THE MIDDLE DEVONIAN ELK POINT GROUP IN MANITOBA

by

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ABSTRACT

The Middle Devonian Elk Point group in the subsurface of Manitoba is from 0 to 550 feet thick and comprises, in ascending order, the Ashern, Winnipegosis and Prairie Evaporite formations. The Elm Point formation of Baillie (1951) is not continuous in the subsurface and is treated as a lower unit of the Winnipegosis.

Ninety-six wells were studied, and samples and/or cores from twenty-two of these wells are described. Stratigraphic maps and cross-sections are presented for the group and its formations. The formations are age-dated and a correlation chart equates the Elk Point of Manitoba to other formations in Western Canada. The depositional environment of each formation is reconstructed.

The Ashern formation is a brick-red dolomitic shale or brown-red argillaceous dolomite and is from 10 to 60 feet thick. It is a residual shale reworked and redeposited by a transgressing Devonian sea.

The Elm Point unit of the Winnipegosis formation is a thin (0 - 60') light colored limestone deposited in a normal marine environment. The Winnipegosis is a buff saccharoidal dolomite and contains organic reefs. It ranges from a normal thickness of 60 to 160 feet, to as much as 360 feet where reef structures are present. It represents a normal marine carbonate episode in a stable shelf region. Dolomitization of the Winnipegosis is attributed to a seepage reflux action under conditions of aridity and slight restriction.

The Prairie Evaporite is principally halite and anhydrite, and rarely potash salts. It ranges in thickness from 0 to 400 feet and is the result of basin subsidence with a high degree of restriction in an arid climate.

The Winnipegosis is shown to be a potential hydrocarbon reservoir and its possibilities in this regard are discussed.

I

INTRODUCTION

GENERAL REMARKS

A thick succession of dolomites, dolomitic limestones, and evaporites of Devonian age underlies most of the northern Great Plains of North America. The Williston Basin occupies the central portion of the northern Great Plains; within it Middle Devonian strata are represented by a carbonate and evaporite section. The Elk Point group comprises the three lowest Middle Devonian formations of this area.

The area of discussion includes, in general terms, all of the Williston Basin area, and, in detail, that portion of the basin which lies within the province of Manitoba.

The Elk Point group is well suited for a stratigraphic study. Regional correlation markers are present within and adjacent to the group, and control density is sufficient to ensure accurate correlations. The group is present both in the subsurface and in outcrops, and is a mappable unit of moderate thickness. Well logs, sample information, core, and other data are readily accessible, permitting detailed study. Primary and diagenetic textures are not complicated by metamorphism, and with the possible exception of salt solution within the Prairie Evaporites, the group has been only slightly deformed since deposition.

The general Devonian stratigraphy and terminology for the Williston Basin area has been described by Baillie (1953). Wherever possible and applicable, the stratigraphic terms he defined will be used in this paper.

PREVIOUS WORK

Most of the wells drilled in Manitoba prior to 1900 were in search of water and the geological information which they afforded was merely a by-product. The 1930's saw a renewed interest in oil and gas exploration, and during that decade 4 wells were drilled into the Palaeozoic formations. From 1944 to 1950 approximately 6 more wells penetrated Palaeozoic horizons. Interest in the oil possibilities of Manitoba started in February, 1951, when the California Standard Company's Daly #15-18 well, near the town of Virden, obtained Mississippian production. Several good showings and semi-commercial discoveries in 1952 commenced active oil exploration in Manitoba. Since then about 85 wells have penetrated the Middle Devonian in Manitoba.

The term Elk Point formation was proposed by McGehee (1949) for a sequence of red shales, salt, anhydrite, and dolomite that underlies the Waterways formation in east-central Alberta. As a result of detailed palaeontologic studies, Crickmay (1954) concluded that the Elk Point formation, which previously was considered to be in part Silurian, was probably entirely of Devonian age. In 1953, Baillie elevated the Elk Point to group status including in ascending order the Ashern, Winnipegosis, and Prairie Evaporite formations.

The first detailed geological description embracing a part of the study area was made by Tyrrell (1892) whose excellent account describes in considerable detail Devonian strata of the Manitoba outcrop area. Whiteaves (1891, 1892) figured and described the fauna collected by Tyrrell. Whiteaves pointed out the relationship of the Manitoba Devonian with the Devonian of Europe on the basis of the occurrence of the brachiopod *Stringocephalus burtini* and the associated fauna. Kindle (1914) also described Middle Devonian strata of the outcrop area.

In 1950, Baillie published detailed descriptions of a number of Middle Devonian outcrop sections in the Lake Winnipegosis area of Manitoba. Webb (1951) showed the regional distribution of the Elk Point salt and discussed the general lithologic character of Middle Devonian strata. The cyclical aspect of Devonian sedimentation was emphasized by Andrichuk (1951) and he indicated the depositional thinning and disappearance of Elk Point strata toward southwestern Saskatchewan. Baillie (1953) described subsurface sections from Manitoba, Saskatchewan and North Dakota, and by integrating subsurface lithologic data with previous knowledge of the outcrop relations, he interpreted regional environments of deposition for the various Devonian units.

Ower (1953) discussed the general Elk Point lithology in southwestern Manitoba. McLennan and Kamen-Kaye (1954) published cross sections showing correlation and thickness of various Devonian units in Saskatchewan. In a comprehensive work, Warren and Stelck (1956) illustrated suites of Devonian fossils (including Winnipegosis species) from various localities in Western Canada. Greiner (1956) presented detailed petrographic descriptions and faunal lists of the Methy dolomite (Winnipegosis equivalent) in northeastern Alberta. Check (1956) pointed out the presence of Winnipegosis reefs buried by the Prairie salt unit in central Saskatchewan. Walker (1956) showed complex facies changes within the Winnipegosis - Prairie Evaporite sequence. In a later paper, Walker (1957) discussed the lithologic character, correlations, and geologic history of the Middle Devonian rocks in western Saskatchewan. In 1956, Van Hees presented a cross section of the Elk Point group from east central Alberta to western Manitoba. Goudie (1957) discussed the Middle Devonian salt of central Saskatchewan and her report included isopach maps of the Prairie Evaporite. Edie (1959) discussed Middle Devonian sedimentation in Central Saskatchewan and suggested the presence of huge atoll-like reefs within the Winnipegosis.

PRESENT STUDY

The results of an investigation of the lower part of the Devonian sequence in Manitoba are presented in this report. This detailed study in a local area is intended to amplify the regional analysis of Baillie (1953) and to complement further detailed local studies within other parts of the Williston Basin area.

A literature study of the Elk Point group in the Williston Basin was made to establish the relationship of the group as a whole to the major features responsible for its history. Based on this background information, a sedimentary-stratigraphic analysis of the Elk Point group in Manitoba was undertaken.

The geological history of the Elk Point group in Manitoba was interpreted through regional correlation sections, and isopach and lithofacies mapping. The study involved the determination of formation tops and thicknesses from mechanical logs for approximately 100 wells, and correlation of these wells. Detailed sample examinations and core studies were made for approximately 25 of these wells. Lithologic data for approximately 10 other of these wells were available from the Manitoba Mines Branch and Mines Branch publications. Picks of formation tops were substantiated by sample checks where any doubt existed as to a definite top. The results of the study have been integrated with published reports relating to the Elk Point group.

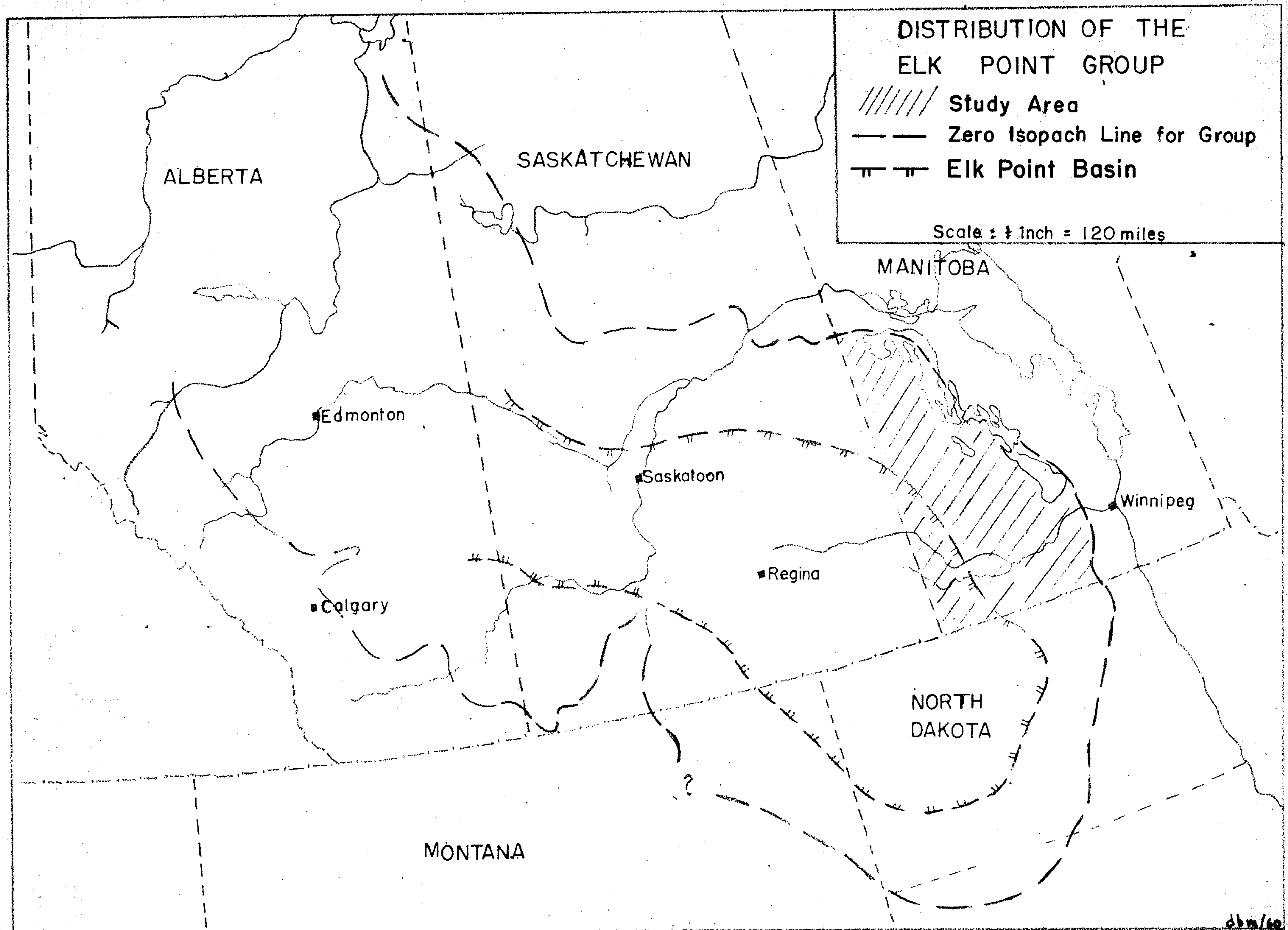

FIG. I Area of Elk Point Group, Area of Study, and Area of Elk Point Basin.

AREA OF STUDY

The distribution of the Elk Point group and the area of study are shown on Figure 1. (After various sources).

The area of detailed study (Figure 1) covered by this report is a triangular area of some 35,000 square miles, occupying the southwestern portion of Manitoba. The area is bounded to the south by the International Boundary, to the west by the Manitoba-Saskatchewan border, to the north and northeast by the western edge of the Precambrian shield and to the east by the Principal Meridian.

CONTROL WELLS

The location and type of control available for each well used in the study is shown in Plate 1. (In Pocket). Nearly 100 wells were studied, giving an average control density of approximately one point for every 350 square miles. Each well has been given a reference number and pertinent data are included in Appendix I. Lithologic descriptions of selected wells are given in Appendix II.

ACKNOWLEDGEMENTS

The preparation of this thesis was done under the direct supervision of Professor E. I. Leith of the University of Manitoba. The writer greatly appreciates the continued guidance, advice and constructive criticism rendered by Professor Leith throughout the course of the study.

The writer is greatly indebted to the Manitoba Department of Mines and Natural Resources, Mines Branch, for assistance in selecting the thesis topic and for their continued assistance, encouragement, and advice throughout the preparation of this report. In particular, the writer wishes to express his sincere gratitude to H. R. McCabe, provincial stratigrapher, who gave freely of his time to discuss stratigraphic problems and make suggestions regarding this dissertation. Thanks are also due to Miss B. Mills whose familiarity with the subsurface of Manitoba was of great assistance to the writer.

The writer wishes to thank the staff of the Department of Geology of the University of Manitoba, and his student colleagues for the many stimulating discussions and the free exchange of ideas on problems of Palaeozoic stratigraphy.

Permission was obtained from the Manitoba Mines Branch to make use of their stratigraphic base map for some of the plates presented with this report.

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II

D E S C R I P T I V E   S T R A T I G R A P H Y

GEOLOGICAL SETTING

Manitoba is situated geologically on the northeastern edge of the Williston Basin, an area characterized by intermittent differential subsidence and accumulation of sediments since Ordovician time (McCabe, 1959, p. 9). Palaeozoic sediments, chiefly carbonates of Ordovician to Mississippian age, dip gently to the southwest at an average of 30 feet per mile. Mesozoic sands and shales overlie the Palaeozoic sequence in marked unconformity and dip to the southwest at about 12 feet per mile. Flat-lying Cenozoic sediments are present locally in the Turtle Mountain area.

Cenozoic erosion and particularly Pleistocene glaciation have produced an erosion surface with a northeast slope resulting in the exposure at the erosion surface of a series of linear, north-northwest trending outcrop belts with successively older strata exposed to the northeast.

THE MIDDLE DEVONIAN BASIN OF DEPOSITION

The depositional basin in which the Middle Devonian sediments were laid down differed in shape and location from the present-day structural Williston Basin, and it is termed the Elk Point Basin. As used in this paper, the term Elk Point Basin refers to an elongated trough trending northwest-southeast from North Dakota and southwestern Manitoba to eastern Alberta, with its structural axis running between Regina and Saskatoon (Figure 1). The Elk Point Basin extends to the western limits of the area of reference. It shows closure on all sides except in the northwest where the axis of the basin continues into eastern Alberta.

THE ELK POINT GROUP

General Remarks. --The Middle Devonian Elk Point group comprises in ascending order, the Ashern, Winnipegosis, and Prairie Evaporite formations. The Elm Point formation, included in the Elk Point group by Baillie (1953), is not continuous in the subsurface and is discussed in this report as a lower unit of the Winnipegosis formation. The Ashern rests unconformably on the Silurian Interlake group and the Prairie Evaporite formation is overlain by the basal red beds, referred to as the 2nd red, of the Middle Devonian Dawson Bay formation. This stratigraphic sequence is illustrated in Figure 2.

Definition. --The term Elk Point formation was first proposed by McGehee (1949) for a red shale, salt, anhydrite and dolomite section underlying the Waterways formation of east-central Alberta. In 1953, Baillie elevated the Elk Point to group status to include the Ashern, Winnipegosis and Prairie Evaporite formations.

Expanded definitions of the Elk Point group in the central portion of the Elk Point Basin of Alberta by Van Hees (1956) created a Lower and Upper Elk Point group. The Upper Elk Point

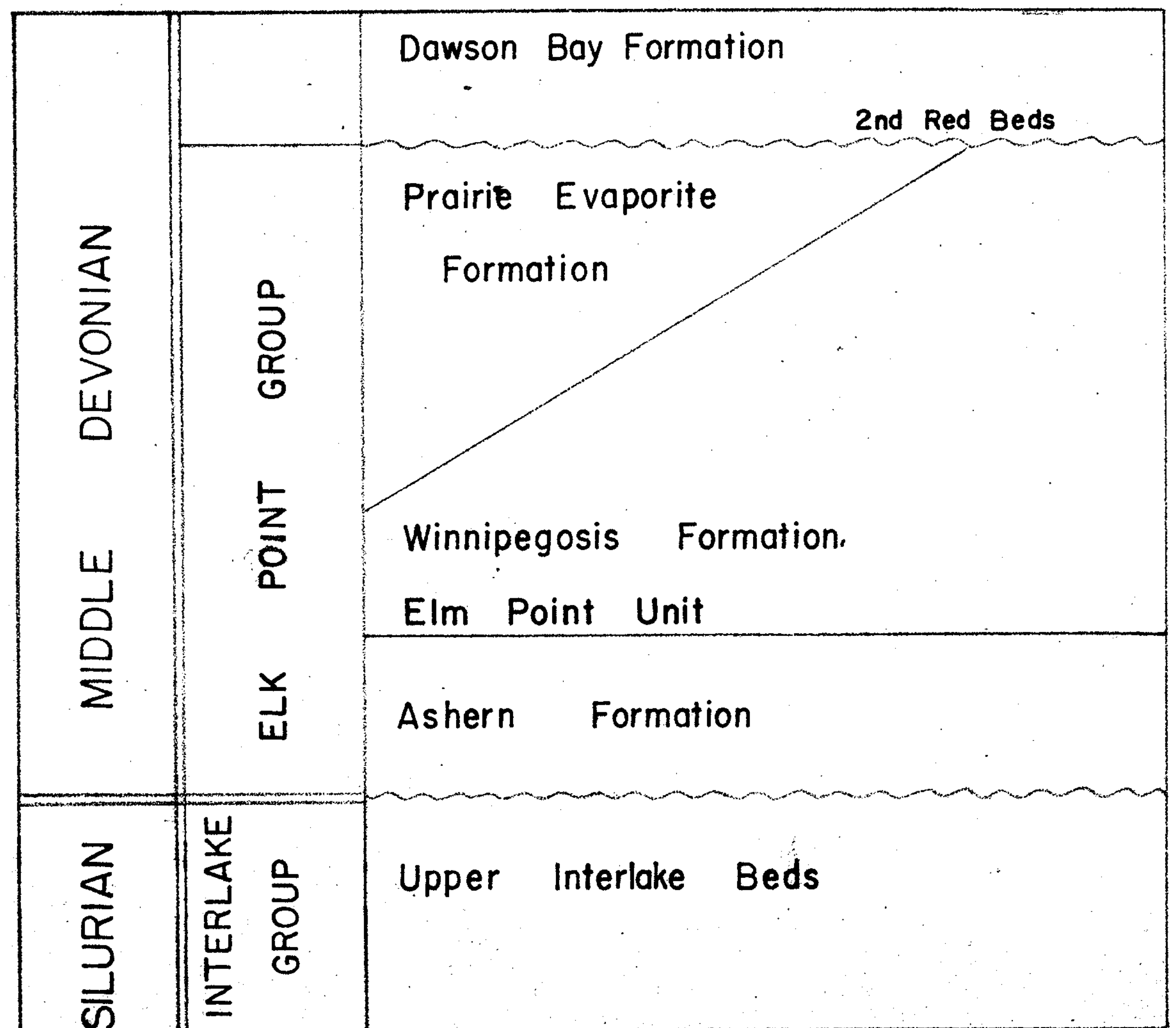

Fig. 2 Middle Devonian Stratigraphic Units in Manitoba

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group had previously been established as Middle Devonian by Crickmay (1954). The Upper Elk Point of Van Hees (1956) is equivalent to the Elk Point of Baillie (1953) and of this paper. The Lower Elk Point does not extend east of western Saskatchewan and the possibility exists that it is Ordovician rather than Devonian in age.

For the Williston Basin area and Manitoba, the lower limit of the Elk Point group is taken at the base of the Ashern formation which unconformably overlies older Palaeozoic strata throughout the area. The upper limit is taken at the top of the Prairie Evaporite formation or at the top of the Winnipegosis formation where evaporites are absent. The upper and lower limits of the Elk Point group are indicated for all wells on the cross sections (Plates 2, 3, and 4).

Underlying Beds. --Within the area of study, Middle Devonian strata of the Elk Point group rest unconformably on the Silurian Interlake group of Niagaran age. The uppermost Interlake beds in the Manitoba area are commonly a cream to white, crypto-crystalline to lithographic, high calcium limestone, which may be chalky in part. In many wells, however, these beds are a buff to pink, microcrystalline dolomite which may be argillaceous and/or silty. Typically, as in well number 14, a cream to white crypto-crystalline dolomite marks the top of the Silurian sequence. In a few places, as in well number 17, a thin, very argillaceous facies may develop in the Interlake some 20 to 40 feet below the Interlake carbonate top. Mechanical logs in areas where such a zone is developed near the top of the Interlake group show two typical Ashern "shale kicks" between Winnipegosis carbonate and well developed Interlake carbonate, leading to possible miscorrelation of the Ashern formation. In these wells the upper argillaceous zone was considered to be the Ashern formation. The lower zone can be correlated to known Interlake beds and an actual facies change from a highly argillaceous zone through slightly argillaceous to non-argillaceous Interlake carbonate can be traced on well logs.

Overlying Beds. --The Elk Point group is overlain by a widespread argillaceous zone that has been referred to as the '2nd red'. The 2nd red beds are the basal beds of the Middle Devonian Dawson Bay formation and it is thought that they are, in part, the residual product of minor subaerial solution erosion of the Prairie Evaporite salts (Walker, 1956). No definite evidence is available, however, to indicate whether or not an unconformity is present at the top of the Elk Point group.

Distribution and Thickness. -- Late Middle Devonian (Elk Point) seas were extensive through much of western and northwestern Canada and their areal distribution is shown on Figure 3 (after Warren & Stelck, 1958, Fig. 8, p. 37).

The areal extent of Elk Point sediments is shown on Figure 1. The group has the widest distribution of any Devonian strata in the Williston Basin area and ranges in thickness within the basin from 300 feet at its margins to over 700 feet at its centre (Baillie,

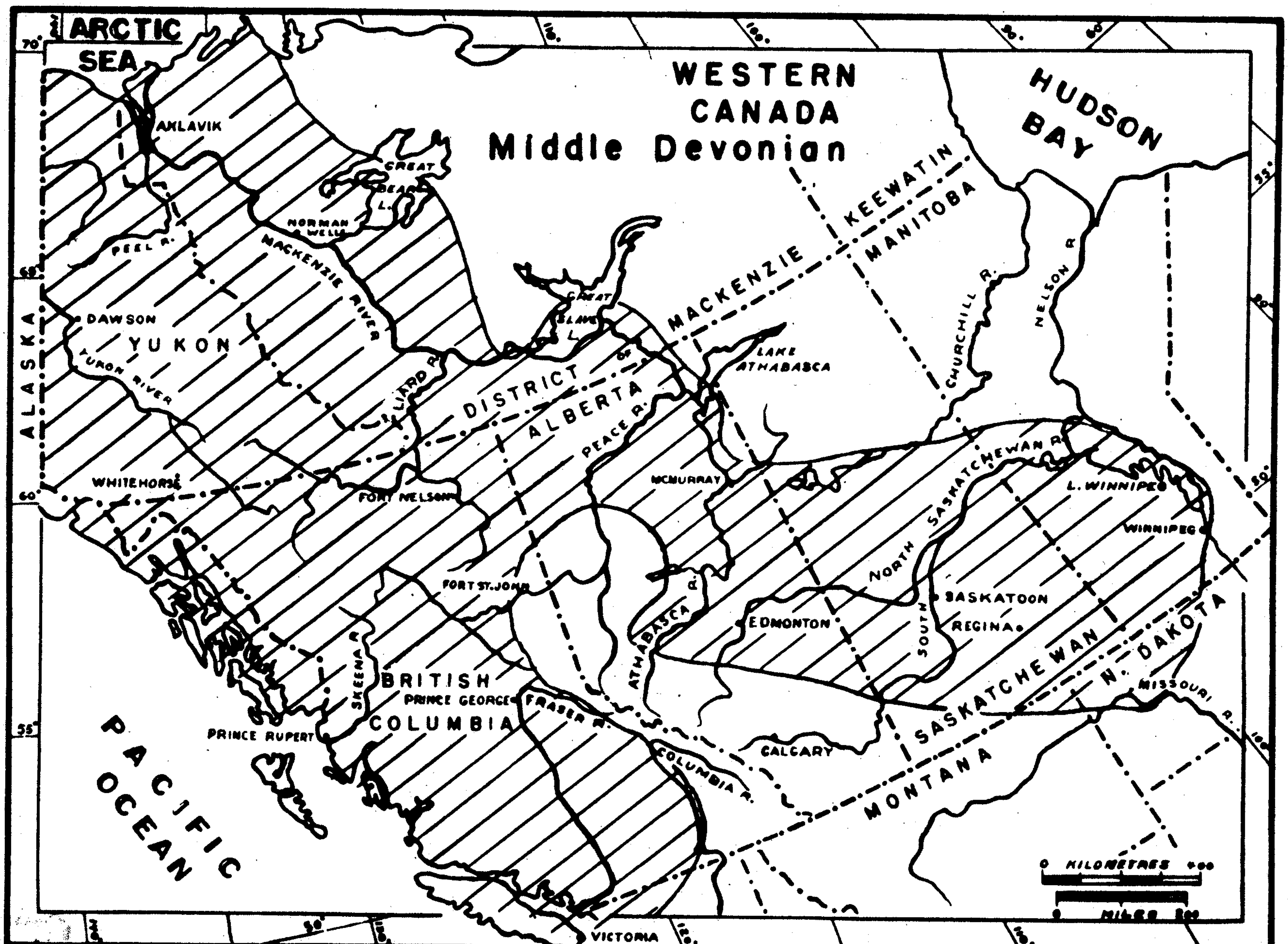

Figure 3 **Late Middle Devonian (Elk Point) seas.**

1953). Elk Point strata are present in the subsurface of Montana, North Dakota, Saskatchewan, Alberta and Manitoba and rise to outcrops at several places along the southwestern margin of the Precambrian shield. The principal outcrop belt is along the shores of Lake Manitoba and Lake Winnipegosis in Manitoba.

The distribution, thickness, and lithofacies of the Elk Point group in Manitoba is shown on Plate 5. Here the group ranges in thickness from its zero erosional edge in the north and east to a maximum of about 550 feet along the southern part of the western boundary of the province.

ASHERN FORMATION

Definition. -- The term Ashern formation was proposed by Baillie (1950) for the brick-red to greyish-orange argillaceous dolomites immediately overlying Silurian strata in the outcrop area. In the subsurface of Manitoba the Ashern formation is a reddish dolomitic shale. The upper contact with the overlying Winnipegosis is commonly gradational, and the lower contact with the Silurian Interlake group displays much evidence of the unconformable relationship with the underlying strata. Despite the gradational and erosional nature of the contacts, the limits of this thin argillaceous unit, between relatively thick carbonate units, can usually be distinguished on mechanical logs.

Lithology. --The Ashern formation in the subsurface of Manitoba consists typically of a brown-red to maroon-red, slightly silty, dolomitic shale, which is earthy and without bedding.

Locally, small anhydrite and gypsum lenses occur in the basal beds. The basal few feet may consist of a breccia which may or may not include fragments of the underlying rock. In the core from well number 76, the basal few feet is a breccia of dark reddish brown shale, greenish shale, anhydrite and white dolomite. The dolomite fragments are similar to the uppermost Silurian beds in this well. Uppermost Silurian beds commonly exhibit a brick-red coloration which may persist for 50 feet or more beneath the base of the Ashern and in some instances may cause difficulty identifying the Ashern-Interlake contact.

The silty aspect of the Ashern formation is best developed in the basal beds in the southeastern portion of the study area, where quartz of silt size grading to sand size is present.

In well number 51, the Ashern is represented by a dark grey to black shale with abundant, small, iron sulphide nodules and white anhydrite lenses.

In several places, a grey green dolomitic shale marks the top of the Ashern formation. Well number 49 illustrates the relationship of the grey green bedded shale to other Ashern lithologies. Here this shale overlies the typical reddish-brown dolomitic shale, with reddish brown anhydritic shale at the base of the formation.

In several wells the upper contact of the Ashern formation is difficult to discern lithologically because of a complete gradation from dolomitic shales of definite Ashern type through grey argillaceous dolomites to the purer carbonates typical of the overlying Winnipegosis formation. In well number 18 the entire Ashern sequence consists of 33 feet of grey and green-grey, dense, argillaceous dolomite with only the basal 5 feet developing a pinkish color.

Distribution and Thickness. --The Ashern formation underlies the Elk Point group in Manitoba and Saskatchewan. It rests on the Silurian Interlake group which thins westward so that at the Alberta border the Ashern directly overlies Ordovician carbonates.

The thickness and distribution of the Ashern formation in the subsurface of Manitoba is shown on Plate 6. The thickness is somewhat erratic and ranges from a few feet to over 60 feet.

WINNIPEGOSIS FORMATION

Definition. --The Winnipegosis formation was originally called Winnipegosan by Tyrrell (1892) but, as the adjectival suffix had a time connotation, the term Winnipegosis was recommended by Baillie (1953). This formation occupies the interval between underlying Ashern shales and overlying Prairie Evaporites, or the 2nd red zone where evaporites are absent.

In the outcrop area the upper contact of the Winnipegosis formation is sharp and distinct with the overlying red and green shales (Baillie, 1951). The upper contact is similarly sharp in the subsurface, and only in areas where a highly anhydritic Winnipegosis top is overlain by massive anhydrite of the Prairie Evaporites is the contact somewhat gradational lithologically. As has been previously discussed, the relationship of the Winnipegosis to the underlying beds may be somewhat gradational. The limits of the Winnipegosis formation are easily recognized on mechanical well logs.

Elm Point Unit. --The Elm Point was originally defined by Kindle (1914, p. 251) for the limestone exposed near Elm Point on the east shore of Lake Manitoba. The Elm Point is a mottled, yellowish grey limestone underlying Winnipegosis dolomite and overlying Ashern shales throughout the outcrop area (Baillie, 1951, p. 13). Baillie (1953) included the Elm Point limestone in his definition of the Elk Point group although he did not utilize it as a formation through the subsurface area of his study.

In the present study, Elm Point strata were recognized in only a few wells. Probable Elm Point beds are found in well number 17, where over 70 feet of brown-grey, microcrystalline limestone with small brown spores occurs immediately above the Ashern formation. This represents the maximum thickness for the Elm Point limestone. Throughout the subsurface of the area studied the Elm Point is difficult to distinguish, probably because of complete dolomitization, and therefore is apparently discontinuous. As it is not a definable formation in the subsurface, strata equivalent to the Elm Point formation are included within the Winnipegosis formation in this study.

Areas where the Winnipegosis formation has a high limestone content, most of which may be an Elm Point limestone unit, are readily discernible on the limestone-dolomite ratio map for the Winnipegosis formation (Plate 7). The best and most continuous development of the Elm Point limestone is found in the outcrop belt, particularly along the eastern shores of Lake Manitoba (Baillie, 1951).

Reef Development. --Structures which have been interpreted as reefs have been observed in field outcrops of the Winnipegosis formation on the islands and shores of Lakes Winnipegosis and Manitoba (Baillie, 1961), and in several of the wells examined in the present study.

Thick-bedded to massive dolomite cliffs of the outcrop area are considered by Baillie (1951) to be eroded remnants of organic reefs or bioherms. The structureless central cores, with rather steeply dipping, flanking beds draping over them, together with the presence of such reef-building colonial elements as corals and stromatoporoids, are evidence for the acceptance of these as true organic reefs.

The evidence for the presence of bioherms within the subsurface is of a somewhat different and necessarily less complete nature.

In determining the presence of reefs, any thickening of the suspected formation or strata may indicate reef growth. If this thickness is somewhat erratic in distribution, and appears not to be merely associated with the depositional "wedging" of the rock units, added evidence is provided. Isopachs of the Winnipegosis formation (Plate 7) show marked, erratic, local thickenings of from 75 to 150 feet which are explained by the presence of bioherms or reefs.

It is well known that reef cores are notably lacking in stratification. In a few of the well cores examined, unlayered or structureless sections are present. Undoubtedly, some of this appearance is due to the massive nature of the rock but in many places it is found with other features, such as unusually thick sections and the presence of organic material, in such a way as to suggest reef cores.

An abundant and varied fauna is one of the essential criteria for biohermal growth. Colonial reef building forms -- corals, stromatoporoids and algae -- are particularly necessary, but other faunal types, which contribute fossil debris to the structures, are also important. Winnipegosis time was extremely favourable for organic growth. Corals, stromatoporoids, and brachiopods were numerous (Baillie, 1951). Bryozoans and sponges were less so; algal growths are not easily recognized, but may have been extremely important as reef builders. In brief, the mere presence of colonial types of corals and stromatoporoids within the formation is enough to make one suspect that there may have been reef building.

The presence of fragmental material may provide another criterion for reefs. Due to complete dolomitization, it is difficult to identify all of the fragmental material of the Winnipegosis as fossil fragments. However, the fact that much of the fragmental material observed in the Winnipegosis appears to be pieces of fossils, points to an origin in a fossil-rich source, such as a bioherm or biostrome.

Finally, combinations of the foregoing observations may substantiate that a reef exists.

Winnipegosis reefs in Manitoba exist as isolated structures with the possible exception of a large reef buildup developed near the northwest edge of the study area trending northwestward to the Manitoba-Saskatchewan border.

Lithology. --The Winnipegosis formation consists of reefal and shelf-type lithology. Shelf-type lithology makes up by far the greatest portion of the Winnipegosis formation in Manitoba. It is typically a buff to light grey brown dolomite with very fine sucrosic, or very fine crystalline, to microsucrosic or microcrystalline texture and patches of poor intercrystalline porosity. This lithology may be fragmental in part, or may be interbedded with fragmental dolomite which suggests a biostromal character for those parts of the Winnipegosis of the shelf province.

The best development of reef lithology occurs in well number 75. The reef zone here is represented by an unbedded, partly fragmental, fine crystalline, buff dolomite, with abundant algal and/or stromatoporoid material and excellent vuggy porosity. The reef dolomite of well number 75 is slightly calcareous and much recognizable organic material has been preserved. Occasionally, in wells penetrating a completely dolomitized reef section, as in well number 92, almost no organic material can be recognized.

Inter-reef deposits consist largely of biostromal or shelf-type dolomites, overlain by Prairie Evaporite salts.

The lowermost Winnipegosis beds are a dense to microcrystalline, buff to brown, sometimes argillaceous, dolomite, which commonly contains bituminous laminae. These basal Winnipegosis beds are thought to be equivalent to the brown-grey, microcrystalline limestone of the Elm Point formation of the outcrop area.

Throughout the shelf area of Manitoba where the Winnipegosis formation is directly overlain by the 2nd red beds, the upper contact of the Winnipegosis formation is sharp and distinct. However, close to the basin area where the Winnipegosis is overlain by the Prairie Evaporite, the contact is considerably less sharp although still discernible on mechanical logs. There, the uppermost Winnipegosis beds commonly contain white, crystalline anhydrite as vug or fracture fillings, or irregular inclusions which may be several inches or larger in size. The upper contact of the Winnipegosis may, in fact, be gradational through an anhydrite-bearing dolomite to pure anhydrite of the Prairie Evaporites. Black or brown, argillaceous or bituminous partings also occur in the upper beds of the Winnipegosis formation. The presence of anhydrite and thin partings in this zone were observed best in core from wells 27, 36, and 51. In well cuttings minor amounts of anhydrite and shale in the Winnipegosis are difficult to distinguish from the cavings from higher horizons of the same lithology. As these minor lithologies are difficult to assign to the Winnipegosis on the basis of well cuttings, and as they are almost always present in upper Winnipegosis core, it is concluded that this characteristic may be much more common than is generally indicated on lithologic descriptions of wells in the area.

Minor beds of calcitic dolomite are found throughout the Winnipegosis formation, both in the reefal and shelf-type deposits. The calcareous content is variable and thin interbeds of limestone may occur within the Winnipegosis. However, most of the limestone within the Winnipegosis occurs at the base of the formation and this has been designated as the Elm Point limestone unit. The relative amount of limestone to dolomite in the Winnipegosis formation, and therefore the degree and distribution of dolomitization within the Winnipegosis, is shown on Plate 7.

