand, boulders, etc. visible in Riding Mountain park and its surrounding region are formed from the erosion or wearing away of earlier rocks. Ancient retreating glaciers deposited a mantle of rock debris over most of the bedrock.

Erosion and Deposition

Erosion and the moving and deposition of its products are closely connected with the atmosphere and have operated on the earth's crust ever since the first rains and winds. Everyone has noticed how winds raise the dust in clouds, moving it from

place to place. Sand dunes can be seen along many lake and sea shores. In deserts the 'sand-blast' effect of wind-blown sand on rock outcrops is readily visible.

The most effective agents of erosion, transport and deposition are, however, related to the precipitation cycle, in which the evaporation of bodies of water causes clouds that are carried over the land to produce rain or snow; these return as run-off or as underground circulation. Water does some eroding of rock surfaces by dissolving soluble minerals or rocks, and by expanding as ice in cracks, splitting off fragments of rock after penetrating cavities and cracks. More effective is the loosening of soil or gravel by water to form landslides, and the way moving water in streams and waves erodes shores and bottoms and carries away the eroded material. Such erosion results from the pressure of hurtling water, and the abrasion of sand particles carried in the water. A little observation along valley sides or streams will show small-scale examples of slides or slumping, or the manner in which streams undercut their banks, erode the outsides of bends, and form bars and shallows on the insides of bends. Also, lake shores may show the slow erosion of beaches and shore-side cliffs.

Moving water carries along mud, silt, sand and pebbles, and in large streams cobbles and boulders are rolled along. Where the force of the current lessens, as in the slack water on the inside of a bend, or at a delta, the particles of silt and sand drop to the stream bed and, depending on the strength of the current, are sorted into different sizes. Stronger currents carry coarser debris, so gravels are deposited in stream beds and parts of some deltas, and sand, in some slacker stream beds or

GSC photo 10-4-72

This shale near the top of a cliff in the eastern part of the park was hardened and compacted from mud deposited in a sea that covered this part of North America millions of years ago. The black masses are nodules of iron with a little manganese. These are comparable to nodules being deposited now on the continental shelves offshore from the coasts.

near the shore in lakes. Mud may be deposited in very sluggish streams, but is mainly carried into the deeper parts of lakes or seas; it is sometimes carried great distances by currents.

Thus land areas are worn down slowly and sediments accumulate on land, in fresh water, or in a sea. These processes are accompanied by slow rising of the eroded land and a corresponding sinking of the larger sedimentary basins, because of

the increased weight on the yielding material that lies deep beneath them.

Some sediments consist of thick layers of similar composition, but many are clearly interbedded by thinner layers of different colours and compositions. Sediments are compacted by the weight of overlying beds, and the grains are cemented together by minerals carried in solution by water passing through the tiny pores left even after compaction has taken place. In these ways sediments gradually become hard rock, known as sedimentary rock.

Geological Time

Knowledge of the origin of sedimentary rocks and the thick sequences of such rocks seen at some places caused early naturalists to recognize that the earth must be much older than was generally supposed. Later, as the true nature of fossils found in this type of rock became understood, these remnants of prehistoric life indicated the vastness of geological time. The fact that similar fossils were contained in sedimentary rocks of the same age but in different places permitted the sequence of strata in Europe to be understood. Thus it was concluded that an enormously thick total sequence of beds had been laid down, whose accumulation must have required many millions of years. It was also realized that fossils represented a gradual evolution from primitive to advanced forms of life, which could have occurred only over very long periods of time.

In this century research on minerals containing certain elements that disintegrate slowly at known rates has not only corrobo-

Eon	Era	Period	Epoch	Approximate years since beginning
	Cenozoic	Quaternary	Recent	7 thousand
			Pleistocene	1 to 2 million
		Tertiary		65 million
	Mesozoic	Cretaceous		120 million
		Jurassic		185 million
		Triassic		210 million
	Paleozoic			535 million
Precambrian				3 to 4 billion

rated the general principle that the earth is very old, but has permitted reasonably accurate dating for many rocks and geological events. The oldest rocks from the earth's crust that have been dated in this way are between 3 and 4 billion years old. As no sign of the original crust has ever been found, these dates are reasonably in accord with estimates of astronomers and physicists that our solar system was formed about $4\frac{1}{2}$ billion years ago.

Early geologists decided that the succession of strata in Europe could be assigned to *eras** of time, which could be subdivided into *periods*. Soon it was shown that these divisions

*Geological terms are printed in italics where first used and explained.

could be applied to other continents, thus permitting a standard geological 'calendar' to be used. More recently, new dating methods have permitted fairly accurate ages to be assigned to the divisions of the calendar. Some of these are shown in the accompanying table.

Subdivision of only the Mesozoic and Cenozoic eras are shown here because the bedrock visible in and near Riding Mountain park is of Cretaceous age, and the widespread glacial deposits of the region are of Pleistocene age. Paleozoic and Precambrian times have also been subdivided, but this is not of concern in this booklet. Precambrian time was formerly classed as an era but, because it represents the greater part of geological time, it is now given the name *eon*.

Causes and Effects of Glaciers

Glaciers are powerful agents of erosion, transport, and deposition. They form during periods of abnormally cold climate, when the winter snowfalls fail to melt completely during the summers. At the maximum of such a cold cycle, snow falls both in winter and summer over large parts of the earth's surface. As the snow becomes thicker, pressure on the older and lower snow causes it to freeze together and become ice. Even the low-lying parts of a region may be covered by an ice sheet. With continued thickening, to hundreds and even thousands of feet, the ice begins to behave like a very viscous substance and to flow.

Glaciers erode by removing loose material from the earth's surface and by scraping and gouging the bedrock. These forms of erosion result partly from a 'bull-dozing' effect at the front

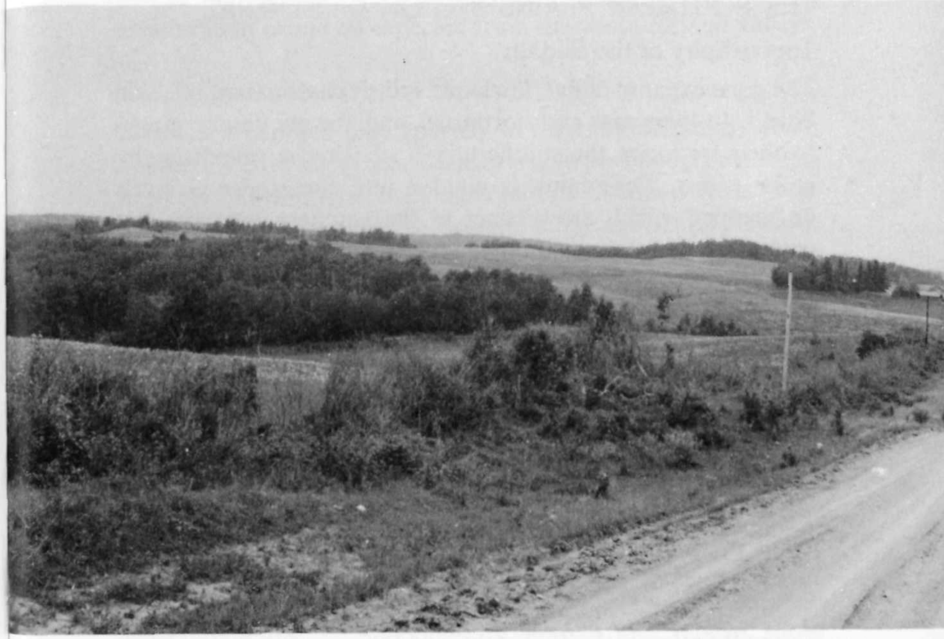
GSC photo 12-45-44

The power of glacial erosion is shown by this worn down, scratched and polished boulder left by an earlier advance of ice. The boulder came from one of the Paleozoic formations bordering the Canadian Shield some 250 miles from its present site 7 miles east of Cardale.

of advancing ice, partly by the plucking away of rock fragments around which the ice freezes, partly by the scouring effects of sand and other debris carried along under the ice, and partly by the gouging caused by larger rock fragments frozen into the base or sides of a glacier as they scrape against the bedrock.

Loose material can be transported within a glacier, either near its top or bottom or on its surface. Some debris is left behind as the ice advances, huge piles of rubble are often left along the lines marking the farthest advance of the ice, and still other accumulations are left as the ice melts away. The collective

name for all the various kinds of glacial debris is *drift*. Drift that is a mixture of clay, silt, sand, stones, cobbles or boulders is called *till*, large accumulations of which form *moraines*. Much of the drift is not deposited as till, but is carried off in streams of water that form from melting ice, where it becomes sorted and deposited as stratified or partly stratified *outwash* in temporary streams, ponds, and lakes that lie along the margins of the ice.



GSC photo 12-45-49

Hummocky stagnation moraine south of the park, one mile north of Marco.

97739—2

Moraines are of many kinds, including *ground moraine* formed under the ice, and various kinds of *disintegration moraines* formed where material is dropped by the ice as it melts; this material may be dropped on top of ground moraine. Some large, thick, hummocky disintegration moraines form where large parts of an ice sheet remained stagnant while the rest of the sheet melted.

THE SOUTHERN PLAINS REGION IN GENERAL

Topography of the Region

The great expanse of flat 'lowlands' lying between the Canadian Shield, to their east and northeast, and the mountain ranges to their west, are the southern part of what is called the *Interior Plains*. The region is divided into three general levels or 'steppes' which are distinct in the southern stretches but tend to grade into one another farther north.

The most easterly level, known as the Manitoba Plain, is a true plain with a flat or gently undulating surface about 800 feet above sea level. It extends from Lake Winnipeg westward to a rise in the surface which is called the Manitoba Escarpment. In places this is abrupt, rising to about 1,500 feet above the Manitoba Plain, and in other places it slopes more gradually and is not as high. The escarpment extends northwestward across southwestern Manitoba, except where cut into segments by easterly flowing rivers. The Manitoba Plain contains many bodies of water, including the large lakes—Winnipeg, Manitoba, and Winnipegosis—which lie in slight depressions. The middle level, the Saskatchewan Plain, is a gently rolling, hilly surface from 1,500 to 2,600 feet above sea level. Its

southern part extends westward from the Manitoba Escarpment for about 250 miles, where it ends at a line of low hills known as the Missouri Coteau. The still higher Alberta Plain lies between the Saskatchewan Plain and the Foothills of the Rocky Mountains.

The Saskatchewan and Alberta Plains contain valleys up to 400 feet deep and 1 to 2 miles wide. Because these valleys were eroded by large temporary floods of meltwater at the end of the Ice Age, some are dry and others contain streams smaller than would be expected from the width of their valleys.

The Bedrock Beneath the Plains

Bedrock is exposed only sparsely in the Interior Plains, which are mainly covered by glacial drift. There are enough outcrops, however, to combine with information obtained from wells and geophysical surveys to provide fairly satisfactory knowledge of the bedrock conditions.

The Interior Plains region is, in geological terms, a *platform*, so called because it is underlain by a fairly flat succession of rocks that have been relatively stable for a long time. This is largely because the base of the succession is composed of hard Precambrian rocks.

