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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

BULLETIN 108

ORDOVICIAN STRATIGRAPHY OF NORTHERN HUDSON BAY LOWLAND, MANITOBA

S. J. Nelson

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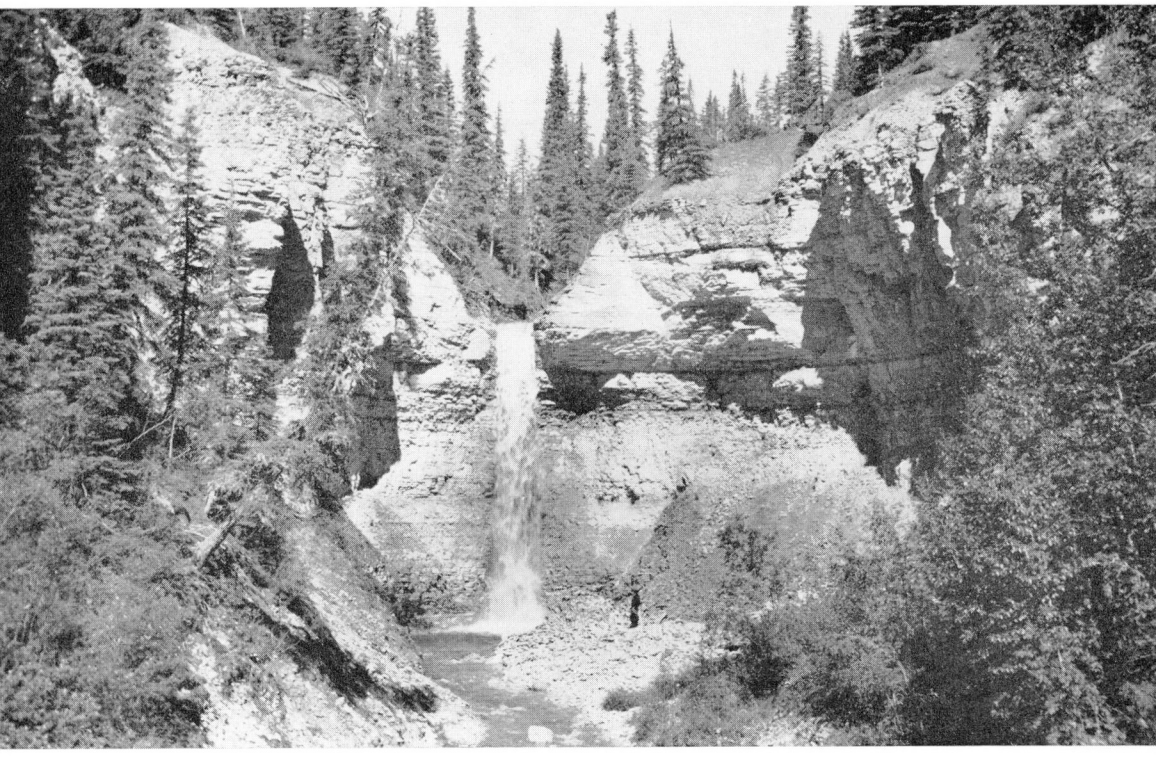

Nelson, 22-6-51

PLATE I. Surprise Creek, a tributary of Churchill River. Lower beds are Surprise Creek Formation; upper, Caution Creek Formation. Contact between the two is the first well-defined bedding plane below the lip of the falls. Man at base of falls indicates scale.

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PREFACE

Lower Palaeozoic rocks extend in a belt along the western shores of James Bay and Hudson Bay. Little detailed stratigraphic work had been done in this region, and prior to the present study geological information on the northwestern part was based on limited reconnaissance observations, mainly from early canoe traverses along the main rivers.

The author spent two field seasons making detailed observations of the Ordovician and Silurian rocks, which are well exposed on Nelson, Churchill, North Knife, and South Knife Rivers. In this report the various rock groups and formations are described, and faunal lists based on a thorough study of the fossils by the author are given. The faunas assist in establishing the geological history and provide a ready means of correlation with other regions of Canada and elsewhere.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, December 2, 1963

Bulletin 108—Ordovizische Stratigraphie des Nördlichen Hudsonbai-Tieflands in Manitoba.

Von S. J. Nelson

Бюллетень 108 — Самуэль Дж. Нельсон. Стратиграфия ордовикской системы северной Низменности Гудзонова залива. Манитоба.

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Abstract

The Ordovician and Silurian formations on Nelson, Churchill, South Knife, and North Knife Rivers, in the northern part of the Hudson Bay Lowland, are described and their faunas listed. The succession along Churchill River is taken as the type for the Ordovician of the region. The formations consist mainly of carbonates and, in ascending order, are the Portage Chute and Surprise Creek Formations of the Bad Cache Rapids Group; the Caution Creek and Chasm Creek Formations of the Churchill River Group; the Red Head Rapids Formation, and the Port Nelson Formation.

The Bad Cache Rapids Group rests on Precambrian and is correlated with the Red River Formation, considered to be of Upper Ordovician age. The Churchill River Group is coeval with the Richmondian and Gamachian Stony Mountain Formation of the same area. The Red Head Rapids Formation is questionably referred to the Ordovician and is correlated with the Stonewall Formation of southern Manitoba. The Port Nelson Formation is exposed only on Nelson River and is considered to be Middle Silurian.

Résumé

L'auteur décrit les formations de l'Ordovicien et du Silurien dans les régions des rivières Nelson, Churchill, Knife-Nord et Knife-Sud dans la partie Nord des basses terres du Manitoba et donne une liste de leurs faunes. La succession que l'on trouve le long de la rivière Churchill est caractéristique des roches ordoviciennes de la région. Composées surtout de carbonates les formations sont, dans l'ordre ascendant, celles de Portage Chute et de Surprise Creek du groupe de Bad Cache Rapids; les formations de Caution Creek et de Chasm Creek du groupe de la rivière Churchill et celles de Red Head Rapids et de Port Nelson.

Le groupe de Bad Cache Rapids repose sur le Précambrien et est corrélatif à la formation de Red River, qui daterait de l'Ordovicien supérieur. Le groupe de la rivière Churchill serait du même âge que la formation Stony Mountain du Richmondien et du Gamachien que l'on trouve dans la même région. La formation de Red Head Rapids qui appartient semble-t-il à l'Ordovicien est corrélative à la formation Stonewall du Sud du Manitoba. Quant à la formation Port Nelson, elle n'affleure qu'à la rivière Nelson et remonterait au Silurien moyen.

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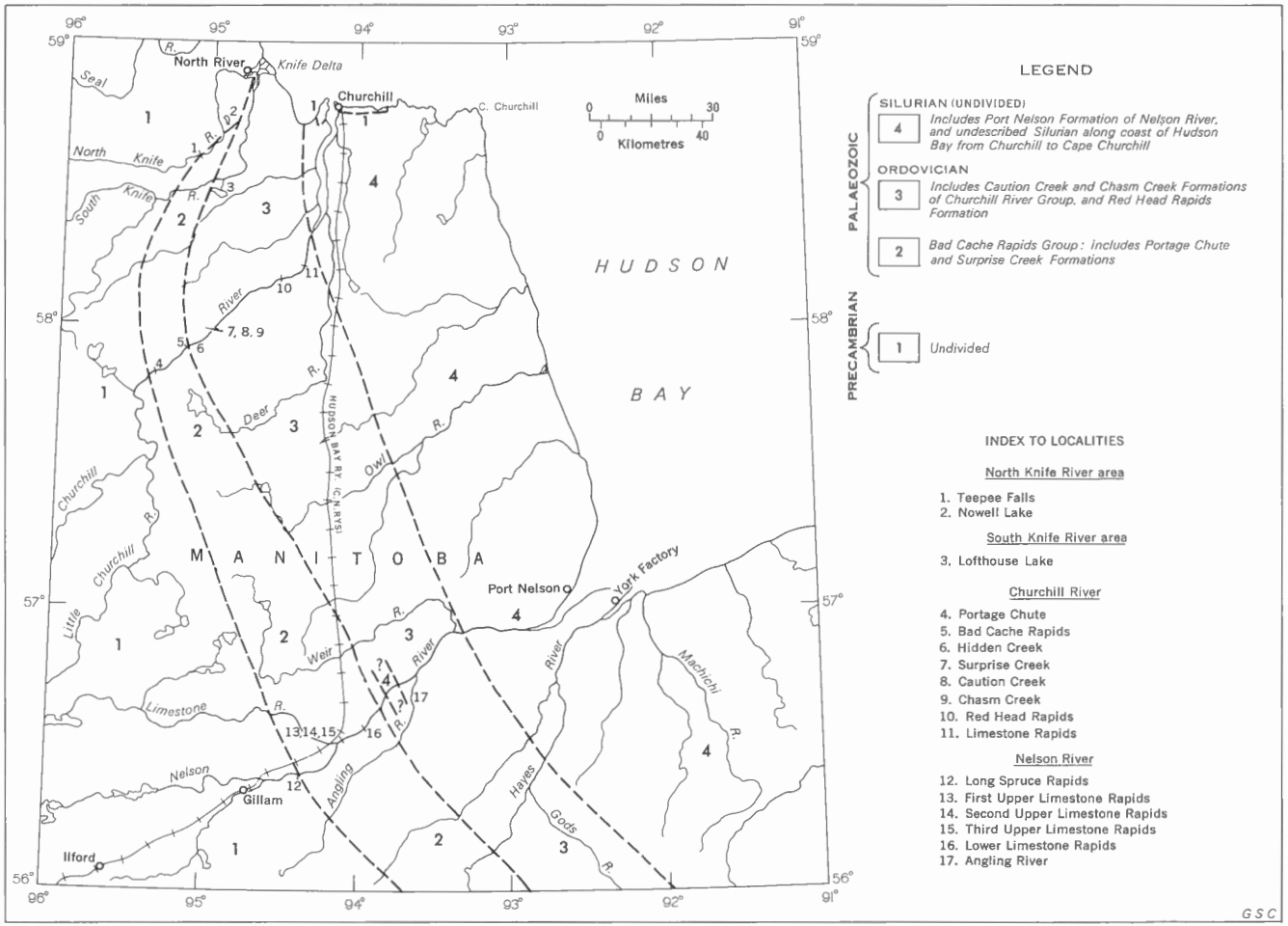

FIGURE 1. Geological sketch-map, north part of Hudson Bay Lowland.

INTRODUCTION

The Hudson Bay Lowland (Caley, 1947, p. 184)[1] is a plain bordering Hudson Bay on the southwest and extending from North Knife and South Knife Rivers (nearly 25 miles northwest of Churchill, Manitoba) southeast to the south end of James Bay. Near the southeast end, the plain is about 200 miles wide; to the north in the area studied it is less than 100 miles wide. On the south and west it is bordered by the Canadian Shield. Except for a small area of Mesozoic sedimentary rocks in the southern part and Proterozoic strata at Sutton Ridges in the central part, the Lowland is underlain by beds of Ordovician, Silurian, and Devonian marine sedimentary beds dipping gently to the east. The Ordovician and Silurian sedimentary rocks of the north part of the Lowland are described here (*see* Fig. 1).

Because the surface of the Lowland is low and swampy, most exposures occur along major rivers or on the shore of Hudson Bay. Outcrops were examined along the lower part of Nelson, Churchill, North Knife, and South Knife Rivers and tributary creeks, and the coast of Hudson Bay from Churchill to a short distance south of Cape Churchill. The exposures studied, therefore, are linear and limited vertically. Along rivers, strata of Ordovician age are the only well-exposed formations except for some Silurian beds on Nelson River. Along the coast from Churchill to Cape Churchill and beyond, fossiliferous Silurian strata either outcrop or, as the presence of fossiliferous boulders suggests, underlie the drift. Near Churchill *Virgiana*-bearing dolomite rests on Precambrian Churchill quartzite, which apparently formed shoals or islands in the Silurian sea. From Cape Churchill south for at least 10 miles stromatoporoidal biostromes outcrop intermittently along the shore. Although the area from Churchill to Cape Churchill is shown as mainly underlain by Ordovician strata on the Geological Map of Canada (Map 1045A, 1955), actually, as suggested by Williams (1948, p. 41), formations of Silurian age are present in the vicinity of Churchill.