Distribution and Thickness. --The Winnipegosis formation occurs throughout the area of study and its distribution and thickness in Manitoba is shown on Plate 7. In the subsurface of Manitoba, the Winnipegosis formation shows a considerable variation in thickness due to the presence of biohermal-type reefs. In wells that do not penetrate reef strata, the thickness ranges from just under 50 feet to over 150 feet, whereas in wells drilled on reef structures the formation may be as much as 350 feet thick.

The Winnipegosis shelf-type strata thicken southwestward from their zero edge until they attain a maximum thickness of just over 150 feet along the line where the most easterly well-developed Prairie Evaporite overlies the Winnipegosis. Southwest of this line the Evaporite thickens but the underlying Winnipegosis actually becomes thinner, decreasing from 150 feet to about 50 feet near the Manitoba-Saskatchewan border. By comparing a combined isopach of Winnipegosis and Prairie Evaporite thicknesses (approximately equal to the total Elk Point isopach, Plate 5) with separate isopachs of the Winnipegosis (Plate 7) and the Prairie Evaporite (Plate 8), it can be observed that the thinning (or thickening) of the Winnipegosis is compensated for by thickening (or thinning) in the Prairie Evaporite. Striking evidence of this is offered by a comparison of wells number 66 and 67 which are but 3 miles apart. Well number 67 penetrates 237 feet of Prairie Evaporite salt and 77 feet of Winnipegosis carbonate. Well number 66 passes through only 156 feet of salt, but penetrates 150 feet of reefal Winnipegosis dolomite. This represents 73 feet of additional Winnipegosis section, whereas the Prairie Evaporites become thinner by 71 feet. Thus, irregularities in Winnipegosis or Prairie Evaporite thicknesses disappear in isopachs of the total Elk Point group.

The distribution of Winnipegosis reefs in Manitoba is somewhat erratic and the present information seems to indicate that these reefs exist as isolated structures. Three reefs in the west central portion of the study area were penetrated in wells 66, 75 and 76, where the Winnipegosis formation is from 150 to 200 feet thick. Wells number 75 and 76 are shown on Stratigraphic Cross Section B-B_1, Plate 3. These reefs exist on the approximate line of demarcation between the shelf province to the east and the basin province, in the extreme west portion of the study area. Other Winnipegosis reefs were found in the northern portion of the study area where well control is sparse. Reefs in the Winnipegosis and Mafeking area, encountered in wells 86, 92 and 93, appear to be isolated structures within the shelf province. Reefs in the vicinity of the Duck Mountain Forest Reserve have been postulated to exist as one large trend, and this interpretation correlates with work done in Saskatchewan by Walker (1956). In wells penetrating reefs in the northern portion of the study area, the Winnipegosis formation ranges in thickness from 250 to 300 feet.

The erratic and discontinuous distribution of the Elm Point limestone makes it evident that it does not deserve formation status in the subsurface, despite its being regarded as such in the outcrop area by Baillie (1951). It occurs irregularly in the southern portion of the study area and uniformly throughout the southern portion of the outcrop belt. It shows no distinctive areal development except near to and in the outcrop belt, especially along Lake Manitoba, where its presence is continuous and it exists as a well developed, distinctive, and unlike its subsurface occurrences, as a traceable unit.

P R A I R I E   E V A P O R I T E   F O R M A T I O N

Definition. --The term Prairie Evaporite formation was proposed by Baillie (1953) for the salt and anhydrite beds that form the upper unit of the Elk Point group throughout most of the Elk Point basin area. The upper limit of the formation is marked by the base of the 2nd red beds, and the lower limit is the top of the Winnipegosis formation.

The type section lies between the depths 4,350 feet and 4,990 feet in the Imperial Davidson No. 1 well, Lsd. 16-8 27-1-W3, Saskatchewan (Baillie, 1953, p. 24).

Lithology. --In Manitoba, the Prairie Evaporite formation consists principally of anhydrite in areas where the thickness of the formation is less than 100 feet. Wherever the formation exceeds 100 feet in thickness the principal lithology is rock salt (halite), although interbeds of anhydrite are not uncommon. Potash salts are also present.

The anhydrite of the Prairie Evaporite formation is white and crystalline or blue-grey and massive, and commonly contains minor interbeds of buff, dense dolomite. The halite is white, occasionally pink, crystalline or massive, and may contain thin, soft, green shale bands near the base of the salt section.

The salt is almost exclusively sodium chloride (halite) but potassium salts are present in places near the top of the salt section. Potash salts, primarily sylvite and carnallite, occur in a few wells along the southwestern border of Manitoba. Potassium chloride or potash zones are usually indicated by very prominent deflections on the gamma ray curve and can be identified in well 28 (see Stratigraphic Cross Section $C-C_1$, Plate 2), and well 53 (see Stratigraphic Cross Section $C-C_1$, Plate 4).

Distribution and Thickness. --The present distribution and thickness of the Prairie Evaporite in Manitoba is shown on Plate 8. West of approximately the 100 foot isopach, that is, in areas where the thickness exceeds 100 feet, the formation consists mainly of salt, although anhydrite may occur as interbeds. East of the 100 foot isopach, to the eastern edge of the Prairie Evaporite, the formation consists almost entirely of anhydrite. This relation is shown in two wells less than 20 miles apart. Well number 77 penetrates about 40 feet of Winnipegosis dolomite overlain by about 210 feet of salt and anhydrite, whereas, in well number 73, a few miles to the southeast, the Winnipegosis is about 90 feet thick and is overlain by 85 feet of anhydrite and minor anhydritic dolomite, but no salt occurs. This indicates the very rapid thickening of the Prairie Evaporite formation coincident with the occurrence of rock salt. From well number 77 the formation thickens westward to the Manitoba - Saskatchewan border at an average rate of 13 feet per mile.

Anhydrite overlies salt near the basin margins and in places this anhydrite extends to the shelf area where it overlaps shelf-type Winnipegosis strata. Such a relationship is exhibited in the above comparison of wells number 77 and 73. A large embayment of anhydrite extends out onto the shelf province in the Brandon - Minnedosa - Neepawa area. Over this area the anhydrite is uniformly thin averaging 20 to 40 feet in thickness.

The wells in which potash salts occur are along the southwestern edge of the study area, where the evaporite thickness exceeds 350 feet. These wells penetrate the thickest evaporite sections in Manitoba, and are closer to the centre of the evaporite basin than any other wells in the study area.

Evidence for Salt Solution. --Salt solution within the Prairie Evaporite and collapse of the overlying beds, has been recognized in Saskatchewan. The evidence for solution has been extensively reviewed by Tompkins (1955), Milner (1956), Walker (1956), and Goudie (1957).

Evidence for salt solution is based on the fact that the sudden thinning of the Prairie Evaporite salt along the eastern flank of the Elk Point evaporite basin, and elsewhere, appears to be too abrupt to be a normal depositional feature. Also, units above very thin salt, or no salt, areas may be anomalously thick or anomalously low on structure suggesting that salt removal has caused collapse of the overlying beds.

The only place in Manitoba where there is any direct

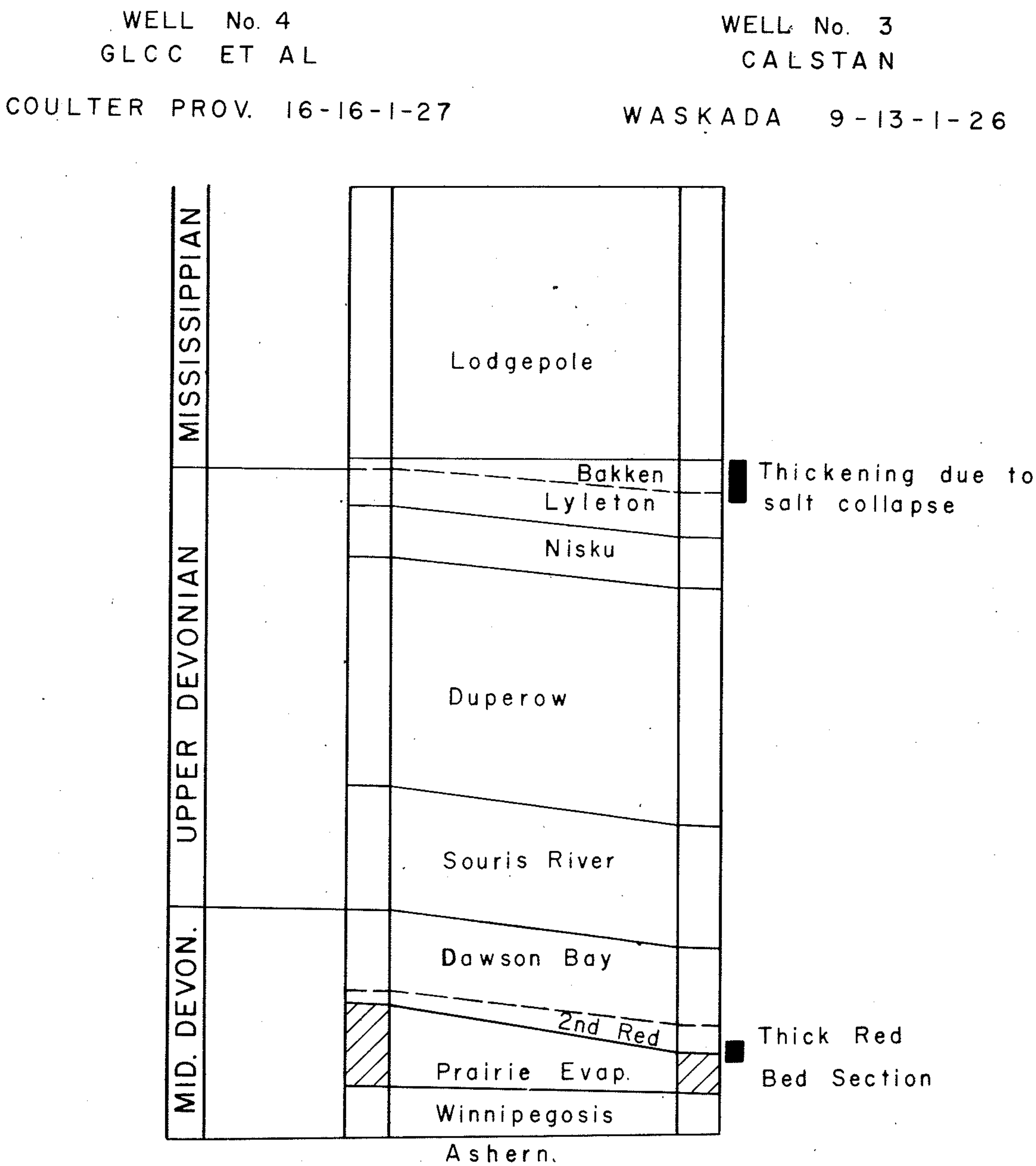

Fig. 4. Evidence of Salt Solution

Stratigraphic correlations between the Coulter and Waskada wells. The indicated thickening of the Bakken and Second Red Bed sections in the Waskada well possibly is due to salt collapse during Bakken time.

evidence suggesting that salt solution took place is in the Waskada area (McCabe, 1959, p. 52). The Bakken formation, of Mississippian age, is anomalously thick in this area and McCabe attributes the anomaly to salt solution and collapse. Correlation between wells number 3 and 4 (Figure 4; after McCabe, 1959, Fig. 17, p. 50) shows that the thickness of the section between the base of the Devonian (Ashern) and the top of the Bakken is almost identical in both wells. However, in well number 4 the Elk Point group is over 100 feet thicker than in well number 3 due to the presence of a thick bed of salt, which is not found in the number 3 well.

McCabe states, "The Devonian section overlying the Prairie Evaporite correlates uniformly between the two wells, with only a slight thickening in the number 4 well, which would be expected on the basis of regional trends. The Bakken section, however, is approximately 100 feet thicker in the number 3 well. The thickening of the Bakken section, along with complementary thinning of the Devonian salt section by almost the same amount, is very strongly suggestive of salt collapse in the Waskada area during early Bakken time. .... In addition, the Devonian 2nd red in the number 3 well is unusually thick (60 feet) suggesting that the added thickness is the insoluble residue from the dissolved salt beds."

Walker (1956) suggested a post-Mississippian to Triassic age for the salt collapse in Manitoba. However, McCabe's data would indicate that salt collapse took place at least in part during Mississippian time.

The solution of the salt is attributed to movement of subsurface waters through the area. Studies of the salinity and formation pressures by Milner (1956) indicate that this movement is in a general northeast direction and is still taking place today. A number of brine springs, high in sodium chloride content, flowing from the upper beds of the Winnipegosis formation at Salt Point in Dawson Bay, Lake Winnipegosis, were noted by Baillie (1951). This suggests that removal of salt by solution is still going on.

Undoubtedly appreciable quantities of salt and anhydrite have been removed so that the original areal extent of the evaporite formation was likely much greater than its present distribution, especially to the north-east.

AGE AND CORRELATION

The Middle Devonian age of the Elk Point group has long been established. It is based on the occurrence, in outcrops of the Winnipegosis formation, of *Stringocephalus burtini* Defrance, one of the index fossils of late Middle Devonian (Givetian) age. This age has been confirmed by potassium - argon dating methods, applied to potash salts within the Prairie Evaporite formation (Folinsbee et al., 1956). Computations made from a sample of sylvite from the Verbata No. 2 well (Lsd. 7-24-41-24-W3, Saskatchewan) have indicated an age between 285 and 347 million years, or upper Middle Devonian (Givetian) age, for the potash.

The exact age of the Ashern formation has not been as well established. Baillie (1951, p. 11) considered that either a Devonian or Silurian age was possible. The material which constitutes much of the Ashern began to form soon after the initial uplift of the Lower Paleozoic carbonates, indicating a post-Middle Silurian to pre-Middle Devonian age for this material. However, as will be demonstrated later, much of the Ashern formation was laid down during the transgression of the Middle Devonian sea, and consequently (as was noted by Van Hees, 1956) the Ashern formation should be considered of Middle Devonian age.

Figure 5 is a correlation chart for the principal Middle Devonian formations of Western Canada. It shows the relationship of the Manitoba Elk Point group to other Middle Devonian formations throughout Western Canada.

The Elk Point group of Manitoba and Saskatchewan correlates with the Upper Elk Point group of Van Hees (1956) in the central and southern Alberta plains. The Prairie Evaporite is a direct correlative of the "first salt" of McGehee (1949) of the Elk Point type section in Alberta. Crickmay (1954) set up informal members to designate the units of the Elk Point in Alberta. Crickmay's member 1 can be taken as correlative with the 2nd red beds of the Manitoba area. His member 2 is equivalent to the "first salt" of McGehee, and the Prairie Evaporite formation. Member 3 is shown by Crickmay as continuous with the Winnipegosis formation. Member 4 could not be individually traced to the Manitoba section. Members 1 - 4 of Crickmay constitute the Upper Elk Point group of Van Hees.

The Ghost River formation of the central and southern Alberta foothills and mountains has been correlated with the Elk

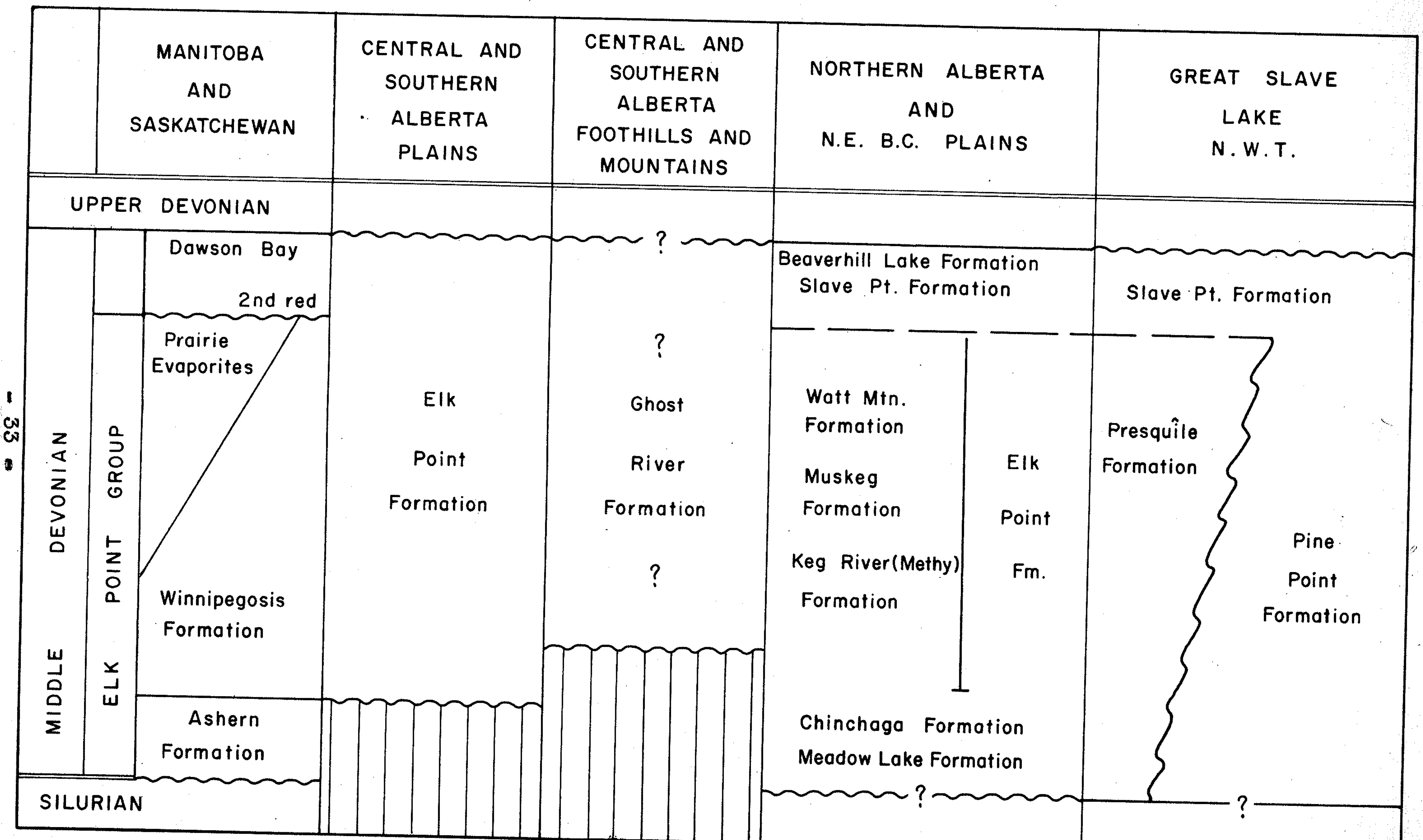

Fig. 5 Middle Devonian Correlation Chart, Western Canada.

Point strata by Webb (1951) and Andrichuk (1951). As the Ghost River formation is unfossiliferous it has been a subject of controversy and the possibility exists that it is pre-Devonian. However, its present position within the Middle Devonian appears to have been more or less accepted.

The Methy formation of northeastern Alberta bears a striking petrologic resemblance to the Winnipegosis of the Manitoba outcrop area (Greiner, 1956). The Methy is correlated with the Winnipegosis on the basis of fossils; both formations contain _Stringocephalus burtini_ and generally similar faunas. Both formations outcrop as klints, or eroded bioherms, and portray a great number of similar characteristics.

The Methy formation is equivalent to the Keg River formation of northwestern Alberta and the northeastern British Columbia plains. Here, the Keg River is overlain by the Muskeg and Watt Mountain formations, all three of which are considered to constitute the Elk Point in this area. The Watt Mountain has been correlated with member 1 of Crickmay (1954) and if this correlation is correct it is possible that the upper part of the Elk Point of this area is in fact somewhat younger than the Elk Point of Manitoba and Saskatchewan.

In the Great Slave Lake area the Presquile formation is correlative with the Winnipegosis of Manitoba. Again it is the presence of _Stringocephalus burtini_ and its associated fauna that establishes the correlation of these formations. Greiner

(1956, p. 2078) shows also that a striking petrologic similarity exists between the Winnipegosis, the Presquile, and the Methy formations. The Pine Point formation of the Great Slave Lake area was correlated by Baillie (1950, 1953) to the Elm Point formation of the Manitoba outcrop area because of a marked similarity in the faunal assemblage of the two units. Present information suggests that the Pine Point limestone has a somewhat similar relationship to the Presquile dolomite as the Elm Point limestone facies has with the Winnipegosis dolomite.

Correlation of the Winnipegosis formation with the Ramparts formation of the Northwest Territories has been established on the basis of similar fauna, both containing Stringocephalus burtini. In addition, micropaleontologic evidence from the Ramparts formation of the northern Rocky Mountains in the vicinity of the Alaska Highway indicates that this formation may be correlative to the Winnipegosis of Manitoba (McKennitt, 1959, pp. 22, 23). Correlation of the Middle Devonian of the Northwest Territories with strata to the south is a complex problem. Much geological work is now in progress in this area and the Ramparts beds are being set up under a new terminology. As this information becomes available, it appears evident that the Winnipegosis formation is not equivalent to the entire section which was formerly lumped under the name "Ramparts formation". However, as the determination of formations and their correlations in the north is still in a highly controversial stage, it is considered adequate for this report to say that the Winnipegosis correlates with the "Ramparts formation" of the Northwest Territories.

III

INTERPRETIVE STRATIGRAPHY

GENERAL REMARKS

The consideration of Elk Point strata in the first part of this report has consisted of the presentation of pertinent factual data, with little or no interpretation of these data. In the following pages the significance of the data is considered and the depositional history of the Elk Point group is inferred from this information.

The reader is asked to keep in mind that the interpretation presented covers the Elk Point group for only the Manitoba area. However, every effort was made to keep this interpretation compatible with information assimilated from publications concerning the Elk Point outside of Manitoba.

THE SUB-ASHERN UNCONFORMITY

In many wells the surface of the Silurian Interlake formation is oxidized and reddened. Also, in some cored sections it has been observed that the Interlake surface has been slightly anhydritized. The carbonates immediately below the Ashern have undergone minor replacement by anhydrite through a process of secondary alteration. The occurrence of large secondary "prophyroblasts" of anhydrite in dolomite has been described by Fuller (1956, p. 42). Furthermore, the Ashern-Interlake contact may be marked by a shale and dolomite 'breccia'. The 'breccia' resulted because the carbonates immediately below the Ashern were cavernous and the vugs have been infilled by shales and silts of Ashern lithology. These circumstances suggest that the Silurian surface was subjected to sub-aerial solution - weathering, and was later infilled by residual clay deposits. In short, from the truncation of the Silurian surface, and the altered character of the carbonates at the Interlake-Ashern contact, it can be deduced that the base of the Ashern represents a stratigraphic unconformity.

ORIGIN OF THE ASHERN FORMATION

Much of the material of the Ashern formation was derived as a product of erosion of the Silurian surface. The isopach map of the Ashern formation does reflect the palaeotopographic conditions at post-Silurian time. However, the products of Silurian erosion probably filled depressions in the Silurian peneplain to create what must have been a monotonous topography of low relief. The Middle Devonian sea transgressed over this surface.

The origin and exact age of the Ashern have for some time been in doubt. Recent work by Van Hees (1956) and Walker (1956) has established a probable Middle Devonian age for the Ashern formation. Previous workers have stressed the red coloration of the Ashern shales and from this, concluded that the shales were a residual lateritic deposit. They further argued that since it was of a residual origin it could have started to form soon after the initial uplift of the Lower Palaeozoic carbonates. Walker (1956, p. 132) suggested that undue emphasis may have been placed on red coloration, for much of the color seen in drill cuttings may have been due to the reddened Interlake carbonates, fragments of which could be wrongly interpreted as lagging samples of the Ashern formation. Red beds within the Ashern formation may, therefore, be less abundant than previously supposed. Furthermore, some red beds, and all grey beds within the Ashern, are thinly bedded and presumably water lain. These bedded shales are thought to be clay deposits eroded, transported, and reworked, probably in a near-shore environment of the transgressing Devonian seas. Hence the bedded Ashern red beds are dominantly a reworked and redistributed laterite deposit.

In general it can be stated that although the greater part of the Ashern was derived from a residual clay it was actually laid down during the Middle Devonian marine transgression. Consequently, it is Middle Devonian in age. This argument alone does not rule out the possibility that Ashern sediment was deposited by a Lower Devonian sea. However, since no known Lower Devonian sediments are found anywhere near the area of Ashern occurrence, it is assumed that no Lower Devonian inundation took place here.

It has been noted that unbedded basal red shales of the Ashern may pass upwards through poorly bedded variegated green and red shales into bedded grey shales and grey, argillaceous carbonates.

Color changes within the Ashern are interpreted as being related to a transgressive Middle Devonian sea.

The red coloration is due to the highly oxidizing conditions that prevailed during the late Silurian to Middle Devonian erosion interval, and the oxidizing environment of an extremely shallow water condition existing in the very initial stages of the transgression of the Devonian sea. Local developments of anhydrite and gypsum near the base of the Ashern suggest extremely shallow water depths, and the evaporites might even have been deposited in playa lakes or on tidal flats. The transition from a highly oxidizing environment to the very slightly oxidizing conditions of a normal marine environment, took place with the deepening of the transgressing sea. The variegated red and green shales were deposited during this transition period. The establishment of a slightly reducing environment brought about the reduction of ferric iron oxides within the laterite clay during its redistribution, and consequently the red coloration has been removed from the upper Ashern sediments. Stronger reducing conditions are thought to have influenced the sediment of well number 51 where the Ashern is represented by a black shale, with associated iron sulphide nodules.

The occurrence of quartz silt and very fine sand in the Ashern formation in the extreme southeast part of the study area suggests that an area to the south and/or southeast was emergent during this time, and provided a source of clastic material. This source area was probably the positive element Souixia that was a prominent tectonic feature during much of Palaeozoic time.

WINNIPEGOSIS SEDIMENTATION

General Remarks. --The lithologic character and uniform distribution of Winnipegosis strata throughout Manitoba indicate that this area was essentially tectonically stable and a normal marine environment prevailed throughout this depositional episode.

A normal marine environment is characterized by unrestricted open circulation of sea water that results in uniform normal salinity and slightly oxidizing conditions throughout. Normal marine carbonate strata are typically light-colored, well-bedded, and fossiliferous. The texture is uniform, and fine to microcrystalline, or fragmental. Dolomitization of these strata usually produces saccharoidal textures.

Shelf-type Deposits. --The Elm Point limestone of the outcrop area is a typical, normal marine, shallow water deposit of a stable shelf area. However, the Elm Point unit, in many subsurface occurrences, is a darker colored, denser, argillaceous, apparently unfossiliferous unit. This lithology represents the typical carbonate deposit of a mildly unstable shelf area. Much of the lowermost Winnipegosis dolomite is a dense, buff to brown, partly argillaceous, non-fossiliferous dolomite, which is also typical of mildly unstable shelf deposits. It is postulated therefore, that from the time of transgression of the Devonian sea until the end of Elm Point deposition most of southwestern Manitoba was subsiding at a slightly greater rate that subsidence would have occurred in a true stable shelf area.

A mildly unstable shelf has a greater net rate of subsidence with time, than a truly stable shelf. The most important change this introduces is a reduction in the length of time during which environmental agents operate on the sediment before it is buried. In subsurface areas where the Elm Point limestone is developed there was insufficient time for the magnesium-bearing sea waters to replace the limestone with dolomite. Furthermore, in general, dolomitization is effected in shallow waters and limestone is the product of deeper water sedimentation. The occurrence in the Elm Point of perfectly preserved, delicately frilled brachiopods (Atrypa artica, Warren; Baillie, 1953) indicates a marked absence of wave or current agitation and supports a theory of slightly deeper water deposition for the limestone. Only lithologic evidence is available to indicate that areas of limestone deposits were more unstable than areas of contemporaneous dolomite deposits. There is no apparent increase in thickness of sediment accumulated in areas of limestone occurrence. However, it is concluded that the Elm Point limestone facies represents deposition in mildly unstable shelf areas, where the water was slightly deeper, and burial slightly more rapid, than in areas where dolomite is the resulting deposit.

Increased stability of the shelf region following Elm Point time gave rise to uniform deposition throughout the study area. The greatest portion of the Winnipegosis formation is a widespread, light-colored, microcrystalline to finely sucrosic dolomite, which is typical of the normal marine environment of a stable shelf. Interbedded fragmental dolomites are typical of the same conditions, and where the fragmental beds attain a significant thickness, they suggest a biostromal character for those parts of the formation.

The presence of colonial organic remains in the Winnipegosis dolomites implies warm, shallow water. Today, abundant colonial type organisms are rarely found at depths greater than 300 feet. The warm, shallow, Winnipegosis sea favoured the development of a prolific fauna which was capable of organic precipitation of limestones. The Winnipegosis, therefore, represents a shallow water calcareous mud deposit.

Where the Winnipegosis is overlain by evaporites, the uppermost Winnipegosis beds commonly are anhydritized. In these instances a metosomatic replacement of dolomite by anhydrite has given rise to an intimate mixture of dolomite and anhydrite at the Winnipegosis - Prairie Evaporite contact. The invasion and replacement of a porous dolomite by evaporitic solutions has been described by Walker (1956). Interbedded primary dolomites and anhydrites also occur during the latest stages of Winnipegosis sedimentation, and some difficulty arises in distinguishing primary and secondary evaporites at the Winnipegosis-Prairie Evaporite contact. Hence, in some places this contact is not well defined.

Reef Deposits. —Biohermal reefs appear in the shelf environment in isolated and discontinuous masses rather than in the linear trends typical of basin margin environments (Sloss, 1947). Such reefs are commonly coral-stromatoporoidal or algal in formation, and are relatively small and of limited vertical extent. Two textures are associated with reef masses; one is fragmental, and occurs on reef flanks where material torn from the reef by wave action comes to rest; the other is associated with the reef core and results from the accumulation of a compact mass of coral, algal, and other calcareous structures with numerous voids marking the positions of soft tissues. Ordinarily, the reef core is altered to a nearly structureless, porous, saccharoidal dolomite in which the original organic constituents are unrecognizable.

The foregoing comments by Sloss (1947) apply explicitly to the Winnipegosis reefs of the Manitoba shelf area.

Winnipegosis time was extremely favorable for organic growth, and coral and stromatoporoid colonies built upward and outward from slightly higher parts of the ocean floor. Winnipegosis reefs began to grow shortly after the stabilization of the shelf area at the close of Elm Point sedimentation, and continued to grow until the end of Winnipegosis time. In the extreme northern and northeastern portions of the study area, where no Elm Point phase is present in the Winnipegosis, it is probable that reef growth was initiated following Ashern deposition, continuing until the close of Winnipegosis time. The largest reefs in the Winnipegosis are found in this area and presumably this reflects a longer period of growth for these reefs.

All the reefs appear to be the shelf-type with the possible exception of a large reef trend in the northwest part of the study area. This large reef trend may be the result of greater differential subsidence along a linear belt which has given rise to a larger, more definitely oriented reef mass.

The presence of huge atoll-like reefs within the Winnipegosis of Saskatchewan has been postulated by Edie (1959). No evidence was found in Manitoba to suggest that these reefs are atoll-type reefs. However, as no single reef body was penetrated by more than one well it would be difficult, if not impossible, to suggest or deny, that the Manitoba reefs were atoll in nature. Much closer well control will be necessary before this can be decided.

Dolomitization. --In spite of their abundance, stratigraphic span, and geographic range, the origin of bedded dolomites is a controversial subject. Geologists generally agree that most bedded dolomites were produced by post-depositional alteration of limestones. Disagreement arises over the time of alteration and the nature of the processes involved. In general, however, it is agreed that dolomite forms best when the following environmental conditions are met (Steidtman, 1917; Fairbridge, 1957):

(1) Marine, rather than non-marine, surroundings.

(2) Shallow, rather than deep, waters.

(3) Warm temperatures.

(4) Increase in salinity, especially of magnesia salts, stimulates dolomitization. This condition finds its maximum expression in enclosed basins or arms of the sea.

(5) Reducing conditions generally exist where dolomitization is active. How can warm, shallow, marine conditions exist together with reducing conditions? The answer probably lies in the favourable conditions existing for the production of life in these shallow warm seas. A high life incidence means a high death incidence; hence, on the sea floor proper, where actual conditions of sediment deposition are most important, dead and decomposing organisms are extremely abundant. Reducing conditions can also exist with the development of saline environments. A surprisingly high percentage of bedded dolomites are associated with evaporites.

(6) Major dolomite deposits of both normal marine and restricted environments are limited to, or closely associated with, shallow epicontinental shelves or oceanic banks. On the shelf area, sediments are maintained for long periods of time within the diagenetic realm, and dolomitization is the rule.

Dolomitization of the Winnipegosis carbonate was effected prior to compaction, but following the deposition of the original sediment.

The fact that the Winnipegosis dolomite is overlain by evaporites suggests that there was a gradual restriction of the Winnipegosis seas. Thus, even during the deposition of the Winnipegosis the concentration of dissolved solids, in particular magnesium, may have been greater than normally found in shallow shelf seas. This slight excess of magnesium could have been the essential condition that produced penecontemporaneous dolomitization. Chemical replacements and changes occurred in the original sediment, an aragonite mud, while it was slowly being precipitated on the sea floor, and it was altered to dolomite before compaction. A discussion of the chemical processes involved in displacing the calcium by magnesium is beyond the scope of this report. However, the essentially geological problems involved will be analysed.

The Winnipegosis was deposited in an open marine environment where warm shallow water lay over a broad, gently sloping shelf. Evaporation of water in shallow, near-shore areas caused an inflow of normal marine sea waters, from more basinal areas, toward the depressions in the surface of the sea caused by evaporation. As this sea water flowed across the wide shelf areas it became more and more concentrated because of evaporation, and both its salinity and density increased. In near shore areas, the concentration eventually increased until these heavier brines sank and began to drain seaward down the sloping shelf. Seaward escape of dense brine is called reflux action (King, 1947). Water flowing in from the open ocean, replaced that lost by refluxion and by evaporation, and maintained circulation across the shallow shelves. With free refluxion, concentrations on even the broadest shelves seldom become great enough to inhibit organic activity. Hydrodynamic currents pushing down these almost imperceptible slopes were persistent, but reflux was not rapid. The reflux of this brine along the shelf slope produced a thin zone at the depositional interface which had essentially a penesaline environment. Recalling the optimum conditions of dolomite formation mentioned previously it is evident that such an environment provides all of the conditions necessary for dolomite formation.

A hot, heavy, highly alkaline, carbon-dioxide free, magnesium supercharged brine existing at the depositional interface provides both a chemically favourable environment for magnesium-calcium exchange and a vehicle for removing displaced calcium. This concentrated brine could displace connate waters in already precipitated limestones and in so doing alter them to dolomite (Adams and Rhodes, 1960). The heavier concentrated brine waters would displace connate waters of normal concentration or the heavy brine would itself be the original connate water in the unconsolidated sediment. The seepage of these brines into the unconsolidated sediment provides the necessary conditions for the evolution of lime-muds to dolomite.

The maximum secretion of magnesium (the highest magnesium to calcite ratio) by primitive organisms and calcareous algae occurs in the warmest waters (Fairbridge, 1957). It has already been established that the Winnipegosis sea was a warm sea, so that the original carbonate precipitate might well have been a magnesium-rich calcite mud. Fairbridge (1957) states that such magnesium-rich calcites are highly susceptible to early diagenetic (pene-contemporaneous) dolomitization. With a pH of high alkalinity and a slight increase in pressure and temperature (as provided by concentrated brine of the type under discussion in association with the sediment) the calcite mud sediment will change into dolomite.

The concept of dolomitization by refluxion and seepage was introduced by Adams and Rhodes (1960). They attributed the formation of bedded dolomites in the Permian Basin of Texas to the alteration of metastable limestones by hypersaline brines refluxing from restricted evaporite lagoons. The present writer proposes that the alteration of metastable limestone can also take place by the refluxion of a penesaline brine over an essentially unrestricted evaporite shelf. Such a process is submitted to explain the dolomitization of the Winnipegosis formation. In the Winnipegosis, however, partial and local restrictions may have been provided by Winnipegosis reefs.