The Precambrian Basement

During the long ages of Precambrian time great amounts of sedimentary and volcanic rocks accumulated. These were subjected to stresses that changed, warped, and uplifted them into mountains. Large bodies of granite and related rocks crystallized coarsely from molten or nearly molten material

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GSC photo 9–10–72

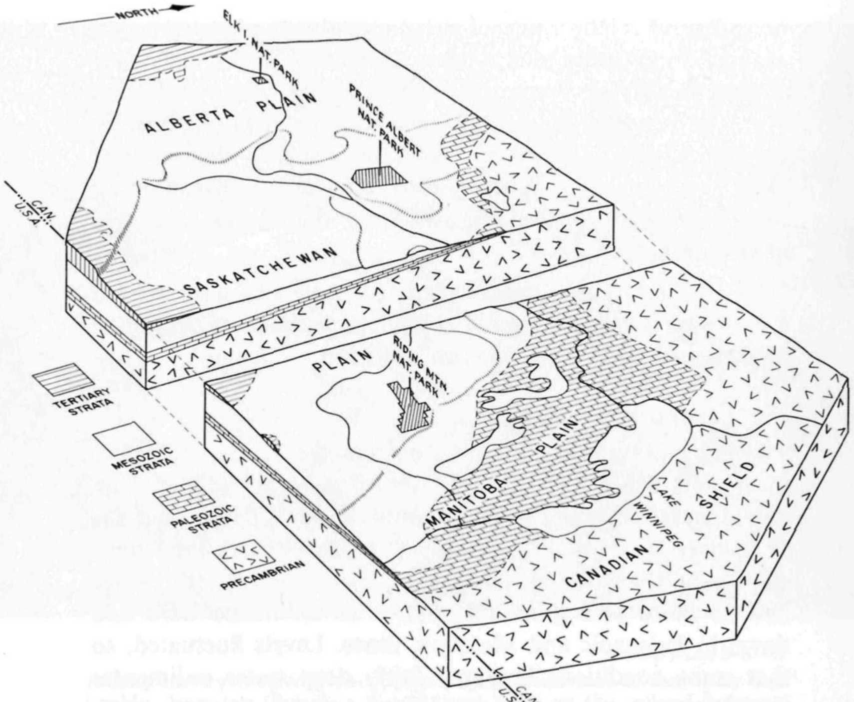
A long history involving several geological processes is shown by this boulder from the Canadian Shield, now lying on the upland between Highway 19 and the summit of Riding Mountain. The dark rock is schist and the light bands are felsite intruded in molten state along fractures in the schist. The curved light band indicates squeezing while both kinds of rock were in a semi-plastic state. These show that the processes took place hundreds or thousands of feet below the land surface then existing. The rock was eventually exposed at the surface of the Shield by prolonged erosion. Then a chunk larger than the original boulder broke off, was carried in an ancient river, and rounded by being pounded and rolled against other rocks. A large glacier froze around the boulder and slowly moved southward 200 miles or more. When the ice melted the boulder dropped to its present resting place. The schist is soft and flaky and would not have survived as a boulder had it not been reinforced by the much harder felsite.

were formed in the roots of the mountains, and many rocks changed by pressure into banded *gneisses* or flaky *schists*. The ancient mountains were worn down by erosion, seas encroached over the resulting low lands, and the cycle of deposition, mountain building, and erosion began anew. In many places these processes were repeated several times, with the result that the older Precambrian rocks were altered and deformed in very complex ways.

Near the end of the Precambrian eon the rocks were eroded down to a fairly flat, undulating land surface to form the hard, strong base of the Interior Platform.

The Younger Bedrocks

The Precambrian rocks that now form the base of the platform, and most, if not all, of those that form the Canadian Shield were depressed some 500 million years ago, about the beginning of the Paleozoic era. This permitted inland seas, similar to today's Hudson Bay, to encroach over the land, and in those seas great thicknesses of sediments were laid down in Paleozoic and Mesozoic times. Levels fluctuated, so that some conditions favoured fairly deep water sedimentation that produced limestones, dolomite and shale. Some areas of seas were almost at sea level, permitting evaporation that resulted in beds of salt and gypsum. Other conditions caused thick beds of sand that became sandstone. At other times the seas withdrew, allowing the newly formed land to be eroded and some deposition to take place on land. Thus the Paleozoic and Mesozoic successions of sediments here contain gaps and are far from representative of the entire worldwide successions of those eras.



This block diagram shows the structure of the rocks that underlie the southern Interior Plains. Because the height of the Alberta Plain above the Saskatchewan Plain, and the height of the Saskatchewan Plan above the Manitoba Plain, are small compared with the horizontal distances covered by the diagram, these heights have been exaggerated to make the relationship clearer. This causes an exaggeration of the thickness shown for the Mesozoic strata. The slope of the Precambrian basement that extends east and south from the Canadian Shield has also been exaggerated, because this slope and that of the Paleozoic and Mesozoic strata above the basement are actually so slight that in any one locality the strata appear flat to the eye.

The smallest sedimentary units that can practicably be shown on a geological map are called a *formation.* It may consist only of one kind of rock, but most formations comprise bands of different types. The thickness of individual formations, and of the total succession of formations at any particular place, varies considerably. The total reaches a maximum of roughly 10,000 feet in parts of Alberta.

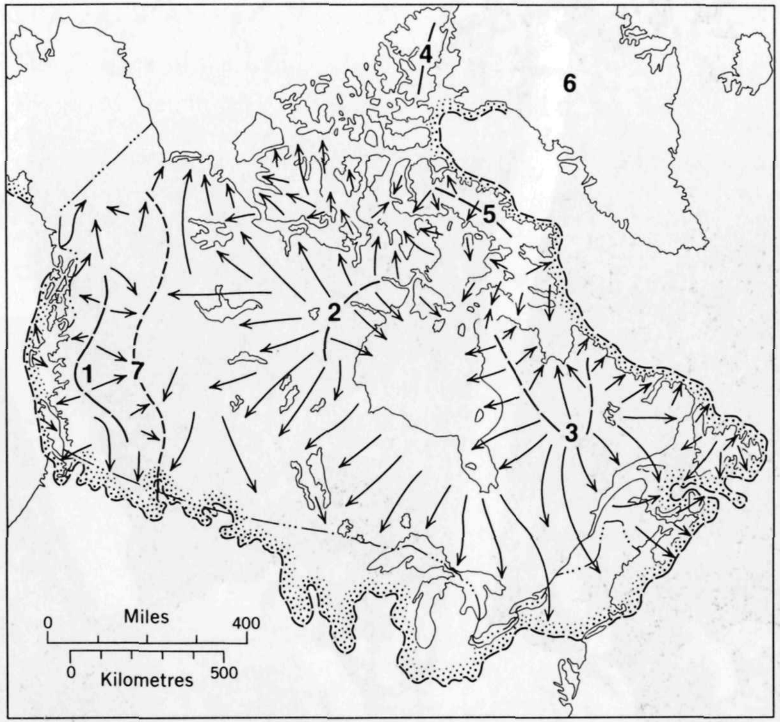
The Precambrian surface and the overlying sedimentary layers were tilted slightly toward the west, probably about 60 million years ago, in early Tertiary time when the Rocky Mountains were being built. This tilt averages 15 feet to the mile. It is not apparent to the eye, but is sufficient to cause the great amounts of erosion that took place in later Tertiary times to 'bevel' the formations. Thus the Paleozoic formations, being oldest, are at or near the surface in the eastern part of the Manitoba Plain; the Mesozoic formations are at or near the surface in its western part and in much of the Saskatchewan Plain; and the Tertiary beds occur in parts of the Saskatchewan and Alberta Plains. These conditions are illustrated on page 16; also shown is the manner in which relatively thin groups of formations underlie much wider distances because of the bevelling.

By the end of Tertiary time the Manitoba, Saskatchewan, and Alberta Plains and their main river systems had been sculptured by erosion fairly closely to their present levels—perhaps within an average of about 100 feet of the present surface.

The Coming of the Ice Sheets

The most widespread effects on landscapes now visible in Canada were caused by ice that began to form at the beginning of the Pleistocene Epoch one to two million years ago. The ice has not yet left some parts of the country, but Pleistocene time is now regarded as having ended in Canada about 7,000 years ago.

Pleistocene time included several glaciation and intervening episodes. As the early part of the period became colder and colder great amounts of ice accumulated, and then spread out to cover most of Canada and large parts of the United States. When the climate moderated the ice melted. Climatic cycles of this kind were repeated several times during the Pleistocene Epoch; it is generally assumed that there were four major episodes of glaciation. During the intervening times, which were longer, the climate was as warm or warmer than nowadays, and sea levels were as high or higher. A complete glacial–interglacial cycle probably required between 150,000 to 300,000 years. Each glacial advance tended to erase the evidence of the previous one. Most of the effects seen today are, therefore, those of the last glaciation, although earlier drift has been found in places, mainly by drilling. The ice is estimated to have been as much as 10,000 feet thick in places, and at its maximum it extended well into the northern part of the United States, as shown on page 19, and covered about 5 million square miles of North America. The last ice sheet is estimated to have left Riding Mountain park about 12,500 years ago. The amount of drift that accumulated in the Interior Plains region during the Ice Age probably averages 100 to 200 feet, although it varies greatly and ranges from more than 1,000 feet deep in some places to almost nothing in others.



Generalized map showing farthest extent of ice in North America during the last Pleistocene glaciation, which greatly influenced present-day scenery by ice erosion of soils and rock, and by deposition of the resulting debris. The accumulation of snow and the resulting formation of ice caused flowage in different directions from ridge-like divides in the following localities: 1. Cordilleran; 2. Keewatin; 3. Labrador; 4. Queen Elizabeth Islands; 5. Baffin Island; and 6. Greenland. The largest ice sheet, formed by combining Keewatin and Labrador ice, is called the Laurentide Ice Sheet. The line marked 7 indicates the approximate eastern limit of the advance of Cordilleran ice, and the western limit of Keewatin ice. This map was modified from Map 1253A, Glacial Map of Canada, maps by V. K. Prest in the 4th and 5th editions of the Geology and Economic Minerals of Canada, and D. M. Baird in A Guide to Geology for Visitors in Canada's National Parks.

National Parks Service photo

Parts of the low Manitoba Plain can be seen in the distance in this view from the top of the Manitoba Escarpment, north of Highway 19.

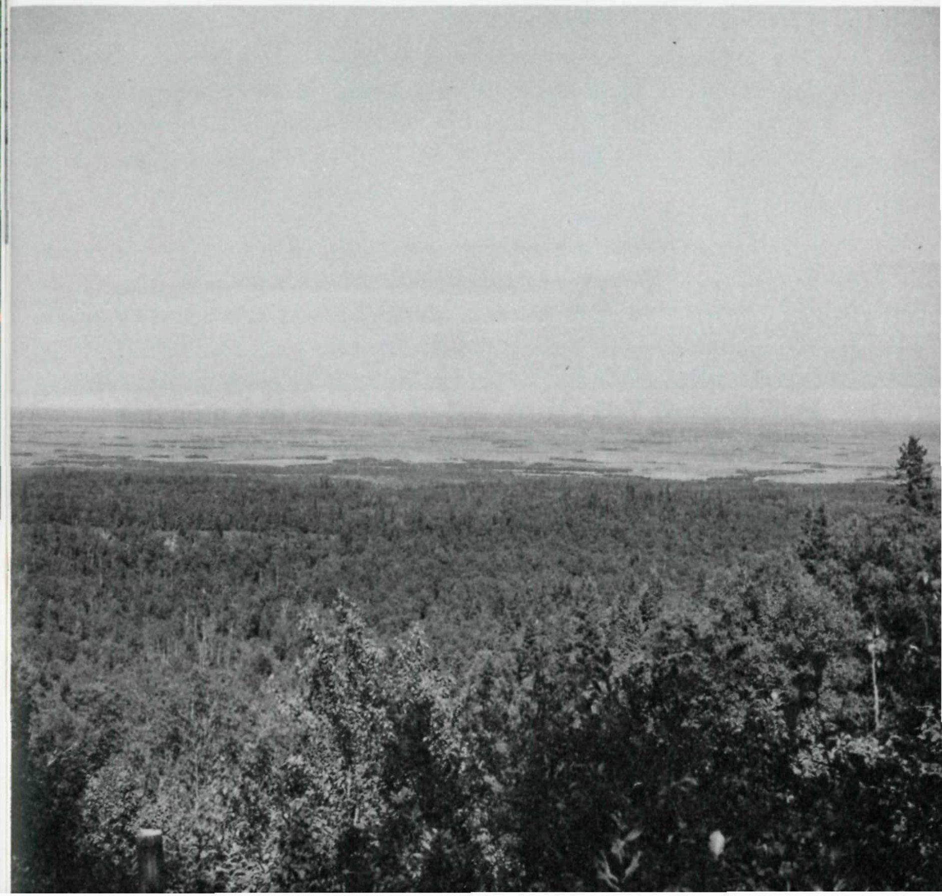
THE PARK AND ITS VICINITY

The Surface of the Land

Riding Mountain park is mainly rolling upland of the Saskatchewan Plain, although it includes a section of the Manitoba Escarpment and a little of the Manitoba Plain.

GSC photo 10–2–72

The Manitoba Plain as seen from a point near the top of the escarpment.



The fertile, flat Manitoba Plain, lying some 850 feet above sea level in this region, can be seen to good advantage by driving along Highway 5 or from lookouts near the east and north entrances of the park. Streams flowing from the upland have deposited sediments on the general surface of the plain, forming a surface that slopes eastward in places, such as between the east entrance and Highway 5. These slopes may be partly deltas in glacial Lake Agassiz, a feature explained in a later section, and partly more recent sediments forming what is called an *alluvial fan*. The largest delta is between Assiniboine River and Neepawa.