Field Work

The rivers were traversed mainly by canoe. Nelson River is accessible by a short portage, from mile 352 on the Hudson Bay Railway, and can be ascended and descended rather easily from the end of the portage (*see* Fig. 4). The exposures of Ordovician strata nearest to Churchill on Churchill River are about 40 miles upstream, and can be reached by either aircraft or canoe, although canoe travel is difficult because of swift water and rapids (*see* Fig. 2). Several

[1] Names and/or dates in parentheses are those of *References* cited at the end of this report.

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good landing spots for aircraft equipped with floats are available on the river. The Ordovician strata there are best studied by landing below Bad Cache Rapids or above Portage Chute. Between these two points, except for the 13-mile stretch that is dangerous in low water, rapids do not present much difficulty to experienced canoemen, but portaging around most of them is advisable. The formations in the 13-mile stretch may be studied by proceeding upstream from Bad Cache Rapids as far as possible by canoe and continuing the remaining distance on foot.

South Knife and North Knife Rivers are best approached by flying to nearby lakes and portaging to the river (*see* Fig. 3). They can be descended easily but are difficult and slow to ascend because of numerous small rapids. The passage along Hudson Bay shore from Knife Delta to Churchill is best made early in the morning and at a high tide. The water near the shore is shallow and boulders are plentiful for some distance from land. On many days, particularly in August, high winds rise suddenly during late morning and afternoon. On calm days fog may obscure the low flat shoreline.

The field season in this area is short. On Nelson River the ice does not usually break up until the last week in May and cliffs of ice up to 30 feet high may conceal outcrops along the river bank for several weeks after the river itself is free (*see* Pl. II). Break-up does not usually occur on Churchill River and the Hudson Bay coast until the last part of June and, because of ice-banks, field work may be delayed until after the second or third week in July. North Knife and South Knife Rivers are usually free of ice in early June, but they are difficult of access during this month as ice along the coast blocks their mouths, and nearby lakes upon which it might otherwise be possible to land are still partly frozen.

The best period for field work is from the middle of July to the middle of August. Numerous short thunder showers can be expected during this time, and in late August and September very high winds are fairly common and may last for several days.

Wild Life

Animals are abundant, among the more common being caribou, black bear, wolf, and fox. Geese, duck, and ptarmigan are plentiful. Caribou usually migrate north of Churchill before the beginning of summer, and thus cannot be relied upon as a source of food. East of Churchill, towards Cape Churchill, however, several large herds apparently spend the summer. Polar bears are relatively common about Churchill and along coastal areas as far south as Ontario. Fish are abundant in the rivers, pike and pickerel being most common. Hordes of black flies and mosquitoes are a great nuisance and danger.

Acknowledgments

The writer was ably assisted in the field by J. W. Wishart, R. M. Proctor, and L. F. Keating in 1950 and by R. M. Proctor, D. W. Walker, and G. W. Goodwin in 1951.

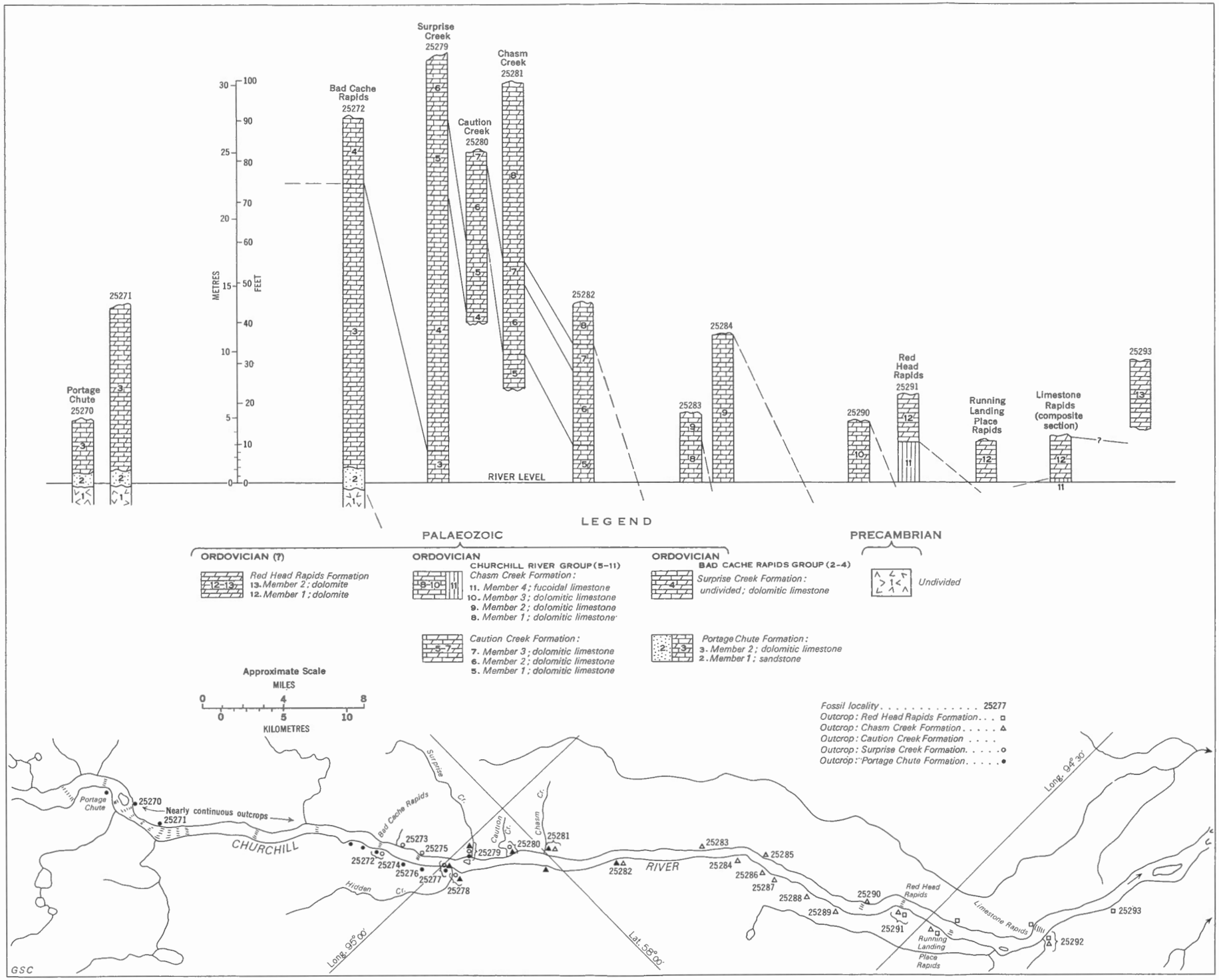

FIGURE 2. Selected sections, fossil localities, and distribution of Ordovician outcrops along Churchill River

PLATE II. Nelson River, near Upper Limestone Rapids. Ice-covered banks are typical of river during June. *Nelson, 4-2-51*

Professor T. H. Clark of McGill University gave many helpful suggestions during the preparation of a doctoral thesis based on the field investigations. Professor V. J. Okulitch of the University of British Columbia helpfully criticized the correlations between the Ordovician of the Hudson Bay Lowland and that of Lake Winnipeg. Professor A. K. Miller of the State University of Iowa freely imparted his knowledge of Arctic faunas, gave valuable help in the identification of the cephalopods, and permitted the writer to read the report on the Baffin Island faunas (Miller, Youngquist, and Collinson, 1954) before its publication.

Residents of the area extended hospitality and assistance, and special thanks are due to Mr. and Mrs. J. Kinaschuk formerly of mile 352, Hudson Bay Railway, and to Messrs. T. Williams, F. Martin, O. Sigurdson, E. Kronlund, A. McIvor, F. Beckett, and T. Twolin of Churchill, Manitoba.

Previous Work

Prior to 1950 only reconnaissance geological investigations had been made of the northwestern end of Hudson Bay Lowland. In 1879 Bell (1880) descended Churchill River from the mouth of Little Churchill River, and described the main outcrop area of limestone but gave few details of stratigraphy or palaeontology. Alcock (1916) in 1914 followed the same route as Bell and discussed the Ordovician exposures as follows (p. 135):

> On the lower portion of the river, Ordovician limestone is exposed, through which the river has cut a canyon. For the greater part of this distance, the river flows over the granite floor, exposing a complete section of the horizontal limestone. At one point, a flat-lying sandstone, 15 feet in thickness forms the basal member. The limestone reaches a thickness of at least 60 feet, is fossiliferous and apparently of the same horizon throughout. The uneven surface of the ancient floor upon which the limestone was deposited is well displayed in the limestone canyon, islands of red granite projecting in the middle of the river, at places, where on the adjacent banks the limestone descends beneath the surface of the river, but at no points were the irregularities more than 10 to 20 feet.

Bell (1879-80) also described the main outcrop areas of the limestone along Nelson River based on his reconnaissance in 1878. Whiteaves identified the fossils collected by Bell and referred most of the limestone to the Trenton (Middle Ordovician) considered to be equivalent of the Galena limestone of Wisconsin and Illinois as then known. Bell recognized the presence of Silurian beds in the lower part of the river from the occurrence of a poorly preserved pentameroid brachiopod in an outcrop about 50 miles from the mouth of the river.

Tyrrell in 1912 made a survey for the Province of Ontario along the northwest boundary of the province and collected fossils from drift at the mouth of Nelson River. Most of these were of Silurian age. Parks (1915; *in* Tyrrell, 1913) identified some of these fossils, but his reports dealt mainly with the Ordovician and Silurian fossils from the rivers to the south. In 1913, McInnes summarized Bell's work but no new data were added concerning the stratigraphy (*see also* Tyrrell, 1916).

Palaeozoic stratigraphy of Nelson River was studied by Savage and Van Tuyl in 1916. In addition, they also traversed Gods (then called Shamattawa), Severn, Winisk, Ekwan, Moose, and Abitibi Rivers. On the basis of this field study, Savage and Van Tuyl (1919) divided the Palaeozoic exposed along Nelson River into three formations: Nelson River, Shamattawa, and Port Nelson. The first two are Ordovician and the last Silurian. These authors described the formations in some detail with measured sections, fossil lists, and a probable correlation of some of the formations with those occurring near Lake Winnipeg, in Wyoming and in New Mexico. Foerste and Savage (1927) published a detailed description of cephalopods some of which were collected from Nelson River, along with a map as a frontispiece showing the localities of sections and collections. Miller and Youngquist (1947) described fossils collected in the vicinity of Churchill and suggested that Ordovician strata occur along the lower part of both North Knife and South Knife Rivers.

Shortly thereafter Williams (1948), from a study of drift in the vicinity of Churchill, suggested that Silurian strata underlay the immediate area. To the north, Ethington and Furnish (1959) obtained a conodont fauna from the Knife Delta region, which suggested that the containing rocks were Upper Ordovician.

The present writer (Nelson, 1963) has recently given a detailed description of the Ordovician palaeontology of Nelson, Churchill, South Knife, and North Knife Rivers. Stromatoporoid, coral, gastropod, and cephalopod species were described and illustrated. Brachiopod species were listed only.

STRATIGRAPHY

The known Ordovician strata of the northern Hudson Bay Lowland rest on Precambrian and form an essentially conformable sequence of marine sedimentary carbonate rocks. These beds dip gently to the east, so that downstream, in most river sections, successively younger strata are exposed. The sequence, at least 300 feet thick possibly 400, is best exposed along Churchill River where five new formations are recognized. In ascending order these are the Portage Chute and Surprise Creek Formations of the Bad Cache Rapids Group; the Caution Creek and Chasm Creek Formations of the Churchill River Group; and the Red Head Rapids Formation. The Bad Cache Rapids and Churchill River Groups are considered Upper Ordovician. The former correlates with the Red River Formation and the latter with the Stony Mountain Formation of southern Manitoba. The Red Head Rapids Formation is questionably referred to the Ordovician and considered coeval with the Stonewall Formation of southern Manitoba.

Silurian strata have been found only on Nelson River, where they constitute the type section of the Port Nelson Formation of Savage and Van Tuyl.

The Ordovician section along Nelson River, reported on by Savage and Van Tuyl (1919), was restudied in 1951. The section is less complete, and exposures are much more scattered and less fossiliferous than those on Churchill River. It was found that the Nelson River Formation of Savage and Van Tuyl apparently embraced representatives of both the Portage Chute and Surprise Creek Formations and that their Shamattawa Formation (not type) similarly included parts of the Surprise Creek and Chasm Creek Formations. Thus in the interests of clarity the nomenclature proposed by Savage and Van Tuyl is discarded and the above new formational names are used for the northern Hudson Bay Lowland. The excellent Ordovician succession along Churchill River is proposed as the type section for the region.