Minor amounts of dolomite occurring at the top of the Winnipegosis in intimate association with, and in some cases inter-bedded with evaporites, is regarded as a primary precipitate. It is thought that the waters of the basin that were partially isolated under conditions of aridity were enriched in magnesium by the continuous inflow of normal sea water and by the precipitation of calcium carbonate and sulfate. Enrichment in this manner would favour the formation of magnesium carbonate or dolomite.

PRAIRIE EVAPORITE DEPOSITION

Increasing restriction of the Middle Devonian seas initiated evaporite deposition. Prairie Evaporite time was characterized by a marked basining and a restricted arid or evaporitic environment.

The deposition of thick evaporite sequences implies both a connection with the open sea and some barrier which restricts free circulation with the open sea. During Prairie Evaporite time the Elk Point basin was probably connected to an open seaway to the northwest and north. However, within the area of reference, there is no evidence of the barrier which isolated the Elk Point basin from the open sea.[1] Edie (1959) suggested that a tectonic barrier may have been present to the northwest of the Elk Point basin. A natural barrier in the seaway at this point would have effectively cut off the central evaporating basin to the east and south from the open sea, and from the higher parts of the basin to the northwest

[1] Between Fort Nelson B.C., and south of Great Slave Lake, there is a major reef sill of Middle Devonian age. It is bounded to the south by the Peace River high and to the north by the Providence high, and is believed to have separated the Elk Point evaporite basin from the open sea to the northwest.

and north. It is also probable that reef growth along the tectonic barrier augmented the silled effect and restriction.

The considerable thicknesses of relatively pure evaporites deposited during Prairie Evaporite time can be explained only by uniform subsidence contemporaneous with precipitation. The thickness and purity of evaporites in the central basin area in Saskatchewan reflect a strong basinal tendency and suggest that the salt was deposited very rapidly, possibly in the order of one inch per year (Edie, 1959).

Near the margins of the basin anhydrite is an important constituent of the evaporite sequence particularily in the upper beds. A large anhydrite 'embayment' covers much of the central portion of the study area. This relatively thin anhydrite appears correlative with the anhydrite near the eastern basin margin. This indicates that the greatest expansion of the evaporitic environment occurred during the final phases of Prairie Evaporite deposition and in many places evaporites seemingly overlap shelf deposits.

The development of potash salts in the upper Prairie Evaporite beds mark conditions of extreme restriction and desiccation. The concentration of rare residual bitterns results from prolonged evaporation of an enclosed saline sea, after the removal by precipitation of calcium sulphate (as gypsum or anhydrite) and sodium chloride.

Elk Point sedimentation closed with a cessation in the subsidence of the basin area. As subsidence ceased, the basin quickly filled up with precipitated sediment and a base level of deposition was reached. The final stage of sedimentation was the precipitation of potash salts from the highly concentrated, residual brine of the central basin area.

DISCUSSION OF MAPS

General Remarks. -- Although the plates presented are largely self-explanatory and are referred to elsewhere in this report, a brief description of each is given below and their important features are discussed.

Plate 1, Index Map. -- All the control points used and the type of control available at each point are given on Plate 1. This map also shows the erosional edge of the Elk Point group and the edge of the Precambrian shield, and locates the three cross-sections presented on plates 2, 3 and 4.

The outcrop area of the Elk Point group as shown is considered to be that area of occurrence of Elk Point rocks that is not overlain by younger bedrock, although in places it may be drift-covered. Accordingly, the eastern limit of the overlying Manitoba group marks the western edge of the Elk Point outcrop belt. The eastern margin of Jurassic rocks marks the southwestern edge of the outcrop belt.

Plates 2, 3 and 4, Stratigraphic Cross Sections. -- These plates illustrate the correlations from well to well throughout the area of study. They show the uniformity of the Winnipegosis formation over the shelf area. These sections illustrate the very rapid westward thickening that accompanies the appearance of evaporites, particularly halite, at the basin margin.

Plate 5, Isopach-Lithofacies Map, Elk Point Group. -- The Elk Point group is characterized by a marked differentiation between carbonate and evaporite facies and a low clastic content. Except in the southeastern peripheral area of the map, clastic ratios do not exceed $\frac{1}{4}$.

The shelf area is well delineated by a high carbonate facies and a marked uniform thickness of sediments. A rapid increase in the rate of change of thickness and lithofacies marks the margins of the Elk Point basin, and, in places, the evaporite ratio increases from $\frac{1}{4}$ to 4 in less than 20 miles. The evaporite ratio line of 4 approximately delineates the basin area. The evaporite ratio line of 1 encloses essentially all areas of salt deposition. The evaporite ratio line of $\frac{1}{4}$ approximately delineates the basin margin and shelf areas except in the Brandon area where this ratio line seemingly overlaps shelf areas.

Winnipegosis reefs on the northern shelf area which are not covered by evaporites appear in the isopachs of the Elk Point group. Reefs along the basin margin are not evident because, as has been discussed, thickened reef sections are overlain by compensating thins in the Prairie Evaporite.

Plate 6, Isopach Map, Ashern Formation. -- The Ashern isopachs show an irregular pattern which strongly suggests an erosional surface. This map is a reflection of the paleotopographic conditions at post-Silurian time. However, the character of the isopachs suggest that Ashern material probably filled depressions in the Silurian peneplain surface to create what must have been a monotonous topography of low relief.

Plate 7, Isopach and Limestone-Dolomite Ratio Map, Winnipegosis Formation. -- The Winnipegosis shows a uniform thickening westward across the southern portion of the Manitoba shelf. It reaches a thickness of just over 150 feet and then thins westward towards the basin area. The line of westward thinning of the Winnipegosis is approximately the basin margin zone and approximately where evaporites begin to appear in significant thicknesses.

The isopachs delineate reefs within the Winnipegosis both on the shelf and along the basin margin. All appear to be isolated structures except for the large thick trend in the Duck Mountain Forest Reserve area. This trend is thought to be the result of greater subsidence and/or better conditions for reef growth along this belt.

The limestone to dolomite ratios are significant in only two areas. The relatively higher limestone content in the southwestern corner of the map area is probably a result of carbonate deposition in slightly deeper waters than the surrounding area. This has been discussed under the section on dolomitization of the Winnipegosis. The higher limestone content along the southeastern tip of the study area is probably due mainly to erosion of much of the overlying dolomite, leaving the Elm Point limestone facies to dominate the ratio calculation.

Plate 8, Isopach Map, Prairie Evaporite Formation. -- The Prairie Evaporite isopach shows a very rapid basinward thickening west of the basin margin.

The 100-foot isopach approximately delineates an area of dominantly halite deposition to the west, and dominantly anhydrite to the east.

The large broad evaporite "embayment" over the central area of the shelf consists of from 20 to 40 feet of anhydrite. This area could represent a true minor depositional embayment. It could also represent the remains of a thin cover of anhydrite which once spread over all of the shelf province and which has been subsequently removed everywhere by erosion except in the central Manitoba area. No evidence to support either theory was found in the present study.

SUMMARY OF ELK POINT SEDIMENTATION

Deposition during the Middle Devonian appears to have been cyclical. Walker (1957) recognized three major depositional cycles within the Middle Devonian of Saskatchewan. Each cycle starts with a red shale and passes upwards through saccharoidal dolomite into an evaporite. Each of the cycles can be recognized in Manitoba. The first cycle is the Elk Point group.

The geologic events of the Elk Point group can be summarized with the following statements. Initially, the Middle Devonian seas flooded over an old erosion surface and reworked and redeposited much of the residual clay developed on that surface. Following this relatively rapid transgression there was a period of tectonic stability, and normal marine environment prevailed throughout this depositional episode. This was a period of extremely favourable conditions for the development of marine life, as indicated by Winnipegosis reefs. The development of strong basinal tendencies and a high degree of restriction in the Elk Point basin caused increasingly evaporitic conditions. Evaporitic conditions first produced penecontemporaneous dolomitization of the Winnipegosis, but as restriction of open marine circulation increased it resulted in precipitation of anhydrite, then salt, and lastly, potash. Finally active deposition was terminated as the base level of deposition was reached. This completed one major cycle of sedimentation for the Middle Devonian.

Succeeding cycles in late Devonian were essentially similar and the reader is referred to Walker (1957, p. 135) for a discussion of these.

IV

E C O N O M I C   C O N S I D E R A T I O N S

PETROLEUM POSSIBILITIES

In the area of study no commercial oil or gas fields have been discovered in the Winnipegosis formation. However, oil is being produced from the Winnipegosis (in addition to the Silurian reservoir unit) at the Outlook field in northeastern Montana, and a number of wet gas and oil occurrences have been reported from the equivalent Muskeg formation in northwestern Alberta. Three hundred and ninety feet of oil-cut mud (estimated to be 50% oil) has been reported from the Ashern-Dawson Bay interval at a well on Cedar Creek anticline in eastern Montana (Edie, 1959, p. 1052).

In central Saskatchewan, heavy black oil (or bitumen) has been noted in samples near the top of the Winnipegosis, and a few drill stem tests of the Winnipegosis have recovered slightly oil-cut mud, from wells outside of the present limits of the Prairie salt. Within the present limits of the salt only one or two cases of oil-stained samples have been noted (Edie, op. cit.)

The Winnipegosis provides structures and lithologies favorable for the accumulation of hydrocarbons. Winnipegosis reefs have the necessary porosity and permeability to be hydrocarbon reservoirs. Significant amounts of salt water have been obtained on drill stem tests of the upper part of reef carbonate sections in central Saskatchewan, indicating a good development of porosity and permeability.

The most porous and permeable reef dolomite sections are those in which abundant stromatoporoids are present. The sections are interpreted to represent the fore-reef facies (Edie, 1959). Pores comprise fossil cavities, including cellular pores in stromatoporoids and corals, hollow stems of crinoids, and interfragmental vugs. Very little solution porosity appears to be present in the reef masses. The presence and amount of secondary infilling of pores by anhydrite and/or salt in the upper reef section greatly influences the porosity and permeability. Sections within the present limit of the Prairie Evaporite show a variable development of a zone of secondary infilling near the top of the reef section. Outside of the present limit of the Prairie Evaporite, secondary infilling of Winnipegosis pore space is minor and does not influence porosity.

Porosity in the Winnipegosis is not confined to the reef sections, and poor to fair intergranular porosity also occurs in thin beds in off-reef sections.

The presence and control of permeability barriers in these thin porous zones is thought to be related to the extent of dolomitization of these strata, more complete dolomitization giving a better porosity development. These permeable units in off-reef sections should be considered as possible carrier beds for the migration of hydrocarbons.

Winnipegosis reefs should be favorable sites for the accumulation of petroleum. These reefs should be excellent traps because they are overlain by a good cap rock. Evaporite beds such as anhydrite and rock salt will effectively seal in fluids. Outside of the present area of evaporites the Winnipegosis is overlain by the "Second Red" shale. Variations in the thickness and development of the Second Red make it a poorer cap rock than the evaporites, but it should act as an effective seal to the migration of hydrocarbons.

Possible source beds for petroleum occur within the Elk Point group. Baillie (1953, p. 60) describes a thick Winnipegosis black limestone-shale sequence as follows:

> "The dark-colored dense basinal limestone that occurs below and adjacent to the salt in northwestern North Dakota and eastern Montana was deposited under euxinic conditions that

> favored preservation of organic matter. Oil shows and staining on fracture surfaces suggest the oil is indigenous and that the dark limestone can be considered as a source rock. -- Reef occurrences marginal to such euxinic basins would have greater (oil) possibilities than the shelf reefs."

For reefs in the vicinity of the study area to trap oil originating from the above source involves a long distance of migration for the oil. The migration paths of oil would be expected to follow paths of least resistance (highest permeability) in a general up-dip direction. From a regional dip standpoint, and from the presence of permeable off-reef carrier beds in the Winnipegosis, it could be postulated that hydrocarbons would migrate from this source into Manitoba.

Black bituminous shale partings up to $\frac{1}{4}$ inch thick are common within the Winnipegosis, particularly in the off-reef facies. The partings are dull to shiny black on a fresh surface and have a dark greyish-brown streak. These black bituminous shale partings are considered a possible source rock for oil with a migration of short distance.

The presence of large shelf or pinnacle-type reefs in the northern part of the study area and along the northern shelf of the Elk Point basis in

Saskatchewan, indicate a reefal area exists over a distance of at least 250 miles. Bioherms built up either continuously or intermittently along this trend. The possibility exists that this reefal trend continues westward to where it is represented by Methy dolomite reefs in east-central Alberta.

Biohermal reef development over a possible trend of several hundred miles greatly enhances the hydrocarbon prospects of the area. Furthermore, drilling to date has evaluated only a small percentage of the possible reefal area of this trend. Most of this area lies outside the limits of the Prairie Evaporites and presumably conventional seismic methods of exploration could be used to locate these reefs. These reefs are shallow and could be tested economically. A serious drawback to the prospects of these northern reefs is their great distance from any known source beds. However, if these are atoll-type reefs, such as Edie (1959) postulated to exist in the Winnipegosis of central Saskatchewan, then petroleum could have been generated within the lagoonal facies of these reefs.

The best prospects for petroleum in the Winnipegosis appear to be the reefal bank adjacent to the source bed facies of the center of the Elk Point basin. These reefs were referred to by Baillie (1953, p. 60) and lie near the Saskatchewan-North Dakota border in southeastern Saskatchewan and may be present in the southwest corner of Manitoba.

Results of exploration of Middle Devonian reefs associated with evaporites in Saskatchewan and Manitoba have been disappointing. However, in view of the favorable aspects of the Winnipegosis, and in view of oil production found in the Michigan Basin under very similar conditions, further work seems to be demanded.

Exploration for Winnipegosis reefs presents some special problems. The low contrast in velocity between anhydrite, reef dolomite, and the surrounding salt present special problems in seismic interpretation (Edie, 1959). This makes the precise location of Winnipegosis reefs buried in salt, difficult if not impossible to locate with presently developed geophysical methods. Gravity methods have been at least partly successful in locating reefs buried in salt in Ontario. Edie (1959, p. 1055) suggested a program of lithofacies and biofacies analysis, combined with stratigraphic test drilling as a relatively effective and economical method of exploration. Certainly, knowledge of the controls of porosity, of the relationship of lithologic facies to structure and the facies significance of isopach trends should be a means of delineating favorable areas and localizing exploration.

POTASH OCCURRENCE

Potash salts in Manitoba underlie a narrow crescent-shaped area from Township 19 south to the International Boundary and from the western boundary of Manitoba as far east as Range 27. They are found at a depth of approximately 2600 feet along the northern extremities of their occurrence, but are at a depth of over 4000 feet in the extreme southwest corner of the Province.

The main potash zone in the Prairie Evaporite of Manitoba is overlain by 60 to 85 feet of halite; a substantial "salt back" is considered essential for the successful mining of potash beds. The potash zone is about 6 to 8 feet thick, and composed principally of halite and sylvite, and grades 25% K_2O or better (Bannatyne, 1960, p. 3).

The potash deposit in Manitoba occurs a few hundred feet closer to the surface than most of the deposits in Saskatchewan. Despite the greater abundance of potash in Saskatchewan this factor makes the Manitoba potash deposit a potential economic asset.

V

S U M M A R Y   A N D   C O N C L U S I O N S

This report has described the stratigraphy and lithology of the Middle Devonian-Elk Point group in Manitoba. An attempt has been made to reconstruct the depositional environment for each of the formations within the Elk Point group.

The Ashern formation is a residual shale which originated by erosion of the Silurian surface. It was reworked and redeposited by a transgressing Devonian sea.

The Elm Point facies of the Winnipegosis formation marks the initial subsidence phase of the Elk Point basin. As the basin was taking shape this was a period of mild instability, but nevertheless, a normal marine carbonate episode. Winnipegosis dolomites reflect a relatively stable shelf and a normal marine environment. Shelf-type reefs were built up in an environment that was highly favorable for the development of organic life. An arid climate and the development of slightly restricting conditions led to the development of a zone of penesaline waters refluxing basinward across the shelf area. This penesaline brine seeped into unconsolidated lime-muds to cause their dolomitization.

A high degree of restriction accompanied by a marked increase in subsidence led to the deposition of the Prairie Evaporite. As subsidence slowed or ceased, sediments filled the Elk Point basin and the drying up of the basin, with the evaporation of the residual brines, led to potash precipitation.

Several aspects of epicontinental sea sedimentation are present in the deposits of the Elk Point group. The deposits are a result of transgressive deposition across an erosional surface of large areal extent and low relief. Shelf carbonate and intracratonic deposition is involved with reef and other organic deposition. The deposits reflect changes in deposition associated with the restriction of a large epicontinental sea and the development of an evaporite facies.

It is hoped that this study has produced, for the Elk Point group, basic information about depositional environments, regional variations in intracratonic carbonate deposition, relations between open and restricted marine environments and the development of an evaporite facies, and the influence of low order structure on sedimentation. The writer has attempted to present information regarding the control of reef development, the development and control of porosity, the nature, extent and control of salt solution in the Prairie Evaporite , and diagenesis, including dolomitization and replacement of carbonates by evaporites.

This information may be applied to petroleum exploration. It can be shown that the Winnipegosis formation contains a source rock for hydrocarbons, a reservoir rock, and an effective cap rock over these reservoirs.

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APPENDIX I

WELL DATA

1. Well locations are given according to legal subdivision, section, township, and range west of the Principal Meridian. Wells are arranged according to township number, range number, section number and legal subdivision number, in ascending order from twp. 1, range 1, sec. 1, Lsd. 1. All wells are west of the Principal Meridian.

2. All measurements represent depth below Kelly Bushing in feet.

3. Legend:

   — - formation not present

   ? - top of formation uncertain

   blank space - total depth of well insufficient to penetrate formation

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
1	Cego Gretna	1	28	1	2	830	—	—	—	—	—	290?
2	B.A. Union Arbuckle	13	24	1	12	1536	2233	2278	—	2278	2350?	2365?
3	Calstan Waskada	9	13	1	26	1534	4925	4986	4986	5054	5152	?
4	GLCC et al Coulter Prov	16	16	1	27	1497	5158	5180	5180	5354	5472	5508
5	Robert Moore	5	20	1	27	1491	5183	5210	5210	5430	5520	5557
6	Commonwealth Manitou #2	8	26	2	9	1270	—	1450	—	1450	1470	1490
7	Nipiron Purves	16	11	2	10	1578	1970	1997	—	1997	2052	2061
8	Dome Holmfield	13	5	2	15	1561	2872	2905	—	2905	2998	3007
9	Jumping Pound Horton	8	15	2	20	1914	4000	4048	—	4048	4183	4206
10	Calstan Whitewater	15	36	3	22	1638	3868	3893	—	3893	4063	4088
11	Sweet Grass Pilot Mound	3	9	4	11	1546	1985	2022	—	2022	2075	2090

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP					Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation		
12	Dome et al Greenway	16	33	4	13	1427	2138	2160?	2160?	2170?	2253		2269
13	Dome Pelican Lake	7	34	4	15	1498	2460	2480	—	2480	2577		2596
14	Western Orthez	13	36	4	19	1628	3242	3270	—	3270	3444		3474
15	Red River Lowe Farm	3	1	5	2	807			Started within the Silurian				
16	Sweet Grass Altamont	2	35	5	8	1449	1386	1410	—	1410	1457		1480
17	Landa Warnez	5	13	5	22	1635	3722	3750	—	3750	3916		3957?
18	Calstan Hartney	16	33	5	24	1420	3590	3620	3620	3668	3772		3805
19	Amerada Lauder Prov. "M-F"	9	35	5	25	1425	3996	4020	4020	4040	4118		4148
20	Sun Manitoba Core Hole #1		19	6	1	787	—	—	—	—	—		75

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
21	Western Graysville	9	22	6	6	951	—	638?	—	638?	650	664
22	Baysel Bruxelles	1	27	6	11	1682	2010	2040	—	2040	2095	2100
23	Dame St. Alphonse	13	16	6	12	1331	1833	1863	—	1863	1945	1960
24	B.A.Wiebe	7	35	7	4	826	—	—	—	—	—	283
25	B.A.Gates	16	22	7	10	1415	1550	1580	—	1580	1647	1658
26	Cego Hilton	13	5	7	15	1258	2178	2204	2204	2230	2330	2350
27	Calstan Findlay	9	26	7	25	1421	3693	3720	3720	3838	3905	3950
28	Calstan Linklater	2	21	7	28	1618	4285	4312	4312	4730	4785	4840
29	Canadian Superior Jones	7	32	8	5	914	—	470	—	470	508	540
30	Canadian Superior Crown Rusywich	6	11	8	7	1006	722?	745	—	745	802	838
31	Cego Treherne	13	7	8	9	1205	1248	1282	—	1282	1356	1378

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
32	GLCC Spruce Woods Province	16	21	8	12	1145	1480	1505	—	1505	1620	1634
33	Cego Glenboro	8	36	8	14	1047	1548	1568	1568	1585	1689	1702
34	Dillman Spruce Woods	7	35	8	15	1220	1882	1895	1895	1924	2020	2030
35	Canadian Superior Rounthwaite	10	17	8	17	1278	2342	2367	2367	2390	2505	2520
36	Calstan Wawanesa	3	1	8	18	1364	2518	2550	2550	2573	2676	2694
37	Calstan Ewart Province	4	14	8	28	1611	4095	4122	4122	4519	4575	4625
38	Cego Elm Creek	5	26	9	5	836	—?	350?	—	350?	382	412
39	B.A. Morisseau	8	20	9	6	977	547	570	—	570	625	642
40	NBC North Holland Province	13	10	9	11	1187	1334	1360	1360	1380	1478	1492

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
41	Dome Brandon	3	5	9	19	1374	2645	2670	2670	2698	2810	2826
42	Dome Brandon	16	27	9	19	1329	2438	2463	2463	2496	2606	2627
43	B.A.Lavenham	5	3	10	10	1182	1142	1173	—	1173	1251	1260
44	Dillman Spruce Woods	11	9	10	16	1238	1943?	1964	1964	1984	2106	2121
45	Brandon Coutts No.2	14	16	10	19	1319	2395	2420	2420	2447	2569	2605
46	Calstan South Virden SWD #2	3	11	10	26	1441	3480	3510	3510			
47	Calstan Daly	15	18	10	27	1641	3730	3770	3770	4132	4178	4238
48	Sun Manitoba Core Hole #1		13	11	1	793	—	—	—	—	—	28
49	Cego Gregg	5	31	11	13	1303	1553	1576?	1576?	1605	1720	1732
50	B.A.Mitchell	7	26	11	17	1311	1972	1998	1998	2028	2137	2162
51	Dome Harding	4	27	11	22	1381	2728	2753	2753	2787	2928	2940

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
52	Calstan Imperial Lenore	2	20	11	24	1563	3220	3245	3245	3260	3420	3455
53	Calstan Elkhorn	7	8	11	29	1783	4042	4080	4080	4505	4565	4610
54	Portage la Prairie #1	3	9	12	7	850	—	390?	—	390?	480?	500?
55	Imperial Blossom	3	17	12	24	1550	3152	3183	3183	3225	3357	3397
56	Cego Westbourne	16	20	13	9	853	493	515	515	532	634	642
57	Canadian Superior Hockin	3	19	13	15	1285	1625	1643	1643	1673	1790	1820
58	Baum Bonnie Doon	7	11	14	5	830	—	180?	—	180?	194?	210?
59	Langford Neepawa	5	29	14	14	1142	1258	1285	1285	1300	1430	1465
60	Dome Minnedosa	16	26	14	18	1824	2285	2305	2305	2330	2461	2477
61	B.A.Union Brazell	2	7	14	20	1824	2690	2712	2712	2745	2890	2910

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
62	Dome Arrow River	12	10	14	25	1643	3097	3120	3120	3148	3285	3303
63	Calstan Woodlands	4	6	15	2	889	—	—	—	—	—	154
64-	Cego Springhill	13	12	15	16	1371	1562	1586	1586	1608	1732	1780
65	Gridoil Minnedosa	2	21	15	18	1941	2398	2403	2403	2413	2560	2578
66	Homestead Birdtail	10	8	15	27	1535	3070	3102	3102	3258	3408	3430
67	Homestead Birdtail	9	21	15	27	1540	3010	3040	3040	3267	3344	3368
68	Cego Plumas	12	13	16	13	966	790	812	812	840	970	988
69	Dome Strathclair	8	34	16	21	1991	2632	2668	—	2668	2823	2848
70	Dome Naco Lazare	12	34	16	29	1576	3020	3047	3047	3470	3500	3543
71	B.A.Birnie	16	11	17	15	1218	1165	1188	1188	1210	1340	1356
72	Canadian Superior Strathclair	6	23	17	23	1862	2640	2674	2674	2702	2840	2890

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
73	Imperial Birtle	1	27	17	26	1791	2990	3015	3015	3100	3188	3234
74	S.A.M.Lazare	6	29	17	29	1582	2932	2958	2958			
75	Anglo-American Birdtail	4	30	18	26	1809	2929	2957	2957	2984?	3150	3182?
76	Imperial Madelaine	16	18	18	29	1597	2890	2920	2920	3120	3317	3354
77	Imperial Foxwarren	16	32	19	27	1821	2832	2868	2868	3080	3120	3150
78	S.A.M. Boundary #1	13	6	19	29	1588	2828	2854	2854			
79	S.A.M. Exploration #1	7	15	19	29	1352	2526	2556	2556			
80	Lundar Test Hole	8	23	20	6	828	—	—	—	—	—	—?
81	Dauphin No.1	SE¼	14	24	20	1100	—	1090?	1090?	1150?	—?	1260
82	B.A.Grandview	16	30	24	23	1426	1675	1705?	—	1705?	—	[illegible]
83	Imperial Bluewing Lake	13	4	24	27	1881	2458	2494	2494	2705	2760	2815

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Top	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
84	B.A. Grandview	16	15	25	25	1574	1830	1862	—	1862		
85	B.A. Grandview	13	34	26	23	1539	1502	1536	—	1536		
86	Winnipegosis #4	7	29	30	17	840	—	70?	—	70?	360?	370
87	Sapphire Duck Mountain #1	16	18	30	25	2346	2213	2260	—	2260		
88	Sapphire Duck Mountain #2	2	2	31	25	2657	2118	2157	—	2157	2387	2410
89	Sweet Grass Duck Mountain #3	16	35	34	26	1834	1658	1683	—	1683	1788	1806
90	Shell Swan River #2	13	3	35	29	1369	1230	1260	—	1260	1566	1597
91	Shell Swan River #1	9	1	37	28	1186	855	868	—	868	1221	1232
92	Johnson-Mafeking #2	4	23	43	26	1150	—	390	—	390	660?	680

Well No.	Well Name	Location				K.B. Elevation	Second Red Beds	ELK POINT GROUP				Silurian
		Lsd.	Sec.	Twp.	Range WPM			Elk Point Group	Prairie Evaporites	Winnipegosis Formation	Ashern Formation	
93	Mafeking #1		14	44	25	841	—	20	—	20	300	325
*94	Woodley Ada Thunderhill	4	5	35	31	1604		1748	—	1748	2012	2045
*95	Riddle Tidewater Rocanville Crown	16	32	15	31	1755		3668	3668	4091	4130	4166
*96	Tidewater Canadian Superior Imperial Flint Cutarm #1	1	4	20	32	1666		3088	3088	3540	3594	3625

*Wells Nos. 94, 95 and 96 were all drilled in Saskatchewan. They were used as check points in projecting the isopach lines into the Manitoba-Saskatchewan border.

APPENDIX II

DESCRIPTIONS OF SELECTED LITHOLOGIC SECTIONS

1. Descriptions include the total Elk Point Group in most cases.

2. For some wells only the cored section was described. These wells are marked accordingly.

DESCRIPTIONS OF SELECTED LITHOLOGIC SECTIONS

Well No. 2. **B.A. UNION ARBUCKLE**
lsd. 13, sec. 24, twp. 1, rge. 12, WPM.

Second Red Beds

2233 - 2245	Shale; red, calcareous, blocky; with Limestone; buff, microgranular, chalky in part.
- 2265	Shale; red, calcareous, blocky; with trace pink Limestone.
- 2278	Shale; as above.

Elk Point Group

Winnipegosis Formation

2278 - 2285	Limestone; very light grey, dolomitic, irregular fine clastic texture with some medium to coarse, well-rounded grey Limestone grains; with Shale, red, calcareous.
- 2295	Limestone; very dolomitic, with fine-grained pelletoid texture composed of buff granules in a pink argillaceous matrix.
- 2305	Dolomite; pink, micro-sucrosic to fine sucrosic, calcareous, argillaceous, trace intercrystalline porosity in part.
- 2315	Limestone; white, chalky, finely granular in part with floating sub-angular quartz grains up to coarse-grained size.
- 2335	Dolomite; pink and buff, very finely sucrosic, calcareous, argillaceous.
- 2350	Dolomite; red to buff with Shale; brown, with clear calcite grains and buff dolomite grains.

Ashern Formation

2350 - 2365 Shale; brown and red with Dolomite; pink, buff and green-grey, microcrystalline.

Silurian

2365 - 2375 Limestone; white, chalky, with Shale; brown, trace gypsum, with Dolomite; buff and pink, very finely sucrosic, argillaceous, calcareous.

- 2385 Limestone; white, chalky.

Well No. 3. <u>CALSTAN WASKADA</u>
lsd. 9, sec. 13, twp 1,
rge. 26, WPM.

(Samples are poor and contain much caved material, especially through evaporite section.)

Second Red Beds

4925 - 4976 Dolomite; grey, buff and grey-green, marly in part, reddish at top, very argillaceous.

<u>Elk Point Group</u>

Prairie Evaporites

4976 - 5000 Anhydrite; white and grey, crystalline, with Dolomite; grey, microcrystalline.

- 5010 Dolomite; grey and buff, very finely sucrosic, with Anhydrite; white, clear.

- 5054 Anhydrite; white.

82

Winnipegosis Formation

5054 - 5065 Dolomite; buff, microcrystalline.

- 5085 Dolomite; buff to brown, microcrystalline to very finely crystalline.

- 5105 Dolomite; buff, very fine to finely crystalline, slightly calcareous, poor intercrystalline porosity, black spores noted at 5090 feet.

- 5115 Dolomite; buff to brown, very finely crystalline to microcrystalline, with poor intercrystalline porosity.

- 5140 Dolomite; as above, but with fair to good intercrystalline porosity.

- 5152 Dolomite; buff to brown, microcrystalline to very finely crystalline

Ashern Formation
(E-Log top at 5152)

5152 - 5175 Dolomite; light grey and grey to buff, microcrystalline.

Well No. 8. **DOME HOLMFIELD**

lsd 13, sec. 5,
twp. 2, rge. 15,WPM

Second Red Beds
(E-log top at 2872)

2885 - 2905 Shale; red-brown, dolomitic, silty.

Elk Point Group

Winnipegosis Formation

2905 - 2920 Dolomite; light grey, argillaceous, calcareous, silty, with Limestone; white, argillaceous to chalky.

- 2940 Dolomite; light grey to buff, microsucrosic, silty with trace poor intercrystalline porosity.

- 2950 Dolomite; light brown, microcrystalline.

- 2960 Dolomite; light brown, microcrystalline with poor intercrystalline porosity.

- 2980 Dolomite; light brown, microcrystalline to very finely crystalline with poor intercrystalline porosity.

- 2998 Dolomite; light brown, microcrystalline.

Ashern Formation
(E-log top at 2998)

2998 - 3007 Dolomite; buff, brown, microcrystalline, argillaceous, with trace Limestone, chalky.

Silurian
(E-log top at 3007)

3007 - 3010 Dolomite; buff, microcrystalline, silty, with good microvugular porosity.

3010 - 3020 Limestone; cream to white, chalky in part, dolomitic in part, cryptocrystalline.

3020 - 3040 Dolomite; cream, cryptocrystalline, calcareous.

Well No. 9 **JUMPING POUND HORTON**
lsd. 8, sec. 15, twp. 2, rge. 20 WPM

Second Red Beds
(Top at 4000')

4030 - 4040 Shale; red-brown, dolomitic.

- 4048 Shale; as above, grading to Dolomite; grey-buff, cryptocrystalline, with anhydrite.

Elk Point Group

Winnipegosis Formation

4048 - 4060	Dolomite; grey-buff, cryptocrystalline, argillaceous, with anhydrite.
- 4080	Dolomite; light grey, cryptocrystalline, argillaceous, calcareous in part, with anhydrite; blue-grey.
- 4130	Dolomite; light grey, cryptocrystalline to microcrystalline, slightly argillaceous, with trace anhydrite.
- 4140	Dolomite; as above, with Limestone; buff, cryptocrystalline, dense.
- 4150	Dolomite; buff, cryptocrystalline, with trace Limestone; as above, with trace anhydrite.
- 4170	Limestone; buff, microcrystalline, with Dolomite; buff, microcrystalline.
- 4183	Limestone; buff, cryptocrystalline.

Ashern Formation

4183 - 4200	Limestone; grey and buff, very argillaceous to chalky.
- 4206	Limestone; as above, with trace anhydrite; white.

Silurian

4206 - 4210	Dolomite; very light brown, very argillaceous, slightly silty.
- 4220	Limestone; light grey, cryptocrystalline.

Well No. 11 **SWEET GRASS PILOT MOUND**

lsd. 3, sec. 9, twp. 4,
rge. 11, WPM.

Second Red Beds
(Top at 1984')

2000 - 2022	Shale; pink, dolomitic.

Elk Point Group

Winnipegosis Formation

2022 - 2030	Dolomite; cream to buff, with pinkish tinge, cryptocrystalline to microsucrosic.
- 2040	Dolomite; buff, microsucrosic.
- 2050	Limestone; light grey and buff, microgranular.
- 2075	Dolomite; buff, microsucrosic.

Ashern Formation

2075 - 2080	Dolomite; red-brown, very argillaceous.
- 2090	Shale; red-brown, very dolomitic, with Limestone; buff, cryptocrystalline.

Silurian

2090 - 2100	Limestone; buff, cryptocrystalline, dense.
- 2110	Limestone; very light grey to buff, cryptocrystalline, dense.

Well No. 12 DOME ET AL GREENWAY

lsd. 16, sec. 13, twp. 4,
rge. 13, WPM.

Second Red Beds
(Top at 2138')

2138 - 2160 Shale; red, calcareous.

Elk Point Group

Winnipegosis Formation

2160 - 2170 Anhydrite; blue-white, massive. (Prairie Evaporite?)

- 2200 Dolomite; cream to medium brown, crystalline to fragmental, poor intercrystalline porosity.

2200 - 2220 Samples missing.

2223 - 2226 (core) Dolomite; grey-buff and reddish buff, microcrystalline to microsucrosic, tight, with light grey-green shale or clay partings.

- 2228 (core) Dolomite; as above, with fewer shale partings and with irregular patches of Limestone.

- 2238 (core) Dolomite; as above, interbedded with Limestone; pink to red-brown, microcrystalline to dense, nodular in appearance with irregular shale partings.

- 2253 Limestone; brown-red and light brown, fragmental, poor intercrystalline porosity.

Ashern Formation

2253 - 2260 Shale; pale brown-red to rusty red, calcareous, with Limestone; red, argillaceous.

- 2269 Shale; as above, with trace Dolomite; white, dense.

Silurian

2269 - 2300 Dolomite; white to light grey, microcrystalline to dense, poor intercrystalline porosity.

Well No. 14

WESTERN ORTHEZ

lsd. 13, sec. 36,
twp. 4, rge. 19,WPM.

Second Red Beds
(Top at 3242')

3250 - 3265	Shale; medium grey, calcareous, blocky.
- 3270	Shale; pink, earthy, slightly calcareous, with shale, as above.

Elk Point Group

Winnipegosis Formation

3270 - 3290	Dolomite; very argillaceous, with Shale; pink, earthy.
- 3310	Dolomite; buff, cryptocrystalline to microcrystalline.
- 3350	Dolomite; light grey to buff, cryptocrystalline to microsucrosic.
- 3360	Dolomite; buff, microsucrosic.
- 3380	Limestone; buff, dense, cryptocrystalline, argillaceous in part.
- 3410	Limestone; as above, with Dolomite; buff, dense, microsucrosic.
- 3430	Limestone; as above.
- 3444	Dolomite; light grey to buff, dense to microsucrosic.