The Manitoba Escarpment, rising to about 1,500 feet above the Manitoba Plain, more or less forms the east boundary of the Saskatchewan Plain from south of the International Boundary, across southwestern Manitoba, and into Saskatchewan north of Swan River. The escarpment is interrupted by the broad valleys of former easterly flowing rivers, now occupied partly by Assiniboine and Valley rivers. These old valleys cause the eastern part of Saskatchewan Plain to take the form of a series of uplands, of which the so-called Riding Mountain is one. It is bounded on the east by a segment of the escarpment, on the north by the broad valley occupied by Wilson and Valley rivers, and on the south by a plain that slopes gradually toward Assiniboine valley. Between the west boundary of the park and the Manitoba–Saskatchewan border the upper reaches of Assiniboine River have formed a broad valley which separates Riding Mountain from the rest of the Saskatchewan Plain. The wide valleys to the north and south of Riding Mountain may be thought of as extensions of the Manitoba Plain. Southward from the vicinity of Dauphin

GSC photo 8-2-72

The Manitoba Escarpment as seen eastward from the vicinity of Highway 5.

the north side of the 'mountain' resembles the escarpment, and in a sense is a continuation of it. Farther west, from the vicinity of Grandview, the 'mountain' is still a prominent feature, but its slope to the valley is more gradual. The southern side of the mountain slopes gently toward Assiniboine River, except where it is trenched by its tributary, Minnedosa River.

The highest point in the park is the 'summit' of Riding Mountain with an elevation of nearly 2,500 feet above sea level. It is one of a cluster of three hills of about equal height lying roughly 3 miles north of Highway 19 and 2 miles west of the 'drop off' of the escarpment. From there the plateau stretches to the north, south, and mainly to the west, to form a rolling upland that is mostly 1,800 to 2,100 feet above sea level.

Small, short, precipitous streams in the eastern and northeastern parts of the park have cut deep notches and eroded the escarpment. A divide that separates streams draining the north and south slopes of the park curves in a general westerly direction through the park's central part, then swings north near Birchview. The principal streams in the park are shown on the folded map. They include Vermilion and Wilson rivers, which are the largest of the north-flowing streams; the upper reaches of Minnedosa River, which drains most of the southeastern part of the park; and Birdtail Creek, which drains the western part southward to Assiniboine River.

The headwaters of most streams are interrupted by beautiful lakes, of which Clear Lake is the largest and most visited. With a surface 2,017 feet above sea level, it has an area of $9\frac{1}{2}$ square miles and a depth of 110 feet at the deepest parts. Clear Lake and some of the smaller lakes are fed mainly by springs that provide clear water; for this reason these lakes are not being filled in by silt as rapidly as those fed mainly by streams.

The Rocks Beneath the Park and its Vicinity

The bedrock exposed, here and there, in and near Riding Mountain park is of late Mesozoic (Cretaceous) age. It is, however, interesting to know something of the still older rocks that underlie it and are exposed far beyond the eastern limit of the park, west of Lake Winnipeg.

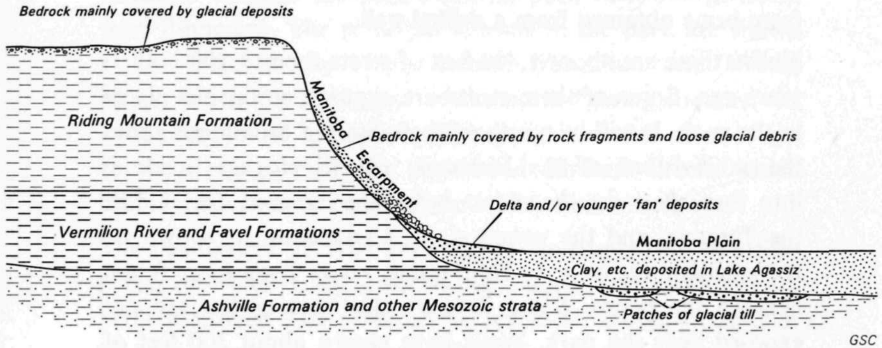
These ancient rocks lie roughly 1,800 feet below the surface in the vicinity of the park. Because they slope gradually to the west, and also because of the height of the Saskatchewan Plain, they lie a few hundred feet deeper at the western side of the park. They are overlain by about 1,000 feet of strata some 500 million years old, composed mainly of limestone, dolomite, sandstone, and shale. Beds of common salt are included in places, as at Neepawa where the salt is recovered from brine obtained from a drilled well.

Above these are about 1,400 feet of strata formed 200 million years ago. Some of these strata are exposed at various places in the park. It will be worth while to learn a little more about the subdivisions of the Mesozoic era. Geologists divide it into three periods, the oldest being the Triassic, the middle the Jurassic, and the youngest the Cretaceous, as shown on the calendar on page 8. No Triassic rocks have been found beneath the plains. Some Jurassic strata occur but are not exposed near the park. Wells have shown about 300 feet of Jurassic beds near the park, some being of the kinds deposited in seas and others being freshwater types.

Cretaceous rocks are abundant and are exposed at several places. Dating of radioactive minerals in the rocks indicates that they were deposited between 136 million years and 65 million years ago.

About 75 feet of soft shale, sandstone, and unconsolidated sand overlie the principal Jurassic beds and form the Swan River Group. The few fossils found indicate that the beds are partly Jurassic and partly Cretaceous. The softness of these beds is largely responsible for the position of the western part of the Manitoba Plain, because they were less resistant to erosion than the younger formations exposed in the escarpment.

Overlying the Swan River beds and forming the base of the escarpment is the Ashville Formation. This consists of about 130 feet of shale, the lower part being dark grey and clayey, and the upper a greasy, black type that weathers brown or



Cross-sectional diagram of bedrock formations and unconsolidated deposits at the Manitoba Escarpment and adjacent part of the Manitoba Plain, looking north. The height of the escarpment, the thickness of the Favel and Vermilion River formations and the unconsolidated deposits, and the dips of formations and alluvial deposits are exaggerated for easier understanding.

pinkish brown and breaks into numerous flakes or flat chips. Several outcrops of the formation can be observed north of the park along Wilson and Vermilion rivers. One outcrop was mapped in the bed of Edwards Creek.

Above the Ashville is the Favel Formation, which is 115 feet thick and consists mainly of grey shale speckled with white limy material; a few bands of limestone are present near the top of the formation. Exposures may be seen along Ochre River, Edwards Creek and Vermilion River.

Overlying the Favel is the Vermilion River Formation, composed of about 240 feet of grey shales of different kinds, some being speckled with limy matter. The Favel Formation is not easy to distinguish from the Vermilion River unless the limestone can be found. These two formations are tougher and more compact than the strata below and above them, causing the erosion of the Manitoba Plain to be slowed, and thus resulting in the preservation of the escarpment. In other words, the Vermilion River and Favel formations act as a retaining wall at the base of the escarpment. As these two formations are thin they are grouped on the accompanying map, where they appear as a narrow band because the formations are projected as though the observer were looking down on their exposures.

An accessible place to see the Favel–Vermilion River rocks is at the entrance to the Agassiz Ski Hill, shown on the route-log on page 65. They can also be seen fairly readily by leaving Highway 5, eight miles north of McCreary, then driving west through Laurier to Ochre River. The Vermilion River Formation is named from the river of that name, along which good

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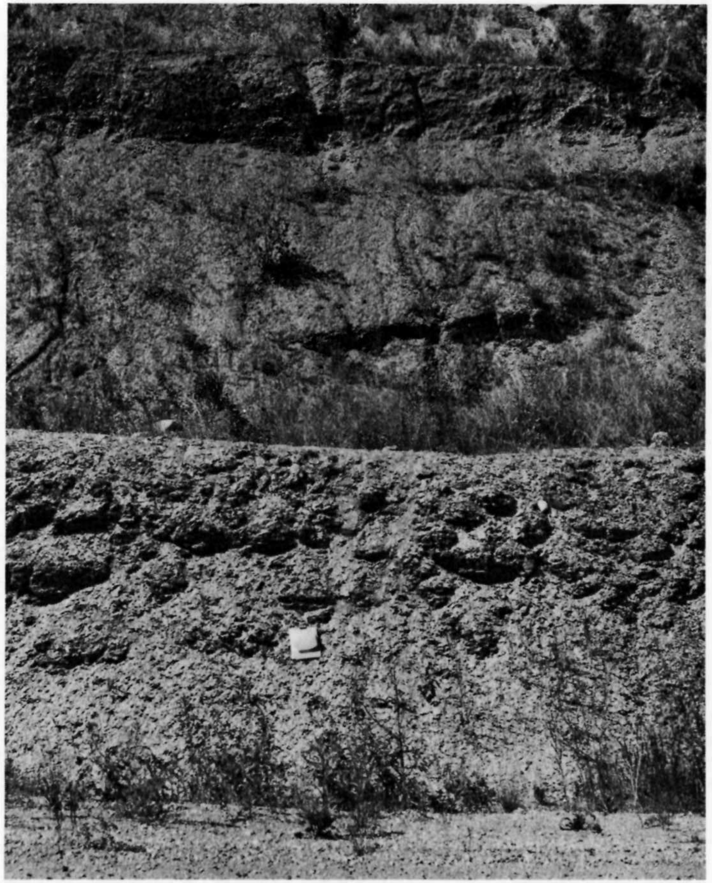

GSC photo 10–11–72
The Favel–Vermilion River sedimentary rocks along the road to the Agassiz Ski Hill.

exposures of this formation and the Favel Formation occur not far north of the park. To see them it is necessary to walk up the river from a road that jogs southwesterly from Dauphin. The two formations are also exposed along the bed of Edwards Creek; to reach them one would have to scramble down to the creek, west of the lookout near the north Park Entrance. It is best to examine outcrops along streams during periods of low water. Anyone with a keen eye can detect the difference in toughness of these two formations, as compared with that of the Ashville and Riding Mountain formations. Understanding this will explain the main reason for the presence of the escarpment.

The Riding Mountain Formation overlies the Vermilion River Formation and is the rock beneath the overburden at most places in the park. Its relatively soft and flaky, greenish grey shale erodes readily, which may be partly responsible for the rolling nature of the upland. The softness of the shale causes the Riding Mountain Formation to be poorly exposed, except at a few places. Some small exposures look so much like clay that it is difficult for inexperienced persons to distinguish them from soil. In places the shales contain bands of bentonite, an altered volcanic ash that swells when wet. There are also bands of ironstone (siderite) nodules containing a little manganese. These nodules are somewhat like those forming now at the bottom of the sea on continental shelves.

Exposures of the Riding Mountain Formation can be found at the east side of Highway 10 in the village of Onanole, and near the top of the hill where Highway 19 begins to descend to the east Park Entrance. Exceptionally fine exposures occur

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GSC photo 10-5-72
Shale of the Riding Mountain Formation forms Bald Hill and the beds in the foreground, near the summit of the escarpment.

at Bald Hill and at cliffs (locally called Mount Dunning) where Bald Hill Creek cuts into the top of the escarpment. These localities have been closed to visitors because they are within an experimental erosion control area, but they can be seen from Highway 5, and resemble light grey scars in the generally wooded slopes. Even if the restrictions should be removed in future, the cliffs are so steep and the shale is so slippery, especially when wet, that they are suitable for close examination only by experienced scramblers. Scattered exposures of the formation occur at other places near the top of the escarpment, and along some of the roads and streams south and west of the park.

The Indians made pipes from at least one soft bed of shale in the Cretaceous sequence, a fact recorded by the first geologist

to visit the region, more than a century ago. He recognized the Cretaceous age of the rocks but did not divide them into formations. He was unable to record the exact place of the 'quarry,' but a later writer stated that it was near the top of the escarpment which, if so, would place it in the Riding Mountain Formation today.

The Surface that the Ice Sheet Covered

Some 60 million years ago, during Tertiary times, the region was eroded by a branching system of large and small rivers that was well established by the end of the Tertiary period. Drainage was in a general easterly direction toward the present site of Lake Winnipeg. The upper reaches of these streams were interspersed by hills and ridges, and the lower reaches had eroded parts of the ancestral (preglacial) Manitoba Plain a few hundred feet lower than the present surface of the plain. This is shown just east of the escarpment by the fact that wells drilled for water showed an abrupt change in the bedrock surface.