Bad Cache Rapids Group

This group outcrops along all rivers traversed, but is best exposed on Churchill River along a 19-mile stretch downstream from about a mile above Portage Chute, or 91 miles from the mouth of the river. To the north it is exposed along a 6-mile stretch of South Knife River east from a point 6 miles west of the northwest end of Lofthouse Lake, or about 40 miles from the mouth of the river. Still farther north it outcrops at intervals for about 1½ miles along the North Knife River from a point 5 miles below Teepee Falls. On Nelson River the formation is exposed over a distance of about 8 miles from near Long Spruce Rapids to Upper Limestone Rapids.

On Churchill River, the group is divided into two formations, the Portage Chute conformably overlain by the Surprise Creek. The latter formation is overlain paraconformably by dolomitic limestone of the Churchill River Group. The fauna of the Bad Cache Rapids Group is distinct from that of the Churchill River Group, only a few species being common to both. An evolutionary lineage of trilobate corals, however, traced from the Bad Cache Rapids (*Lobocorallium goniophylloides*) to the Richmondian and (?) Gamachian Churchill River Group (*L. trilobatum* var. *major*) suggests that the time interval between the two was short so that the former group is probably of Upper Ordovician age (Nelson, 1963).

Portage Chute Formation

This formation is exposed along Churchill River from about a mile upstream from Portage Chute downstream to Surprise Creek, a distance of about 18 miles. For the upper 13 miles of this stretch nearly vertical cliffs of sandstone and limestone, 25 to 75 feet high, form one side or both of the river banks. The formation rests on a peneplaned surface of Precambrian granitic rock and for most of the 13 miles this surface is parallel to the gradient of the river, that is it slopes at between 3 and 4 feet to the mile (*see* Pl. III). East of Bad Cache Rapids, however, the surface dips below the level of the river and progressively younger beds outcrop downstream. Between Bad Cache Rapids and Surprise Creek the calculated easterly dip of the beds, relative to the river gradient, is between 13 and 14 feet to the mile (*see* Fig. 2).

The most complete section of the Portage Chute Formation measured is on the south bank of Churchill River at Bad Cache Rapids, where 75 feet is exposed. The peneplane at the base there is from 1 foot to 2 feet below river level. The formation is divided into two members: a lower sandstone (Member 1), and an upper slightly dolomitic limestone (Member 2).

The sandstone (Member 1) at Bad Cache Rapids is about 2 feet thick, but at places farther upriver is 4 feet. It is rusty weathering and quartzose with a limy matrix. The sand grains are frosted and most are well rounded and less than 2 mm in diameter. In the lower part most quartz grains are larger and more angular, and the limy matrix not so abundant as in the upper part. The division between the sandstone and limestone members is arbitrarily placed where the limy matrix predominates over sand. Small, sparsely scattered sand grains occur in the limestone, however, for at least 20 feet higher. The sandstone and limestone members are interpreted as a typical orthoquartzite-limestone series, the sandstone representing the initial deposit of a transgressing sea. From Portage Chute to Bad Cache Rapids, Member 1, wherever exposed, is uniform in appearance. Above Portage Chute, however, as much as 15 feet of the sandstones exposed on the south side of the river is composed of coarser, more angular grains with granule conglomerate predominating in places.

Fossils are rare in the sandstone member and only an unidentified stromatoporoid, one *Charactocerina kirki* Foerste, a fragmentary *Maclurites manitobensis* (Whiteaves) and a few vague fucoidal impressions were found.

The limestone (Member 2) outcrops from Portage Chute to Bad Cache Rapids forming vertical and, in places, overhanging cliffs (*see* Pl. III). It is difficult to make accurately zoned fossil collections on these cliffs, hence most fossils were collected either from the lower beds or from rubble at the foot of the cliffs. Below Bad Cache Rapids where dips are steeper than the slope of the river, the uppermost exposed bed near Surprise Creek forms an 8-foot outcrop along the river bank just west of the mouth of the creek. A complete section, 73 feet thick, is exposed at Bad Cache Rapids.

The limestone of Member 2 is grey to buff weathering and occurs in beds from 1 inch to 2 feet thick. It contains abundant organic detritus embedded in a matrix of light grey, microcrystalline, slightly dolomitic limestone. A characteristic

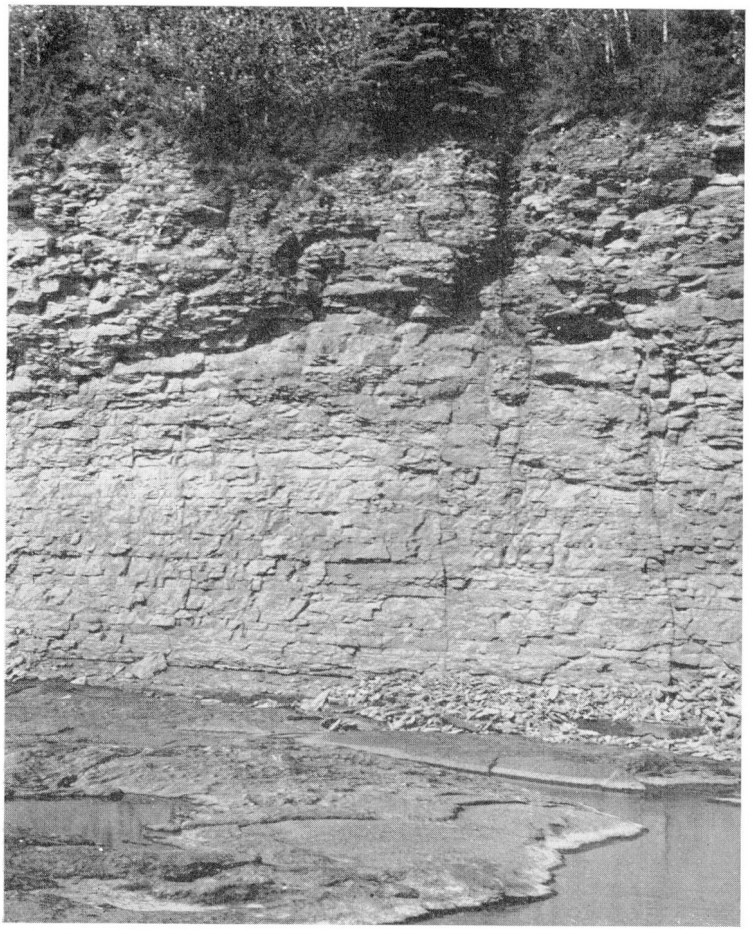

PLATE III

Portage Chute Formation lying on peneplaned Precambrian granitic rock, along Churchill River (locality 25271). The formation here is about 50 feet thick.

Nelson, 5-7-50

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feature is an alternation of rusty weathering laminae and laminae of the grey weathering limestone each from a half to an inch thick. Many rusty laminae anastomose, and this with the grey limestone between them gives the weathered surface an irregularly nodular appearance. The rusty laminae appear to contain more iron than the otherwise similar beds of grey limestone.

Fossils identified from Member 2 include the following species:

Receptaculites sp.
Palaeophyllum stokesi (Milne-Edwards and Haime)
P. halysitoides (Wilson)
Grewingkia robusta (Whiteaves)
Favistella alveolata (Goldfuss)
Saffordophyllum (?) *portagechutense* Nelson
Calapoecia anticostiensis Billings
Plasmopora lambei Schuchert
P. pattersoni Roy
Catenipora rubra Sinclair and Bolton
C. robusta (Wilson)
C. stearni Nelson
C. aequabilis (Teichert)
C. agglomeratiformis (Whitfield)
Manipora amicarum Sinclair
M. irregularis (Teichert)
M. feildeni (Etheridge)
Diceromyonia sp.
Thaerodonta sp.
Strophomena spp.
Trochonema coxi Wilson
Holopea gigantea Nelson
Hormotoma winnipegensis Whiteaves
Maclurites manitobensis (Whiteaves)
M. altus Wilson
M. ungava Wilson
Fusispira gigantea Wilson
Narthecoceras crassisiphonatum (Whiteaves)
Lambeoceras landerense Foerste
L. baffinense Miller, Youngquist, and Collinson
Paractinoceras canadense (Whiteaves)
Whiteavesites winnipegensis (Whiteaves)
Billingsites costulatus (Whiteaves)
B. landerense Foerste
Digenuoceras latum (Foerste)
Exomegoceras wyomingense Miller and Carrier
Neumatoceras churchillense Nelson
Westonoceras nelsonense Foerste
Winnipegoceras laticurvatum (Whiteaves)
Cyrtogomphoceras turgidum Troedsson (?)
C. nutatum Foerste and Savage
C. baffinense Foerste
C. thompsoni Miller and Furnish
C. alcocki Nelson
Charactoceras manitobense Nelson
Wilsonoceras squawcreekense Miller

The Portage Chute Formation of Churchill River is correlated with the Dog Head Member of the Red River Formation, southern Manitoba, on the basis

of seven species common and restricted to these units. These are *Hormotoma winnipegensis, Maclurites ungava, Paractinoceras canadense, Billingsites costulatus, Winnipegoceras laticurvatum,* and *Digenuoceras latum. Winnipegoceras dowlingi* found in the Portage Chute Formation on Nelson and South Knife Rivers is also a Dog Head species.

Fragmental organic material in the Portage Chute limestone suggests waters agitated to either transport or produce this material *in situ*. The colonial corals, gastropods, cephalopods, and *Receptaculites* of this environment either died or moved elsewhere before the deposition of the succeeding Surprise Creek Formation.

On South Knife River one outcrop of sandstone (Member 1) occurs at the west end (near locality 25294) of the area underlain by Ordovician strata. For about 6 miles downstream from this outcrop, limestone is exposed intermittently. For 2 miles downstream from the last outcrop of limestone near locality 25301, bedrock is covered by drift and the next outcrop is of the younger Caution Creek Formation (*see* Fig. 3).

The maximum measured thickness of the limestone (Member 2) is 8 feet. The dip of the beds locally varies in angle and direction, but its average appears to be approximately parallel with the gradient of the river. Good marker beds, however, were not noted, so that neither the details of possible structures nor the maximum thickness is known. The beds are similar to those assigned to Member 2 in the type section on Churchill River, including the rusty weathering laminae, the lower beds carrying sand grains as in the type section. Fossils are plentiful, and include nearly all genera and species listed from the Churchill River section. Colonial corals predominate, although cephalopods and gastropods are numerous. The following genera and species were identified from the Portage Chute Formation on South Knife River:

Receptaculites sp.
Palaeophyllum stokesi (Milne-Edwards and Haime)
Grewingkia robusta (Whiteaves)
Saffordophyllum (?) *portagechutense* Nelson
Calapoecia arctica Troedsson (?)
Plasmopora lambei Schuchert
Catenipora robusta (Wilson)
C. aequabilis (Teichert)
C. agglomeratiformis (Whitfield)
Manipora amicarum Sinclair
M. feildeni (Etheridge)
Diceromyonia sp.
Thaerodonta sp.
Trochonema coxi Wilson
Holopea gigantea Nelson
Hormotoma winnipegensis Whiteaves
Maclurites manitobensis (Whiteaves)
M. altus Wilson
Fusispira gigantea Wilson
Lambeoceras landerense Foerste
L. baffinense Miller, Youngquist, and Collinson
Whiteavesites winnipegensis (Whiteaves)
Digenuoceras latum (Foerste)