Ashern Formation

3444 - 3460	Shale; pink and red-brown, dolomitic, earthy in part.
- 3474	Shale; as above, with gypsum lenses.

Silurian

3474 - 3510 Dolomite; cream to white, crypto-crystalline, dense.

Well No. 17

LANDA WARNEZ

lsd. 5, sec.13, twp. 5, rge. 22, WPM

Second Red Beds
(Top at 3722')

3722 - 3730 Shale; grey, fissile.

- 3750 Shale; light red-brown, calcareous, earthy with shale; as above.

Elk Point Group

Winnipegosis Formation

3750 - 3800 Dolomite; light grey to buff, cryptocrystalline.

- 3810 Dolomite; buff to light brownish-grey, finely crystalline to fragmental, with good inter-crystalline and microvuggy porosity.

- 3830 Dolomite; light grey-brown, very finely crystalline, with poor intercrystalline porosity, with traces of algal(?) remains.

- 3840 Dolomite; buff, microsucrosic to dense, tight, calcareous.

- 3850 Limestone; brown to grey, dense to finely crystalline, slightly argillaceous, with numerous small, round brown "spores".

- 3916 Limestone; brown-grey to buff, dense to microcrystalline.

Ashern Formation

3916 - 3920	Dolomite; grey, very argillaceous.
- 3930	Shale; grey, very dolomitic.
- 3957	Shale; red-brown, earthy, slightly dolomitic, slightly silty.

Silurian

3957 - 3962	Limestone; pink to red-brown, dense, argillaceous.
- 3993	Limestone; pink to white, dense.
- 4010	Shale; red-brown, earthy, very calcareous in part, with white Limestone fragments.
- 4025	Shale; deep red-brown, splintery.
- 4040	Limestone; very light grey to white, dense.

Well No. 18

<u>CALSTAN HARTNEY</u>

lsd. 16, sec. 33, twp. 5, rge. 24, WPM.

(core only examined)

<u>Elk Point Group</u>

Winnipegosis Formation
(Top at 3668')

3675 - 3687	(core) Dolomite; pale yellowish-brown, medium crystalline and saccharoidal to coarsely fragmental with abundant fossil fragments(?), good intercrystalline and minutely vuggy porosity with some infilling of white crystalline anhydrite in the vugs.
3691 - 3700	Dolomite; as above with bituminous partings and abundant fracturing in basal 5 to 6 feet with thin (1 to 2 mm.) bituminous partings along fracture planes.

Ashern Formation
(Top at 3772')

3775 - 3802 (core) Dolomite; grey and green-grey becoming slightly pinkish in basal 5 feet, microcrystalline to cryptocrystalline, dense, argillaceous.

Well No. 22

BAYSEL BRUXELLES

lsd. 1, sec. 27, twp. 6,
rge. 11, WPM.

Second Red Beds
(Top at 2010')

2010 - 2040 Shale; red-brown and pink, earthy, slightly dolomitic, with shale, grey and grey-green.

Elk Point Group

Winnipegosis Formation

2040 - 2060 Dolomite; light grey-brown, cryptocrystalline, dense.

- 2095 Dolomite; light grey-brown, cryptocrystalline to very finely crystalline.

Ashern Formation

2095 - 2100 Shale; brick red, earthy, slightly dolomitic.

Silurian
(Top at 2100')

Well No. 27

CALSTAN FINDLAY

lsd. 9, sec. 26, twp. 7, rge. 25, WPM.

(core only examined)

Elk Point Group

Winnipegosis Formation
(Top at 3838')

3848 - 3850 (core) Dolomite; mottled buff and light brown, microcrystalline, with numerous vertical fractures filled with anhydrite, with black irregular shale partings and some anhydrite inclusions up to 1 inch in width.

3850 - 3853 (core) Dolomite; very finely crystalline, with fair intercrystalline porosity and anhydrite inclusions as above, fractured in part as above.

Well No. 36

CALSTAN WAWANESA

lsd. 3, sec. 1, twp. 8, rge. 18, WPM.

(core only examined)

Elk Point Group

Prairie Evaporite Formation
(Top at 2550')

2568 - 2573 (core) Dolomite; light brown to buff, microcrystalline, and Anhydrite, white, crystalline.

Winnipegosis Formation

2573 - 2578 (core) Dolomite; light brown to buff, microcrystalline, calcareous, with good microvuggy porosity, with irregular anhydrite inclusions, and irregular black bituminous or argillaceous partings, some amphipora(?) remains near top of unit.

Well No. 37 **CALSTAN EWART PROVINCE**

lsd. 4, sec. 14, twp. 8,
rge. 28, WPM.

(core only examined)

Elk Point Group

Prairie Evaporite Formation
(Top at 4140')

4242 - 4252 (core) Halite; white, crystalline, with some pink Halite.

4252 - 4303 (core) Halite; white, crystalline, with some pink Halite, with two soft, green fissile shale bands about 2 inches thick in the basal 4 feet of the unit.

Well No. 42 **DOME BRANDON**

lsd. 16, sec. 27, twp.
9, rge. 19, WPM.

Second Red Beds
(Top at 2438')

2450 - 2463 Shale; pink, earthy, slightly calcareous.

Elk Point Group

Prairie Evaporite Formation

2463 - 2496 Anhydrite; white to grey.

Winnipegosis Formation

2496 - 2510 Dolomite; buff, microsucrosic.

- 2520 Dolomite; light brown to buff, microcrystalline, with trace intercrystalline porosity.

- 2540	Dolomite; light brown, microcrystalline to dense with fair intercrystalline and micro-vuggy porosity.
- 2560	Dolomite; light brown to buff, microcrystalline to dense.
- 2580	Dolomite; light brown, microcrystalline to very finely crystalline.
- 2606	Dolomite; light brown to buff, microcrystalline to dense.

Ashern Formation

2606 - 2620	Shale; light grey, dolomitic, blocky, very silty.
- 2627	Siltstone; light grey, quartzose, argillaceous, dolomitic.

Silurian

2627 - 2640	Limestone; cream to white, cryptocrystalline, dense.
- 2650	Limestone; white, dense, chalky in part.

Well No. 49 **CEGO GREGG**

lsd. 5, sec. 31, twp. 11, rge. 13, WPM.

Second Red Beds
(Top at 1553)

1553 - 1565	Dolomite; red-brown, very argillaceous, with shale, brown.
- 1576	Shale; brown, dolomitic, blocky.

Elk Point Group

Prairie Evaporite Formation

1576 - 1585	Anhydrite; white and blue-white.
- 1595	Dolomite; buff, dense to very finely crystalline.
- 1605	Anhydrite; white and blue-white, with Limestone; light grey, dense, slightly argillaceous.

Winnipegosis Formation

1605 - 1620	Dolomite; buff, very finely crystalline with Anhydrite; white.
- 1630	Limestone; cream, dense, slightly argillaceous.
- 1640	Limestone; light grey, dense with Anhydrite; blue-white, massive,
- 1650	Missing.
- 1670	Dolomite; buff, microcrystalline, with fair to good intercrystalline porosity.
- 1680	Missing.
- 1700	Dolomite; light grey to buff, microcrystalline to dense, very calcareous.
- 1710	Missing.
- 1720	Dolomite; pinkish to buff, very finely sucrosic, very calcareous.

Ashern Formation

1720 - 1728	Shale; grey-green, silty, slightly dolomitic.
- 1732	Shale; red-brown, slightly dolomitic.

Silurian
(E-log top at 1732')

1732 - 1775	Shale; red-brown, with Anhydrite; white, soft.
- 1800	Limestone; cream-grey to white, cryptocrystalline, dense.

Well No. 51

DOME HARDING

lsd. 4, sec. 27, twp. 11, rge. 22, WPM

Second Red Beds
(Top at 2728')

2740 - 2753 Dolomite; grey, argillaceous, and Shale; grey-brown, dolomitic.

Elk Point Group

Prairie Evaporite Formation

2753 - 2760 Anhydrite; grey-brown, massive.

- 2787 Anhydrite; grey-brown and grey, massive.

Winnipegosis Formation

2787 - 2790 (core) Limestone; light grey to light brown, microcrystalline, with abundant, small, elongate carbonaceous fragments, with a thin fossiliferous horizon near top of unit containing abundant crinoid stems and small brachiopods.

- 2926 (core) Dolomite; buff, very finely sucrosic, fair to good intercrystalline porosity, good vuggy porosity near base of unit, with abundant irregular brown argillaceous or bituminous partings and minor anhydrite inclusions. Traces of poorly preserved amphipora(?) noted, and some light brown "spores" observed near base of unit.

- 2932 (core) Dolomite; grey-brown, microsucrosic, with anhydrite inclusions and black carbonaceous partings.

- 2938 (core) Dolomite; mottled buff and grey-brown, very finely crystalline to microsucrosic.

- 2970 Dolomite; buff to light brown, microsucrosic to dense, with poor intercrystalline porosity.

- 2900 Dolomite; brown, dense.

- 2928 Dolomite; brown, dense, with Dolomite; buff, dense.

Ashern Formation

2928 - 2940 Shale; black, with abundant small iron sulfide nodules, with Anhydrite; white, crystalline.

Silurian

2940 - 2960 Dolomite; pink, argillaceous, with Dolomite; white, cryptocrystalline, with Anhydrite; white.

- 2970 Dolomite; white, cryptocrystalline.

Well No. 66 HOMESTEAD BIRDTAIL

lsd. 10, sec. 8, twp. 15, rge. 27, WPM.

Elk Point Group

Prairie Evaporite Formation

3102 - 3232 Halite.

- 3258 Anhydrite; massive.

Winnipegosis Formation

3258 - 3355 Dolomite; light grey to buff, very finely sucrosic, fragmental and finely sucrosic in part, fair to good microvuggy and intercrystalline porosity.

- 3408 Dolomite; chocolate brown, microcrystalline to dense.

Ashern Formation

3408 - 3430 Dolomite; buff, dense, argillaceous.

Silurian
(E log top at 3430 ?)

3430 - 3450	Dolomite; buff and pink, argillaceous.
- 3460	Shale; pink to red-brown, dolomitic, earthy.
- 3480	Limestone; white, dense to cryptocrystalline.

Well No. 69 — DOME STRATHCLAIR

lsd. 8, sec. 34, twp. 16, rge. 21, WPM.

Second Red Beds

2632 - 2640	Shale; pink to brown-pink, slightly dolomitic, blocky.
- 2650	Missing.

Elk Point Group

Prairie Evaporite Formation ??

2650 - 2667	Shale; red-brown, earthy; with Anhydrite, white, crystalline.

Winnipegosis Formation

2667 - 2680	Dolomite; light grey to white, dense; with Anhydrite, grey, dense, and white, crystalline.
- 2690	Dolomite; cream, dense; with Anhydrite, white, crystalline; with Shale, grey, blocky (cave?)
- 2700	Dolomite; cream, dense.
- 2740	Dolomite; cream, microcrystalline to dense, trace intercrystalline porosity. (2710-2720 missing.)
- 2750	Dolomite; cream to buff, microcrystalline, poor intercrystalline porosity.

- 2770 Dolomite; buff, microcrystalline to dense, with trace poor intercrystalline porosity.

- 2790 Dolomite; cream to buff, dense.

- 2823 Dolomite; cream to buff, microcrystalline.

Ashern Formation

2823 - 2840 Shale; red and red-brown, with Dolomite; grey.

- 2847 Shale; red-brown, dolomitic, blocky.

Silurian

2847 - 2870 Dolomite; white, dense, almost lithographic.

Well No. 72 CANADIAN SUPERIOR STRATHCLAIR

lsd. 6, sec. 23, twp. 17, rge.23 WPM.

Second Red Beds
(Top at 2640')

2650 - 2674 Shale; grey, fissile to blocky, with Shale; light grey, earthy.

Elk Point Group

Prairie Evaporite Formation

2674 - 2702 Anhydrite; grey, dense, with Anhydrite; white crystalline, with minor Dolomite; buff, dense.

Winnipegosis Formation

2702 - 2730 Dolomite; cream, dense, with minor Anhydrite; as above in upper 10 feet.

- 2740 poor sample, mostly cave.

- 2750 poor sample, mainly Dolomite, as above.

	- 2760	Dolomite; cream to buff, microsucrosic to dense.
	- 2770	Dolomite; buff, dense.
	- 2780	Dolomite; cream to buff, microcrystalline to dense.
	- 2810	Dolomite; light brown, cryptocrystalline to dense.
	- 2830	Dolomite; buff to brown, cryptocrystalline.
	- 2840	Limestone; buff, cryptocrystalline.

Ashern Formation

2840	- 2860	Shale; grey to red-grey and red-brown, slightly dolomitic in part.
	- 2870	Shale; red-brown, dolomitic, earthy.
	- 2890	Shale; as above, with Shale; medium grey, fissile, soft.

Silurian

2890	- 2910	Dolomite; white, dense, almost lithographic.
	- 2930	Dolomite; as above, and Dolomite; pink and white, mottled.

Well No. 76

IMPERIAL MADELAINE

lsd. 16, sec. 18, twp. 18, rge. 29, WPM.

Second Red Beds
(Top at 2890)

2905	- 2920	(core) Shale; medium brown to slightly more reddish, some greenish mottling, dolomitic, hard, sub-conchoidal fracture, badly leached in part with inclusions of transparent halite. At base of core red and green Shale is finely brecciated with interstitial salt.

Elk Point Group

Prairie Evaporite Formation
(E-log top at 2920')

2920 - 2924	(core) Shale; red, with abundant salt inclusions.
- 2935	(core) Rock salt, reddish shades, some shale inclusions.
- 3035	Samples show mainly red brown Shale; slightly dolomitic, earthy in part; with traces of Anhydrite and evidence of salt casts in the Shale.
- 3050	Anhydrite; white, crystalline, with Dolomite; buff, finely crystalline, with abundant salt casts.
- 3100	Anhydrite; grey, massive, with salt casts and traces of red Shale, as above.
- 3120	Anhydrite; medium grey and blue-grey, massive, with abundant salt casts.

Winnipegosis Formation

3120 - 3135	Dolomite; buff, very finely crystalline, with Anhydrite; with salt casts.
- 3147	Dolomite; light grey to white, finely crystalline with Anhydrite; light blue grey with salt casts (cave?)
- 3157	(core) Dolomite; buff, calcareous, extremely porous, almost totally organic, (stromatoporoids, Bryazoans, etc.) much included Anhydrite.
- 3195	Dolomite; as above, reefal, fragmental in part, with abundant algal and/or stromatoporoid material.
- 3215	Dolomite; light grey to cream, finely crystalline, fragmental in part, organic in part, with poor intercrystalline porosity and fair to good porosity associated with organic material.

- 3270 Dolomite; buff, very finely crystalline to finely sucrosic, fair intercrystalline and microvuggy porosity.

- 3295 Dolomite; medium brown, very finely sucrosic to very finely crystalline, trace pin point porosity, abundant brown spores.

- 3297 (core) Dolomite; buff, calcareous, very finely sucrosic, slightly porous, abundant black stylolitic markings.

- 3310 Dolomite; medium brown, dense, with black argillaceous or carbonaceous, thin partings.

- 3317 Dolomite; buff and greenish-buff, dense,

Ashern Formation

3317 - 3340 Shale; red-brown, dolomitic, blocky.

- 3352 (core) Shale; bright reddish brown, with a little greenish streaking, with Dolomite; light grey to white, finely crystalline, as inclusions near top of core. Some Anhydrite inclusions throughout, with lower few feet a breccia of dark reddish brown Shale, greenish Shale, Anhydrite and white Dolomite.

- 3354 (core) Breccia like lower part of preceding core.

Silurian
(E-log top at 3354')

3354 - 3355 (core) Dolomite; yellowish-grey and pinkish shades, streaked and mottled, dense to very finely sucrosic, calcareous, tight.

- 3357 (core) Dolomite; medium pink, "speckled" with yellowish calcite filling most of the tiny vugs, red Shale partings near base of unit.

- 3362 (core) Dolomite; buff with purplish mottling, dense, with slight vuggy porosity.

- 3385 Dolomite; cream to white, dense to crypto-crystalline.

Well No. 88 **SAPPHIRE DUCK MOUNTAIN**

lsd. 2, sec. 2, twp. 31,
rge. 25 WPM.

Second Red Beds
(Top at 2118')

2118 - 2140	Dolomite; buff and light grey, dense to finely crystalline, carbonaceous flecks, scattered aggregates of calcite crystals; trace of brick-red sandy siltstone.
- 2157	Dolomite; grey-brown, very finely sucrosic, silty, with Dolomite; buff to light grey, calcitic; with trace of orange-red Shale.

Elk Point Group

Winnipegosis Formation

2157 - 2170	Dolomite; buff to light brown, calcitic, dense to finely crystalline, some carbonaceous and pyrite flecks; also some cream to buff, non-calcitic Dolomite, fair porosity.
- 2190	Dolomite; buff, finely crystalline, with fair to good vuggy porosity.
- 2200	Dolomite; buff to light brown, fine to medium crystalline, with fair to good intercrystalline and vuggy porosity.
- 2210	Limestone; light grey to buff, fine to medium crystalline, with fair intercrystalline porosity.
- 2240	Limestone; as above, dolomitic, fossiliferous.
- 2300	Dolomite; cream to buff, fine to medium crystalline, calcitic in part, fair to good intercrystalline and vuggy porosity.
- 2330	Dolomite; buff, fine to medium crystalline, some reef fragments and carbonaceous material, good vuggy and intercrystalline porosity.

- 2340 Dolomite; light brown, fine to medium crystalline, some scattered blotches of carbonaceous material, good vuggy and intercrystalline porosity.

- 2350 Dolomite; as above; with Limestone; cream to light buff, dense to finely crystalline.

- 2360 Dolomite; light to medium brown, dense to finely crystalline, scattered vuggy porosity, carbonaceous material; also some cream Limestone; as above.

- 2387 Dolomite; buff to light brown, dense to finely crystalline, a few scattered vugs (many filled with calcite crystals).

Ashern Formation
(E-log top at 2387')

2387 - 2400 Dolomite; as above, with Limestone; light grey, silty, with Shale; red, silty.

- 2410 Shale; rusty red, soft, silty, slightly calcareous with Dolomite; medium brown, crystalline.

Silurian

2410 - 2440 Dolomite; white to cream, dense to finely sucrosic, some fair vuggy and intercrystalline porosity, with some red shaly dolomite, and brown, porous dolomite.

Well No. 92 JOHNSON-MAFEKING No. 2

lsd. 4, sec. 23, twp. 43,
rge. 26 WPM.

Second Red Beds

- 390 Shale; pink to buff, earthy, calcareous.

Elk Point Group

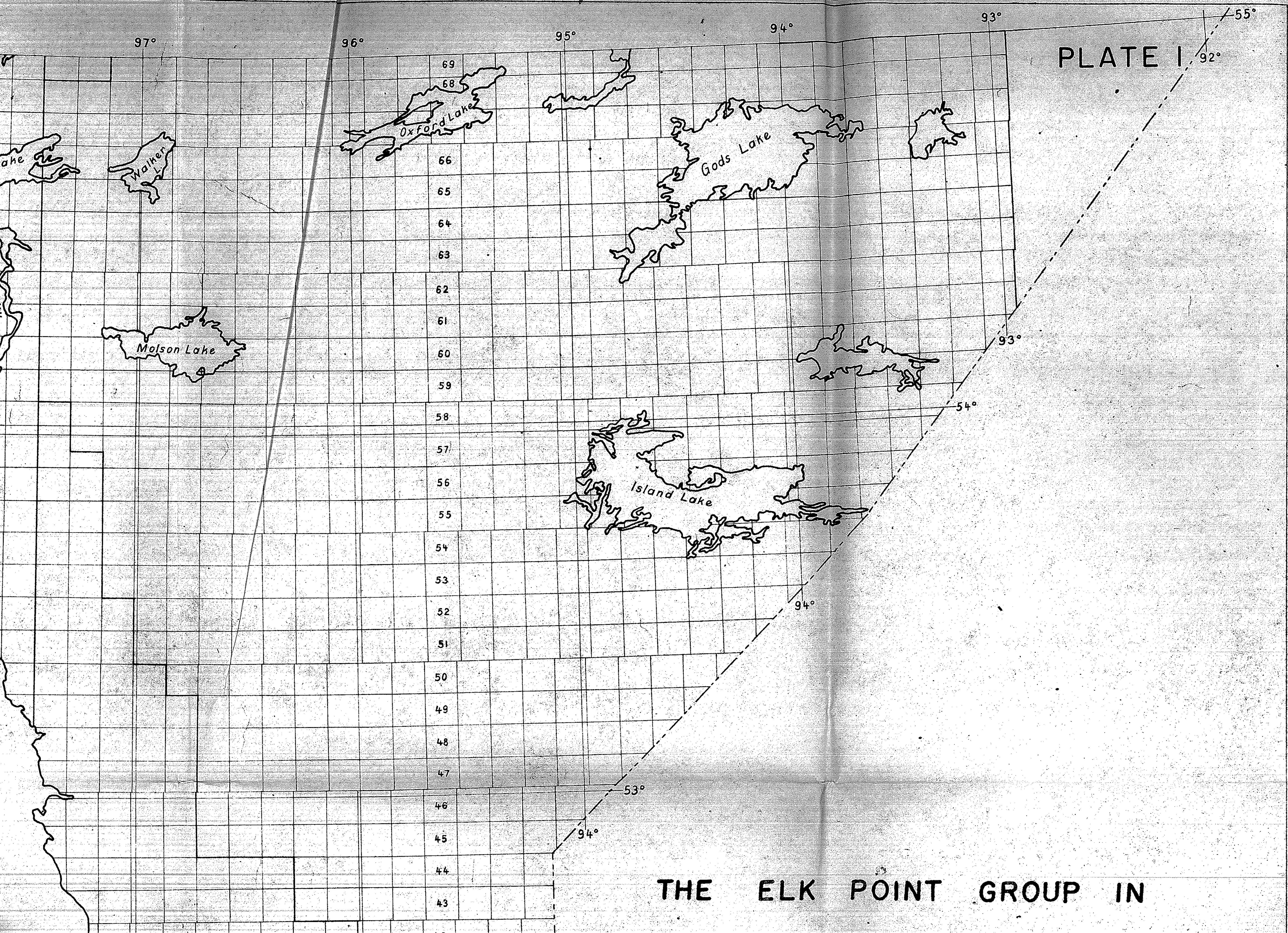
Winnipegosis Formation

390 - 520	Dolomite; white, dense.
- 550	Limestone; white, dense, with Dolomite, white, dense.
- 660	Limestone; as above, with traces of Dolomite, as above.

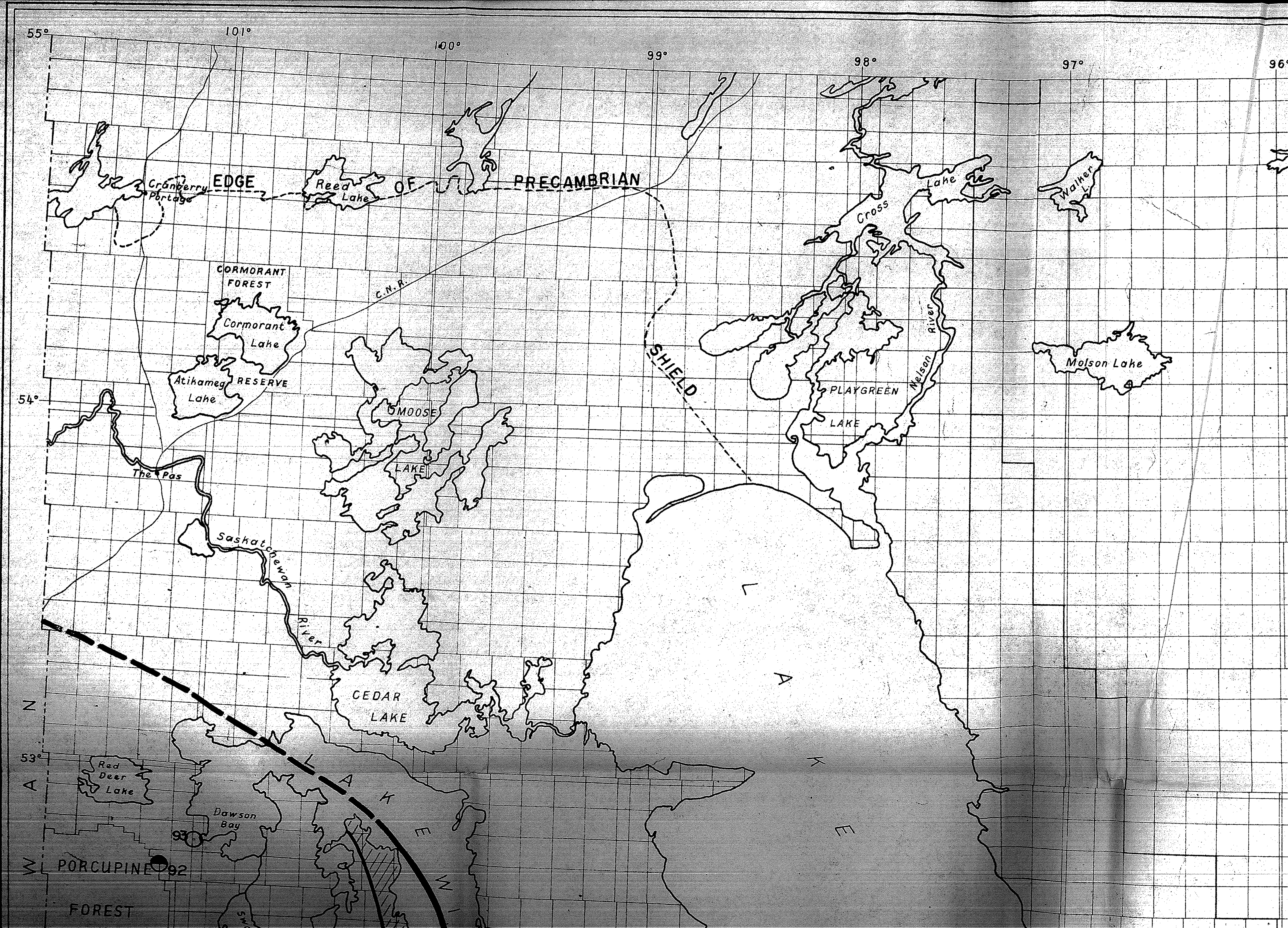
Ashern Formation

660 - 680	Shale; red-brown.

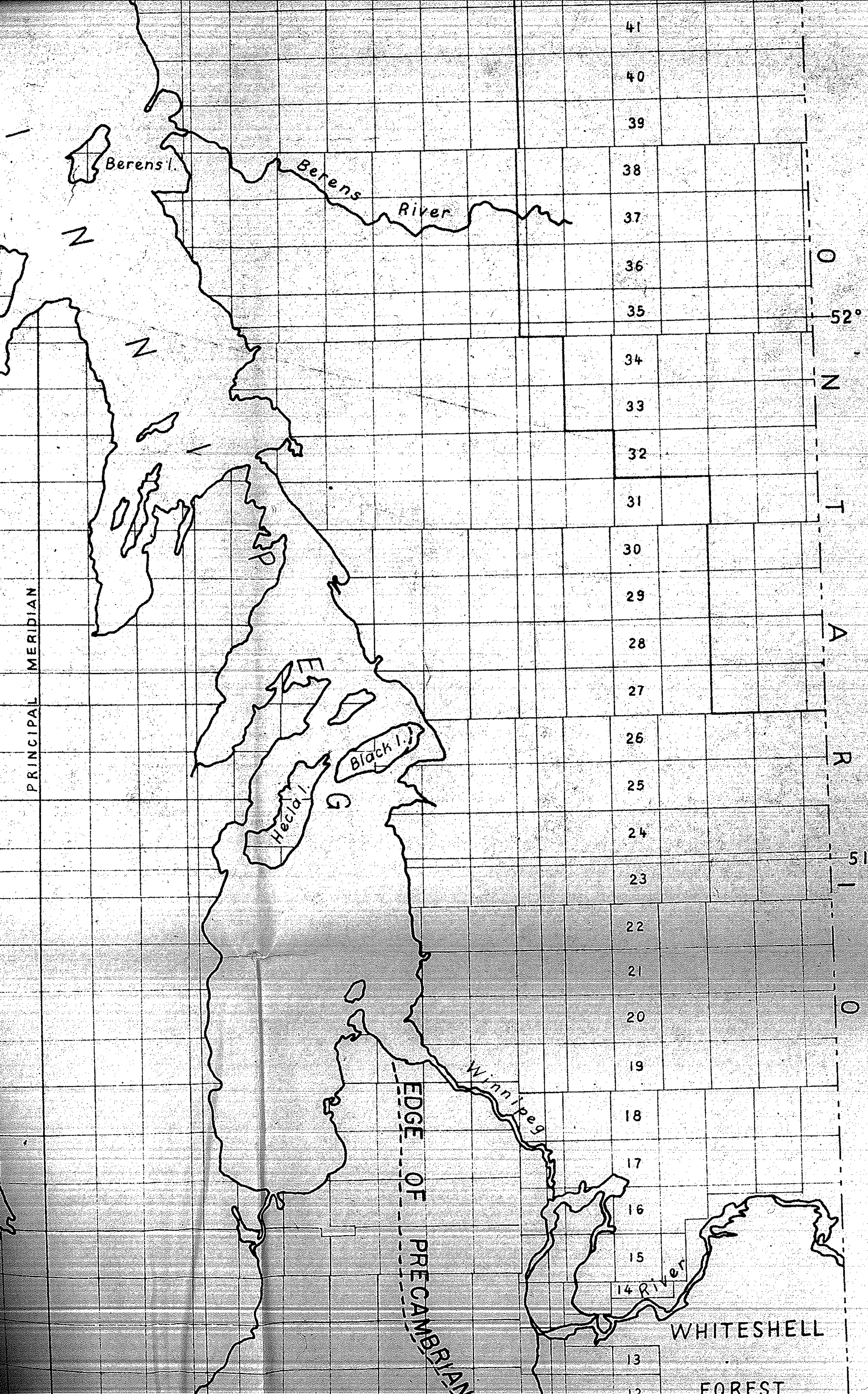
PLATE I



THE ELK POINT GROUP IN



55°
101°
100°
99°
98°
97°
96°
54°
53°
EDGE OF PRECAMBRIAN SHIELD
Cranberry Portage
Reed Lake
Cross Lake
Walker L.
CORMORANT FOREST RESERVE
Cormorant Lake
Atikameg Lake
C.N.R.
MOOSE LAKE
The Pas
Saskatchewan River
Nelson River
PLAYGREEN LAKE
Molson Lake
CEDAR LAKE
LAKE WINNIPEG
LAKE W
Red Deer Lake
Dawson Bay
93
92
PORCUPINE
FOREST
MAN

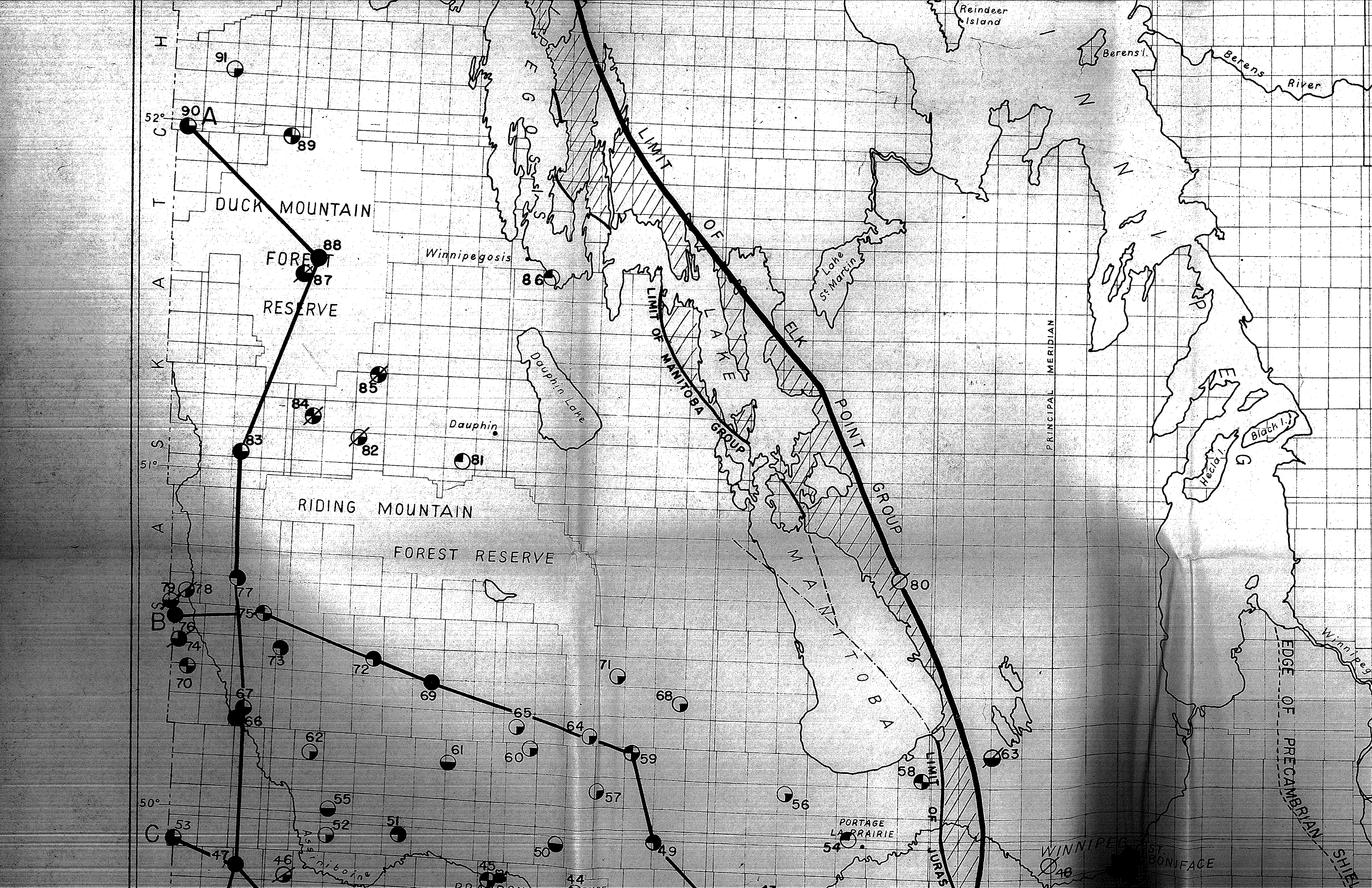


MANITOBA

INDEX MAP

SHOWING CONTROL POINTS AND TYPES OF CONTROL

- 56 — WELL SITE AND REFERENCE NUMBER
- SAMPLES AND/OR CORE EXAMINED BY WRITER
- LITHOLOGIC LOG
- ELECTRIC LOG
- RADIOACTIVE LOG
- COMPLETE ELK POINT GROUP NOT PENETRATED
- OUTCROP AREA OF ELK POINT GROUP
- A——A' CROSS SECTION