Thus, the valleys of the ancestral Assiniboine and Valley rivers existed by the time the Ice Age began, and the Riding Mountain upland stood between them more or less as it does today. The escarpment was at about its present location, although considerably higher and more markedly dissected by the main valleys than it is now. On the upland surface one high area in what is now the northeastern part of the park, including the sites of Edwards and Moon lakes, is estimated to have stood more than 2,000 feet above the present level of the sea, and another at the extreme western part of the park probably had about the same height. Between these was a

National Parks Service photo

The clear expanses of the golf course provide good examples of the hummocky moraines that cover much of the park. These are formed of gravel and sand deposited unevenly by a great sheet of ice that covered the region a few thousand years ago.

saddle with its lower points between 1,800 and 1,900 feet above sea level near the present Lake Audy and the upper part of Vermilion River.

What the Ice Sheet did to the Land

Although the three main topographic features of the park and its neighbourhood—the Riding Mountain upland and the Manitoba Escarpment and Plain—had been carved approximately to their present forms by the end of Tertiary time, the ice sheets of the more recent Pleistocene period modified greatly the appearance of the land and the nature of its drainage. As explained more fully in the earlier, general sections of this booklet, there were four main epochs of Pleistocene glaciation. The first ice sheet scraped away most of the unconsolidated material lying on the Tertiary bedrock surface and eroded some of that bedrock. The later ice sheets scraped off or covered most of the results of previous ones, so that what can be seen now is mostly the work of the last sheet, which here moved generally southeast. Most of the features, however, were formed when that sheet was melting away, some 12,000 to 15,000 years ago.

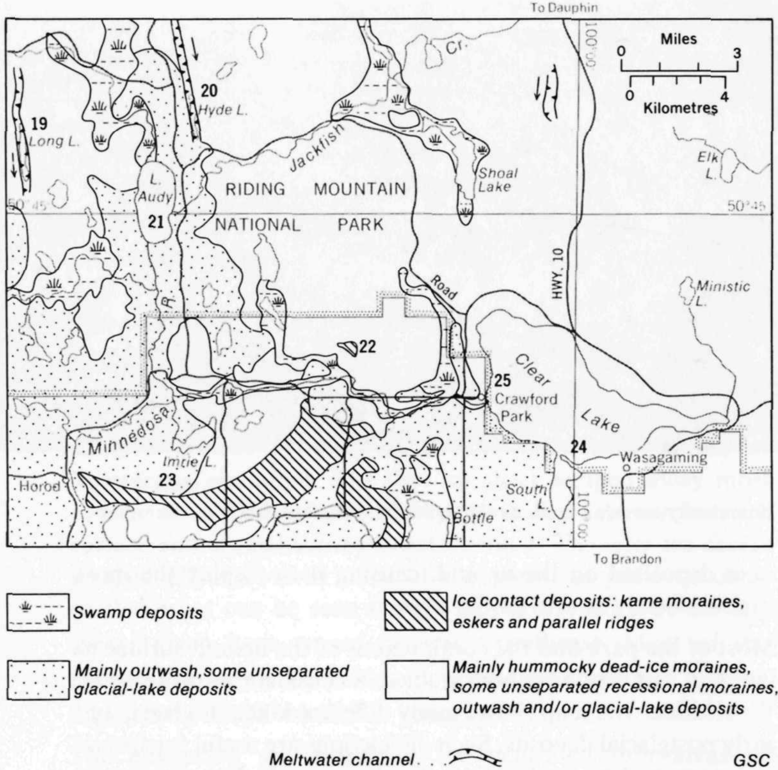
The advancing and retreating ice deposited thin areas of moraine on the Manitoba Plain that were later partly covered by sediments deposited in Lake Agassiz, as described later. The escarpment was probably modified to some extent by the eroding power of the advancing ice, but such effects are not readily apparent now because the sedimentary rocks in which the escarpment is cut are so soft and flaky that they have been eroded still further in recent times. Thick moraines

GSC photo 12-45-41

Hummocky moraine such as this is fairly typical of much of the upland.

were deposited on the upland, causing it to display the most varied glacial features of the region.

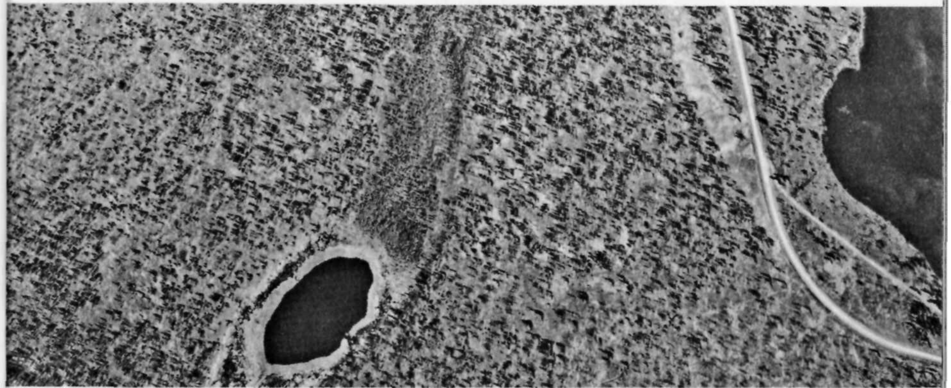
Most of the park and the continuation of the upland surface to its south and west have been studied in considerable detail by R. W. Klassen. His map shows many different kinds of glacial and early postglacial deposits. Such distinctions are useful for special purposes, such as the locating of wells or roads, but many types can be distinguished only by examining air photographs or exposing fresh sections of the drift, as it commonly becomes slumped or grass-grown. For the purposes of this booklet a much more general division of the drift into a few types of moraines and meltwater deposits, and a generalized map of the deposits in the Lake Audy–Clear Lake part of the park, will suffice. Some examples in that part of the upland lying south of



Glacial deposits in Lake Audy–Clear Lake section of Riding Mountain National Park. Geology west of longitude 100°00′ generalized from GSC Map 16–1965, by R. W. Klassen, from which further details can be obtained. Numbers refer to points of interest listed on the folded map.

the park are also mentioned, either because better examples occur there or because the cleared land and more numerous roads in the farmlands provide better visibility and access.

The main effects of glaciation on the upland were to form a locally hilly surface and to fill existing valleys with drift 200 feet or more thick. Huge quantities of glacial meltwater formed new drainage courses by cutting prominent valleys. Some of these valleys or parts of them are now occupied by smaller streams, while others are abandoned and dry. The meltwater sorted out much of the debris (outwash), partly within, alongside, or beyond the ice and left patches of gravel, sand and silt on the upland. Much fine sediment was carried into the huge Lake Agassiz, which covered the Manitoba Plain as the glacier retreated northward. As a result of the moraines and



NAPL photo

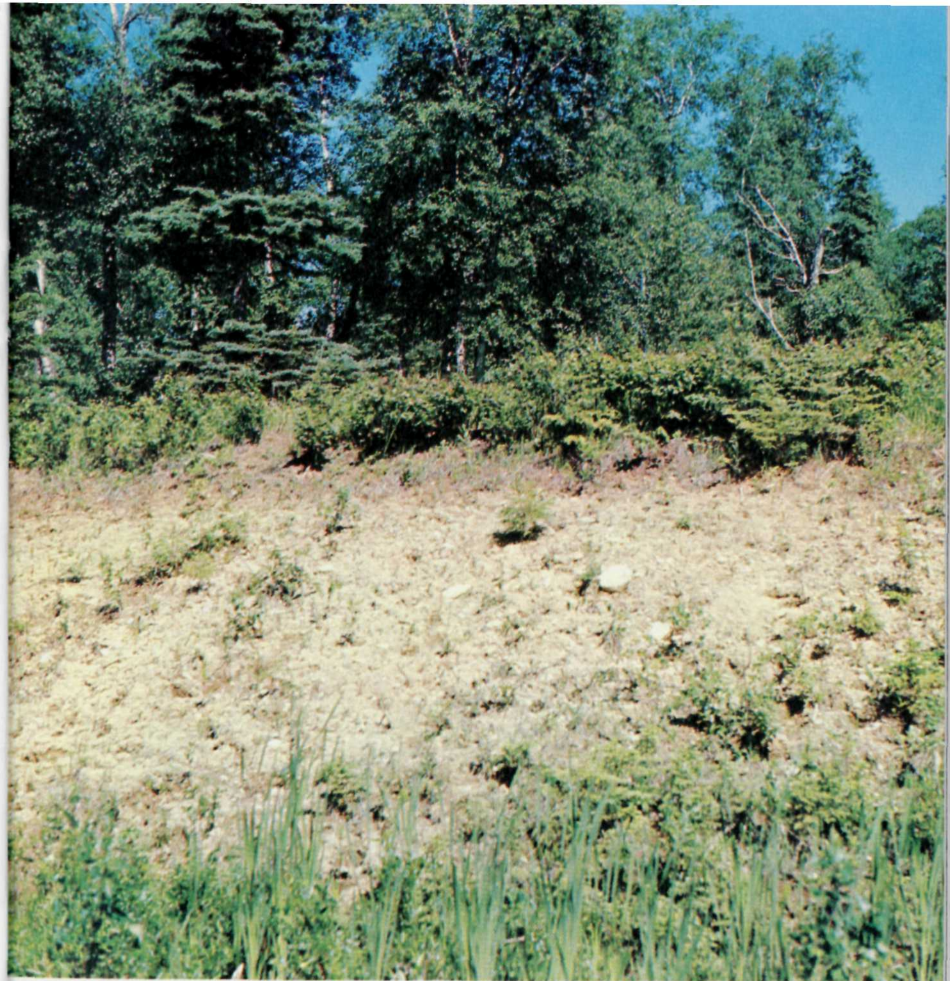
This small lake west of the south end of Moon Lake is fairly typical of many in the uplands of the park. It is probably a small kettle lake occupying a depression formed by collapse of drift after melting of a small, detached block of ice buried in the drift.

other deposits that were dumped on the upland, present drainage is very irregular. Streams flow in various directions; some follow former meltwater channels and others follow courses they have cut recently for themselves. The streams flow in and out of lakes that occur in blocked parts of meltwater channels, ice-block depressions (kettles), or combinations of these two features.

Moraines

Most or all of the upland was probably covered by ground moraine during the advance of the last ice sheet. Morainal material composed largely of till is now exposed in the park mainly near the north boundary, east and west of Vermilion River, where it has been re-worked in places by meltwater. Smaller areas of ground moraine have been found near the eastern and northeastern rim of the escarpment.

Much of the upland is covered by *recessional* and *stagnant-ice* moraines deposited during the final melting and evaporation of the ice sheet. Recessional moraines are formed while the ice is melting away fairly rapidly; stagnant-ice moraines are deposited while a large, detached block of ice melts slowly. They are not easily distinguished without air photographs. On the ground they appear as irregular, hummocky surfaces with knobs up to 50 feet higher than the depressions. Moraines of these kinds occur along the north side of Clear Lake and from there along much of Highway 10 as far as the north Park Entrance. Stagnant-ice moraines tend to occur in the higher parts of the upland. Both kinds of moraine are commonly altered locally by the sorting action of meltwater causing gravel, sand and silt to occur in the till.



GSC photo 11-3-72

Silty sand forms much of the hummocky moraine along the roads a short distance north of Wasagaming. The silt and sand were sorted and redeposited from till by the action of glacial meltwater.

GSC photo 8-11-72

Retaining walls constructed of boulders.