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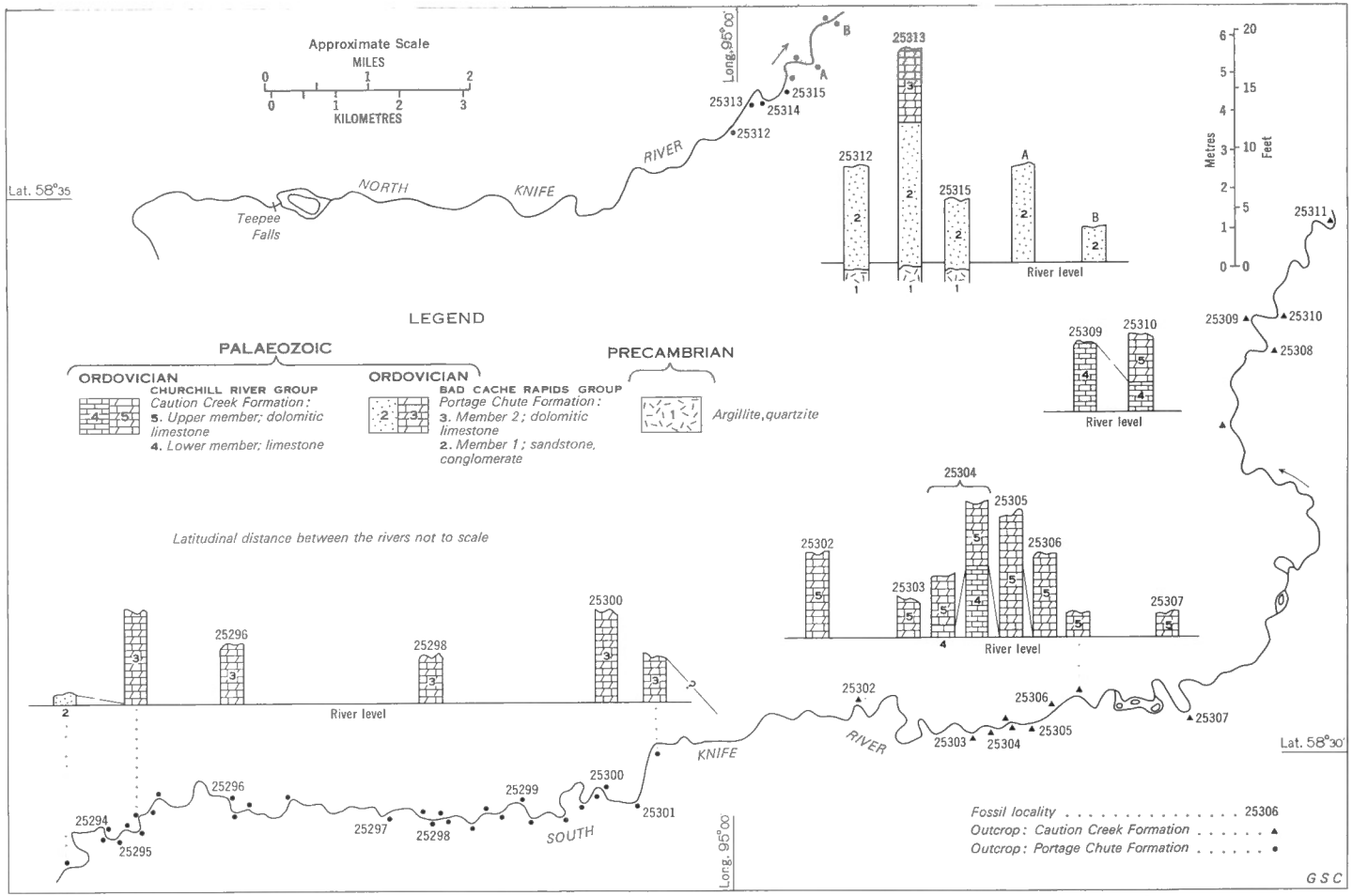


FIGURE 3. Selected sections, fossil localities, and distribution of Ordovician outcrops along North Knife River and South Knife River.

Westonoceras nelsonense Foerste
Winnipegoceras laticurvatum (Whiteaves)
W. dowlingi Foerste
Cyrtogomphoceras turgidum Troedsson
C. rotundum Miller
C. foerstei Miller and Furnish
Charactoceras manitobense Nelson

On North Knife River outcrops of this formation occupy a limited area (*see* Fig. 3). Both sandstone and limestone members are present, but the sandstone member is more extensive, outcropping intermittently along the river for about 1½ miles, starting about 5 miles downstream from Teepee Falls. The limestone member is known only near the western end of the exposure belt at localities 25313 and 25314. The beds in the main exposures dip in various directions at low angles, perhaps representing depositional attitudes. The average dip, however, appears to be approximately parallel with the river gradient.

The sandstone member differs from most of its lateral equivalents on other rivers in that it is relatively thick and, in the western outcrops, locally conglomeratic and fossiliferous. Both sandstone and conglomerate are calcareous. Some sandstone beds carry pyrite vugs. The best section is between localities 25312 and 25313, where 12 feet are exposed. Beds rest on tightly folded, near vertically dipping east-west-striking beds of green to red Precambrian argillite, and grey-green quartzite. The erosion surface appears rather uneven, and dips below river level downstream from locality 25313. The upper beds grade into the overlying limestone member, which is very thin along North Knife River, the maximum thickness seen being 6 feet.

Fossils are exceptionally plentiful in the sandstone exposed at the west end (localities 25312 to 25315), but are absent in that at the east end of the section. Corals are well preserved, but most gastropods and cephalopods occur as moulds and casts. Fossils are scarce in the overlying limestone and only one poorly preserved cast of a *Receptaculites* sp., a *Grewingkia robusta* (Whiteaves), and a *Diceromyonia* sp. were found. Fossils described from North Knife River by Miller and Youngquist (1947) are probably from sandstone outcrops at the west end. The following genera and species were identified from this member by the present writer:

Receptaculites sp.
Palaeophyllum halysitoides (Wilson)
Grewingkia robusta (Whiteaves)
Favistella alveolata (Goldfuss)
Nyctopora (?) *foerstei* Bassler
N. mackenziei Nelson
Calapoecia arctica Troedsson (?)
Plasmopora lambei Schuchert
Catenipora aequabilis (Teichert)
C. agglomeratiformis (Whitfield)
Diceromyonia sp.
Trochonema coxi Wilson
Maclurites manitobensis (Whiteaves)
Fusispira gigantea Wilson

Kochoceras sp. I Nelson
Lambeoceras kronlundi Miller and Youngquist

This fauna indicates that the sandstone is of the same age as the Portage Chute Formation at the type section on Churchill River. The relatively thick sandstone with conglomeratic phases suggests a near-shore facies, and this may also be the reason for the thinness of the limestone although erosion in preglacial and glacial time may have removed most of it. The sandstone is probably not contemporaneous throughout the region, and the thickness of the limestone member on Churchill River compared with its apparent thinness to the north and south suggests a basin of deposition centring along Churchill River. Under such conditions the sandstone to the north or south may be equivalent in age to part of the limestone along Churchill River.

Along the lower part of North Knife River from the most easterly outcrop of the Portage Chute Formation to its junction with South Knife River outcrops are rare. A small outcrop of Precambrian gneissoid rock occurs about 6 miles downstream from the last sandstone exposure, approximately opposite the north end of Nowell Lake. Over a small area near this outcrop, abundant rounded limestone boulders containing dinorthid and strophomenid brachiopods similar to those of the Churchill River Group are found, which suggest the occurrence nearby of strata of that age. Downstream over the remaining 18 miles of river no outcrops were seen, but abundant rounded Precambrian boulders and very few Ordovician ones in the stream bed suggest that Precambrian may underlie the lower part of the river. Only in the delta of North Knife and South Knife Rivers are Ordovician boulders abundant.

Beds of the Portage Chute Formation outcrop along both banks of Nelson River at intervals from near Long Spruce Rapids to a point about a mile below Upper Limestone Rapids (*see* Fig. 4; Pl. IV). As on Churchill River, the formation can be divided into a lower sandstone member (Member 1) and an upper limestone member (Member 2). The best known exposures are about 3 miles below Long Spruce Rapids (locality 25254) and in the area from half a mile above First Upper Limestone Rapids to about a mile below Third Upper Limestone Rapids (localities 25256 and 25258).

On the south bank at the lower end of the Second Upper Limestone Rapids 18 feet of limestone was measured. On the north bank near Third Upper Limestone Rapids, a sandstone bed 4 feet thick exposed above the level of water grades upward into limestone. This sandstone is near a Precambrian outcrop in the middle of the rapids and thus presumably represents most if not all the thickness of Member 1. At locality 25254, some 3 feet of basal calcareous sandstone is exposed followed by 13 feet of limestone. At these localities the beds dip parallel with the average gradient of the river. Bell (1880) mentioned a small isolated outcrop which, from his description, probably occurs at Long Spruce Rapids, 3 to 4 miles above the most westerly outcrop (locality 25254) examined by the writer. The fauna suggests that this outcrop belongs in the Portage Chute Formation.

Most of the quartz grains of the sandstone member are less than 2 mm in diameter. The matrix of the upper beds is calcareous, and the contact between sandstone and limestone is placed where calcite predominates over quartz. Only vague fucoidal impressions were noted in the sandstone. The limestone contains abundant organic detritus, and weathers grey to buff. As on Churchill River, rusty weathering iron-rich laminae alternate with beds of normal grey limestone. Fossils are neither so plentiful nor so well preserved as those in the Portage Chute limestone on Churchill River.

The following genera and species have been identified from collections made on Nelson River:

Receptaculites sp.
Palaeophyllum halysitoides (Wilson)
Grewingkia robusta (Whiteaves)
Saffordophyllum (?) *portagechutense* Nelson
Plasmopora lambei Schuchert
P. pattersoni Roy
Catenipora rubra Sinclair and Bolton
C. robusta (Wilson)
C. stearni Nelson

PLATE IV. Member 2 of the Portage Chute Formation at Upper Limestone Rapids, Nelson River (north end of locality 25256). *Nelson, 2-1-51*

Manipora amicarum Sinclair
M. irregularis (Teichert)
M. feildeni (Etheridge)
Trochonema coxi Wilson
Hormotoma winnipegensis Whiteaves
Maclurites manitobensis (Whiteaves)
M. altus Wilson
Fusispira gigantea Wilson
Cyclendoceras kindlei Foerste
Narthecoceras crassisiphonatum (Whiteaves)
Billingsites costulatus (Whiteaves)
Westonoceras nelsonense Foerste
Winnipegoceras laticurvatum (Whiteaves)
W. dowlingi Foerste
W. nelsonense Nelson
Cyrtogomphoceras turgidum Troedsson
C. nutatum Foerste and Savage
C. thompsoni Miller and Furnish
C. alcocki Nelson

This fauna is clearly equivalent to that of the limestone member of the Portage Chute Formation, Churchill River, and the Dog Head Member of the Red River Formation, southern Manitoba.

Surprise Creek Formation

The best known exposures of this formation on Churchill River are at Surprise Creek, Bad Cache Rapids, and Hidden Creek; others occur at localities 25273 and 25277. Outcrops of the Surprise Creek Formation are not numerous and at most localities are limited to nearly vertical cliffs near the mouths of creeks (*see* Pl. I).

'Units' 5 and 6 of the Shamattawa Formation of Savage and Van Tuyl (1919, p. 346) occurring on Nelson River are correlated with, and placed in, the Surprise Creek Formation on the basis of lithology and contained faunas. The Surprise Creek Formation was not recognized in the sections studied on North Knife and South Knife Rivers.

On Churchill River the contact of the Surprise Creek with the underlying Portage Chute Formation is gradational, the boundary being arbitrarily placed where organic detritus, abundant in the upper part of the Portage Chute, becomes negligible. The microcrystalline material that forms the matrix of the Portage Chute rocks is the dominant constituent of the lower beds of the Surprise Creek, and the rock is a microcrystalline, occasionally cryptocrystalline, dolomitic limestone. As the detritus decreases in quantity, the fauna also changes markedly in character. The predominantly molluscan and coralline fauna of the lower formation changes to one characterized by rhynchonellid and strophomenid brachiopods in the upper formation, the strophomenid being by far the more abundant. The change in lithology from Portage Chute to Surprise Creek is thought to reflect a change from rather turbulent-water to quiet-water deposition.