Reindeer Island
Berens I.
Berens River
DUCK MOUNTAIN
FOREST
RESERVE
Winnipegosis
Dauphin Lake
Dauphin
RIDING MOUNTAIN
FOREST RESERVE
LIMIT OF ELK POINT GROUP
LIMIT OF MANITOBA GROUP
LAKE MANITOBA
LAKE WINNIPEGOSIS
LAKE WINNIPEG
Lake St. Martin
PRINCIPAL MERIDIAN
Black I.
Hecla I.
EDGE OF PRECAMBRIAN SHIE
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
Assiniboine
SASKATCH
52°
51°
50°
A
B
C
91
90
89
88
87
86
85
84
83
82
81
80
79
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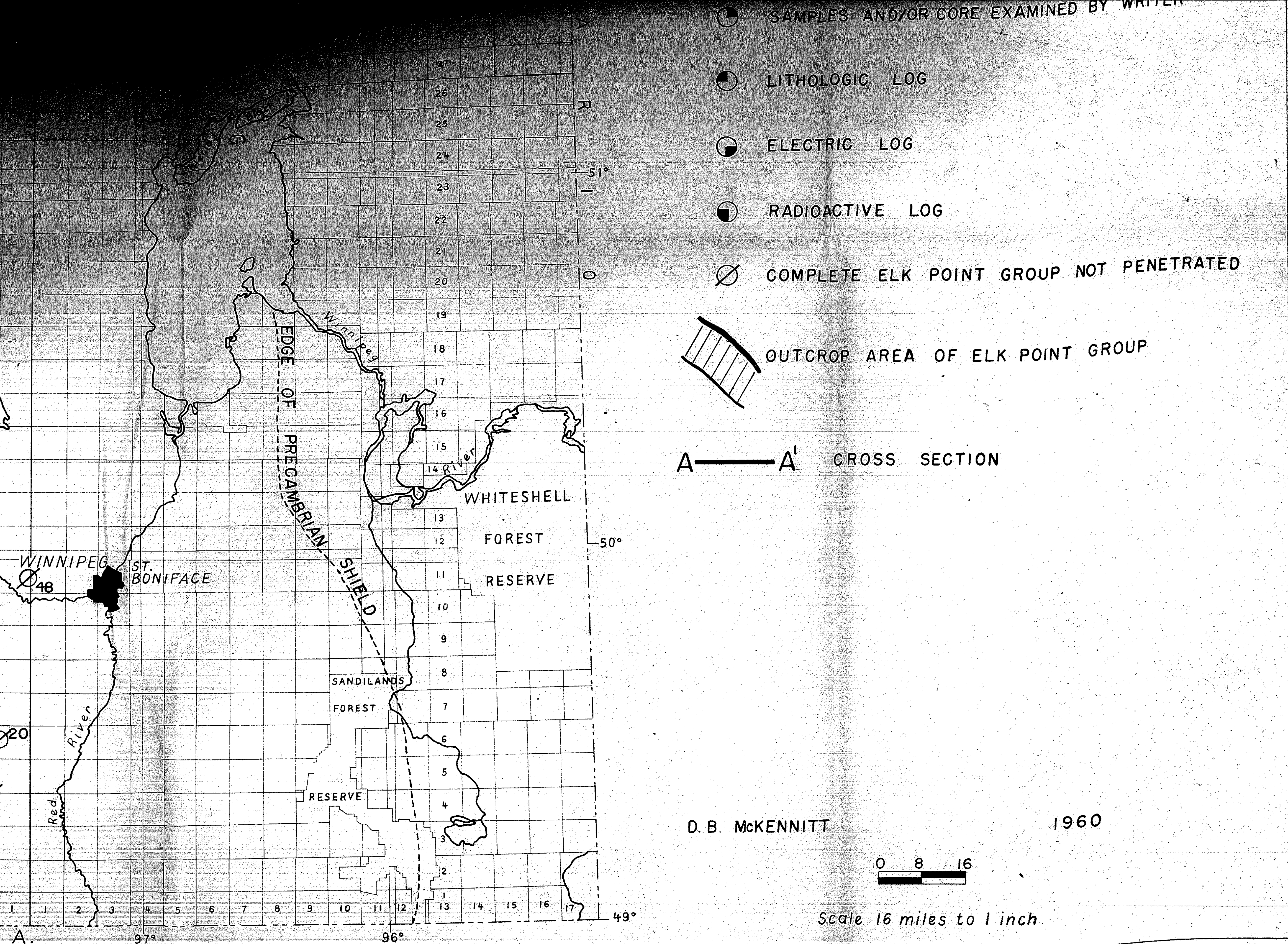
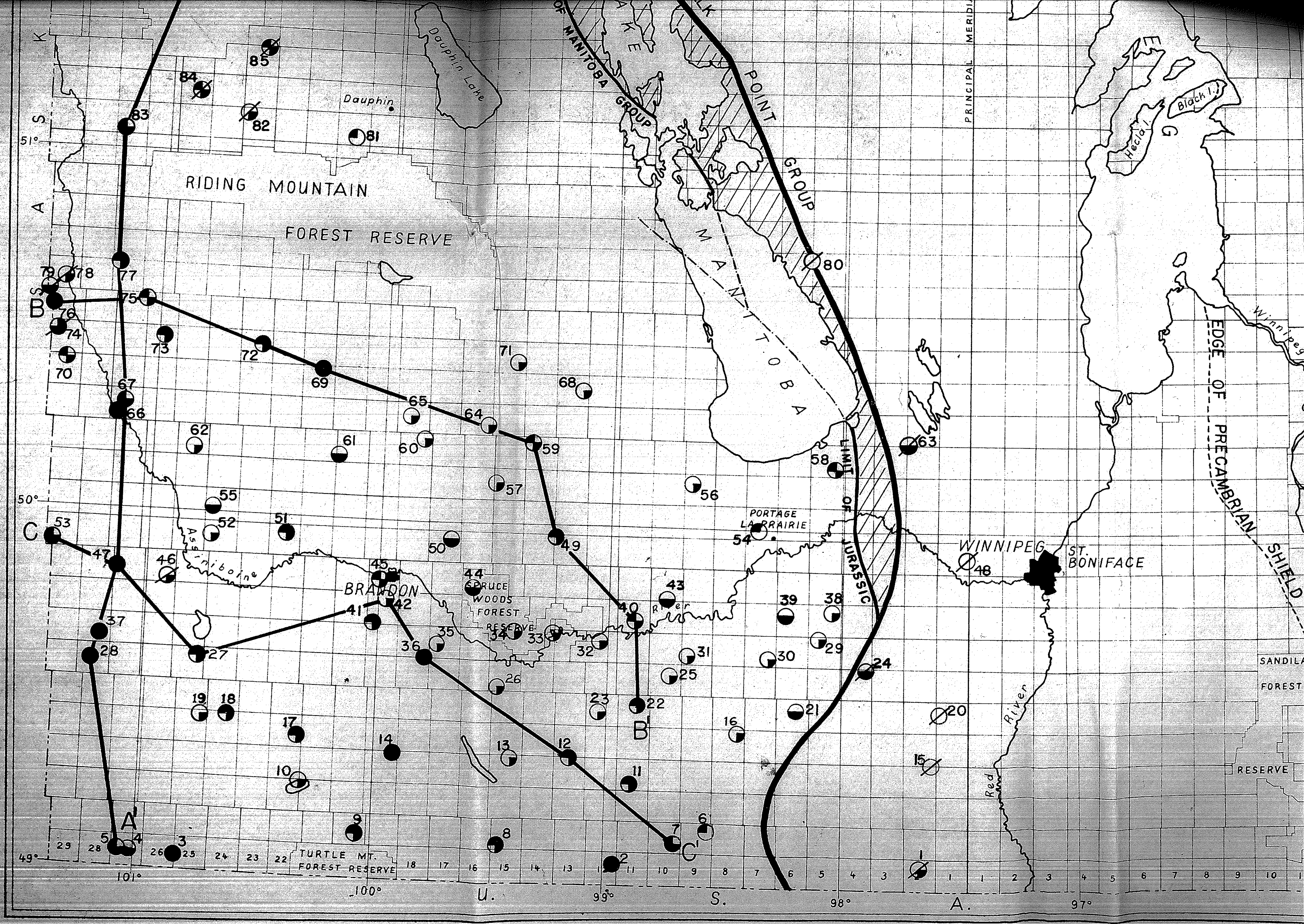
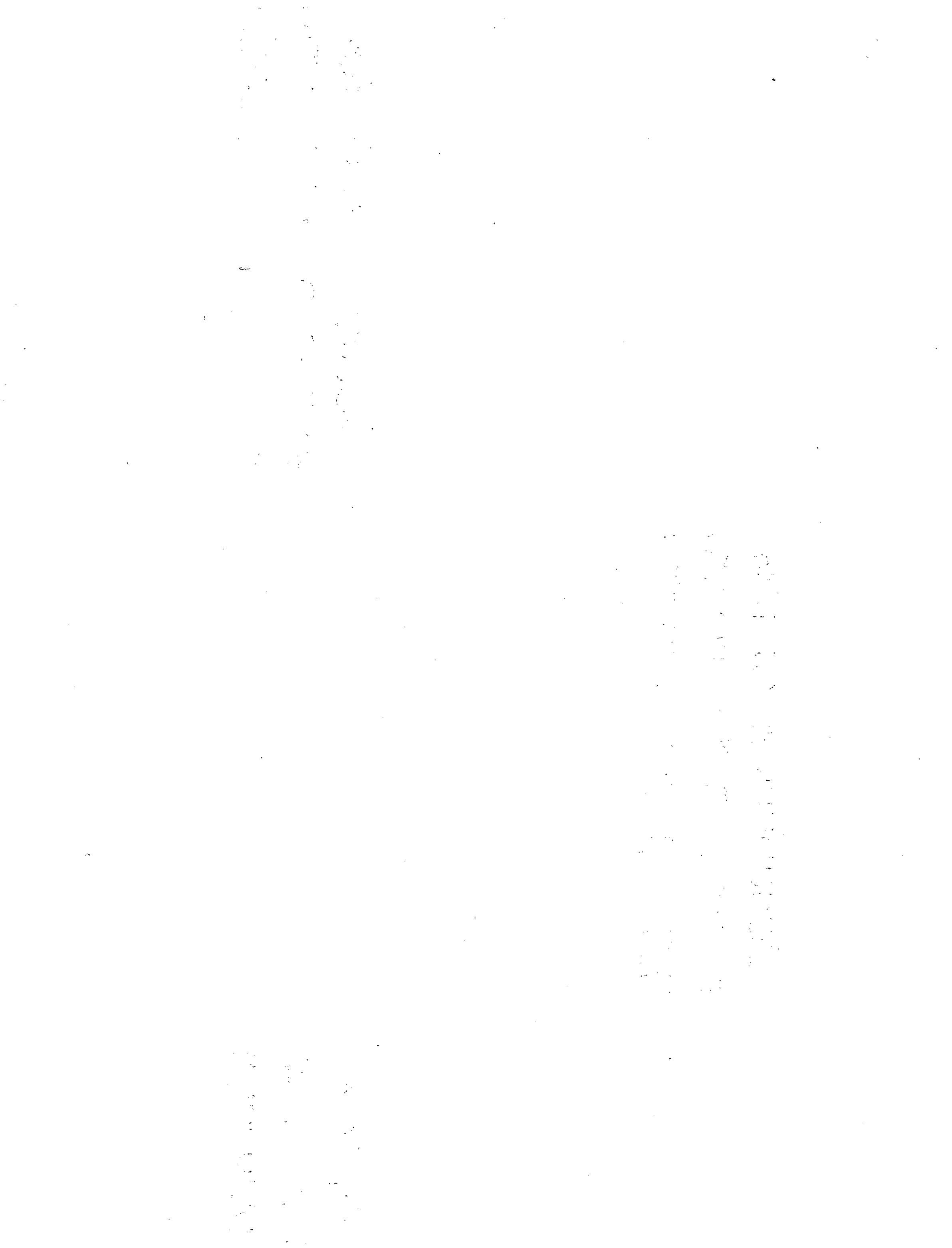


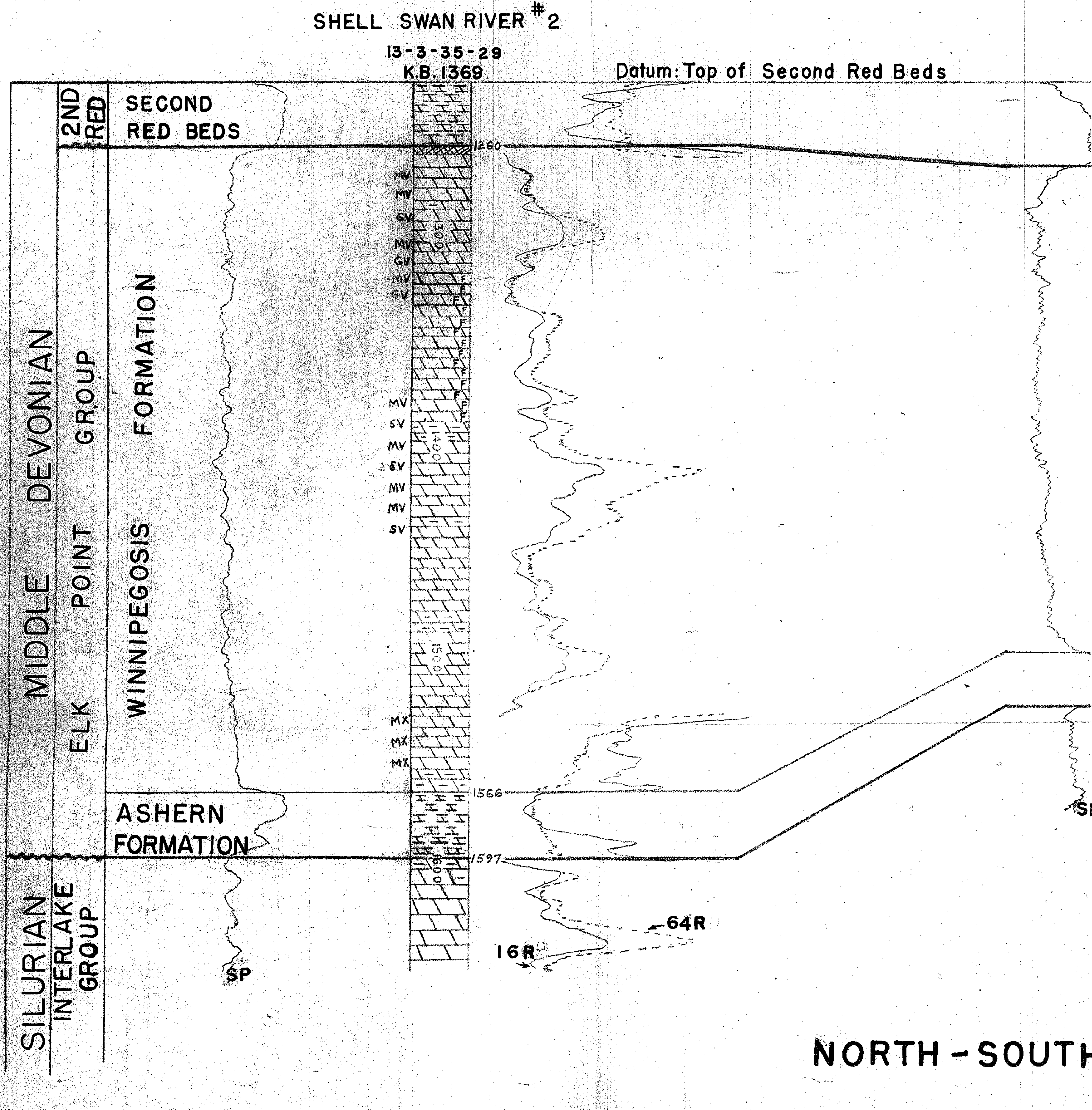
SAMPLES AND/OR CORE EXAMINED BY WRITER
LITHOLOGIC LOG
ELECTRIC LOG
RADIOACTIVE LOG
COMPLETE ELK POINT GROUP NOT PENETRATED
OUTCROP AREA OF ELK POINT GROUP
A——A' CROSS SECTION
D. B. McKENNITT
1960
0 8 16
Scale 16 miles to 1 inch
EDGE OF PRECAMBRIAN SHIELD
WINNIPEG
ST. BONIFACE
WHITESHELL FOREST RESERVE
SANDILANDS FOREST RESERVE
Red River
Winnipeg River
Hecla I.
Black I.
51°
50°
49°
97°
96°
48
20
A.



RIDING MOUNTAIN
FOREST RESERVE
Dauphin Lake
Dauphin
OF MANITOBA GROUP
POINT
GROUP
PRINCIPAL MERIDIAN
Hecla I.
Black I.
MANITOBA
LIMIT OF JURASSIC
EDGE OF PRECAMBRIAN SHIELD
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
BRANDON
SPRUCE WOODS FOREST RESERVE
Assiniboine
River
Red River
TURTLE MT. FOREST RESERVE
SANDILANDS FOREST RESERVE
Winnipeg
51°
50°
49°
101°
100°
99°
98°
97°
U. S. A.
S A S K
A
B
B'
A'
C
C'

PLATE 2





NORTH - SOUTH

POROSITY

S - slight

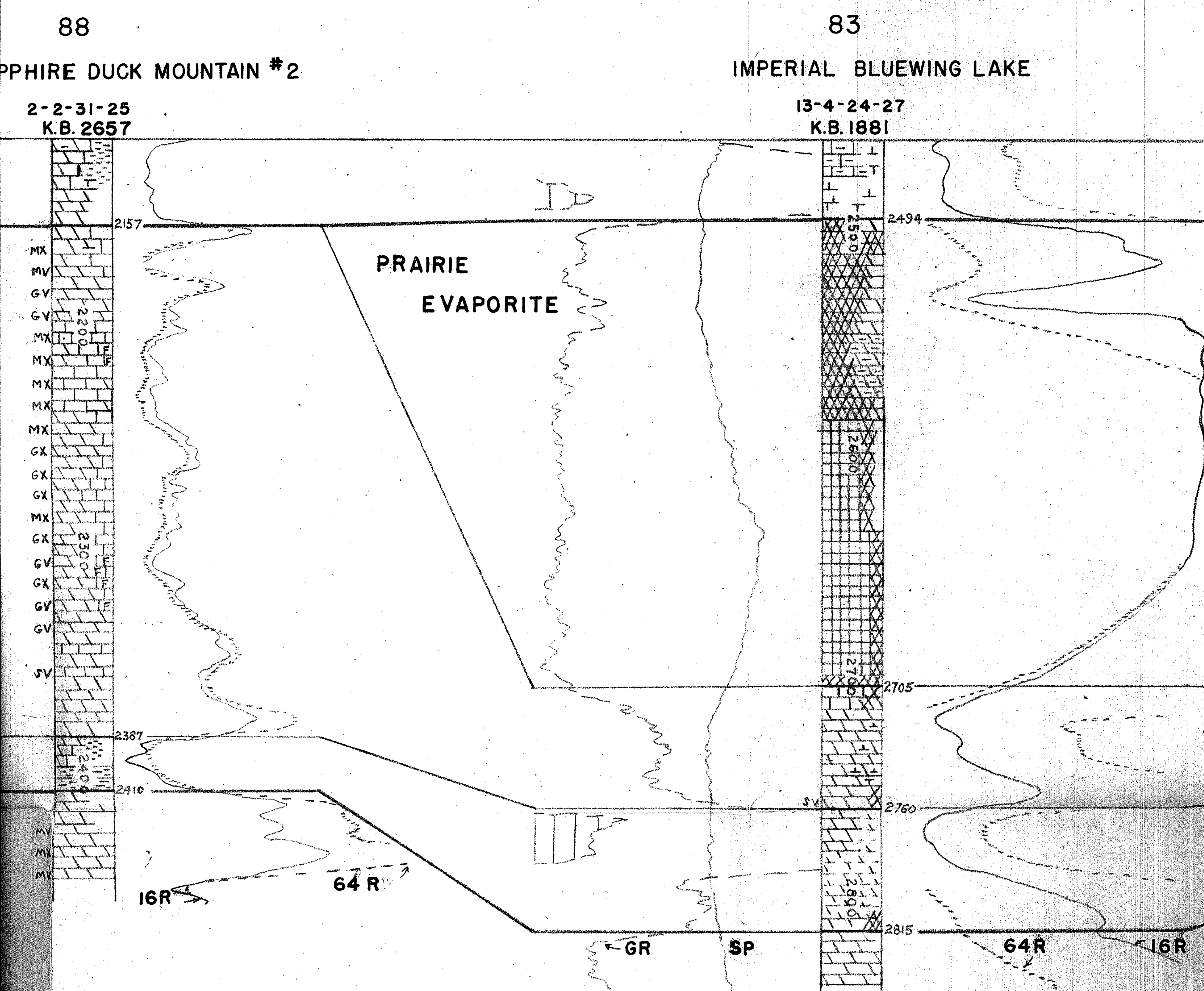
P - poor

M - medium

G - good

X - intercrystalli
intergranul

V - vugular



RATIGRAPHIC CROSS SECTION

TION FROM SHELL SWAN RIVER # 2 TO ROBERT MOOR

LEGEND

LOGS

R- resistivity log
GR- gamma ray log
SP- spontaneous potential log
16R- short normal resistivity log
64R- long normal resistivity log
LR- lateral resistivity log
LO- laterolog

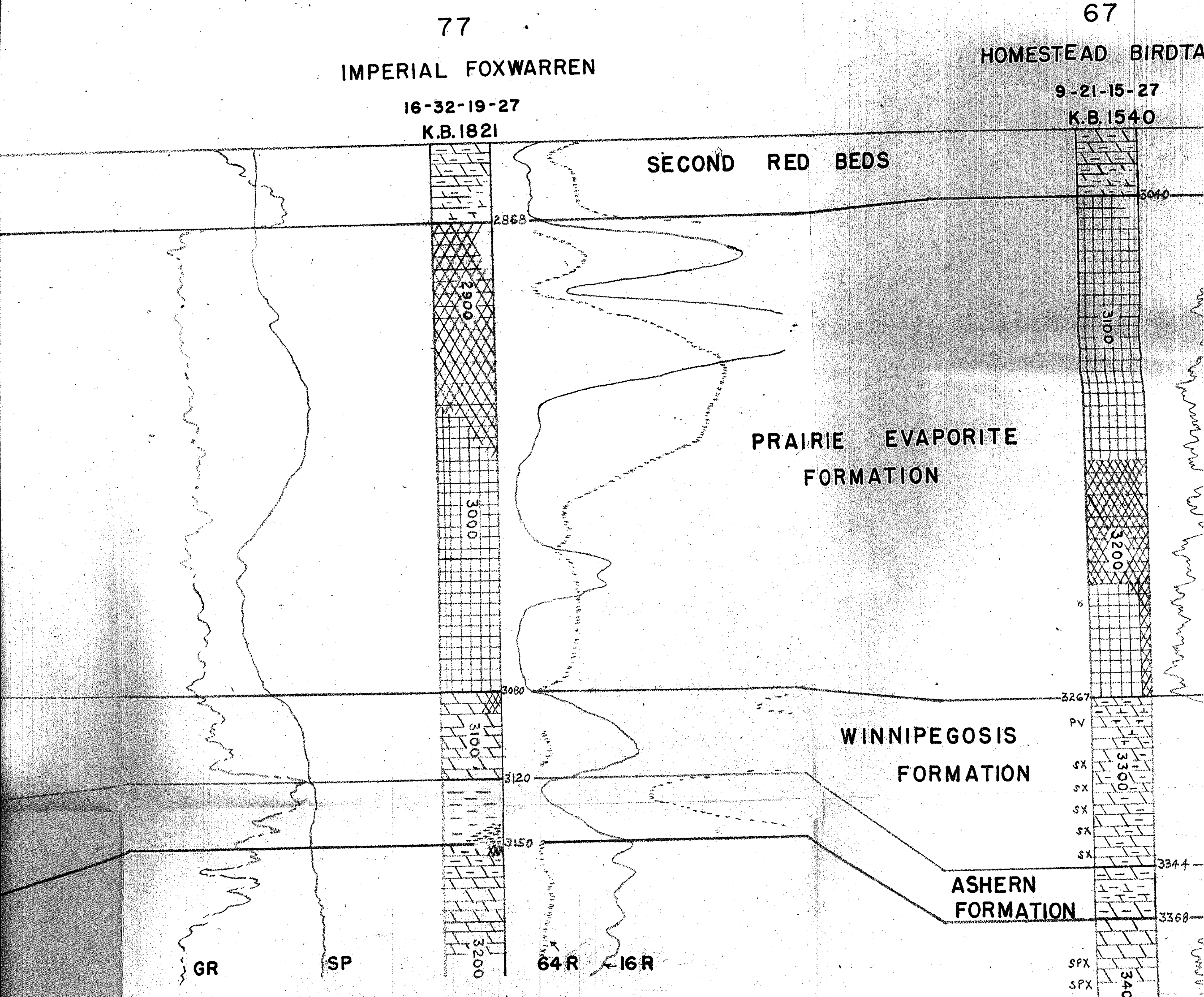
LITHOLOGY

LIMESTONE
- argillaceous
- dolomitic
- anhydritic
- silty

SHALE
- calcareous
- dolomitic
- silty

DOLOMITE
- argillaceous
- calcareous
- anhydritic
- silty

ANHYDRITE
SALT
NS NO SAMPLES
F FOSSILIFEROUS



- A'

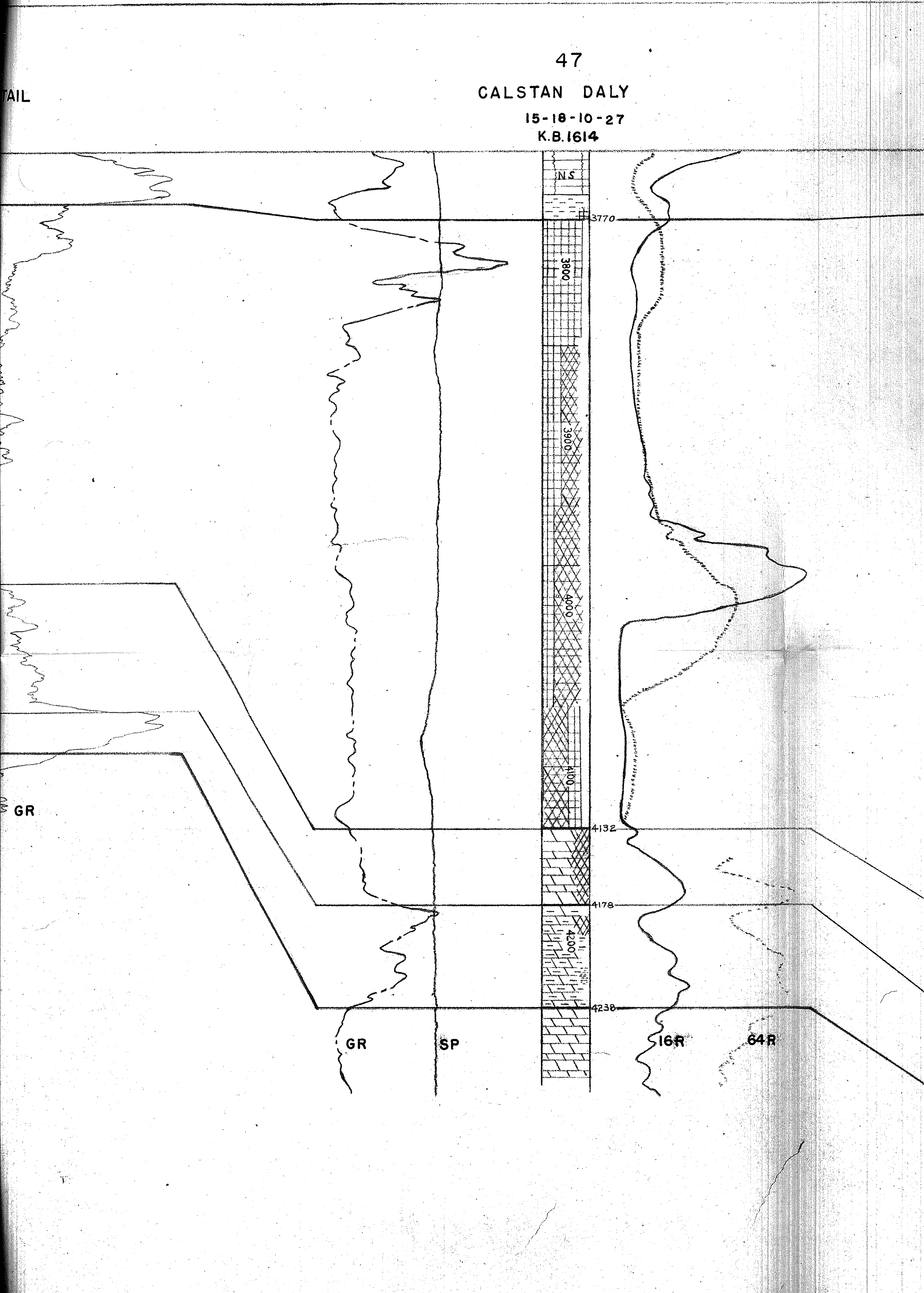
- 20

ES

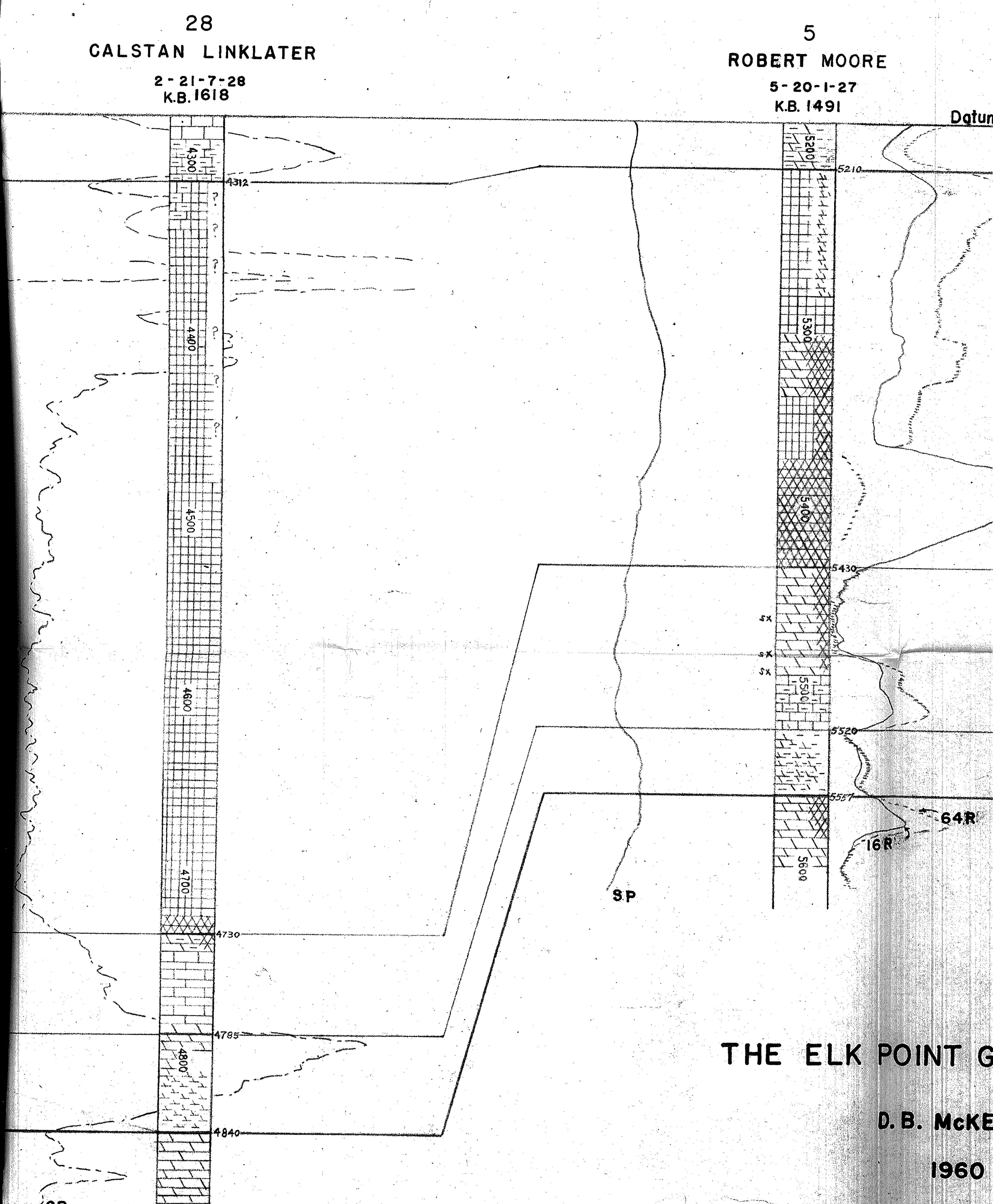
Where SP curve is featureless, wells have been drilled with salt base mud, and SP is unreliable.

All well locations are west of the prime meridian.