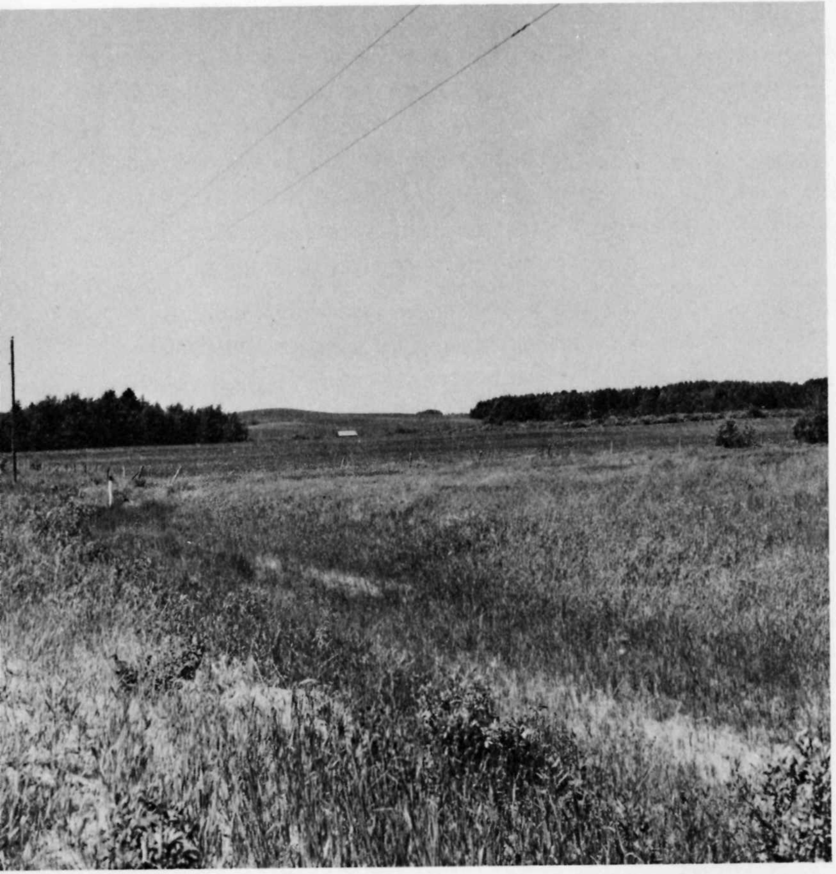
Erratics

Large erratic boulders, mainly composed of granitic, gneissic and carbonate rocks, are commonly seen perched on top of morainal drift, or within it where steep sections are exposed. These boulders were picked up by glaciers as they moved over the Canadian Shield and the plains to its south and were dropped when the ice melted. The trail around Lake Katherine is noted for the number and variety of erratics along it.

Some erratics have been split along fractures or lines of cleavage either by alternate heating by the sun and cooling, or by the expansive force of water that entered a fracture and froze there. Many of the boulders used in retaining walls also have split surfaces, some of which may have been split purposely by workmen.

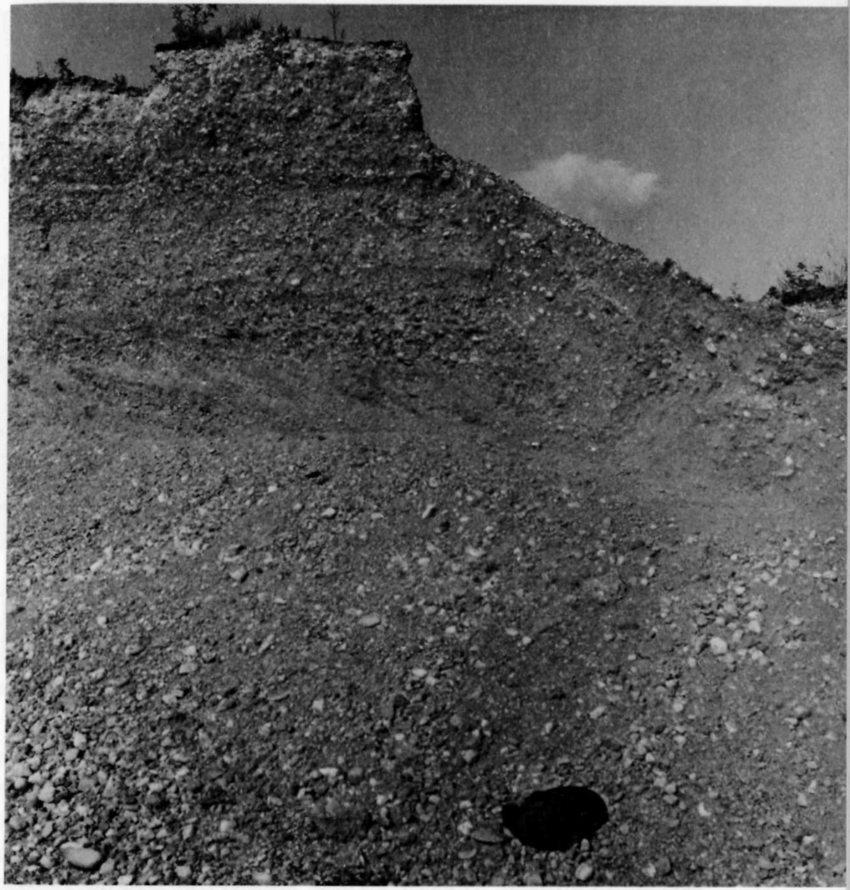
Outwash

Meltwater from the waning ice sheet formed an area of hills, ridges and flats composed mainly of outwash (gravel, sand and silt melted out of the ice) extending southeasterly about 25 miles, from the basin of Whitewater Lake through Lake Audy and along the west side of Clear Lake. At a pit north of Lake Audy Camp and Picnic Ground and in places near Clear Lake the outwash consists almost entirely of tightly packed pebbles. The natural meadows that form the buffalo paddocks near Lake Audy may have been caused because pebbly material such as this would not support the growth of trees. In places the outwash is gradational into lake deposits, an example being a broad belt west and south of Bottle Lake.



GSC photo 11-5-72

Flat area underlain by glacial outwash, south of Clear Lake, with hilly moraine in background.



GSC photo 8-7-72

Pebbly outwash in gravel pit at Lake Audy.

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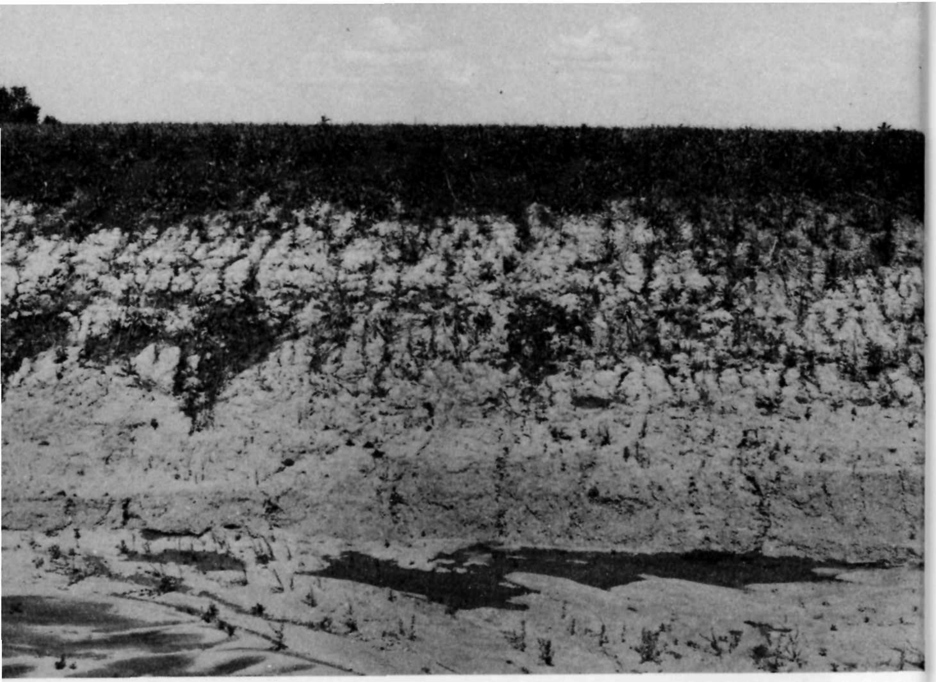

GSC photo 11-6-72

Stratified silt deposited in a temporary lake of glacial meltwater can be seen at several places a short distance south of Clear Lake and south of the park boundary. This exposure is on the road between Crawford Lake and Horod, near the junction of the road to Lake Audy.

Kames and Eskers

These are interesting special forms of glacial outwash that occur at some places as isolated features, and at others as *kame moraines* composed of complex clusters of kames, eskers and linear ridges. Kames consist of stratified drift deposited at the edge of a glacier or ice sheet, commonly where a stream of meltwater under pressure heaped up sand

GSC photo 12-45-36

This esker one mile south of Myra (west of Rivers) is composed of gravel deposited in a semicircular tunnel that existed for a time beneath the ice sheet that covered the land, draining meltwater from the ice sheet. Parts of the tunnel became choked with gravel, which remains as a ridge after the ice melted away.

and gravel against the front of the ice. Isolated kames are generally steeply cone-shaped. Eskers are comparatively long, narrow, winding ridges of stratified drift deposited in a semicircular tunnel excavated under a glacier or ice sheet by a stream of meltwater. The best example of a kame, and the best known examples of eskers, are several miles from Riding Mountain park, as explained below. Those found in and

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closer to the park are mainly kame moraines. As kames and eskers cannot be distinguished with certainty from knobs and ridges of till unless a road-cut or other excavation reveals stratified outwash, they probably exist in greater numbers than is known.

A kame moraine 3 miles west of Clear Lake is about 200 feet wide, 30 feet high, and 900 feet long, but one end is about 1,000 feet wide. Large boulders are common on the surface of the ridge, but internally it is composed of sand and gravel laid down by southeastward-flowing meltwater. This is shown in slightly enlarged size on page 36.

An esker ridge in the NE$\frac{1}{2}$ of section 23, township 17, range 20, about 13 miles southwest of Clear Lake and halfway between Sandy Lake and Ozerna, is 15 feet high, 200 feet wide, and 3,400 feet long. A road-cut exposes more than 10 feet of sand and silt, in places overlain by as much as 15 feet of clayey till.

A moraine composed of kames, eskers and linear ridges forms a belt extending about 8 miles from a point about 4 miles west of Clear Lake. Another occurs in the western part of the park, north of Ruthenia.

Although not close to the park, a prominent kame that has been known as Spy Hill since the days of early travellers is worth mentioning. It is near Deerhorn Creek, about 2 miles east of Spy Hill Station in Saskatchewan. Several eskers were mapped by Klassen west of Rivers, Manitoba.

Meltwater Channels

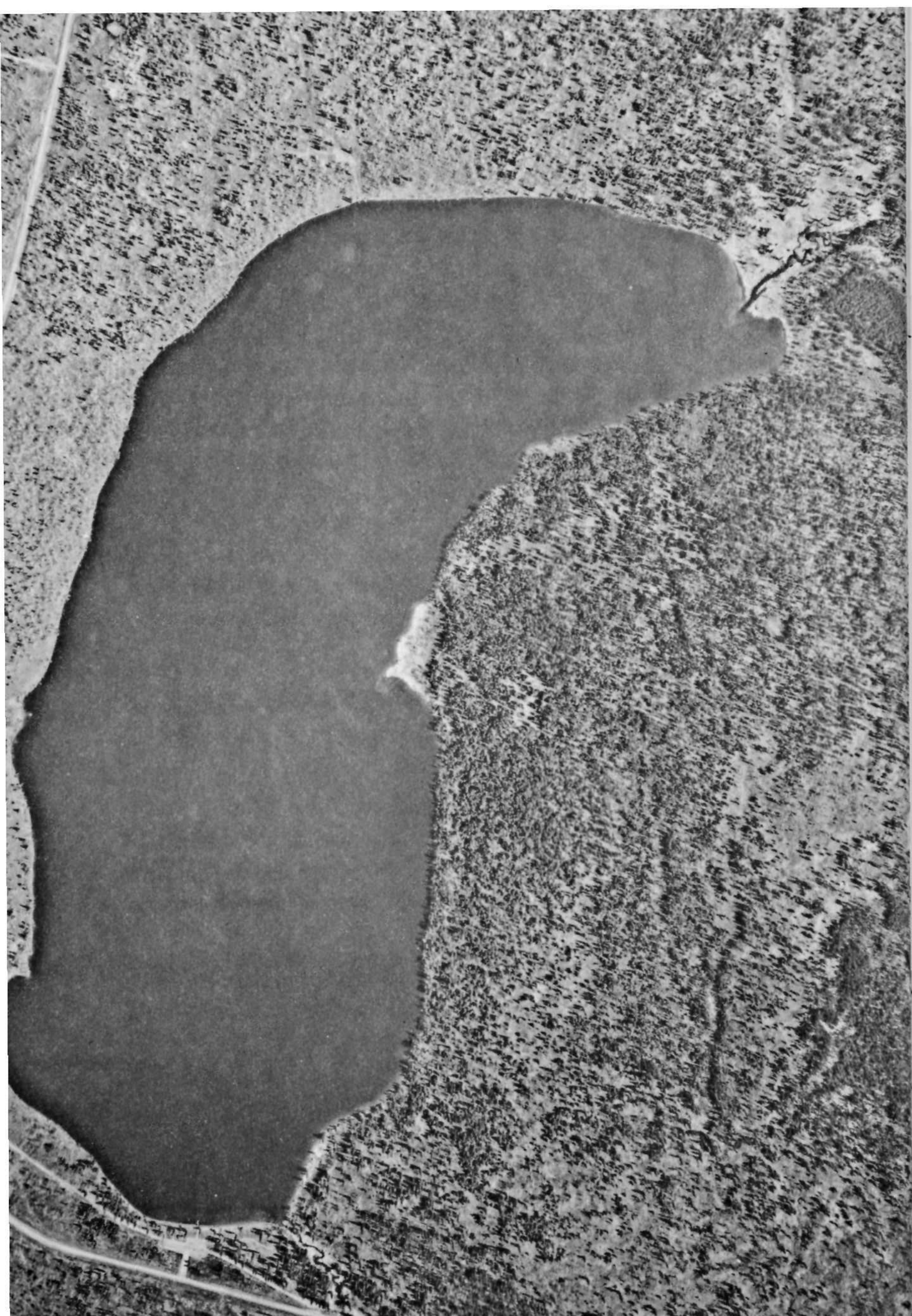
The melting ice caused numerous small and large streams which cut channels up to about 150 feet deep and 1,000 feet