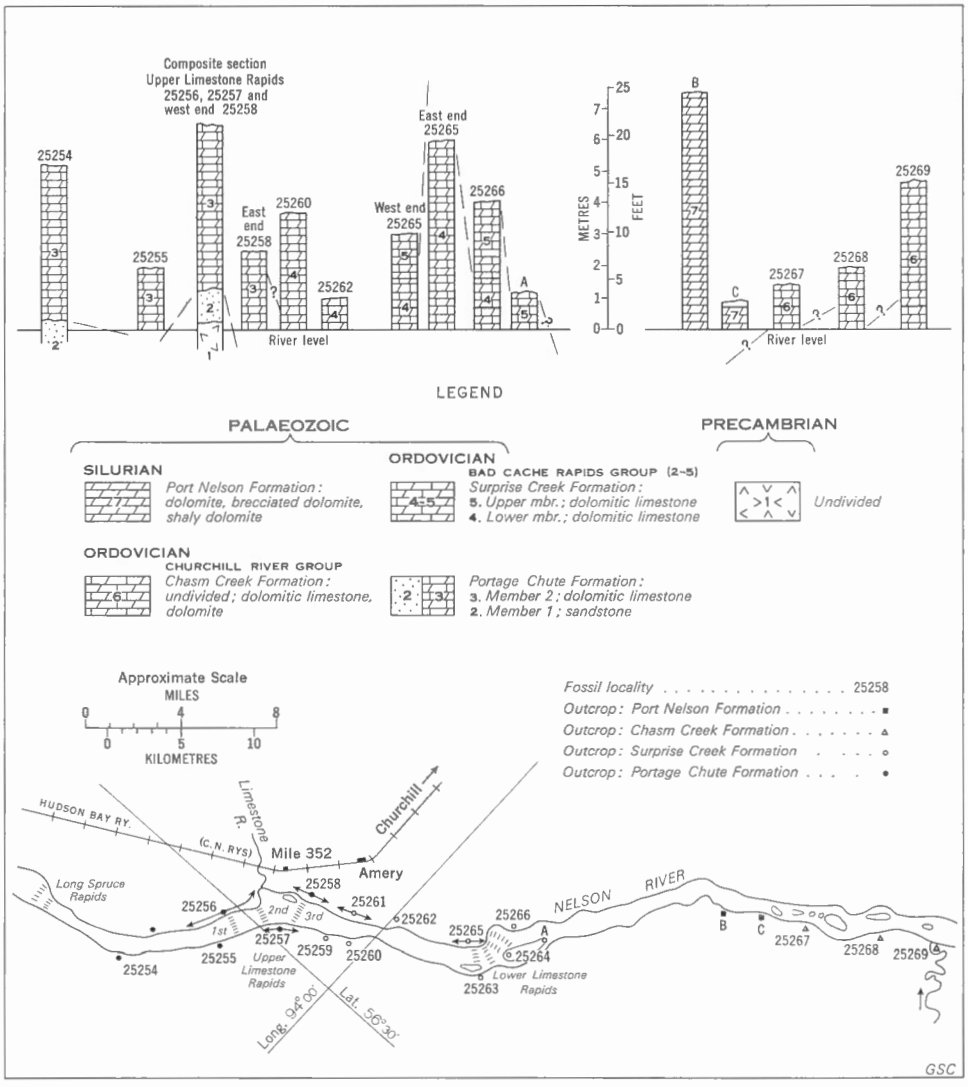
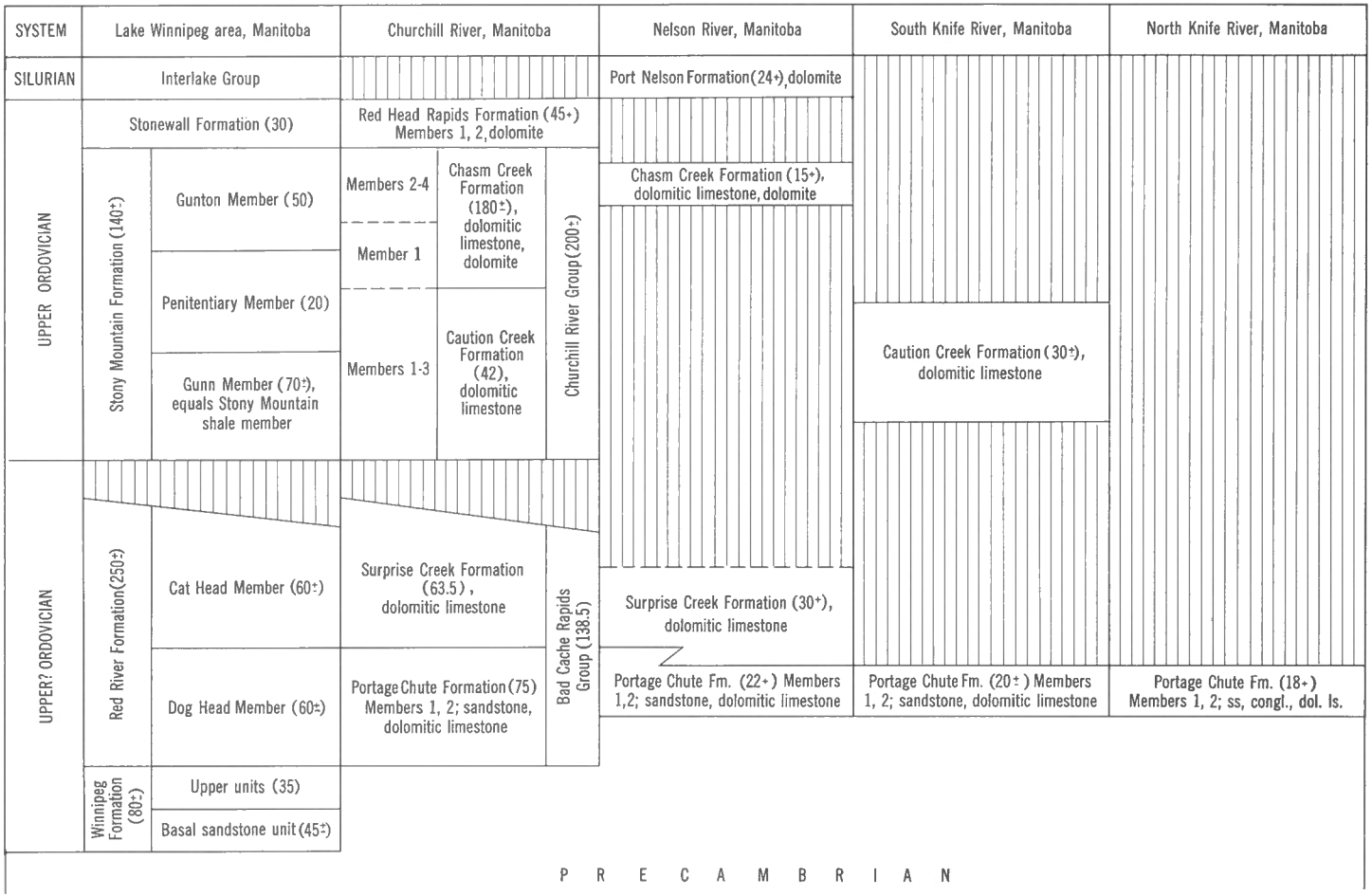


FIGURE 4. Selected sections, fossil localities, and distribution of Ordovician and Silurian outcrops along Nelson River.

The section at Surprise Creek, selected as the type, was measured across the entire formation. At most localities, however, only one contact is exposed. For purpose of description, the formation is divided into seven members, having a total thickness of 63.5 feet. Over the limited areal exposures on Churchill



Note: Numbers in parentheses indicate thickness in feet

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TABLE I: Correlation of Ordovician formations in different parts of the Hudson Bay Lowland and in the Lake Winnipeg area, Manitoba.

River these members can be easily recognized and exhibit little lateral change in lithology. The succession at the type section is as follows:

	Feet
Caution Creek Formation	42.0
..... Paraconformity	
Surprise Creek Formation	
Member 7	
Limestone, dolomitic, buff, microcrystalline to fine grained, massive, weathers buff	4.5
Member 6	
Limestone, dolomitic, light yellowish grey, microcrystalline to fine grained, massive, weathers grey	2.0
Member 5	
Limestone, slightly dolomitic, light yellowish grey, weathers grey to dark grey. Microcrystalline and cryptocrystalline parts alternate in regular beds 2″ thick. Chert abundant in upper part	4.0
Member 4	
Limestone, slightly dolomitic, light yellowish grey to buff, micro- to cryptocrystalline with organic detritus, weathers grey. Mottled with widely scattered, irregularly shaped rusty blotches in lower half; in upper half blotches are more regular in shape and lie parallel to bedding	21.0
Member 3	
Limestone, slightly dolomitic, light yellowish grey, microcrystalline, finely laminated, weathers grey to brown in regular beds 1″ to 3″ thick. Contains numerous lenses of chert	8.0
Member 2	
Limestone, slightly dolomitic, light yellowish grey, microcrystalline, weathers buff to grey, breaking in irregular platy blocks 1″ to 2″ thick. Contains a few lenticular lenses of chert in upper part	10.0
Gap in exposures	2.0
Member 1	
Limestone, slightly dolomitic, light yellowish grey, microcrystalline, fossiliferous, weathers buff to grey, breaking in irregular platy slabs 1″ to 2″ thick	12.0
..... Gradational contact	
Portage Chute Formation	
Limestone, dolomitic, light grey, microcrystalline with abundant organic detritus, weathers light grey	8.0
..... Water level of Churchill River	

From the lowest member of the type section the following fossil species were identified:

Lobocorallium goniophylloides (Teichert)
Plasmopora lambei Schuchert
Rafinesquina lata Whiteaves
R. lata Whiteaves var.
R. pronis Roy
Megamyonia raymondi (Bradley) (?)
M. nitens (Billings) (?)
Thaerodonta sp.
Strophomena planocorrugata Twenhofel
S. hecuba Billings (?)

S. fluctuosa Billings (?)
S. spp. nov.
Rhynchotrema kananaskia Wilson (?)
Hypsiptycha janea (Billings) (?)
Trochonema coxi Wilson

Members 2 to 7 inclusive are practically unfossiliferous and yielded only *Beatricea nodulosa* (Billings). These beds, however, appear conformable and lithologically similar to Member 1.

This formation is thought to correlate with the Cat Head Member of the Red River Formation of southern Manitoba, to which it is similar in lithology and stratigraphic position as the underlying Portage Chute Formation is considered equivalent to the Dog Head Member (*see* Sinclair, 1959).

On Nelson River, the Surprise Creek Formation is exposed in the section studied by Savage and Van Tuyl (1919). In all, 30 feet of the formation is exposed but the total thickness may be considerably more.

Limestone beds assigned to the Surprise Creek Formation outcrop in places on both banks of Nelson River from about three quarters of a mile to 3 miles below Upper Limestone Rapids (locs. 25259 to 25262), and from a mile above to 3 miles below Lower Limestone Rapids (locs. 25263 and 25266). Savage and Van Tuyl (1919) referred the beds near Lower Limestone Rapids to the Shamattawa Formation and presumably included those near Upper Limestone Rapids in the Nelson River Formation (essentially Portage Chute Formation of this report).

The Surprise Creek Formation on Nelson River can be divided lithologically into two members. The lower member is a light grey weathering, light yellowish grey, microcrystalline, dolomitic limestone with some organic detritus, and breaks into beds an inch to 2 inches thick. It is at least 20 feet thick. Anastomosing, yellow weathering, iron-rich laminae are present, but are neither as common nor as dark weathering as those in the underlying Portage Chute Formation. A few thin beds and small nodules of chert are present. The Surprise Creek can be distinguished from the Portage Chute by its lighter colour, both on weathered and fresh surfaces.

The basal beds of the lower member may represent an eastern lateral facies of the upper part of the Portage Chute Formation because the two, although separated by a drift-covered interval of 100 yards near locality 25259, appear to be on strike. It is possible, however, that the Surprise Creek may be faulted down relative to the Portage Chute, the fault occupying some part of the covered interval. Such a dislocation would require a displacement of about 20 feet. Faults are unknown elsewhere in the areas of Ordovician strata although some may be present near Cape Churchill in a small area underlain by Silurian biostrome reefs.

The lower member of the Surprise Creek is exposed in both outcrop areas on Nelson River but as a drift-covered interval of about 3 miles separates the two, the stratigraphic relationship between beds exposed at the two places is uncertain. Attitudes measured suggest that the outcrops near Upper Limestone Rapids are stratigraphically lower than those at Lower Limestone Rapids. Thus the species collected from each area are listed separately.