Vertical Scale: 1 inch = 50 feet



TAIL
47
CALSTAN DALY
15-18-10-27
K.B.1614
NS
3770
3800
3900
4000
4100
4132
4178
4200
4238
GR
GR
SP
16R
64R

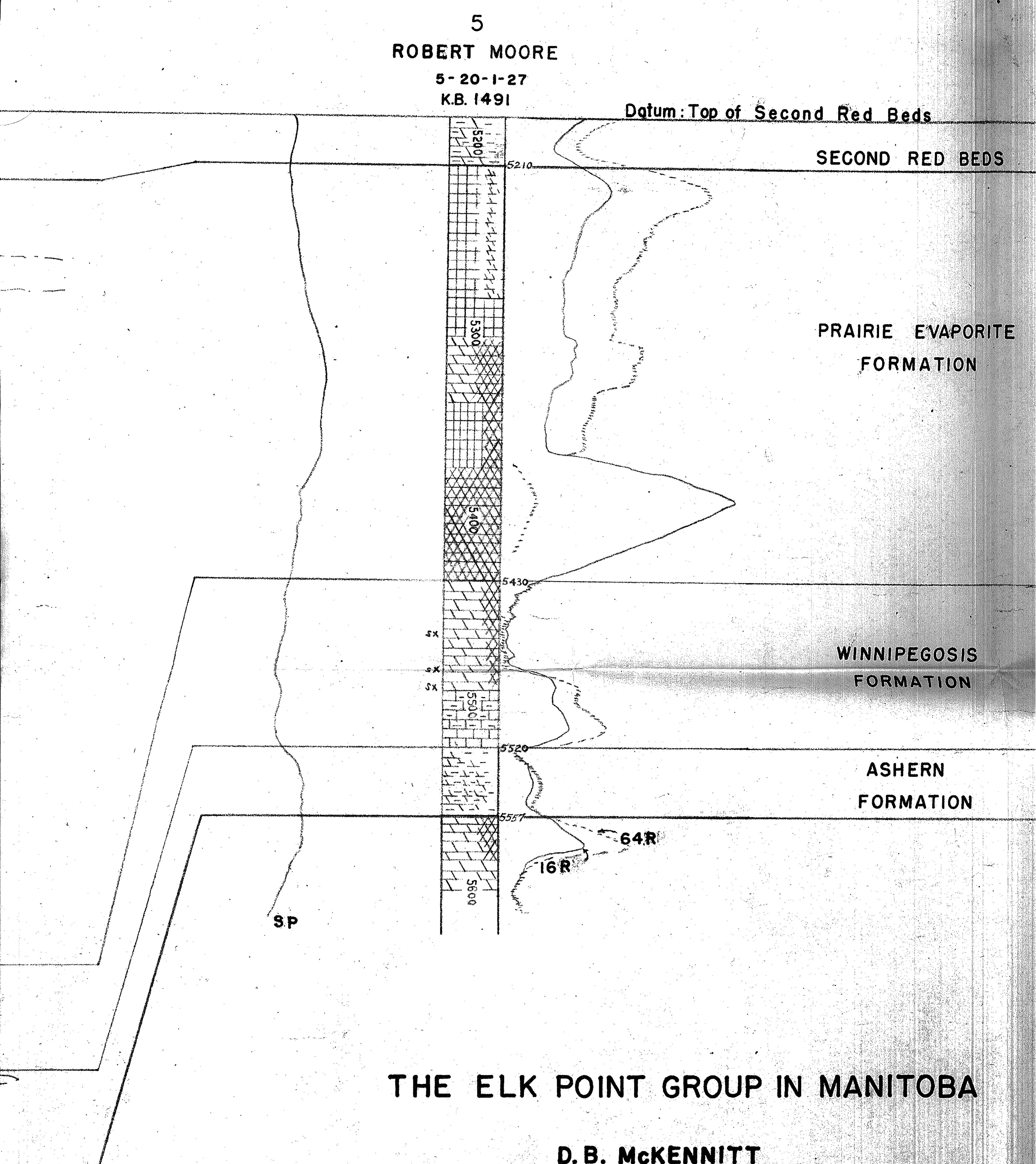


THE ELK POINT G

D. B. McKE

1960

THE UNIVERSITY



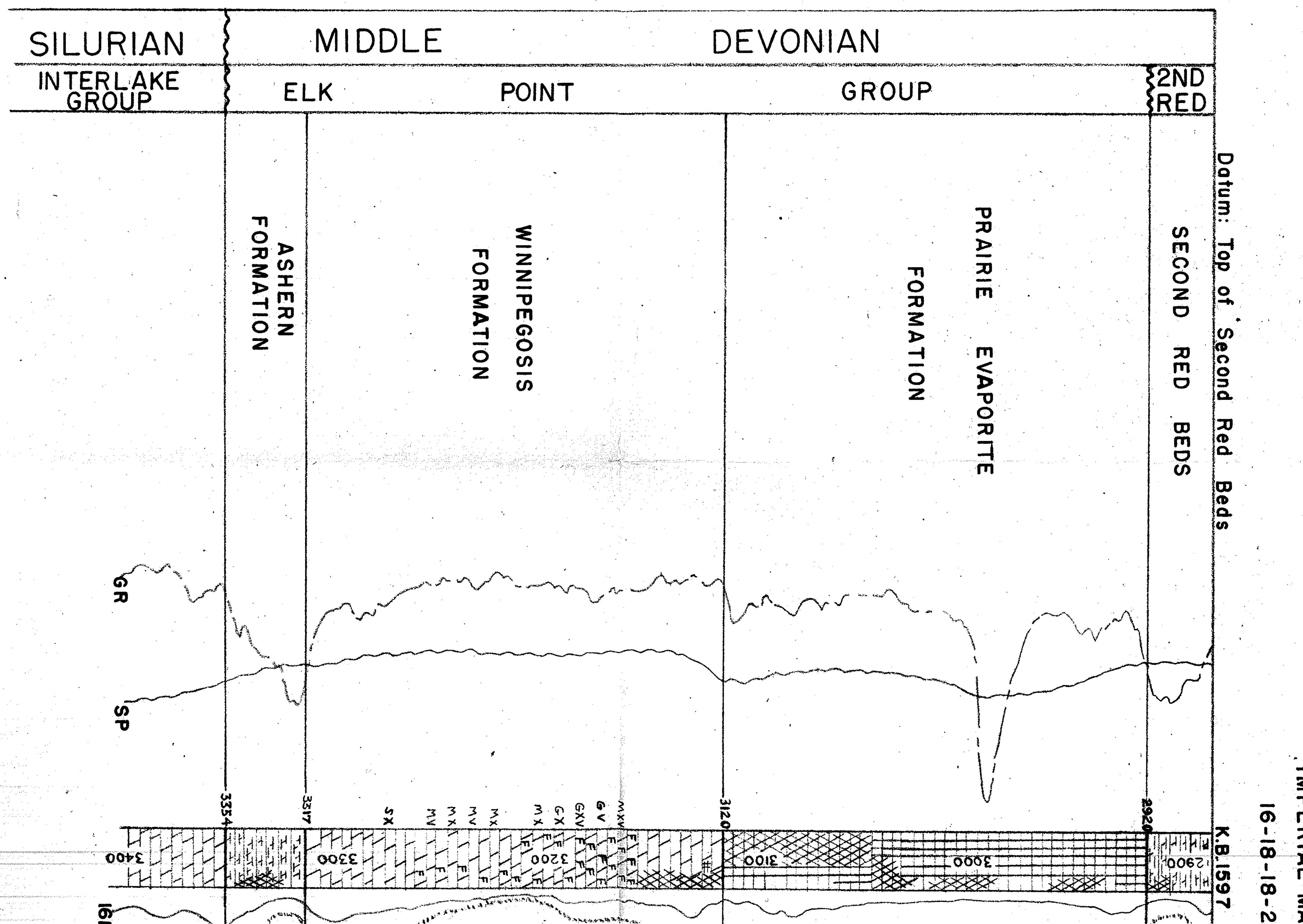
THE ELK POINT GROUP IN MANITOBA

D. B. McKENNITT

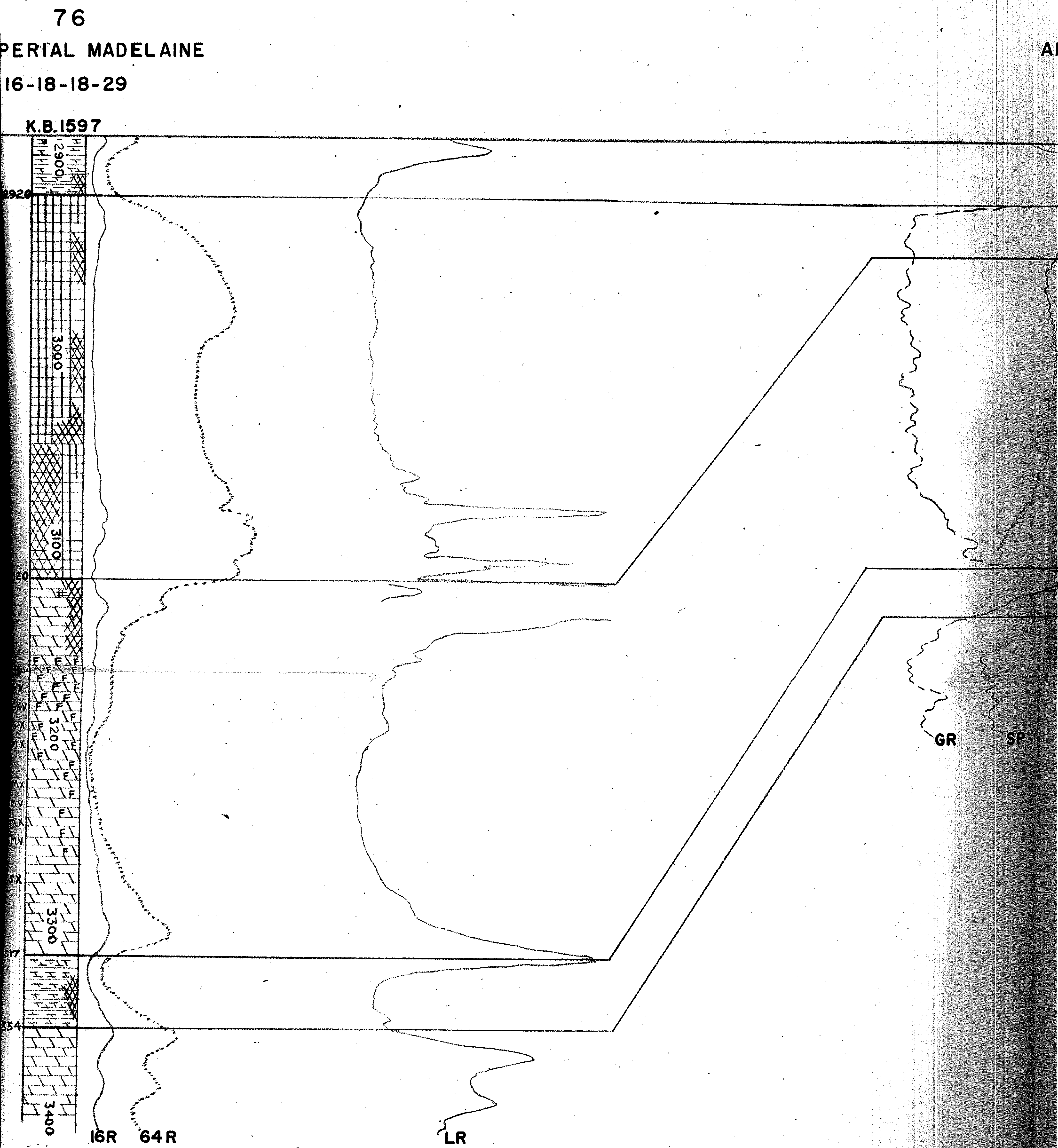
1960

THE UNIVERSITY OF MANITOBA

PLATE 3



SILURIAN
MIDDLE
DEVONIAN
INTERLAKE GROUP
ELK
POINT
GROUP
2ND RED
ASHERN FORMATION
WINNIPEGOSIS FORMATION
PRAIRIE EVAPORITE FORMATION
SECOND RED BEDS
Datum: Top of Second Red Beds
GR
SP
3354
3317
3120
2920
3400
3300
3200
3100
3000
2900
K.B.1597
76
IMPERIAL MA
16-18-18-2



76
PERIAL MADELAINE
16-18-18-29
K.B.1597
2900
2920
3000
3100
3200
3300
3400
16R
64R
LR
GR
SP

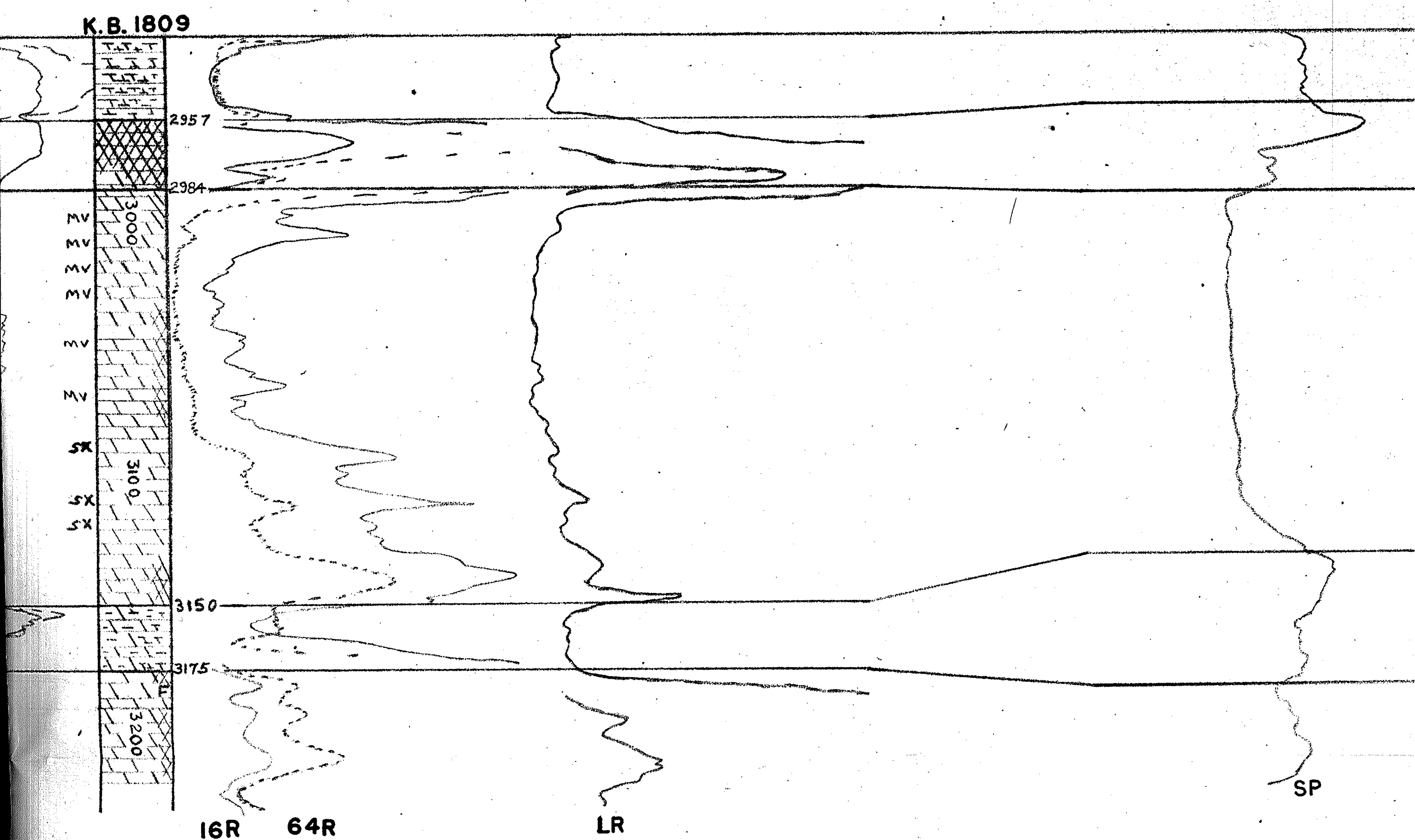
75

IGLO-AMERICAN BIRDTAIL

4-30-18-26

CANADIAN

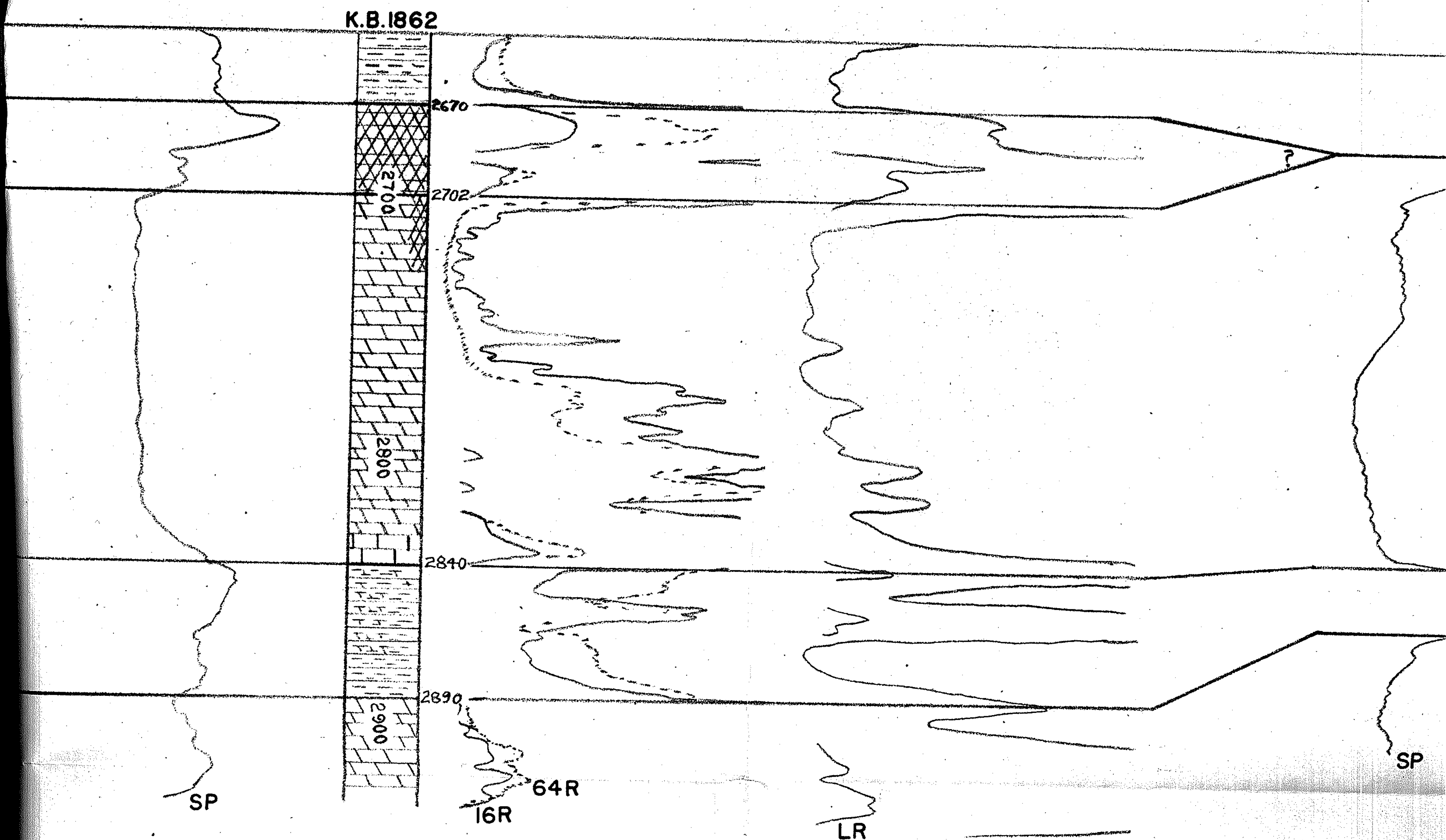
6

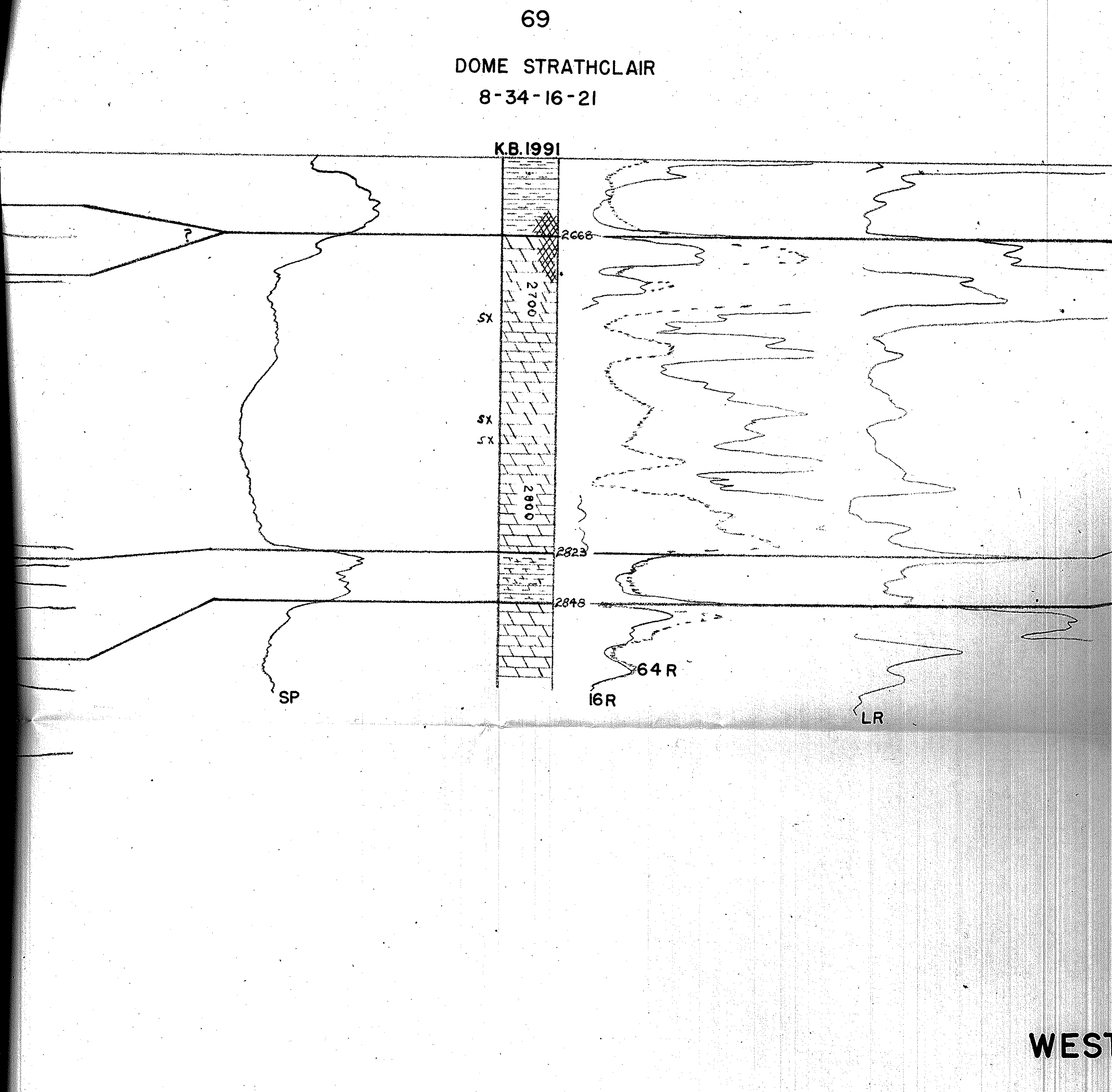


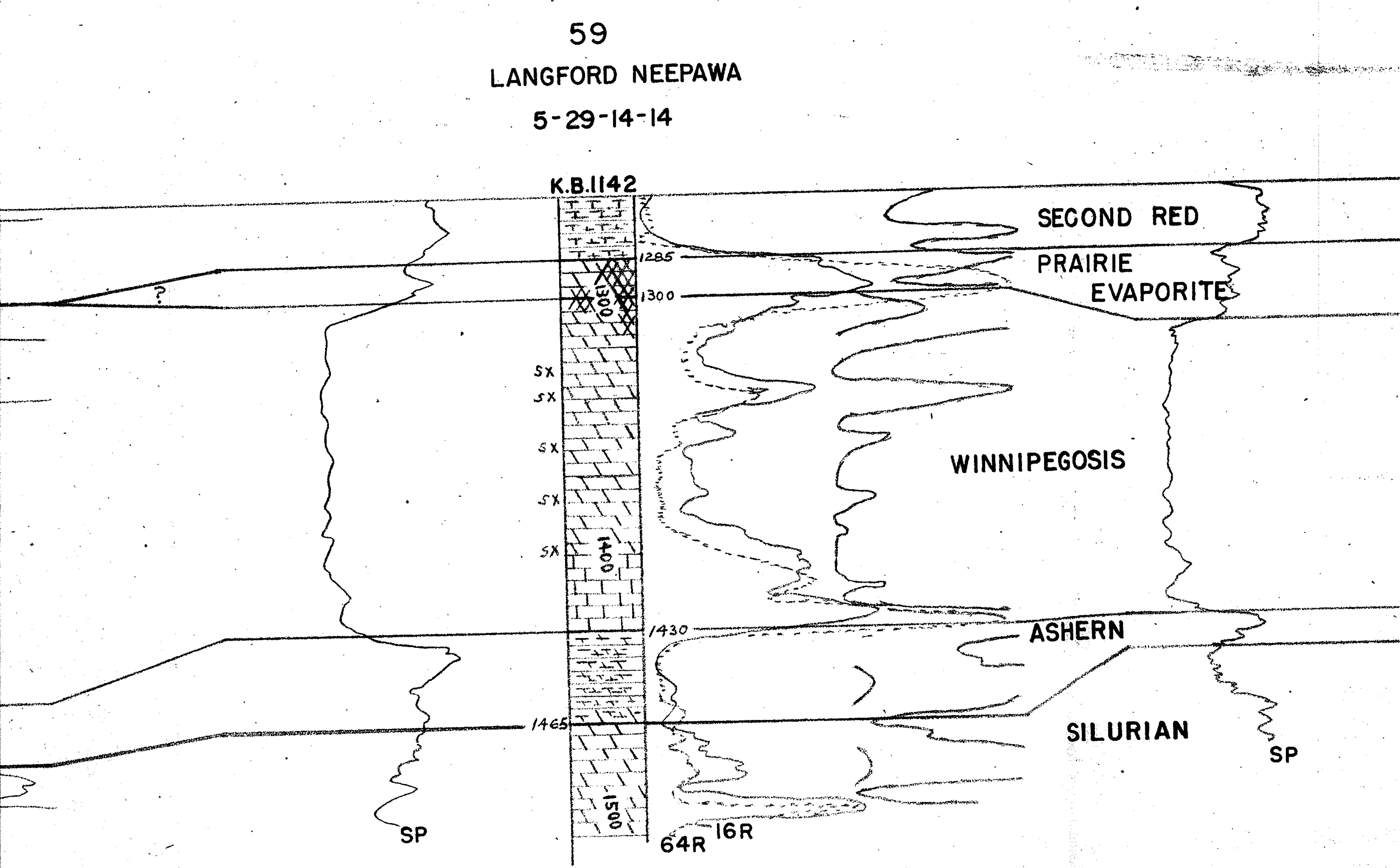
72

CANADIAN SUPERIOR STRATHCLAIR

6-23-17-23



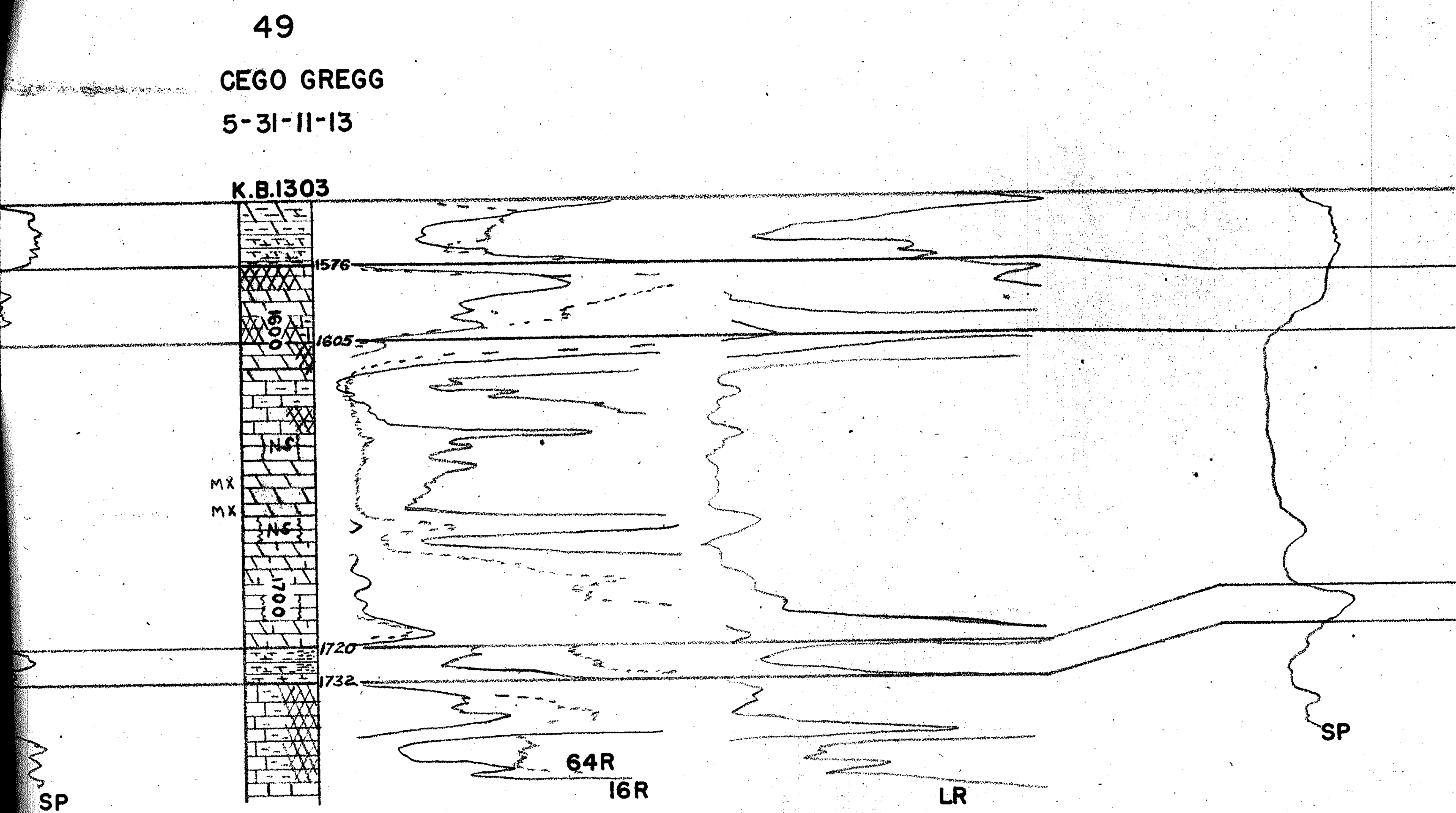

69
DOME STRATHCLAIR
8-34-16-21
K.B. 1991
2668
2700
SX
SX
SX
2800
2823
2848
SP
16R
64 R
LR
WEST



STRATIGRAPHIC CROSS SECT

WEST TO EAST SECTION FROM IMPERIAL MADELAINE 16-18

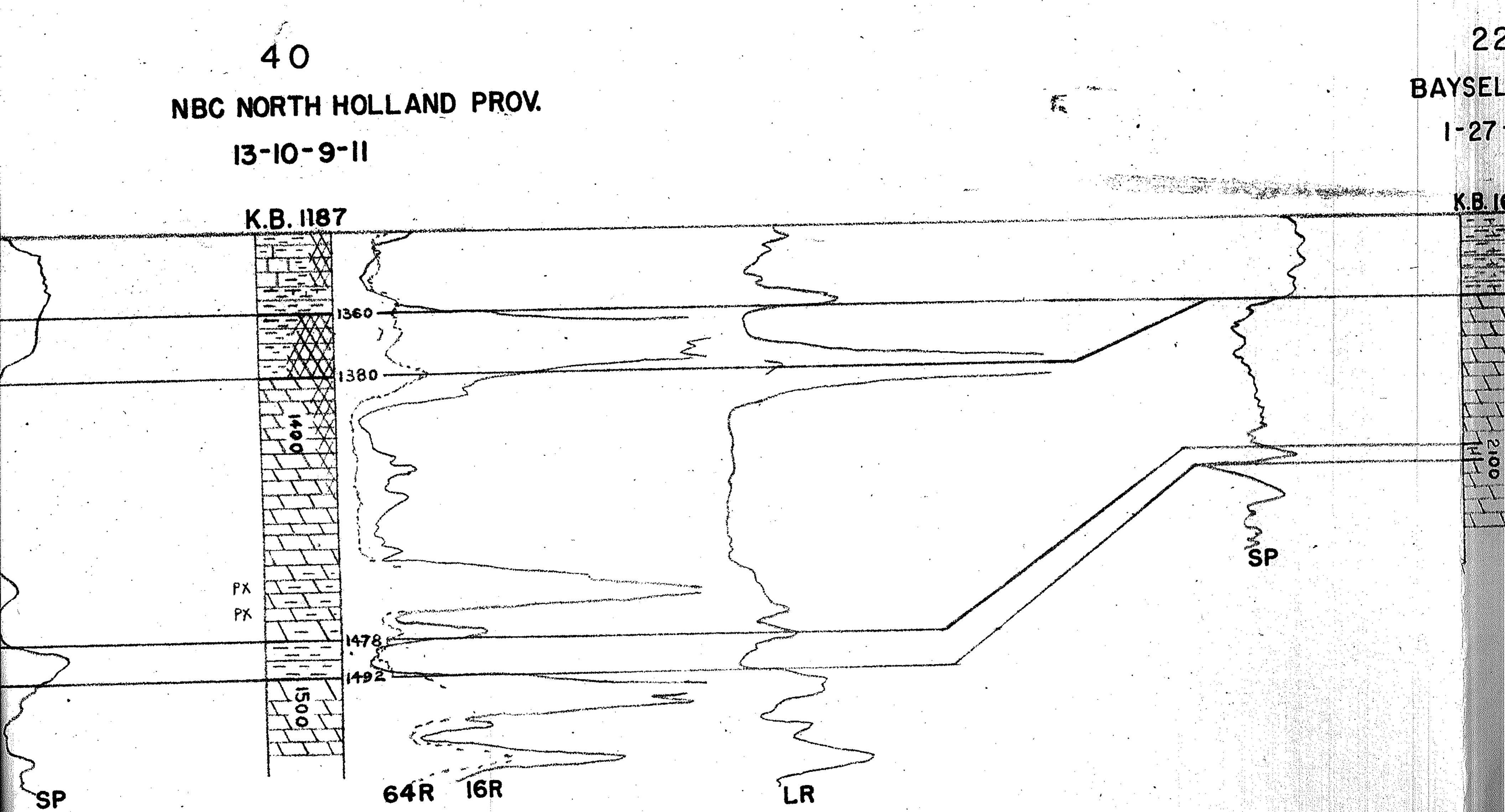
FOR LEGEND SEE PLATE 2, STRATIGRAPHIC



SECTION B - B'

E 16-18 TO BAYSEL BRUXELLES 1-27

APHIC SECTION A-A'