wide. Two examples trending northeast can be seen along Highway 10, near Moon Lake and the microwave tower. Another forms the narrower, east arm of Clear Lake, and appears to have continued near the present Lake Katherine and then southward through the valley now occupied by Rolling River to join a large meltwater channel now occupied by the lower part of Minnedosa River, which is much smaller than the valley it occupies. A wardens' road crosses a prominent channel extending between Gunn and Whitewater lakes. Two channels are filled partly by Long and Hyde lakes. Two channels appear to have been cut in opposite directions from a hill 11 miles northwest of Erickson, one extending westward along the sites of Otter Lake and part of Rolling River, and the other southward near the escarpment and then flowing down it along the present valley of Birnie Creek. Minnedosa valley was formed as a spillway draining meltwater lakes bounded by ice on the upland.

Lake Agassiz

One of the most interesting aspects of the area is the story of the vast lake of meltwater that once covered much of the Manitoba Plain from the time the last ice sheet began to melt until about 7,000 years ago. The most striking evidence of this lake consists of numerous ancient beaches to be seen along its western margins, near the base of the Manitoba Escarpment.

The history of the lake has fascinated many geologists since signs of its existence were first noticed in the northern United States about 150 years ago. It was named in 1879 in honour of Louis Agassiz, the eminent Swiss–American naturalist



and geologist, who did much to explain modern glaciers and the effects of the Pleistocene Ice Age.

Much has been written regarding the extent, beaches and outlets of this lake and its relationship with other glacial lakes in the Great Lakes basins and within the Canadian Shield region in Ontario and Quebec. A study of some of the literature on Lake Agassiz and the tracing 'on the spot' of some of the beaches and outlets would make an interesting hobby for residents of southern Manitoba or neighbouring parts of the United States. Much information is contained in *Geology and Economic Minerals of Canada* and in other references listed at the end of this booklet.

When the last great ice sheet reached its southern limit in Minnesota and North Dakota it left a large moraine that acted as a dam that impounded water from the gradually receding ice sheet, thus forming the first stage of Lake Agassiz. As the ice front receded farther and farther to the north the lake grew to a vast size. Its shape changed and it occupied different areas at different times owing to the topography of the Canadian Shield, which bounded the lake to the east, to varying water levels, erosion of outlets, and location and shape of lobes from the ice sheet. At one time or another it covered about 200,000 square miles, but its greatest area at

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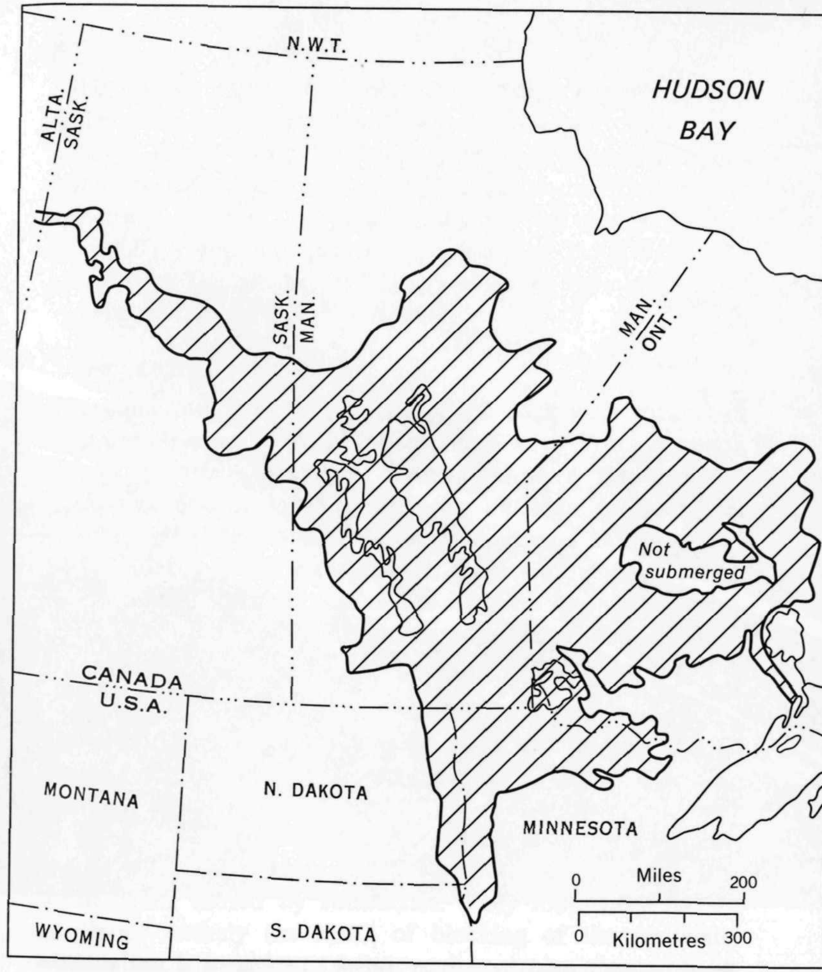
NAPL photo

Moon Lake lies in a meltwater channel eroded by a temporary flood of water resulting from the melting of the last ice sheet. The depression filled by the lake may also have resulted partly from collapse of glacial drift (overburden) after eventual melting of a detached block of ice buried in the drift.

any one time is estimated to have been some 80,000 square miles—the largest body of fresh water ever known.

Lake Agassiz is considered to have evolved in four stages. First the lake drained southward via Red River valley to the Mississippi system. When the ice sheet melted back farther to the north it drained eastward into the Lake Superior basin. That stage was followed by a resumption of the Mississippi drainage during a time when the ice advanced again. During the final melting of the sheet the lake drained through the Nipigon basin. About 7,000 years ago, when the ice had melted farther to the north, the lake disappeared by draining along the present course of Nelson River and emptying into Hudson Bay. Local lakes, such as Lakes Winnipeg, Winnipegosis, and Manitoba, which occupy depressions, are all that remain of this huge ancient lake.

A relatively long-lasting stage of Lake Agassiz, the Campbell stage, is noteworthy because beaches formed at that time have been traced for many hundreds of miles from northern South Dakota through North Dakota, Manitoba, and into Saskatchewan. Campbell Station, located on a railway in the United States near which one of the beaches passes, provided the name for this stage when the history of Lake Agassiz was first studied many years ago. In some places, during the Campbell stage, a beach ridge, or series of ridges, was formed of sand and gravel, some being as high as 30 feet. Examples can be seen along the road to the Agassiz Ski Hill, where two ridges higher than the others can be seen clearly on air photographs because they support vegetation different from that of the adjacent land.



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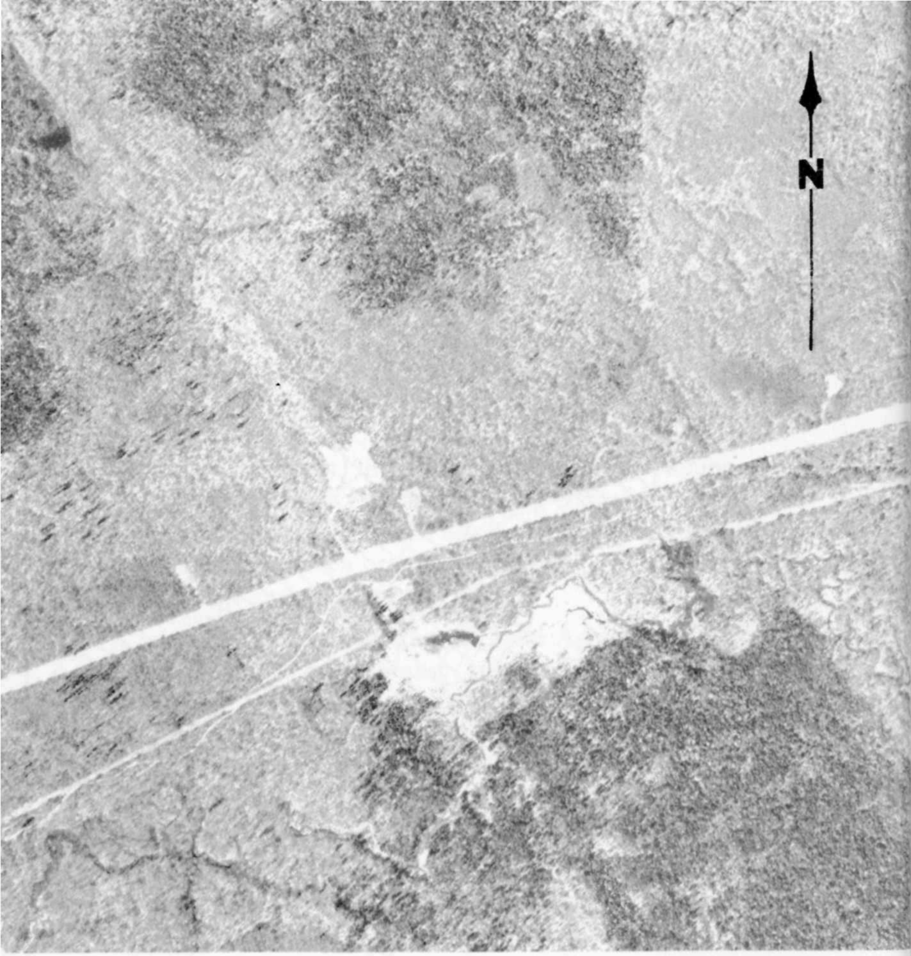
The area covered by various stages of Lake Agassiz. This huge lake, formed of water from the last great ice sheet, was the largest body of fresh water ever known. It had different positions, outlets and shapes, because of the lowering of outlets by erosion and because it was bounded to the north by ice that was melting away gradually. For comparison, the larger present lakes of the region are shown.