Fossils collected from the lower member of the Surprise Creek Formation, near Upper Limestone Rapids include the following species:

Nyctopora mackenziei Nelson
Calapoecia anticostiensis Billings
Lobocorallium goniophylloides (Teichert)
Plasmopora lambei Schuchert
Catenipora robusta (Wilson)
Rafinesquina lata Whiteaves
Thaerodonta sp.
Strophomena amoena Wang
S. sp., cf. *S. concordensis* Foerste
Rhynchotrema kananaskia Wilson
Narthecoceras crassisiphonatum (Whiteaves)

Beds at Lower Limestone Rapids referred to the lower member outcrop from about a mile above to about a mile below the rapids. The lithology is very similar to that of the beds near Upper Limestone Rapids. Well-preserved fossils are not abundant but the following have been identified:

Lobocorallium goniophylloides (Teichert)
Catenipora aequabilis (Teichert)
Thaerodonta sp.
Strophomena fluctuosa Billings
Rhynchotrema kananaskia Wilson
Maclurites manitobensis (Whiteaves)
Lambeoceras walkeri Nelson
Whiteavesites procteri Nelson

The upper member of the Surprise Creek Formation outcrops only in the vicinity of the Lower Limestone Rapids, from about half a mile above to 3 miles below. It is at least 10 feet thick and is fossiliferous only near the rapids. The contact between the upper and lower member is gradational. The upper member consists of a smooth, conchoidally fracturing, buff to grey weathering, light yellowish grey, microcrystalline, occasionally cryptocrystalline, dolomitic limestone, more dolomitic than that of the lower member. The lithology of the upper member is very similar to that of Members 1 and 2 of the Surprise Creek Formation on Churchill River. The surface of the limestone is commonly littered with casts and moulds of strophomenid brachiopods, most of which are unidentifiable. Fossils identified include the following brachiopods:

Rafinesquina lata Whiteaves
Megamyonia nitens (Billings)
Thaerodonta spp.
Strophomena lenta Troedsson
Rhynchotrema kananaskia Wilson (?)

The faunal aspect of much of the Surprise Creek on Nelson River differs from that of the same formation elsewhere in that corals and molluscs are more numerous and varied. However, such species as *Lobocorallium goniophylloides, Rafinesquina lata,* and *Rhynchotrema kananaskia* also occur on Churchill River and relate the beds on Nelson River to those of the Surprise Creek Formation at its type locality. In addition such species as *Nyctopora mackenziei, Plasmopora*

lambei, and *Maclurites manitobensis* further indicate that these Nelson River beds belong in the Bad Cache Rapids Group.

Churchill River Group

Strata of this group outcrop intermittently on Churchill River from about a third of a mile above the mouth of Hidden Creek to Limestone Rapids, a distance of some 30 miles. The main exposures occur in two areas: (1) from above Hidden Creek to 2¾ miles below the mouth of Chasm Creek (localities 25277 to 25282), and (2) from about 4 miles below the last locality to Red Head Rapids (localities 25283 to 25291). The group comprises a lower formation named the Caution Creek, and an upper one, the Chasm Creek, which are conformable. The faunal succession within the group indicates that representatives of all three of Baillie's (1952) members of the Stony Mountain Formation are probably present. The Caution Creek and lowest member of the Chasm Creek Formation correlate with the Stony Mountain Shale (Gunn Member of Sinclair and Leith, 1958) and Penitentiary members of the Stony Mountain Formation. The remaining members of the Chasm Creek correlate with the Gunton Member. The Caution Creek Formation rests paraconformably on the Surprise Creek Formation (*see* Pl. I). The Chasm Creek Formation is overlain by dolomite of the Red Head Rapids Formation (*see* Pl. VII).

Formations of the Churchill River Group also outcrop along Nelson and South Knife Rivers. On Nelson River, the Shamattawa Formation of Savage and Van Tuyl (1919) contains representatives of both the Bad Cache Rapids and Churchill River Groups; their 'units' 5 and 6 of the Ordovician succession appear to be equivalent to the Surprise Creek, and their 'unit' 7 belongs in the Chasm Creek Formation.

Caution Creek Formation

This formation is exposed at Hidden, Surprise, Caution, and Chasm Creeks (*see* Pls. I and V). It attains a total thickness of 42 feet, and consists of three members, in ascending order number 1, 2, and 3, exceptionally well exposed at both Chasm Creek and Caution Creek. The most southerly exposures occur about a third of a mile above the mouth of Hidden Creek (loc. 25277), along the bank of Churchill River; the best exposures occur 1½ miles down Churchill River near the mouth of Caution Creek, where the base and all three members are visible. The section there is designated as the type for the formation. At Chasm Creek, 1½ miles farther downstream, all three members are exposed, but, when visited, the base of the formation was under water. At this locality the top of the formation is well displayed in the narrow gorge of the creek. The last and most northerly known exposures of the formation (loc. 25282) occur on the south bank of the river 2¾ miles down from the mouth of Chasm Creek (*see* Pl. VI). There the base of the formation is beneath river level but a part of the lower and all of the remaining two members and the overlying Chasm Creek

Formation are well exposed. Except for one small patch on the south bank opposite the mouth of Chasm Creek, no other outcrop of the Caution Creek Formation was seen along Churchill River. On the basis of the regional north-eastward dip, the top of the Caution Creek is estimated to pass below the level of Churchill River about 5 miles below the mouth of Chasm Creek, and up-river from locality 25283.

Member 1 is about 18 feet thick, and, wherever exposed, consists of light grey to yellowish grey weathering, cryptocrystalline, light yellowish grey, slightly dolomitic limestone tending to weather in irregular, rather rubbly beds about 1

PLATE V

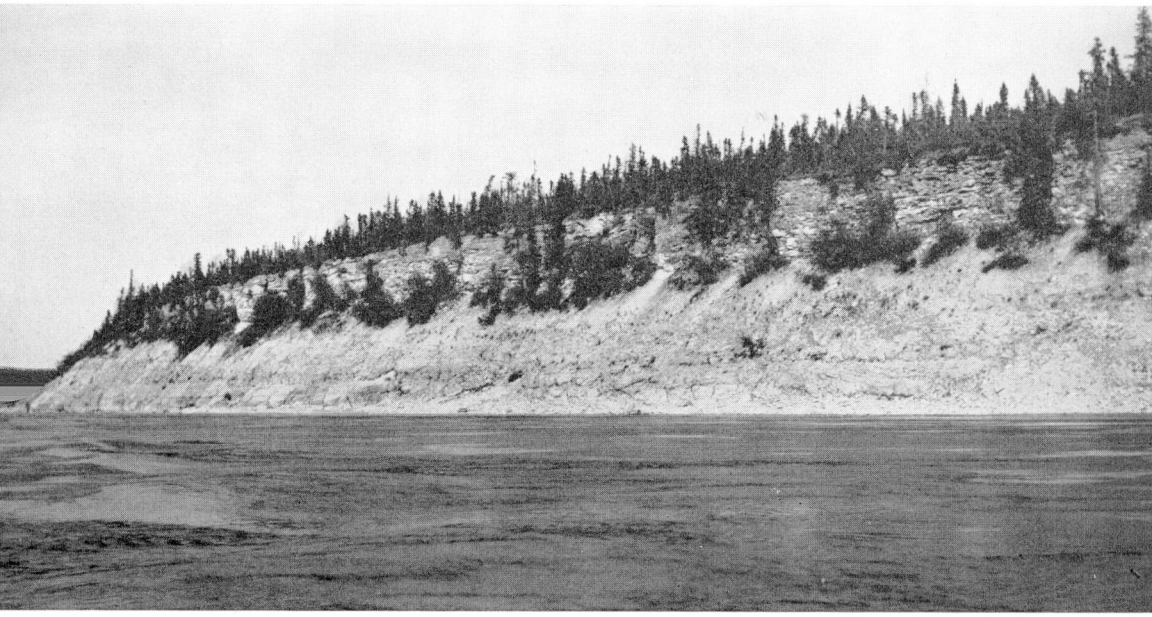
Chasm Creek, a tributary of Churchill River. Lower beds are the Caution Creek Formation; upper massive beds the Chasm Creek Formation.

Nelson, 22-1-51

inch thick. Organic debris is plentiful and small irregular-outlined, yellow weathering blotches, slightly more dolomitic than the matrix are scattered throughout. This member is the most fossiliferous part of the Churchill River Ordovician sequence. The fauna is both varied and abundant, consisting mainly of solitary and colonial corals, bryozoans (not identified), rhynchonellid and strophomenid brachiopods, gastropods, and cephalopods. The following species have been identified:

Palaeophyllum raduguini Nelson
Lobocorallium trilobatum var. *major* Nelson
Deiracorallium manitobense Nelson
Bighornia patella (Wilson)
Lyopora manitobensis Nelson
Calapoecia anticostiensis Billings
C. canadensis var. *ungava* Cox
Protrochiscolithus kiaeri Troedsson
Palaeofavosites capax (Billings)
Favosites wilsonae Nelson
Catenipora rubra Sinclair and Bolton
C. robusta (Wilson)
C. foerstei Nelson
Manipora amicarum Sinclair
Plaesiomys occidentalis (Okulitch)
Megamyonia raymondi (Bradley)
M. nitens (Billings)
M. ceres (Billings)
Strophomena planocorrugata Twenhofel
S. fluctuosa Billings
Lepidocyclus perlamellosus (Whitfield)
L. capax (Conrad)
Hypsiptycha anticostiensis (Billings)
Zygospira resupinata Wang
Trochonema coxi Wilson
Liospira parva Wilson
Cyclendoceras belli Nelson
Lambeoceras nudum Troedsson
Ephippiorthoceras dowlingi Foerste and Savage
Probillingsites harkeri Nelson
Billingsites borealis (Parks)
B. keatingi Nelson
B. canadensis (Billings) (?)
Digenuoceras mclearni Nelson
Winnipegoceras (?) *contractum* (Foerste and Savage)
Charactoceras laddi Foerste
C. warrenae Nelson

The contact between the irregularly bedded Member 1 and the well-bedded Member 2 is placed arbitrarily at the uppermost of two prominent bedding planes, 4 to 6 inches apart as exposed at Caution Creek, Chasm Creek, and locality 25282. Although irregular bedding continues for 3 feet above this, the lower contact of Member 2 is placed at the top of a rather easily recognizable, mauve weathering bed of fucoidal material 3 inches thick that occurs just below the upper bedding plane. Member 2 is 18 feet thick, measured from the top of the fucoidal bed to the plane marking the contact between Members 2 and 3. Member 2 con-



Nelson, 25-4-51

PLATE VI. Caution Creek Formation overlain by resistant beds of the Chasm Creek Formation at locality 25282, Churchill River.

sists of well-bedded, grey to brown weathering, crypto- to microcrystalline, light yellowish grey, slightly dolomitic limestone occurring in layers 1 inch to 2 inches thick, separated by rather wispy yellow dolomite layers from a quarter to half an inch thick. Member 2 differs from Member 1 in being generally well bedded, having little organic detritus, and in having a fairly restricted fauna consisting essentially of dinorthid and strophomenid brachiopods. The following species have been identified:

Plaesiomys occidentalis (Okulitch)
Megamyonia nitens (Billings)
M. ceres (Billings)
Strophomena planocorrugata Twenhofel
S. fluctuosa Billings
S. elongata James (?)
S. sp. nov.
Lepidocyclus perlamellosus (Whitfield)
L. gigas Wang (?)
Zygospira resupinata Wang

Member 3, which is 6 feet thick, is separated from Member 2 by a distinct bedding plane. It differs from Member 2 in its rubbly weathering appearance, in having more irregular bedding, and in containing a slightly more varied fauna of corals with dinorthid, strophomenid, and rhynchonellid brachiopods. The rock is a smooth, grey earthy weathering, microcrystalline almost cryptocrystalline, light yellowish grey, slightly dolomitic limestone occurring in irregular layers about 1 inch thick in the lower 2 feet and about 2 inches thick in the upper 4 feet of the member. The thinner layers in the lower part contain no organic detritus

whereas those in the upper 4 feet contain a considerable amount. The upper 1½ to 2 feet contains rusty weathering laminae, which become increasingly numerous toward the top. These upper slightly ferruginous beds suggest a transition into the overlying rather ferruginous Chasm Creek Formation, although a distinct bedding plane separates the two.