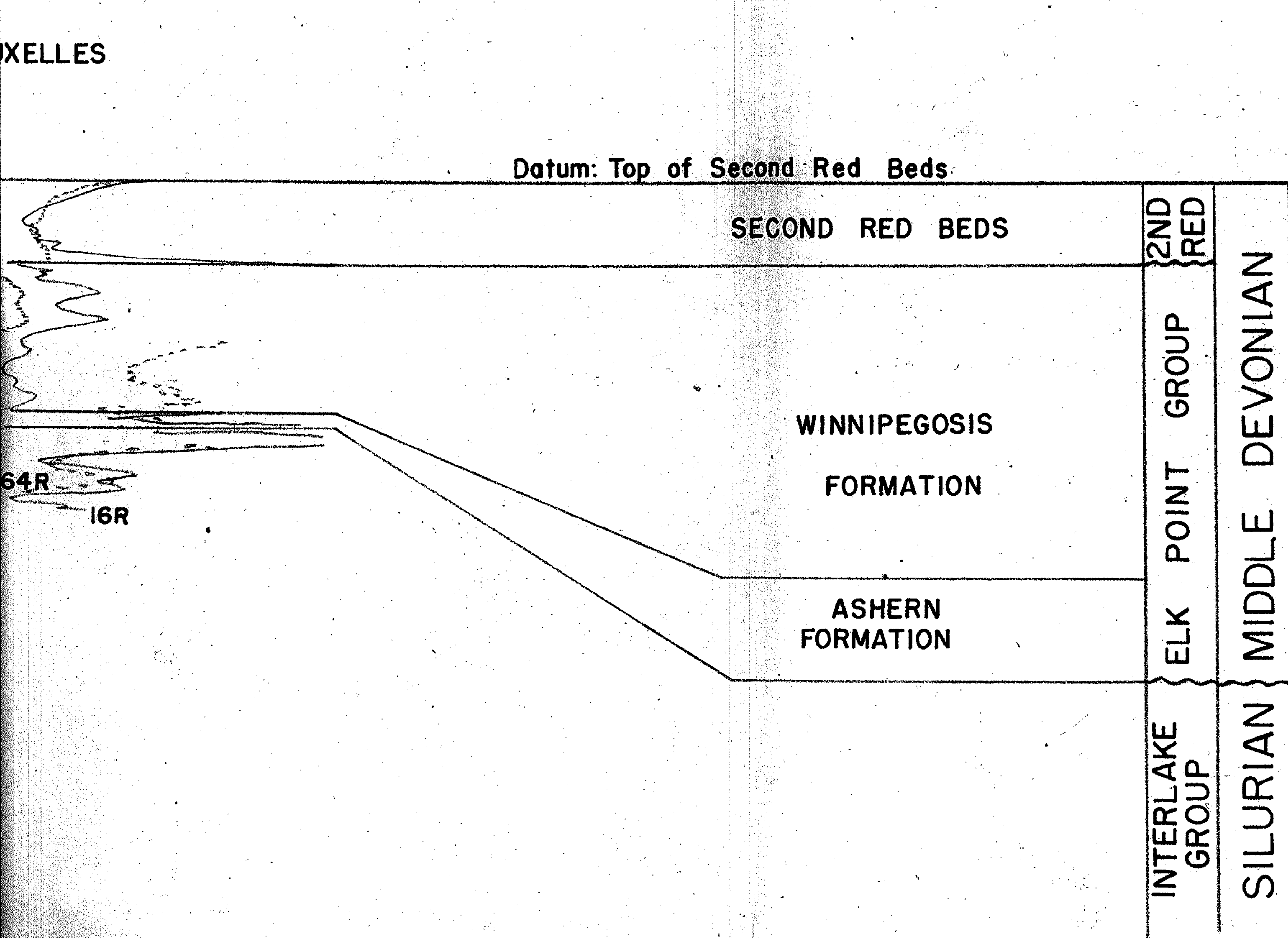


THE ELK POINT G

D. B. McKE

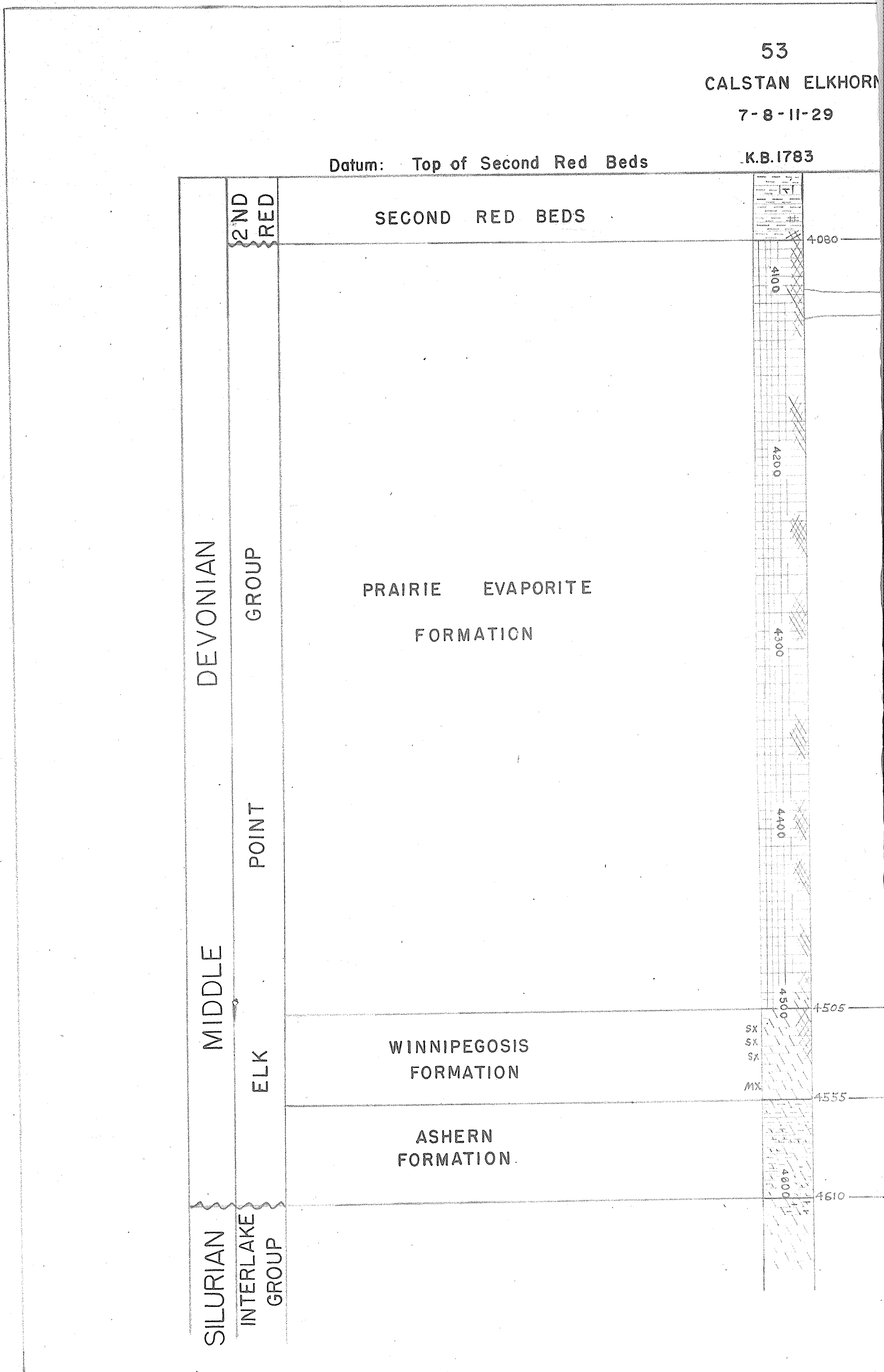
196

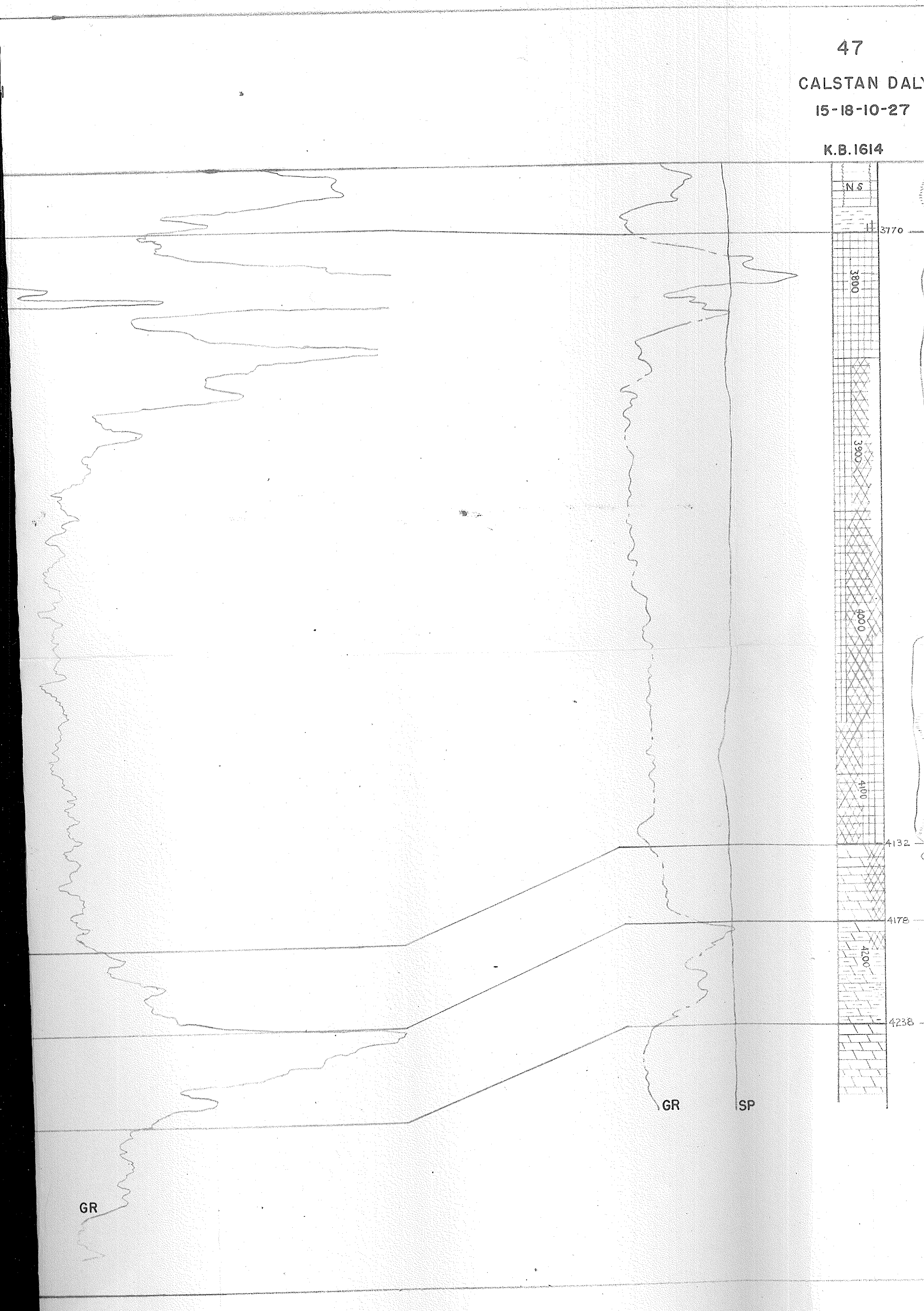
THE UNIVERSITY



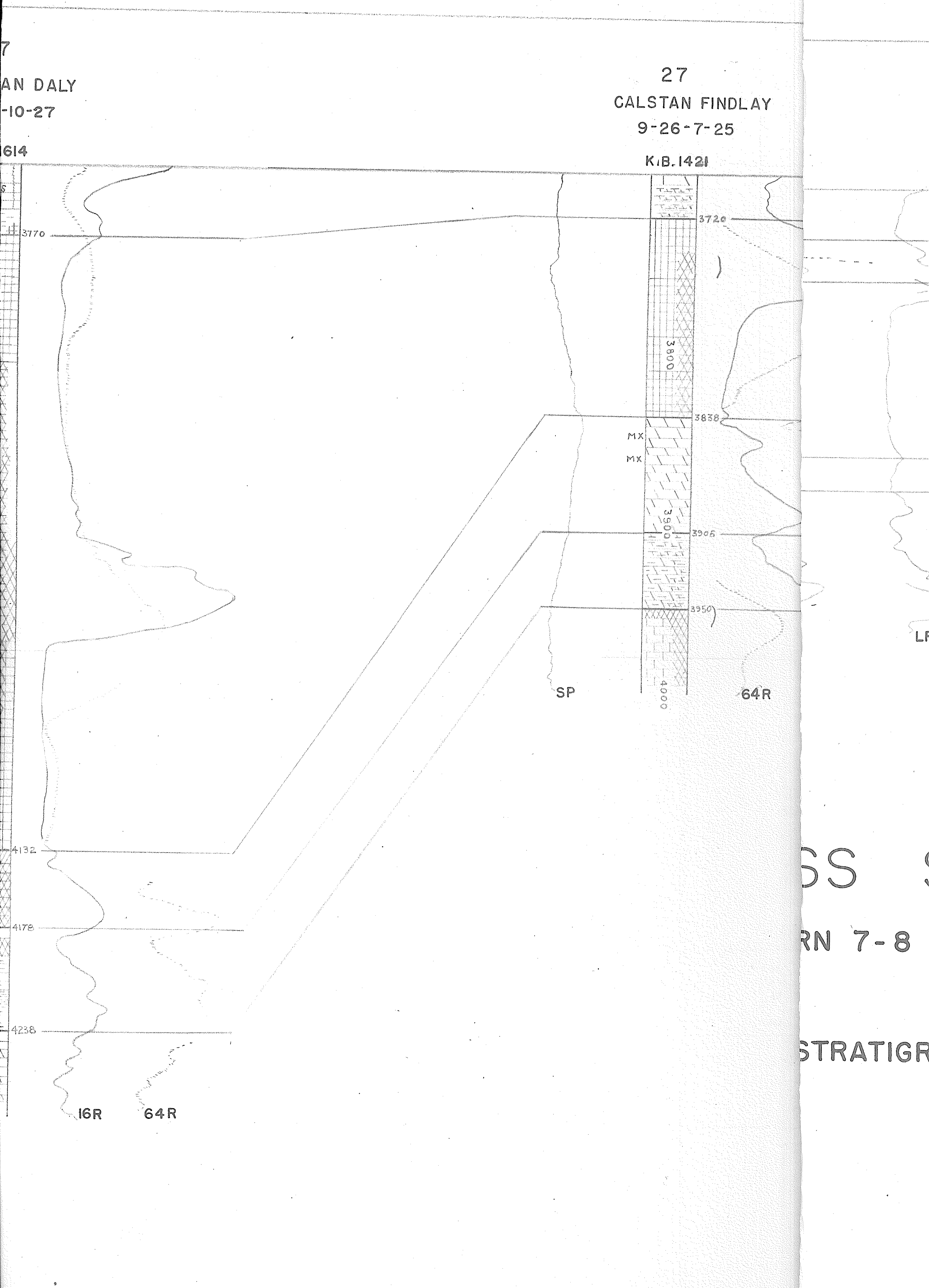
P IN MANITOBA

ANITOBA


53
CALSTAN ELKHORN
7-8-11-29
Datum: Top of Second Red Beds
K.B.1783
2ND RED
SECOND RED BEDS
4080
4100
4200
4300
4400
4500
4505
4555
4600
4610
DEVONIAN
MIDDLE
ELK POINT GROUP
PRAIRIE EVAPORITE FORMATION
WINNIPEGOSIS FORMATION
ASHERN FORMATION
SX
SX
SX
MX
SILURIAN
INTERLAKE GROUP



47
CALSTAN DALY
15-18-10-27
K.B.1614
NS
3770
3800
3900
4000
4100
4132
4178
4200
4238
GR
SP
GR

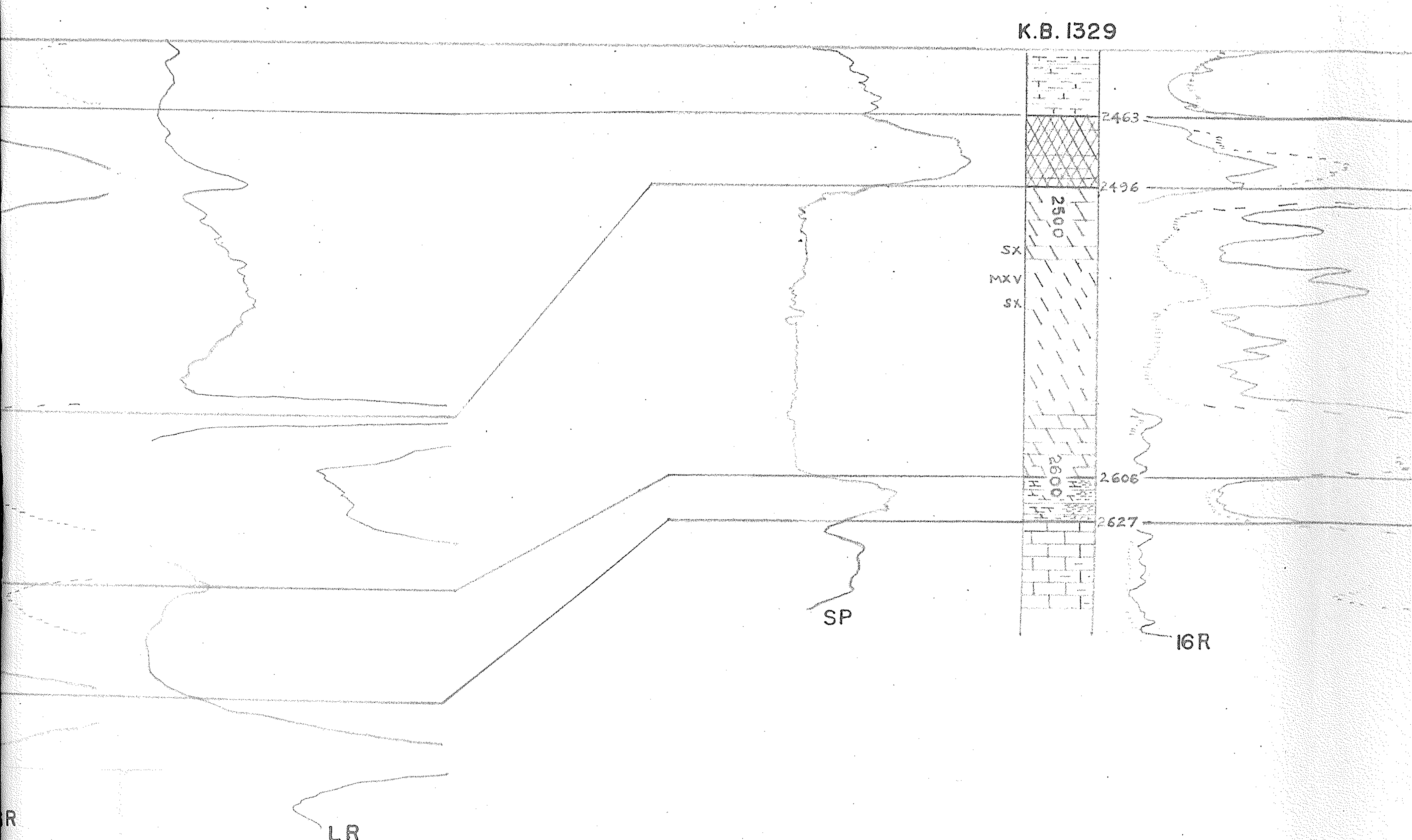


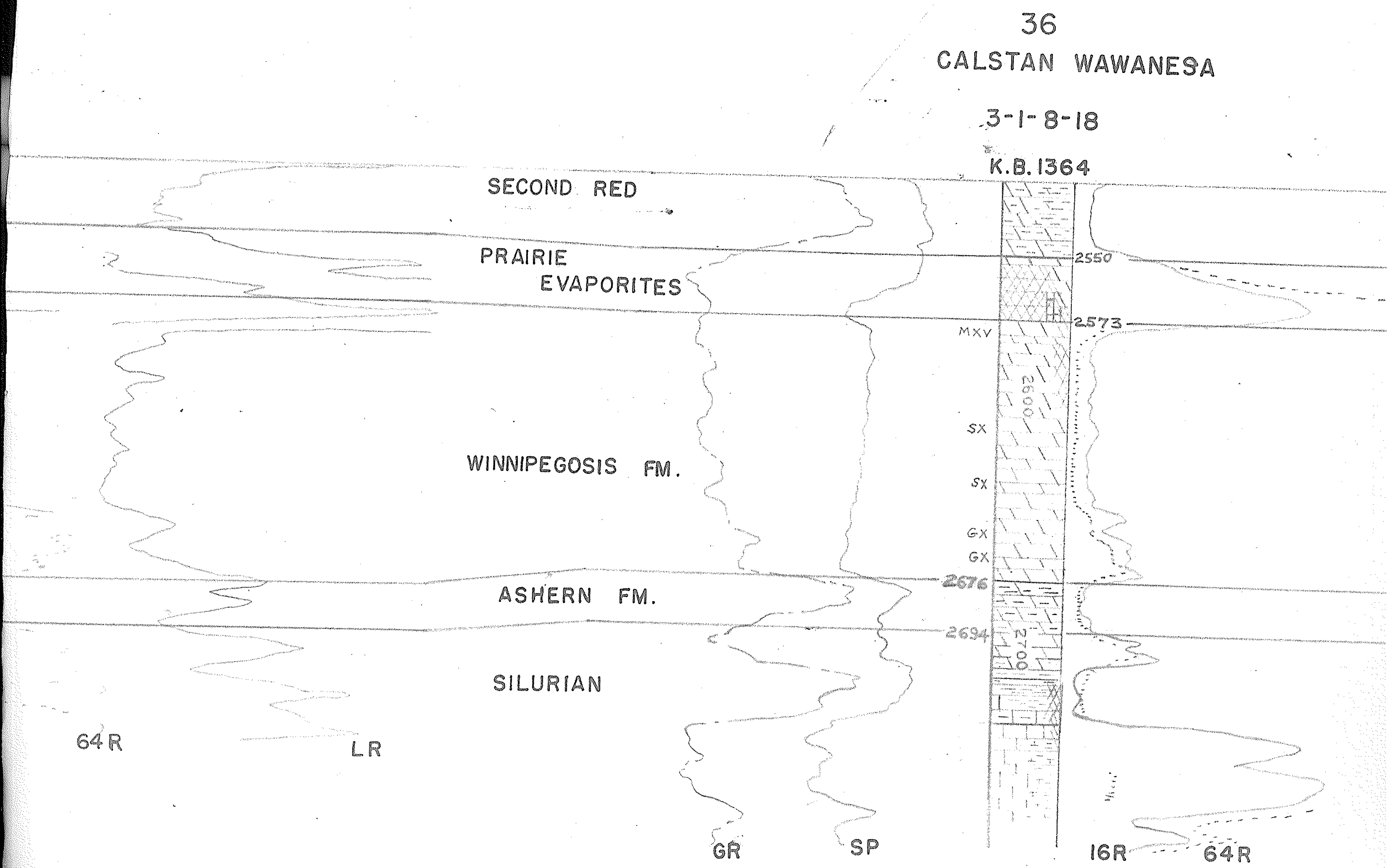
7
AN DALY
-10-27
1614
3770
4132
4178
4238
16R
64R
27
CALSTAN FINDLAY
9-26-7-25
K.B.1421
3720
3800
3838
MX
MX
3900
3905
3950
4000
SP
64R
LR
SS
RN 7-8
STRATIGR

42

DOME BRANDON

16-27-9-19

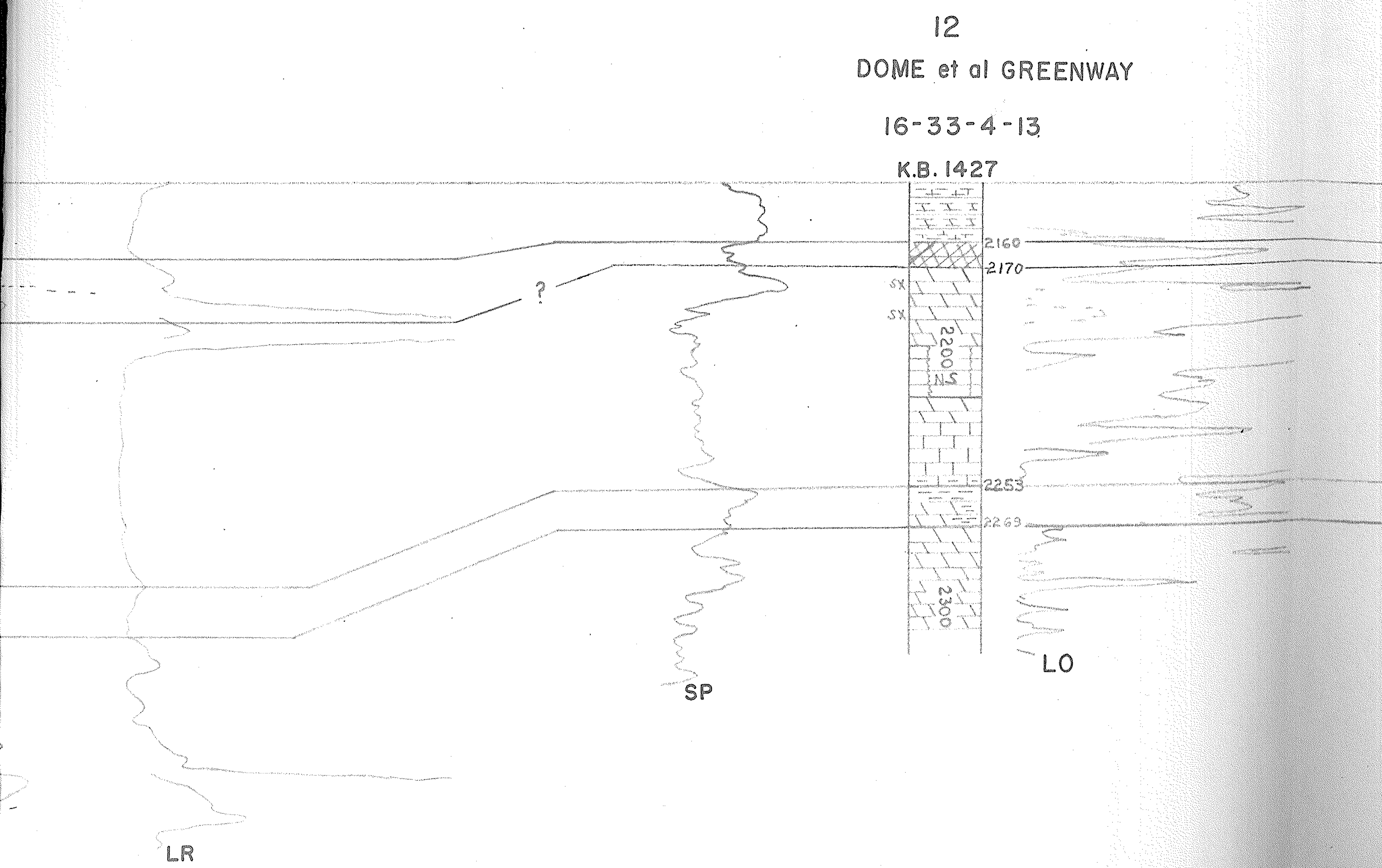




STRATIGRAPHIC CROSS

WEST TO EAST SECTION FROM CALSTAN ELKHORN 7-

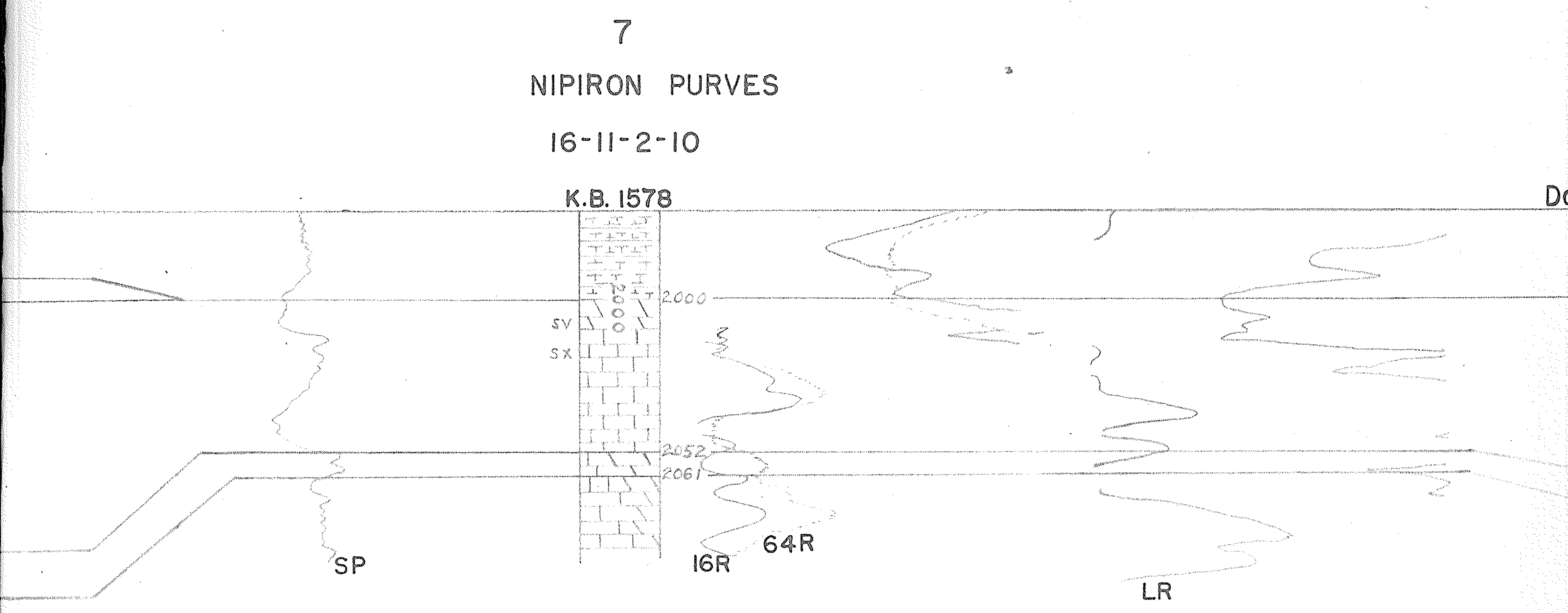
FOR LEGEND SEE PLATE 2, STRAT



SS SECTION C – C'

RN 7-8 TO NIPIRON PURVES 16-11

STRATIGRAPHIC SECTION A-A'