NAPL photo

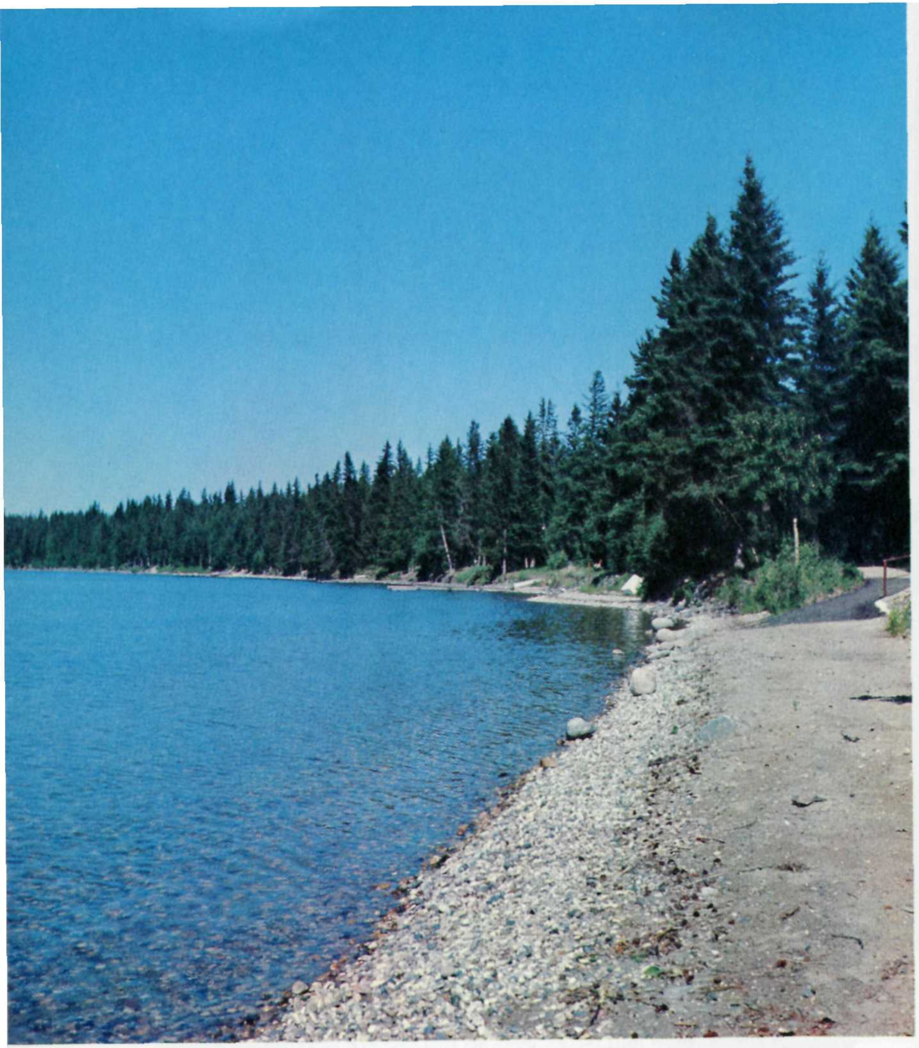
Beach ridges formed by ancient glacial lake Agassiz at and near the road to the Agassiz Ski Hill can be seen as parallel lines on this air photo because they support vegetation different from the intervening areas. The beach ridges trend northwest.

Lake Agassiz in places left behind up to 150 feet of clay and other sediments, derived from the sorting out of the finer material in the glacial drift through which streams of meltwater passed. These sediments, with their lack of pebbles and other 'stones,' are responsible for the excellent farmlands of the southern part of the Manitoba Plain. Sand and gravel from the beaches of Lake Agassiz are valuable sources of construction and road materials.

Present Lakes

The numerous lakes and ponds in the park were formed in different ways, some by combinations of ways. Three common origins of the water-filled depressions were the irregular dumping of drift in moraines, the blocking of meltwater channels by slides, deltas or other means, and kettles caused by subsidence of the ground when a block of ice, left buried and insulated after the rest of the ice sheet had disappeared, finally melted. A kettle may be rounder than the block of ice that caused it, owing to a tendency of loose sand or gravel to take a roundish shape.

Clear Lake, the largest lake in the park and one of its most popular attractions, appears to have been formed as a combination of meltwater channelling and of subsidence after a large block of ice melted and formed the larger, western part of the lake. Moon Lake and Edwards Lake may be smaller kettle lakes caused by subsidence. They may, however, be partly or entirely the result of blocking of the meltwater channel by drift, slides or deltas; such an explanation probably accounts for the origin of other elongate lakes, such as Long Lake. Scattered, round lakes of medium size are most prob-



GSC photo

The beach at Wasagaming.

GSC photo

The hilly golf course and Clear Lake owe their origins to the ice sheet that covered the region during the last Ice Age.

ably kettles, while the numerous small lakes and ponds probably occupy depressions in hummocky moraines, perhaps also with some 'kettle' effect in places.

In a large area west of Assiniboine River interesting 'checkerboard' patterns of ponds in ridged moraines can be seen from the air or on air photographs. These ponds are in depressions between two sets of low ridges, one parallel with the direction of ice flow and the other possibly caused by pauses or forward pulsations of the ice during the general stage of melting.

GSC photo 11–12–72

A small point in Clear Lake, near the golf course. This is probably a spit formed of sediment deposited recently by the action of currents.

What is Happening Now

Examples of various kinds of erosion, deposition by streams and lake currents, and slumping can be seen at many places. Observing some of those that are indicated as points of interest and looking for others would be rewarding for anyone whose curiosity in these matters has been aroused even slightly.

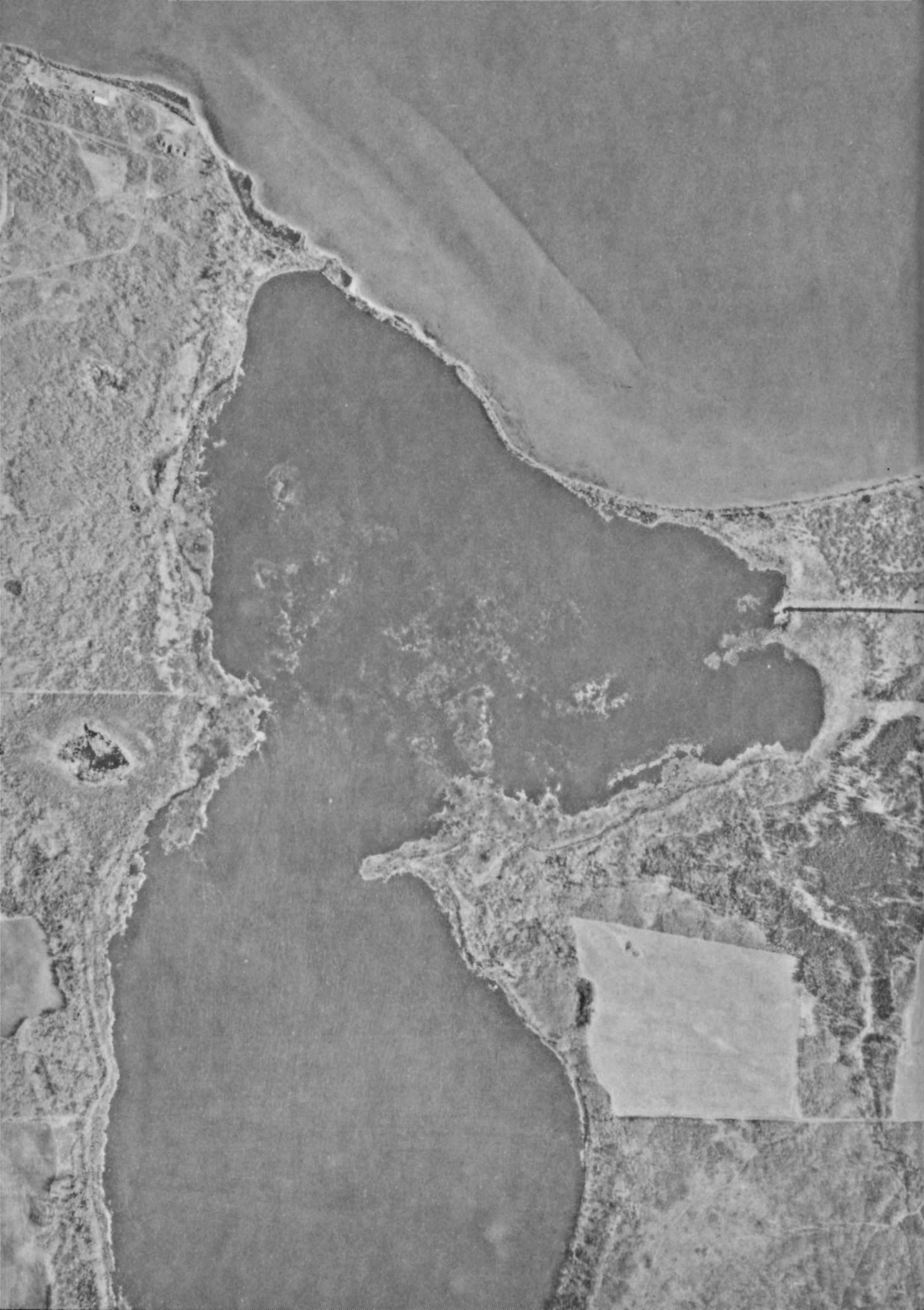
Slumping and sliding are particularly prevalent along the escarpment. Recent effects of erosion can also be seen along the creeks draining it. It is interesting to note the manner in

GSC photo 9–9–72

Ridge of gravel at south shore of Clear Lake, formed by the expansive force of ice in winter.

which the debris is deposited near the change in gradient where a creek enters the plain. An astonishing amount of eroded material has been collected and piled over measured periods of time at the Wilson Creek metering station, which was established near the east boundary of the park in connection with experiments in control of erosion.

Other interesting features are the formation of deltas and spits in lakes, the "silting" of small lakes and ponds, the origin of ponds by beaver dams, and ridges formed along



lake shores by the expansion of ice in winter. A small lake called South Lake, immediately south of Clear Lake, has been separated from Clear Lake fairly recently by a bar probably formed by one or perhaps two spits having developed across the entrance of a former bay; the bar may also be partly a result of wave action.

ROADLOGS

Logs are included for the Wasagaming area and the route from Highway 10 to the Agassiz Ski Hill because these are the only places where bedrock and glacial features can readily be reached. Mileages are not listed for the Wasagaming area because three roads there are close together and bedrock is not exposed along any of them. Reverse mileages are included for the other routes to permit use in either direction. Points of interest are indicated by 'stop' numbers.

Wasagaming Area

Stop 1. Highway 10 reaches the south part of Wasagaming townsite at the south Park Entrance. The Interpretive Centre in the townsite has an excellent display of diagrams, maps and specimens illustrating the geological history of the park;

NAPL photo

South Lake, the darker body of water in the central part of this photo, was once a bay of Clear Lake, part of which appears in the upper part of the photo. Clear Lake is now separated by a narrow bar composed of sediment deposited as a result of the action of currents and waves.

97739—5

these provide useful supplements to this booklet. The wall displays should be studied beginning with the ones describing the older bedrock formations and ending with those dealing with the Ice Age.

The townsite contains the principal beach in the park. Although natural sand beaches occur in a few other places along the lake, this one was made by hauling sand to the site and protecting it by a breakwater and boulders. These boulders, as well as those used in retaining walls and other structures in the townsite, are glacial erratics and provide examples of the harder rocks that form the Canadian Shield. A walk along the water's edge will show how the waves sort the sand into coarse and fine streaks.

One of the best exposures of the Riding Mountain Formation close to a main road can be observed in the village of Onanole, at the east side of Highway 10, 2 miles south of the south Park Entrance. The formation there consists of dark grey, flat-lying, flaky shale that can be broken between the fingers. Most of the side of the road-cut is covered by loose debris, but a little undisturbed shale can be seen between the debris and the thin top layer of drift or soil.

From the townsite three alternative routes lead to the east end of Clear Lake. The main Highway 10 is here called Mooswa Drive. Ta-wa-pit Drive joins this at a point about two thirds of the way to the end of Clear Lake. A third and more scenic road called Wasagaming (Lakeshore) Drive is close to the shore of the lake. Along these routes and along Highway

GSC photo 9-2-72

Shale of the Riding Mountain Formation is exposed at the top of a bank along the highway at Onanole. Two erratic boulders have slid from the top.

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19 are roadside-cuts, mostly in till, and scattered erratic boulders, associated with dead-ice moraine. In places, small streams or ponds of meltwater have sorted the till to produce patches of sand and silt. Mileages along these roads are not listed because each is slightly different, and bedrock is not exposed along any of them.

Stop 2. Here a small spit that can be reached by a trail is forming from sediments carried by currents. Under certain conditions of light and waves, when this point is viewed from a distant place such as the golf clubhouse, different colours of water show that the subsurface part of this spit is considerably larger than the part above water.

Stop 3. Just before reaching the junction of Wasagaming Drive with Highway 10 a small landslide overgrown with grass can be seen between the drive and the highway. This illustrates one kind of erosion. Material reaching the lake from this slide may have contributed to the forming of the spit.

Stop 4. A road to the golf course leaves Highway 10 about 3 miles from the townsite. The golf course, being mainly cleared of trees, provides good examples of hummocky moraine typical of much of the upland surface of the park. This can be observed by driving into the course as far as the parking lot, or by driving slowly along Highway 10 for a half mile.