Few fossils were collected from Member 3 of the Caution Creek Formation, possibly because in most places the beds are almost inaccessible and collecting was limited to a few small exposures. Fossils collected include the following:

Lobocorallium trilobatum var. *major* Nelson
Bighornia patella (Wilson)
Palaeofavosites alveolaris (Lonsdale) (?)
Favosites wilsonae Nelson
Plaesiomys occidentalis (Okulitch)
Megamyonia nitens (Billings)
M. ceres (Billings)
Lepidocyclus perlamellosus (Whitfield)
Hypsiptycha anticostiensis (Billings)
Charactocerina goodwini Nelson

On South Knife River, the Caution Creek Formation is exposed for about 9 miles, from locality 25302 to 25311. The most westerly outcrops are separated from the most easterly outcrops of the Portage Chute Formation by a 2-mile gap in exposures, in which may lie the Surprise Creek Formation. The best exposed and most fossiliferous Caution Creek beds occur upstream from the sharp northward bend of the river (localities 25302 to 25307). A second poorly understood area of outcrops (localities 25308 to 25311) is between 3 to 5 miles north of the same bend. About 4 miles above the junction with the North Knife River a small patch of limestone of unknown age occurs in the river bed. Based on the assumed trend of the Ordovician strata, beds of the Caution Creek Formation probably underlie the area adjacent to South Knife River from the most northerly outcrop (locality 25311) to the junction with North Knife River. The delta of North Knife and South Knife Rivers contains abundant rubble of the Caution Creek Formation, and it is assumed that this area is also underlain by that formation. This assumption is in agreement with Ethington and Furnish (1959) who dated this rubble as Upper Ordovician on the basis of conodont fauna.

Most exposures of the Caution Creek Formation along South Knife River are small, low, and scattered. Diagnostic fossils are absent at many localities. On the basis of the limited exposures the formation is divided into a lower and an upper member, but these cannot be correlated with certainty to the members of the type section of the formation on Churchill River. The lower member is at least 6 feet thick and is exposed in the centre of a low arch at locality 25304. The upper member beds occur both up- and downriver from the arch. The lower member is a smooth conchoidally weathering, cryptocrystalline, light grey limestone. One graptolite and two brachiopod species are the only fossils found:

Desmograptus canadensis (Whiteaves)
Strophomena planocorrugata Twenhofel
Lepidocyclus capax (Conrad)

Desmograptus canadensis is elsewhere known only from the Cat Head Member of the Red River Formation in southern Manitoba. *Strophomena planocorrugata* occurs in both the Surprise Creek and Caution Creek Formations, whereas *Lepidocyclus capax* is most characteristic of strata correlating with the Churchill River Group. Thus faunal elements of both the Bad Cache Rapids and Churchill River Groups are present in the lower member. The lower member is tentatively correlated with the Caution Creek Formation although it may belong to the Surprise Creek Formation.

The upper member along the South Knife has a minimum thickness of 16 feet and a calculated maximum of between 20 and 30 feet. It consists of fossiliferous, mottled orange and grey weathering, crypto- to microcrystalline, light yellowish grey, slightly dolomitic limestone occurring in rubbly weathering beds 1 inch to 3 inches thick. The best exposures (localities 25304 to 25306) are in the half-mile-long outcrop belt east of the arch, where easterly dips of 10 to 15 feet per mile were observed. Within this restricted area the member can be divided into two zones, the lower, which is 5 feet thick, contains numerous pelmatozoan columnals. This lower zone is separated from the upper zone by an easily recognizable 1- to 2-inch thick bed of dark grey weathering, dark grey pelmatozoan limestone. The upper zone is at least 10 feet thick and is similar to the lower one, except that columnals are much more abundant. Lithologically it is very similar to Member 1 of the Caution Creek on Churchill River. Upriver and downriver from these outcrops, however, the two zones cannot be distinguished with certainty.

Fossils identified from the lower member in the area to the west of the bend in the river include:

Lobocorallium trilobatum var. *major* Nelson
Deiracorallium manitobense Nelson
Bighornia patella (Wilson)
Lyopora manitobensis Nelson
Calapoecia anticostiensis Billings
C. canadensis var. *ungava* Cox
Protrochiscolithus kiaeri Troedsson
Palaeofavosites alveolaris (Lonsdale) (?)
P. capax (Billings)
Favosites wilsonae Nelson
Catenipora robusta (Wilson)
C. foerstei Nelson
Manipora amicarum Sinclair
Plaesiomys occidentalis (Okulitch)
Megamyonia unicostata (Meek and Worthen)
M. nitens (Billings)
M. ceres (Billings)
Strophomena planocorrugata Twenhofel
S. hecuba Billings
S. fluctuosa Billings
Lepidocyclus perlamellosus (Whitfield)
Hypsiptycha anticostiensis (Billings)
Trochonema coxi Wilson
Liospira parva Wilson

Cyclendoceras belli Nelson
Parksoceras lepidodendroides (Parks)
Lambeoceras nudum Troedsson
Billingsites borealis (Parks)

This fauna is similar to that of the Caution Creek Formation of the type locality. Such species as *Lyopora manitobensis, Deiracorallium manitobense, Bighornia patella, Favosites wilsonae, Catenipora foerstei, Plaesiomys occidentalis, Strophomena planocorrugata, S. fluctuosa,* and *Billingsites borealis* all occur on Churchill River some 32 miles to the south. A few are known to range either above or below this formation, but their faunal association is distinctly different.

In the numerous but scattered outcrops (localities 25308 to 25311) approximately 5 miles to the northeast of the assumed arch, two members, each very similar lithologically to those in the arch area, are present. The lower member consists of smooth conchoidally weathering cryptocrystalline, light grey limestone containing chert nodules. Except for the chert, the member is almost identical in all details with that of the lower member exposed in the assumed arch at locality 25304. The maximum thickness measured is 5.5 feet. The only fossils found were some poorly preserved trilobites belonging to the genus *Ceraurus* (*s. l.*). The upper member consists of relatively unfossiliferous, brown and grey blotchy weathering, microcrystalline, grey limestone with abundant organic detritus, in beds 3 to 6 inches thick. Among the few fossils found in this member are *Aulacera undulata* (Billings) and *Narthecoceras crassisiphonatum* (Whiteaves).

This meagre fauna gives conflicting information as to the age of these beds. *Aulacera undulata* is most characteristic of the Chasm Creek Formation whereas *Narthecoceras crassisiphonatum* is known chiefly from the Bad Cache Rapids Group. If the *Aulacera* is assumed to be the most reliable fossil then the member, indeed possibly both members in this outcrop area, might be placed in the Chasm Creek Formation. If, on the other hand, *Narthecoceras* is considered the best guide, then the strata could belong to the Bad Cache Rapids Group. These questions of correlation cannot be answered until more diagnostic fossils are available. The writer considers it advisable to tentatively assign both members to the Caution Creek because of their similarity of stratigraphic position and lithology with those beds outcropping in the area between localities 25303 and 25307.

Chasm Creek Formation

On Churchill River the two main occurrences of this formation are separated by a drift-covered area 4 miles long. The westerly exposures are at Chasm Creek and locality 25282 (*see* Pls. V and VI), and the easterly ones are 12 miles above and continue intermittently for 2 miles below Red Head Rapids. Fossil localities 25283 to 25291 are in the latter area. The base rests conformably on the Caution Creek Formation (Pl. V) and the top is overlain possibly paraconformably by the Red Head Rapids Formation (*see* Pl. VII). Thickness is estimated to be about 180 feet.

The formation is divided into four members based on lithology and contained fauna. Member 4, the uppermost, contains fucoidal dolomite and by this

Nelson, 27-6-51

PLATE VII. Member 4 of the Chasm Creek Formation overlain by massive dolomites of Member 1 of the Red Head Rapids Formation on Churchill River about 2 miles below Red Head Rapids. Member 1 here is more thick bedded than usual.

can be readily separated from the lower three members, which are less easily differentiated.

Member 1 is the thickest, being 44 feet at Chasm Creek, where the top beds are bevelled by glacial erosion. The rock is a very resistant, light yellowish grey to buff, microcrystalline, iron-rich dolomitic to slightly dolomitic limestone in massive beds weathering yellow to orange. The surface is mottled with yellow to dark brown dolomitic patches, apparently of fucoidal origin. Beds definitely referable to this member also outcrop along the south bank of Churchill River at locality 25282, $2\frac{3}{4}$ miles below the mouth of Chasm Creek. There, for about half a mile the lower 10 feet of the member is exposed (*see* Pl. VI). At about 4 miles below this occurrence (localities 25283 and 25284) 11 feet of massive dolomitic limestones, questionably referred to this member may possibly represent younger beds than those exposed at Chasm Creek. The total thickness of the member, therefore, may be close to 55 feet.

The fauna of Member 1 consists predominantly of corals. Fossils collected from the lower 44 feet of these beds at Chasm Creek and locality 25282 include:

Lobocorallium trilobatum var. *major* Nelson
Deiracorallium manitobense Nelson
D. manitobense var. *churchillense* Nelson
Bighornia patella (Wilson)
B. solearis (Ladd)
B. bottei Nelson
Lyopora manitobensis Nelson
L. churchillensis Nelson
Calapoecia anticostiensis Billings
C. canadensis var. *ungava* Cox
Palaeofavosites alveolaris (Lonsdale) (?)
P. prolificus (Billings)
P. capax (Billings)
Catenipora robusta (Wilson)
Manipora amicarum Sinclair
Diceromyonia storeya (Okulitch)
Megamyonia nitens (Billings)
M. breviuscula (Foerste)
Thaerodonta sp.
Lepidocyclus perlamellosus (Whitfield)
Hypsiptycha anticostiensis (Billings)
Trochonema coxi Wilson
Kochoceras bailliei Nelson

The Caution Creek Formation and the lower 44 feet of Member 1 of the Chasm Creek Formation, considered together, are roughly equivalent to the Gunn Member (=Stony Mountain Shale) and the Penitentiary Member of the Stony Mountain Formation. The species *Deiracorallium manitobense, Bighornia patella, Dalmanella storeya, Plaesiomys occidentalis, Hypsiptycha anticostiensis, Lepidocyclus capax, Megamyonia nitens, Strophomena planocorrugata,* and *Liospira parva* are confined to one or both of the lower members of the Stony Mountain Formation and have not been recorded from the overlying Gunton Member of this formation. On Churchill River these species are likewise restricted to the Caution Creek and the lower 44 feet of the Chasm Creek Formation.

The relationship of Member 1 to the overlying Member 2 is not well understood, due to lack of significant outcrops along the river. Eleven feet of massive beds, referred to the top phase of Member 1, are overlain, however, by rubbly weathering limestone of Member 2 at localities 25283 and 25284. The fauna of the massive beds is similar to that of Member 1 at Chasm Creek, but contains what is possibly the significant addition of *Palaeofavosites okulitchi* Stearn, which is also found in the stratigraphically higher Members 2 and 3. In southern Manitoba, *P. okulitchi* first appears in the Gunton Member. Thus, although it is possible that the massive beds may belong to a higher horizon stratigraphically than any of Member 1 as exposed at Chasm Creek, the matter cannot be considered settled and these beds are regarded as the top part of Member 1.

The fauna collected from the massive beds include:

Palaeophyllum stokesi (Milne-Edwards and Haime)
P. raduguini Nelson
Lobocorallium trilobatum var. *major* Nelson
Bighornia patella (Wilson)
B. bottei Nelson
Favistella alveolata (Goldfuss)
Lyopora manitobensis Nelson
L. churchillensis Nelson
Calapoecia anticostiensis Billings
Palaeofavosites capax (Billings)
P. okulitchi Stearn
Manipora amicarum Sinclair
M. irregularis (Teichert)
Plaesiomys occidentalis (Okulitch)
Megamyonia nitens (Billings)
Lepidocyclus perlamellosus (Whitfield)
Trochonema coxi Wilson
Fremontoceras sp., cf. *F. loperi* Foerste
Apsidoceras milleri Nelson

The rock fragment containing *Manipora irregularis* was collected from rubble, beside the massive limestone. This species is characteristic of the Portage Chute Formation and may have been rafted downstream from its original position by ice. The lithology, however, indicates that it is probably derived from the massive beds.

Member 2 outcrops for about 8 miles along the banks of Churchill River from localities 25283 to 25289. This unit weathers as rubbly beds and stratification is obscured. The calculated thickness based on the regional dip of the underlying and overlying members is about 100 feet. It is rather similar lithologically to Member 1, except that the rock is less massive, breaking into 1- to 2-inch thick, rubbly weathering slabs, and fucoidal dolomite patches are not so dark a grey as those in Member 1. This member contains corals and a fairly abundant, although not varied, cephalopod fauna. The following species have been identified:

Beatricea nodulosa Billings
Palaeophyllum raduguini Nelson
Lobocorallium trilobatum var. *major* Nelson
Deiracorallium giganteum Nelson
Bighornia bottei Nelson
Lyopora churchillensis Nelson
Calapoecia anticostiensis Billings
Protrochiscolithus kiaeri Troedsson
Palaeofavosites alveolaris (Lonsdale) (?)
P. prolificus (Billings)
P. okulitchi Stearn
Catenipora sp.
Manipora amicarum Sinclair
Megamyonia nitens (Billings)
Lepidocyclus perlamellosus (Whitfield)
Trochonema coxi Wilson
Kochoceras bailliei Nelson
Paractinoceras (?) *churchillense* Nelson

Gorbyoceras giganteum Nelson
Digenuoceras okulitchi Nelson
Winnipegoceras callahani Nelson

The fauna of Member 2, in itself, is not diagnostic enough to permit accurate correlation of the member with the Stony Mountain Formation. If the fauna of the overlying and underlying members are considered, however, it would appear that Member 2 is approximately equivalent to some lower part of the Gunton Member.

Member 3 of the Chasm Creek Formation is exposed only at locality 25290, about 2 miles above Red Head Rapids, where it outcrops for about 1,000 feet along the north bank of Churchill River. The member has a minimum thickness of 15 feet and a maximum probably not much more. The lithology is similar to that of Member 2 except that several 3- to 6-inch thick beds of grey weathering cryptocrystalline, light grey, dolomitic limestone are interbedded with beds of the typical microcrystalline fucoidal dolomitic limestone.

Fossils identified from Member 3 include the following:

Beatricea clarki Nelson
Aulacera undulata (Billings)
Lobocorallium trilobatum var. *major* Nelson
Bighornia bottei Nelson
Phaulactis stummi Nelson
Lyopora manitobensis Nelson
Calapoecia canadensis var. *ungava* Cox
Palaeofavosites okulitchi Stearn
Manipora amicarum Sinclair
Trochonema coxi Wilson
Kochoceras bailliei Nelson
K. giganteum Nelson
Huronia septata Parks
Digenuoceras okulitchi Nelson
Antiplectoceras shamattawaense (Parks)
Charactocerina leithi Nelson

The fauna of this member is related to that of the underlying member, except for the addition of six recognizable species. These are *Beatricea clarki, Phaulactis stummi, Huronia septata, Kochoceras giganteum, Antiplectoceras shamattawaense,* and *Charactocerina leithi.* In southern Manitoba *Antiplectoceras shamattawaense* first appears in the upper part of the Gunton Member (Birse Member *of* Okulitch, 1943) and thus suggests a possible correlation.

Member 4, the uppermost unit of the Chasm Creek Formation, outcrops along Churchill River from about 2 miles above to about 2 miles below Red Head Rapids. At the last locality (*see* Pl. VII) the beds dip below river level and are not again visible except where the river has cut through the overlying Red Head Rapids Formation at Limestone Rapids and exposed a foot of the uppermost part of Member 4. The dip of Member 4 and of the overlying formation between Red Head and Limestone Rapids appears almost horizontal, probably because the river there changes to a more northerly direction nearly parallel with the assumed regional strike of the Ordovician strata.

Member 4 is a well-bedded, very fucoidal, microcrystalline, light grey to light yellowish grey dolomite weathering light grey with an almost bleached appearance, and typically breaking into beds 1 inch to 2 inches thick. The maximum measured thickness, exposed at Red Head Rapids, is 11 feet; the calculated maximum is about 20 feet. This dolomite appears to grade downward and laterally into lithologic types similar to those of Member 3. The Red Head Rapids Formation overlies Member 4 with an abrupt change in lithology (*see* Pl. VII).

Dolomitization has apparently destroyed most of the fossils in Member 4; poorly preserved dinorthid and strophomenid brachiopods, nautilicone cephalopods and trilobites are all that have been found. The only species identified are the brachiopod *Strophomena arcuata* Shaler (?) and the cephalopod *Kinaschukoceras churchillense* Nelson, neither of which is found in the Stony Mountain Formation. *Kinaschukoceras churchillense,* a large, easily recognizable nautilicone cephalopod, is characteristic of the member. Member 4 appears to grade both laterally and downward into Member 3 and thus is tentatively considered equivalent in age to the upper part of the Gunton Member of the Stony Mountain Formation.

On Nelson River beds of the Chasm Creek Formation outcrop at intervals along the south bank for 6 miles upstream from the entrance of Angling River. Downstream rubble of Chasm Creek lithology suggests that this formation underlies the drift for some distance. Although two distinct lithological zones of Chasm Creek strata were recognized they cannot be placed stratigraphically with reference to each other. Beds of the first zone outcrop intermittently for about 3 miles along Nelson River west of a point 3 miles upstream from Angling River. Fossil localities 25267 and 25268 occur in this area. At places, the dip of the beds varies but the average inclination over the area of outcrop is approximately parallel to the gradient of the river. The zone consists of four beds with a thickness of nearly 7.5 feet in descending order as follows:

Bed	4	Dolomite, yellow, microcrystalline, weathers orange. Fossils rare	5.0′ +
	3	Limestone, dolomitic, grey, microcrystalline, containing numerous white pelmatozoan columnals, fossiliferous, weathers orange, Grades upward into (4)	1′ 6″
	2	Limestone, dolomitic, orange-yellow, microcrystalline, rubbly, weathers mottled light grey and orange	4″
	1	Limestone, dolomitic, buff, cryptocrystalline, weathers grey to orange in beds 3 to 6 inches thick	6″+

Bed 3 contains the following fossils:

Beatricea nodulosa Billings
B. clarki Nelson
Aulocera undulata (Billings)
Lyopora manitobensis Nelson
L. churchillensis Nelson
Favistella alveolata var. *stellaris* (Wilson)
Lobocorallium trilobatum var. *major* Nelson
Palaeofavosites capax (Billings)
Catenipora rubra Sinclair and Bolton
C. robusta (Wilson)

The second zone outcrops along both banks of Angling River (locality 25269) between an eighth and a quarter mile upstream from Nelson River. Approximately 15 feet of grey weathering, cryptocrystalline to fine-grained, fucoidal, light brownish grey, slightly dolomitic limestone is exposed.

Fossils collected from this limestone include:

Lyopora churchillensis Nelson
Lobocorallium trilobatum var. *major* Nelson
Bighornia bottei Nelson
Protrochiscolithus kiaeri Troedsson
Palaeofavosites capax (Billings)
P. alveolaris (Lonsdale) (?)
Catenipora robusta (Wilson)
Megamyonia nitens (Billings)
Trochonema coxi (Wilson)
Huronia septata Parks
Digenuoceras okulitchi Nelson
Apsidoceras boreale Foerste and Savage

The fauna of both outcrop areas suggest that these Chasm Creek beds along Nelson River probably correlate with either Member 2 or 3 of the formation as exposed on Churchill River. More accurate correlation is not possible at present.

Red Head Rapids Formation

This formation is intermittently exposed along Churchill River for about 12 miles, from Red Head Rapids to about 4 miles below Limestone Rapids (locality 25293). It is distinguished from the underlying Chasm Creek Formation by an abrupt change in lithology. Wherever seen, the contact between the two formations is planar (*see* Pl. VII). The estimated minimum thickness of the formation, based on the regional dip of the underlying Chasm Creek Formation, is 45 feet; the maximum is uncertain, as the upper limits of the formation are not known.

The formation is divided into a lower (Member 1) and an upper member (Member 2). The lower member is the more widespread and is best exposed for 2 miles immediately downstream from Red Head Rapids. Beyond there outcrops are widely spaced to Limestone Rapids where the last occurs. The member has an estimated thickness of 25 feet and consists of an orange to grey weathering, microcrystalline, light yellow dolomite. This dolomite is well bedded, almost platy, and most beds are from 1 inch to 2 inches thick. At a few localities the rock breaks into massive beds 1 foot to 1.5 feet thick (*see* Pl. VII). An intensive search was made for fossils but no trace of any could be seen.

Beds of the upper member are known only at locality 25293, about 4 miles below Limestone Rapids. They consist of dolomite and cap a cliff with the lowest exposed beds occurring about 17 feet above river level. River deposits cover the lower part of the cliff so that relationships with the lower member are not known. The minimum thickness of the upper member is 17 feet. It consists of grey weathering, grey to yellowish grey, microcrystalline, slightly calcareous dolomite

in beds from 2 inches to 1.5 feet thick. The only fossils found in the upper member are single specimens of *Calapoecia* sp. and *Kochoceras* sp. II Nelson. Although the lithology of the Red Head Rapids Formation is similar to that of Silurian beds outcropping near Churchill, these genera are more suggestive of an Ordovician age for the formation. Thus on the basis of its stratigraphic position the Red Head Rapids is questionably correlated with the Stonewall Formation of southern Manitoba and considered to be Ordovician (*see* Stearn, 1956).

Downstream from locality 25293, Churchill River is devoid of outcrops until the Churchill area is reached. Hence the relationships of the Red Head Rapids Formation with stratigraphically higher strata are unknown.

Port Nelson Formation (Silurian)

This formation was named by Savage and Van Tuyl (1919), and considered by them to be the oldest Silurian formation in the Hudson Bay region. The outcrop of the type section on Nelson River, about 100 yards long, is situated on the south bank at a point about 10 miles downstream from Lower Limestone Rapids. The dip of the beds appears to be parallel with the gradient of the river. Savage and Van Tuyl stated that the formation, as exposed, is 28 feet thick. Beds of Port Nelson Formation probably extend along the river for 2 miles with Ordovician strata outcropping both above and below this. Presumably this occurrence is a synclinal Silurian outlier within the Ordovician.

The Port Nelson Formation at the type locality displays a rather rhythmic repetition of beds of brecciated dolomite, dolomite, and shaly dolomite. The section measured by the writer, 24 feet thick, is as follows:

Bed 18	Dolomite, orange to buff, fine- to medium-grained, weathers grey in irregular beds 6 inches to 1 foot thick	5′
17	Dolomite, grey, microcrystalline, weathers grey in beds about 2 inches thick	2′
16	Dolomite, shaly, greyish green, microcrystalline, weathers grey	6″
15	Dolomite, grey, brecciated, weathers grey	1′
14	Shale, greenish grey, weathers into beds about 1 inch thick	1′
13	Dolomite, grey, microcrystalline, weathers grey into beds about 6 inches thick. Thin green shale laminae at base	1′
12	Dolomite, grey, brecciated, weathers grey	8″
11	Dolomite, grey to greenish grey, microcrystalline, weathers to a rough, grey surface in irregular beds about 1 foot thick. Thin green shale laminae at top	2′ 6″
10	Dolomite, grey, brecciated, massive, weathers grey. Thin green shale laminae at top	1′
9	Dolomite, grey, microcrystalline, weathers grey into beds 1 inch to 6 inches thick, containing contorted laminae	3′
8	Shale, greenish grey	3″
7	Dolomite, grey, microcrystalline, weathers grey. Contains thin green shaly layers	8″
6	Dolomite, grey, brecciated, massive, weathers grey	9″

5	Dolomite, brownish grey, microcrystalline to fine-grained, weathers grey	1′ 9″
4	Dolomite, shaly, grey, cryptocrystalline, weathers light greenish grey	1′7″
3	Dolomite, cherty, grey, brecciated, weathers grey	9″
2	Dolomite, dark grey, microcrystalline, weathers grey with a smooth surface	9″
1	Dolomite, buff, fine- to medium-grained, slightly porous, weathers grey into beds about 2 inches thick	1′
	River level	

A second outcrop of the Port Nelson Formation occurs about 1½ miles down the river from the main outcrop and along the south side of Nelson River. This outcrop, about 50 feet long and 2½ feet high, consists of alternating dolomite and brecciated dolomite. The beds represented cannot be correlated with any particular ones in the type section.

Savage and Van Tuyl (1919) placed the Port Nelson Formation in the Alexandrian (Lower Silurian) Series. The present writer found the outcrops to be completely unfossiliferous although Bell (1880) noted the occurrence of a pentamerid brachiopod in them. Fossiliferous Silurian boulders, however, occur along the river banks for about half a mile above the type section as well as on the opposite side of the river. Savage and Van Tuyl apparently based the Silurian age for the formation upon the fauna they identified from these boulders—"*Zaphrentis* sp., *Favosites* sp., *Dinobolus* sp., *Stropheodonta* sp., *Virgiana decussata, Pterinea occidentalis, Hormotoma* sp., and *Primitia mundula* var *incisa*".

The lithology of the boulders is the same as that of the top 5 feet (bed 18) of the type Port Nelson Formation. Because of the occurrence of *Virgiana decussata* in the boulders a Middle rather than a Lower Silurian age is now indicated for the Port Nelson Formation (*see* Stearn, 1956, p. 19).

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