Highway 10 to East Park Entrance

Stop Number	*Mileage*	*Reverse Mileage*	
	0	17.8	Junction of Highways 10 and 19, a half mile from the east end of Clear Lake. Proceed northeast along Highway 19.
5	2.7	15.1	Small exposures of shale of the Riding Mountain Formation. The shale is too flaky to remain exactly in place, but the material illustrates the nature of the bedrock.
6	14.8	3.0	Outlook parking place at top of escarpment, which can be viewed by looking northward. A good view of the Manitoba Plain can be obtained by looking toward the east.
	16.5	1.3	Small outcrops of shale of the Riding Mountain Formation occur along the steep road from here to mileage 16.8.
	17.8	0	East Park Entrance

GSC photo 10-8-72

Eastward from the east Park Entrance the land slopes gently toward the Manitoba Plain seen in the distance. The slope is partly the result of debris deposited fairly recently from the erosion of the escarpment.

East Park Entrance to Ski Hill

Stop Number	*Mileage*	*Reverse Mileage*	
7	0	18.2	East Park Entrance. Looking east from here you can see that Highway 19 slopes gently downward. This slope is probably caused partly by a delta formed by streams of meltwater that entered Lake Agassiz, and partly by an alluvial fan formed by more recent deposition from creeks, especially during periods of high water in the spring.
	3.0	15.2	Highway 5. Turn north. Good views of the escarpment can be seen from this highway.
	9.3	8.9	Turn west near McCreary and follow road to Ski Hill. The escarpment can be seen well from this point.
	13.4	4.8	Park boundary.
8	13.9	4.3	First of four 'Campbell' beaches of the Lake Agassiz. This one is barely perceptible. The largest, about 15 feet high, can be readily seen from the road.
	15.5	2.7	Last beach.
9	18.0	0.2	Large rock-cut at north side of road, providing good exposure of Favel–Vermilion River strata.
	18.1	0.1	Similar strata are exposed at the south side of McKinnon Creek.
	18.2	0	Entrance to Agassiz Ski Hill.

EPILOGUE

It is hoped that at least once during your visit you will view the Riding Mountain upland from the plain below, and that you will also look out over the plain from the east or north lookout. Better still, perhaps you can begin your return journey by taking the route through the East Entrance, and so have a last and more meaningful sight of places you have seen. Look at Clear Lake sparkling below the hillocks of the golf course, and at the scene from the top of the escarpment. On the way, watch for the few small outcrops of shale and reflect that they were formed from mud in the bottom of a great sea that covered this region millions of years ago. Try to visualize the vastly older Precambrian rocks far beneath these shales. As you pass the banks of gravel and silt and the occasional boulders, envision the huge, country-wide sheet of ice that ground them from solid rock (or, in the case of the boulders, froze around them) and carried the sand, pebbles and boulders southward until the ice became stagnant and finally melted, thus dropping its load of debris. When you look out over the plain, remember that it was eroded to slightly below its present level by a system of creeks and rivers that swung slowly sideways or deepened their courses for many years immediately before the coming of the ice. Then visualize the huge glacial Lake Agassiz that was formed by the meltwater at the close of the Ice Age, being bounded by the escarpment on which you stand, and which extended eastward to the Canadian Shield far beyond the horizon.

When you reach the plain, stop and look back at the escarpment. Think of its long geological history, and how even

today it demonstrates the slow processes of erosion and new deposition that have been going on in one place or another ever since the original crust of the earth took shape.

The following sources of local information may be of interest:

Topographic Map of Riding Mountain Park, MCR 207. Ottawa, 1954. Surveys and Mapping Branch, *Dept. of Energy, Mines and Resources.*

Neepawa (62 J), Riding Mountain (62 K), Duck Mountain (62 N) and **Dauphin Lake (62 O).** Ottawa, 1964–67. Surveys and Mapping Branch, *Dept. of Energy, Mines and Resources.* These adjoining topographic maps cover separate parts of the park and its vicinity in more detail than the above-mentioned map.

Mesozoic Stratigraphy of the Eastern Plains, Manitoba and Saskatchewan, by R. T. D. Wickenden. Ottawa, 1945. *Geological Survey of Canada,* Memoir 239. This is the main source of data on the bedrock geology of the park and its vicinity.

Riding Mountain, Sheet 62 K, by R. W. Klassen. *Geological Survey of Canada,* Ottawa, Ontario. Map 16–1965. A map of glacial deposits and related features providing much information on approximately the southwestern three quarters of the park and much of the areas to its south and west.

Life, Land and Water, Proceedings of 1966 Conference on Environmental Studies of Lake Agassiz Region, edited by W. J. Mayer-Oakes. A booklet containing papers on different aspects of Lake Agassiz, including its geological history.

Glacial Lake Agassiz, with Special Reference to the Mode of Deformation of the Beaches, by W. A. Johnstone. *Geological Survey of Canada,* Ottawa, Ontario, Bulletin 7. This publication contains an interesting map showing the location of the Campbell and other beach remnants of Lake Agassiz.

Any of the publications listed below provide information on basic geology or Canadian geology in general:

Guide to Geology for Visitors in Canada's National Parks, by D. M. Baird. Ottawa, 1960. National and Historic Parks Branch, *Dept. of Indian Affairs and Northern Development*. This is a pocket-size booklet containing 144 pages and 37 illustrations, which outlines in layman's language the general principles of geology with special reference to Canada's National Parks and can be obtained from the National Parks Service (address given below) or from Information Canada.

Geology of Canada. A pamphlet obtainable free of charge from the *Geological Survey of Canada*, 601 Booth Street, Ottawa, Ontario, K1A 0E8.

Geology and Economic Minerals of Canada. An expensive, large, well-illustrated book containing much information on the geology of Canada. It was written with the expectation that the reader would have some knowledge of basic geology, but anyone who has studied the two publications listed above and who is particularly interested in obtaining further information on any part of Canada would find it helpful. Large geological, glacial, and several other maps of Canada accompany the book and can be bought separately at $2.00 each from the *Geological Survey of Canada* at the address given above. The book can be obtained from that address or from Information Canada, the price in 1973 being $20.00.

General information on the National Parks of Canada may be obtained from The Director, National and Historic Parks Branch, *Dept. of Indian Affairs and Northern Development*, 400 Laurier Ave. West, Ottawa, Ontario, K1A 0H4.

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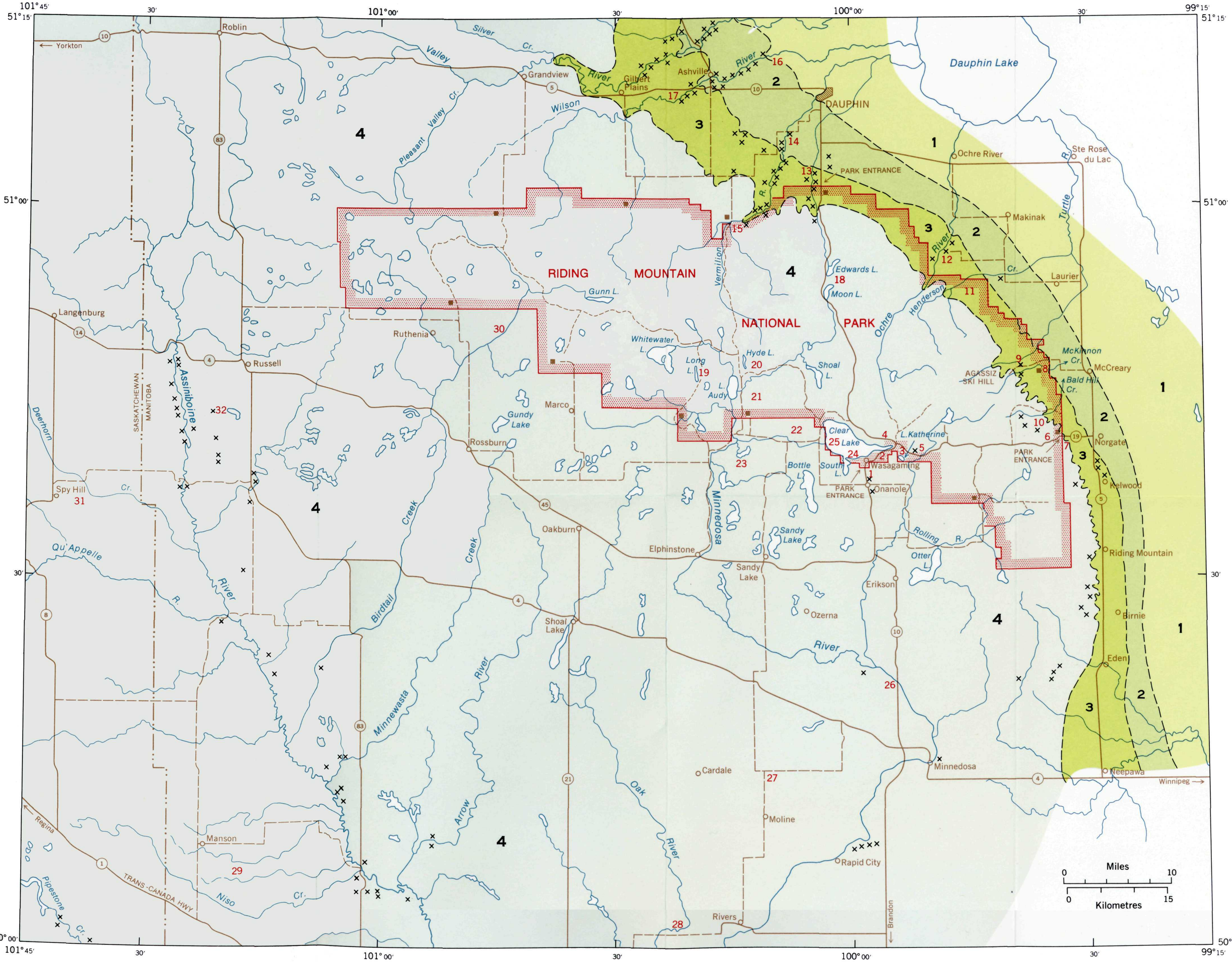

LEGEND

MESOZOIC

CRETACEOUS

UPPER CRETACEOUS

4 — *RIDING MOUNTAIN FORMATION: grey and greenish grey shale, siliceous shale*

3 — *FAVEL AND VERMILION RIVER FORMATIONS: dark grey shale, speckled shale, limestone, bentonite*

LOWER AND UPPER CRETACEOUS

2 — *ASHVILLE FORMATION: dark grey shale; minor silt, sand, limestone, and bentonite*

JURASSIC AND CRETACEOUS

1 — *Sand, sandstone, glauconitic sand; grey, red, and veriegated shale*

Geological boundary

Rock outcrop ×

Point of interest 21

POINTS OF INTEREST

1. Wasagaming townsite: Interpretive Centre and beach
2. Small spit
3. Slumping
4. Golf course on hummocky moraine
5. Outcrop of shale of Riding Mountain Formation
6. Outlook near top of Manitoba Escarpment. Outcrops of shale of Riding Mountain Formation occur along highway, on hill below outlook
7. East Park Entrance. Eastward from here Highway 19 slopes gently on alluvial material deposited on Manitoba Plain. The slope may also be caused partly by a delta in Lake Agassiz
8. The road crosses ancient beaches of Lake Agassiz
9. Good exposures of Favel-Vermilion River strata
10. Riding Mountain Formation well exposed at Bald Hill and head of Bald Hill Creek
11. Beaches of Lake Agassiz near Henderson Creek
12. Outcrops in bed of Ochre River
13. Outcrops in bed of Edwards Creek

14 to 15. Outcrops in bed of Vermilion River

16 to 17. Outcrops in bed of Wilson River

18. Edwards and Moon Lakes in former meltwater channel

19, 20. Elongate lakes in small meltwater channels

21. Pebbly outwash
22. Kame complex
23. Silt deposited in meltwater lake
24. Bar separating South Lake from Clear Lake
25. Ice-pressure ridge
26. Minnedosa River occupies a large, former meltwater channel
27. Boulder eroded and polished by ice sheet
28. Esker
29. Ponds in rectangular pattern of morainal ridges
30. Meltwater channel occupied by Birdtail Creek
31. Spy Hill kame
32. Drumlin with bedrock core

Geology modified from GSC Map 731A, by R.T.D. Wickenden

Geological cartography by the Geological Survey of Canada

Selected main highways

Selected other roads

Trail

Wardens' cabin

Base-map cartography by the Geological Survey of Canada from maps published at 1:500,000 scale by the Surveys and Mapping Branch, 1964

Figure 7. Riding Mountain National Park and its vicinity showing distribution of bedrock formations.

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