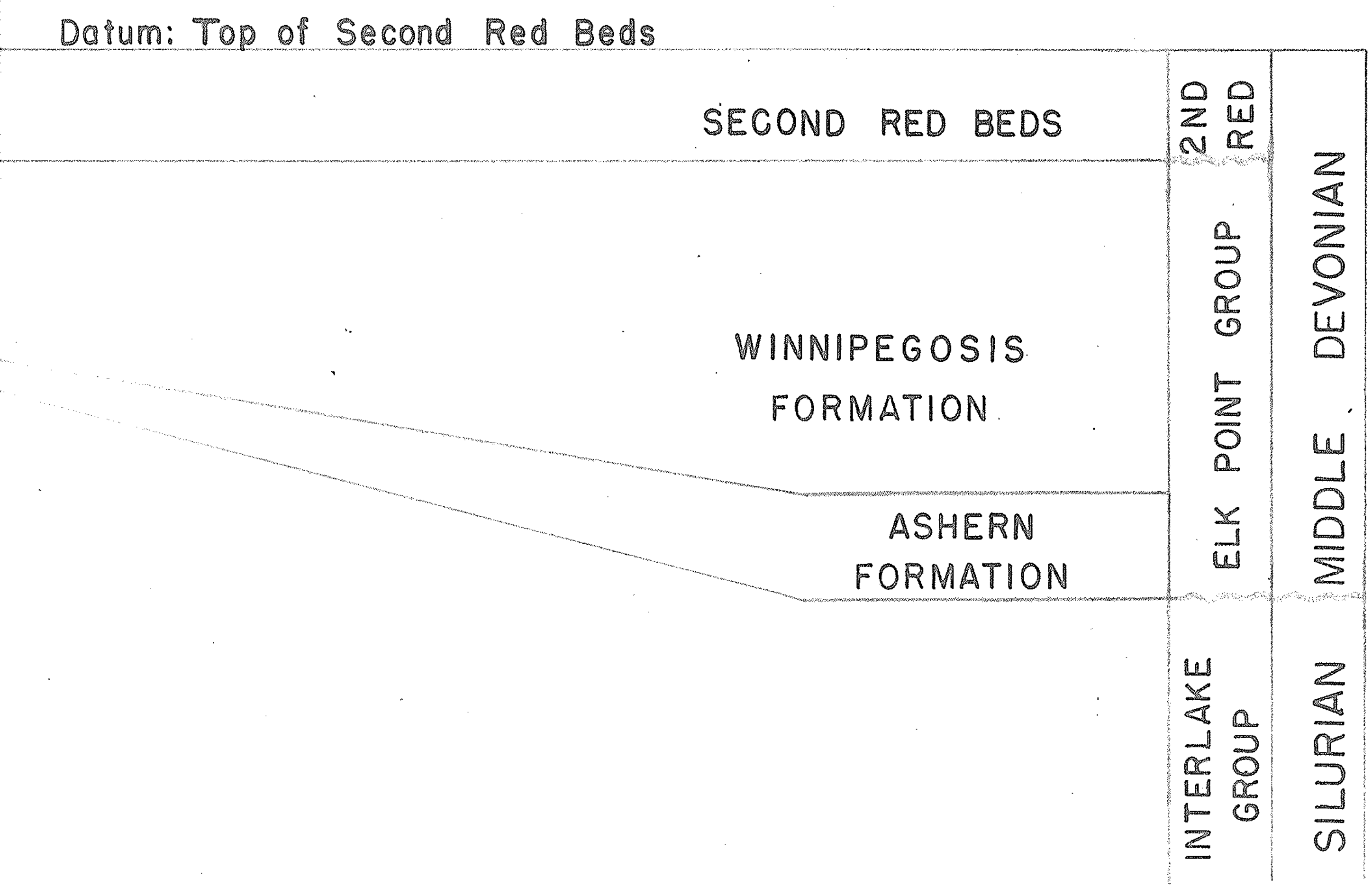


THE ELK POINT

D. B.

THE UNIVERS

PLATE 4

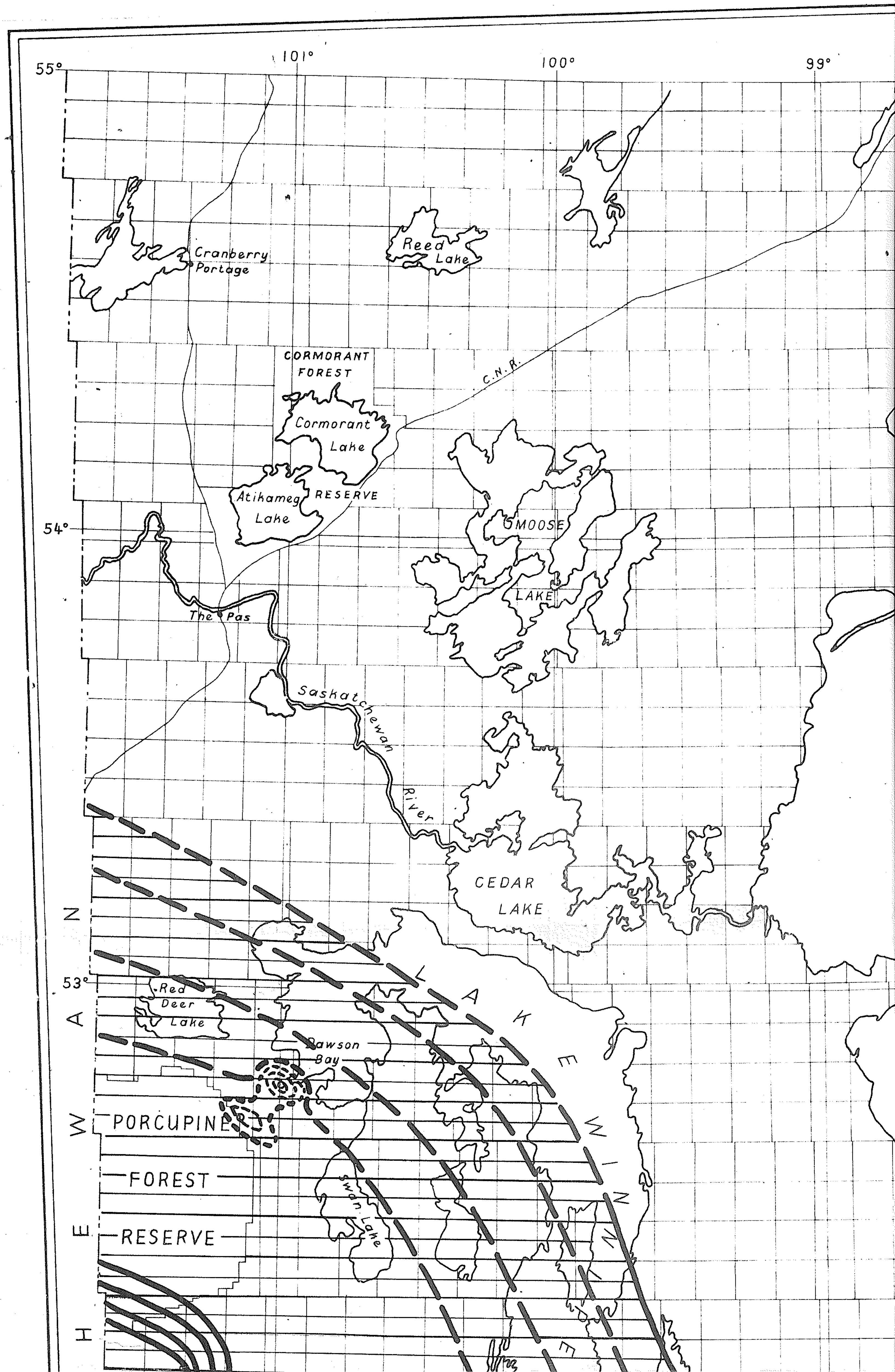


INT GROUP IN MANITOBA

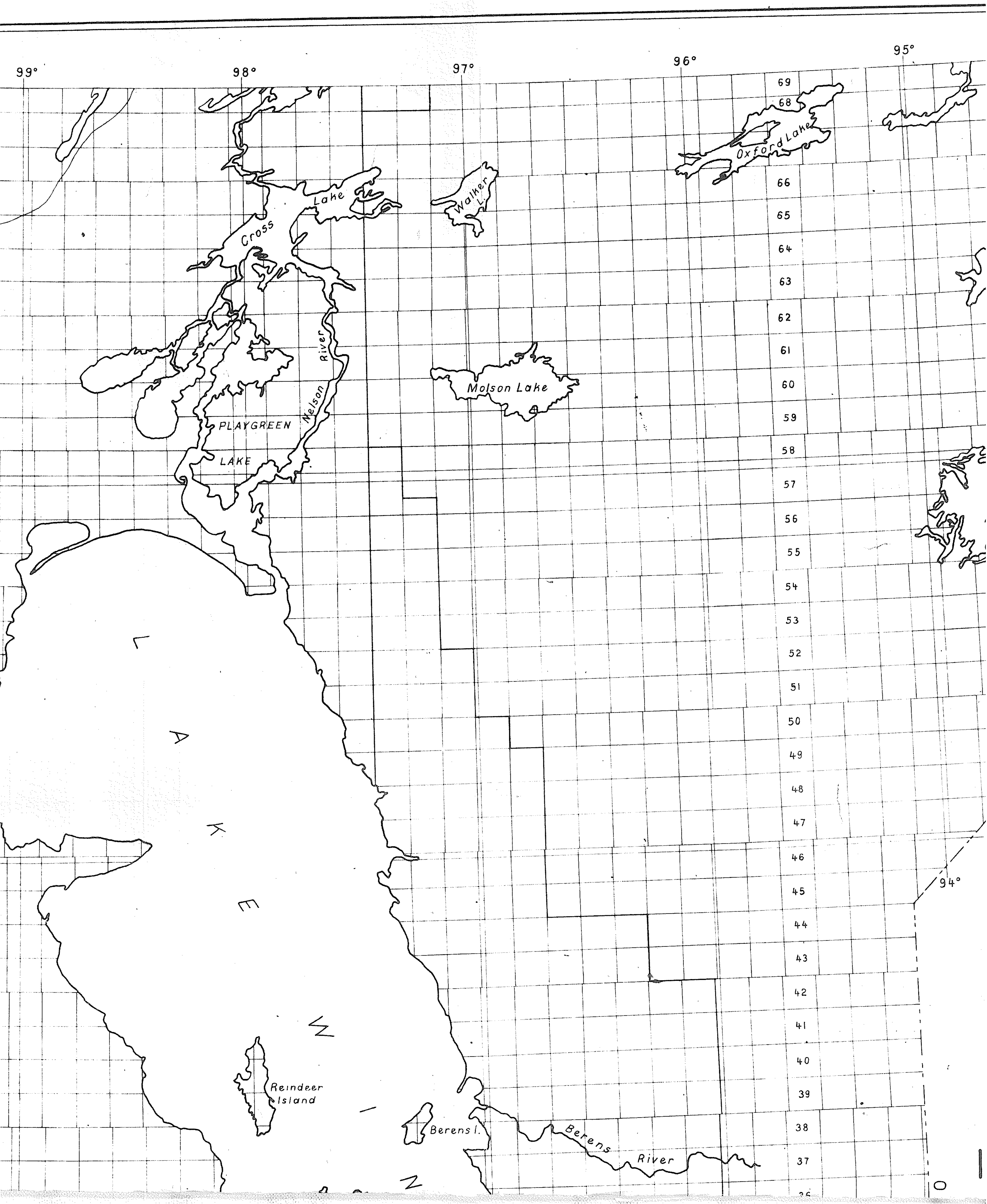
D. B. McKENNITT

1960

IVERSITY OF MANITOBA

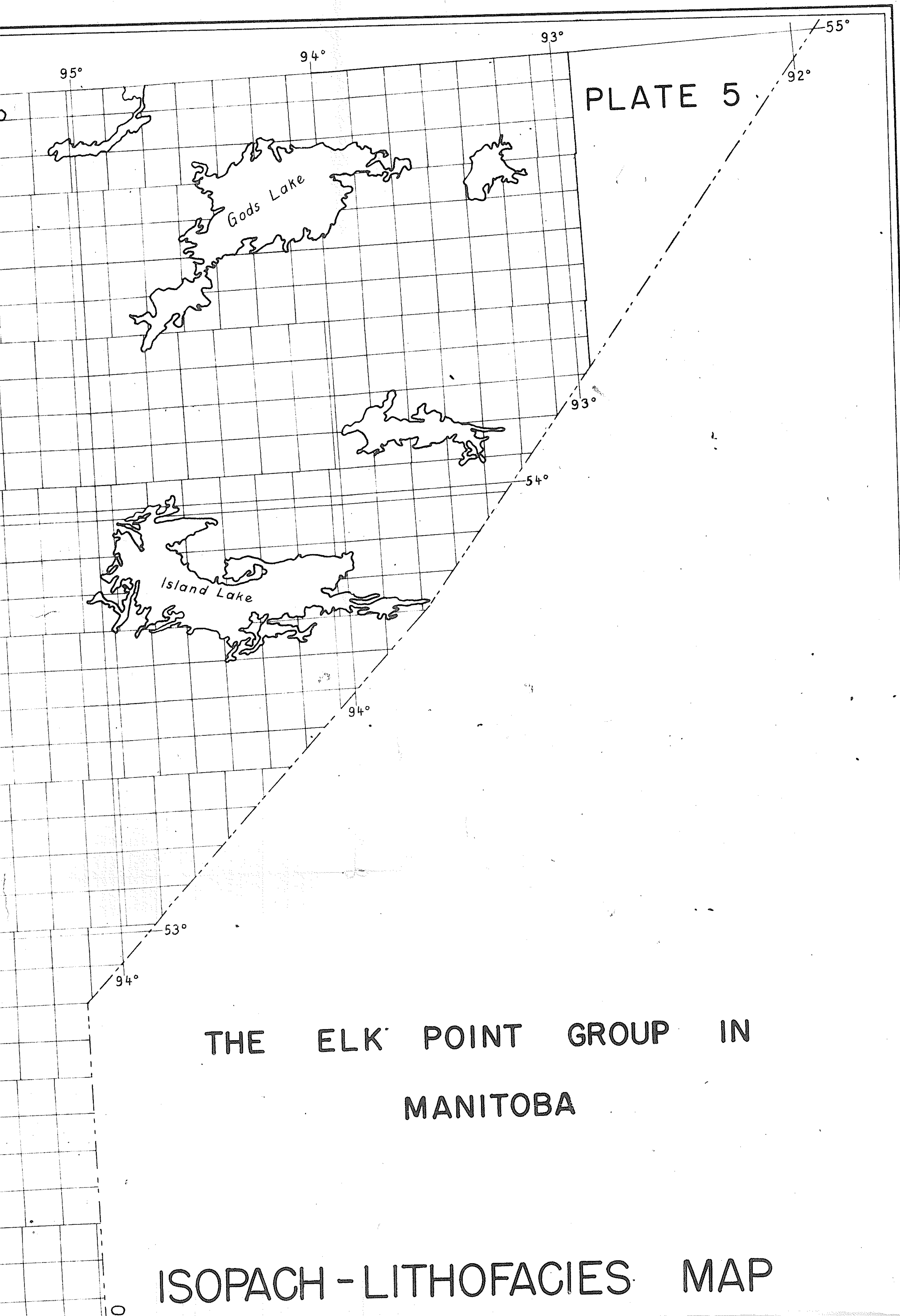


55°
101°
100°
99°
54°
53°
Cranberry Portage
Reed Lake
CORMORANT FOREST
Cormorant Lake
Atikameg Lake
RESERVE
C.N.R.
MOOSE LAKE
The Pas
Saskatchewan River
CEDAR LAKE
LAKE WINN
Red Deer Lake
Dawson Bay
PORCUPINE
FOREST
RESERVE
Swan Lake
H E W A N



99°
98°
97°
96°
95°
94°
69
68
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
Oxford Lake
Walker L.
Cross Lake
Molson Lake
Nelson River
PLAYGREEN LAKE
LAKE WIN
Reindeer Island
Berens I.
Berens River

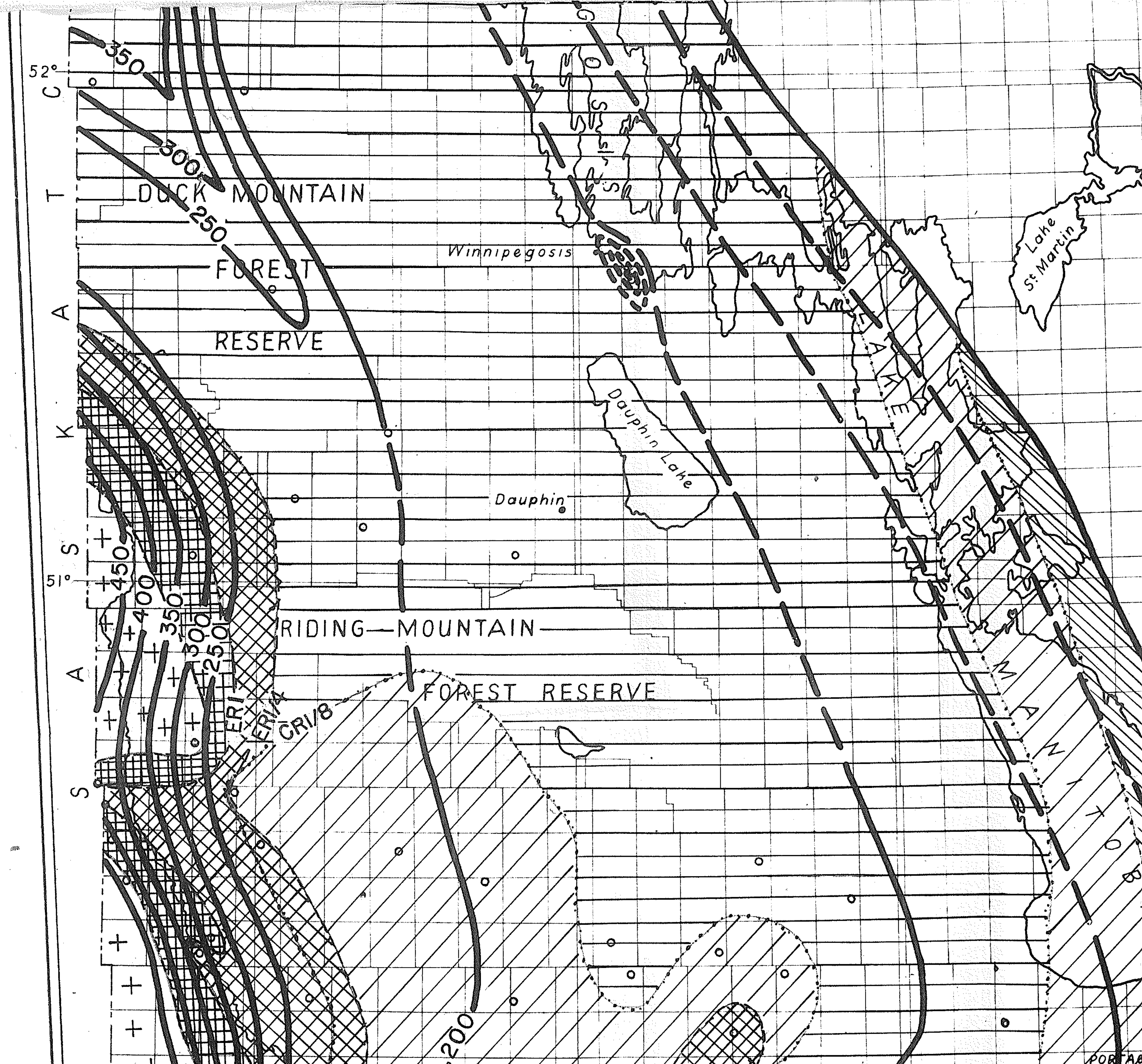
PLATE 5

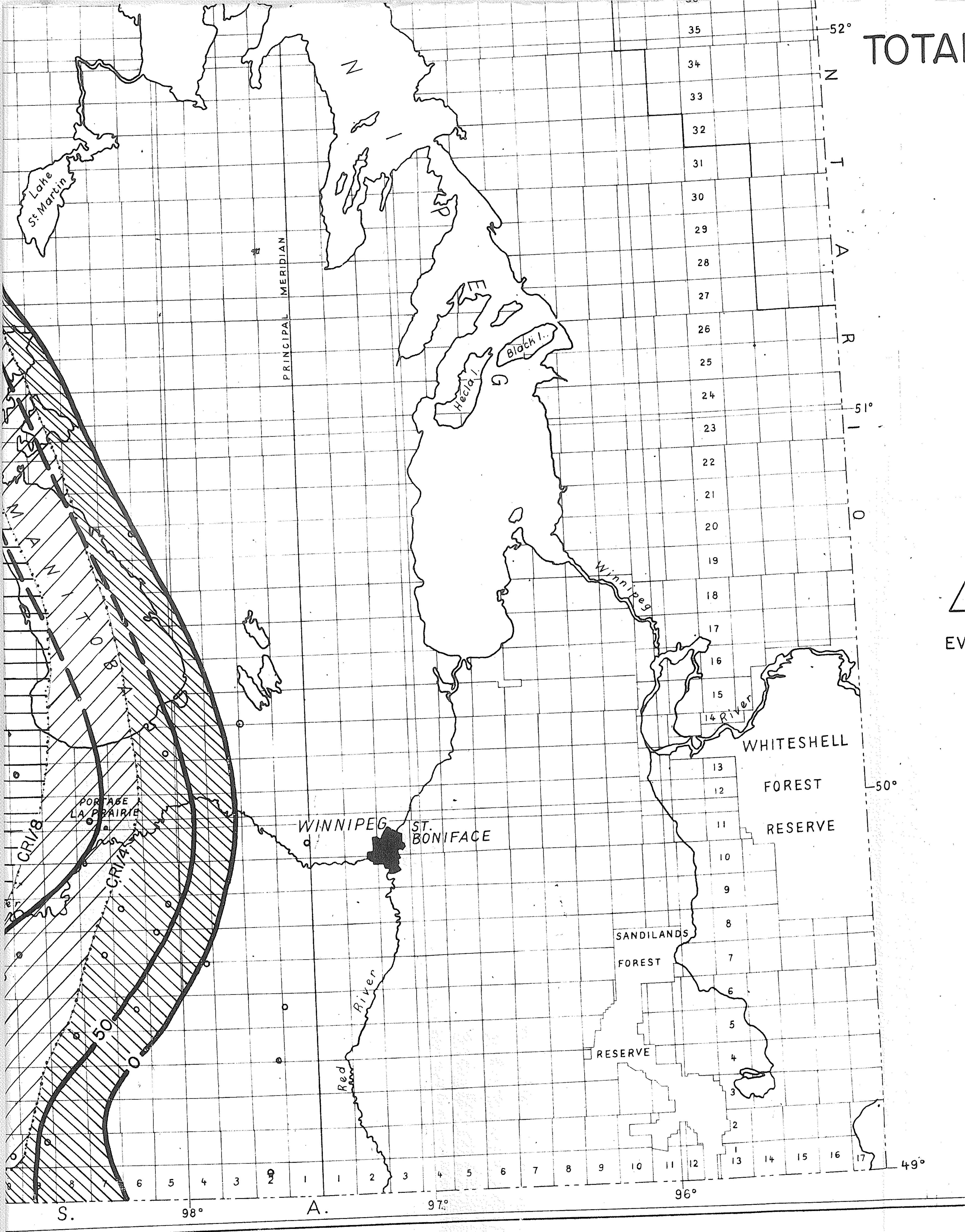


THE ELK POINT GROUP IN

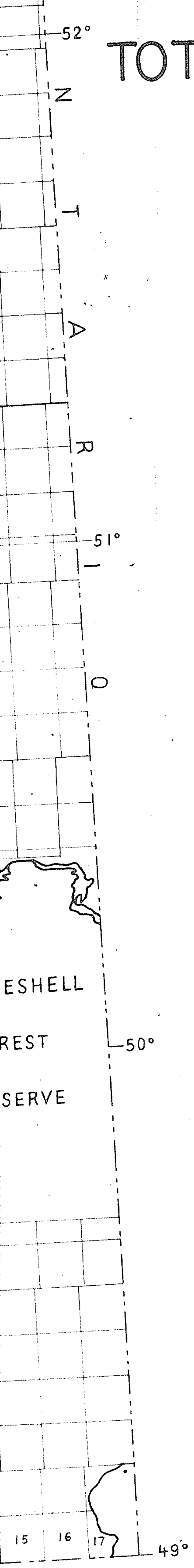
MANITOBA

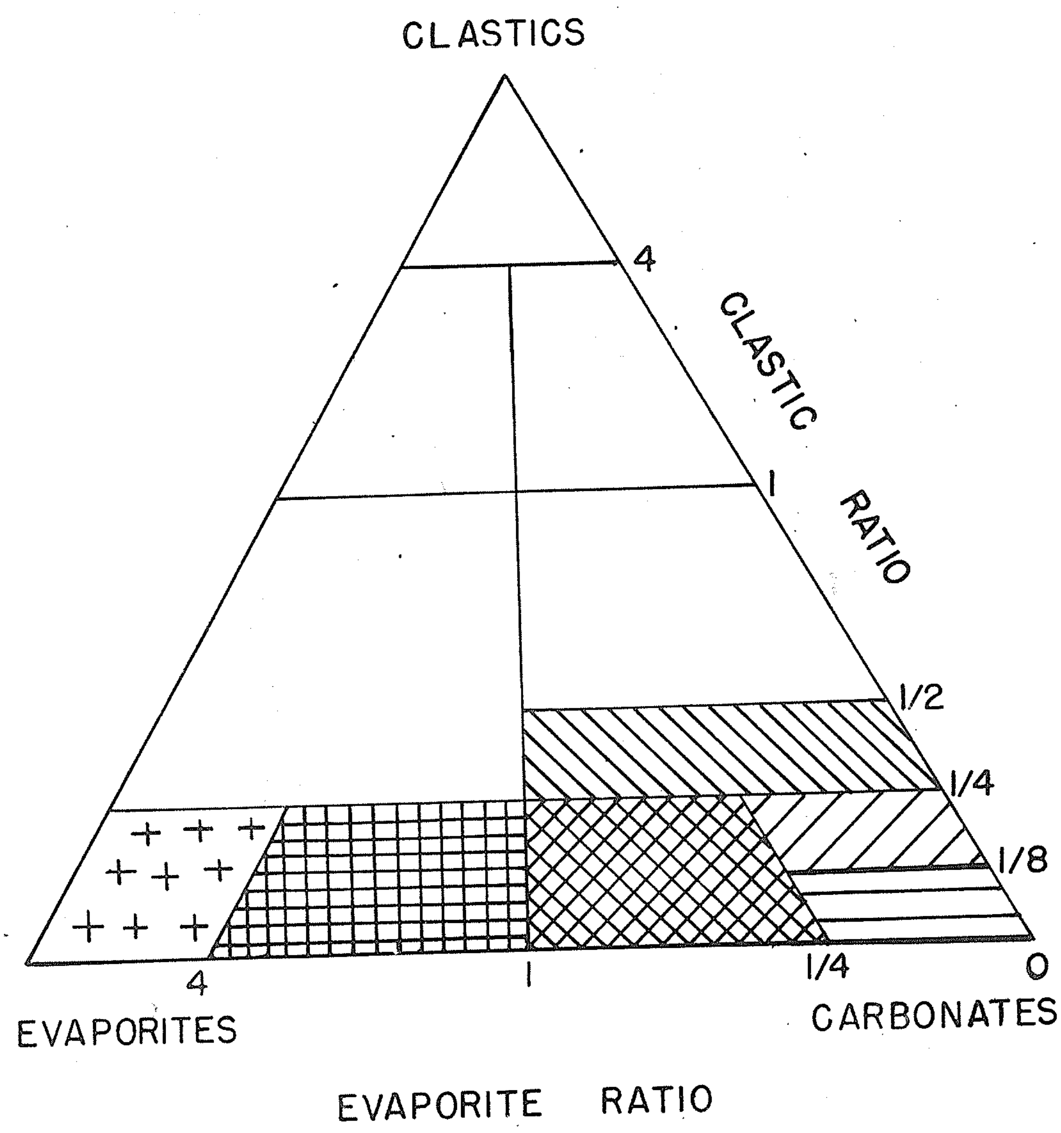
ISOPACH - LITHOFACIES MAP


DUCK MOUNTAIN
FOREST
RESERVE
Winnipegosis
Dauphin Lake
Dauphin
RIDING MOUNTAIN
FOREST RESERVE
Lake St Martin
BRANDON
SPRUCE
WOODS
FOREST
RESERVE
River
PORTAGE LA PRAIRIE
TURTLE MT.
FOREST RESERVE
SASKATCH
MANITOB
U.
S.
ER1
ER1/4
CRI/8
ER 4
350
300
250
450
400
500
200
150
100
50
52°
51°
50°
49°
101°
100°
99°


TOTA
EV
Lake St Martin
PRINCIPAL MERIDIAN
Black I.
Hecla I.
Winnipeg
River
WINNIPEG
ST. BONIFACE
PORTAGE LA PRAIRIE
CRI/8
CRI/4
50
0
Red River
SANDILANDS
FOREST
RESERVE
WHITESHELL
FOREST
RESERVE
52°
51°
50°
49°
98°
97°
96°
S.
A.

TOTAL ELK POINT GROUP





....CR 1/4.... CLASTIC RATIO

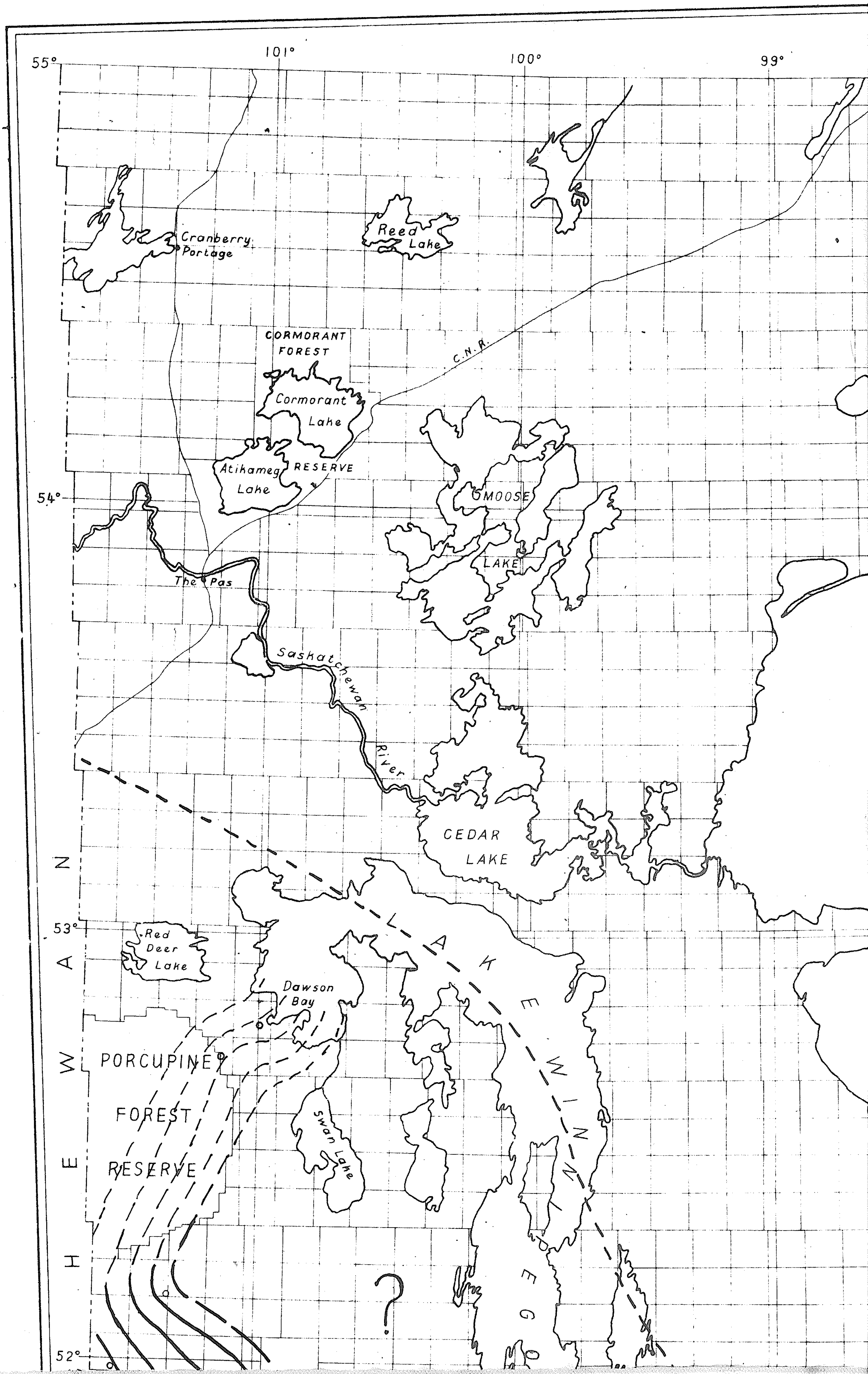
---ER 1/4--- EVAPORITE RATIO

ISOPACH INTERVAL = 50 ft.

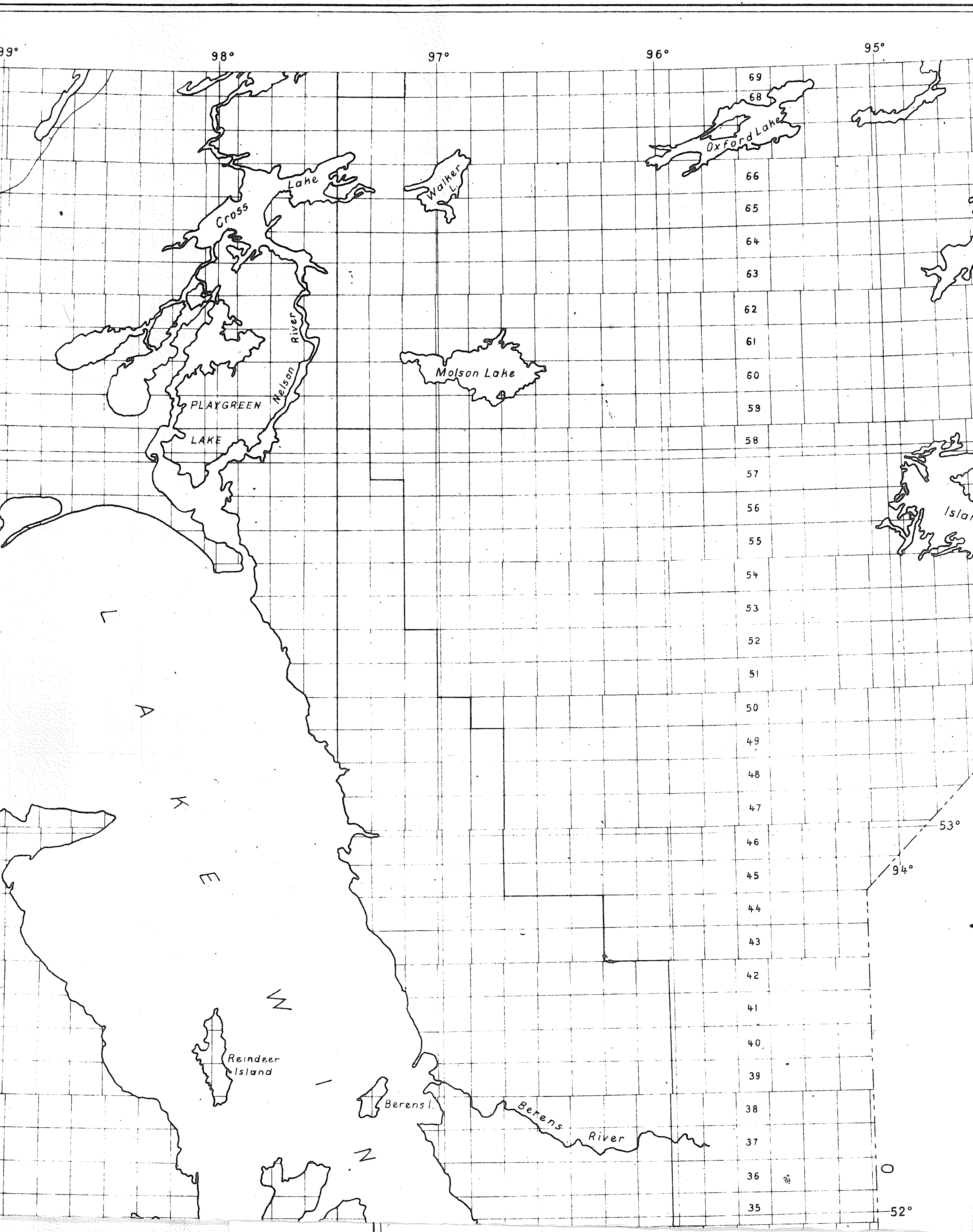
D. B. McKENNITT 1960

0 8 16

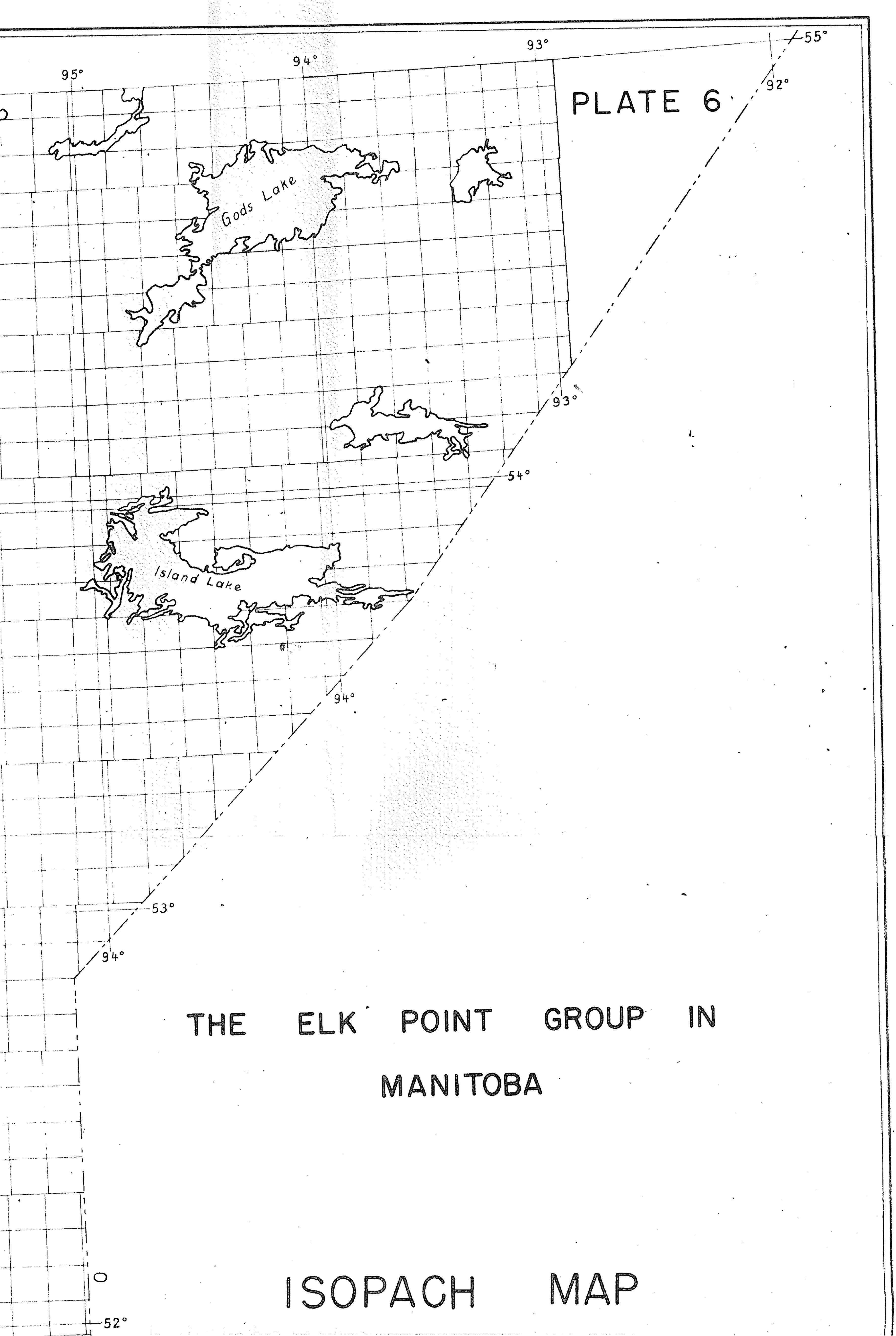
Scale 16 miles to 1 inch



55°
101°
100°
99°
54°
53°
52°
Cranberry Portage
Reed Lake
CORMORANT FOREST
Cormorant Lake
Atikameg Lake
RESERVE
C.N.R.
MOOSE LAKE
The Pas
Saskatchewan River
CEDAR LAKE
LAKE WINNIPEG
Red Deer Lake
Dawson Bay
PORCUPINE FOREST RESERVE
Swan Lake
?
SASKATCHEWAN



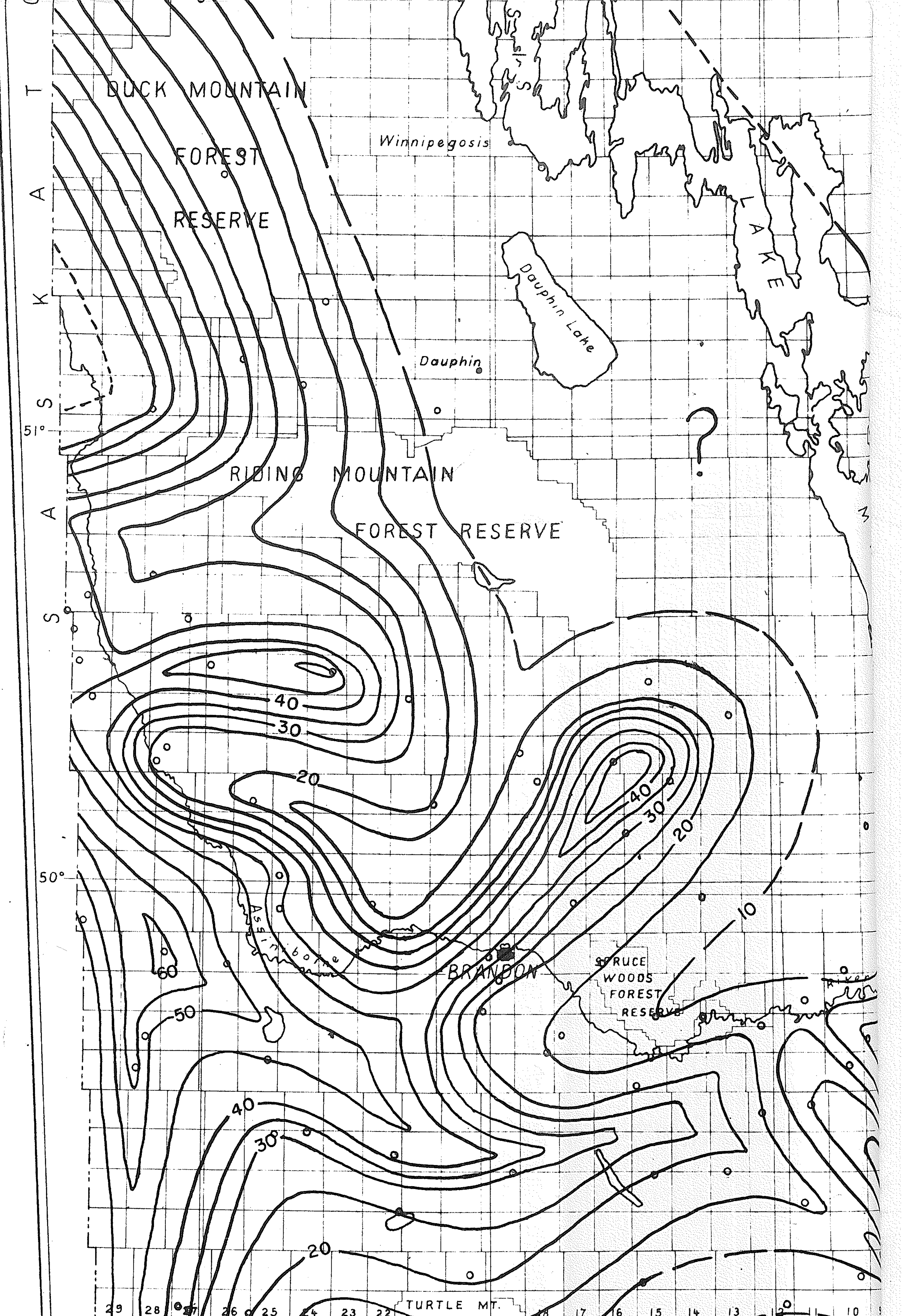
99°
98°
97°
96°
95°
94°
53°
52°
Cross
Lake
Walker L.
Oxford Lake
Nelson River
PLAYGREEN LAKE
Molson Lake
Isla
LAKE WINN
Reindeer Island
Berens I.
Berens River
O
69
68
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35



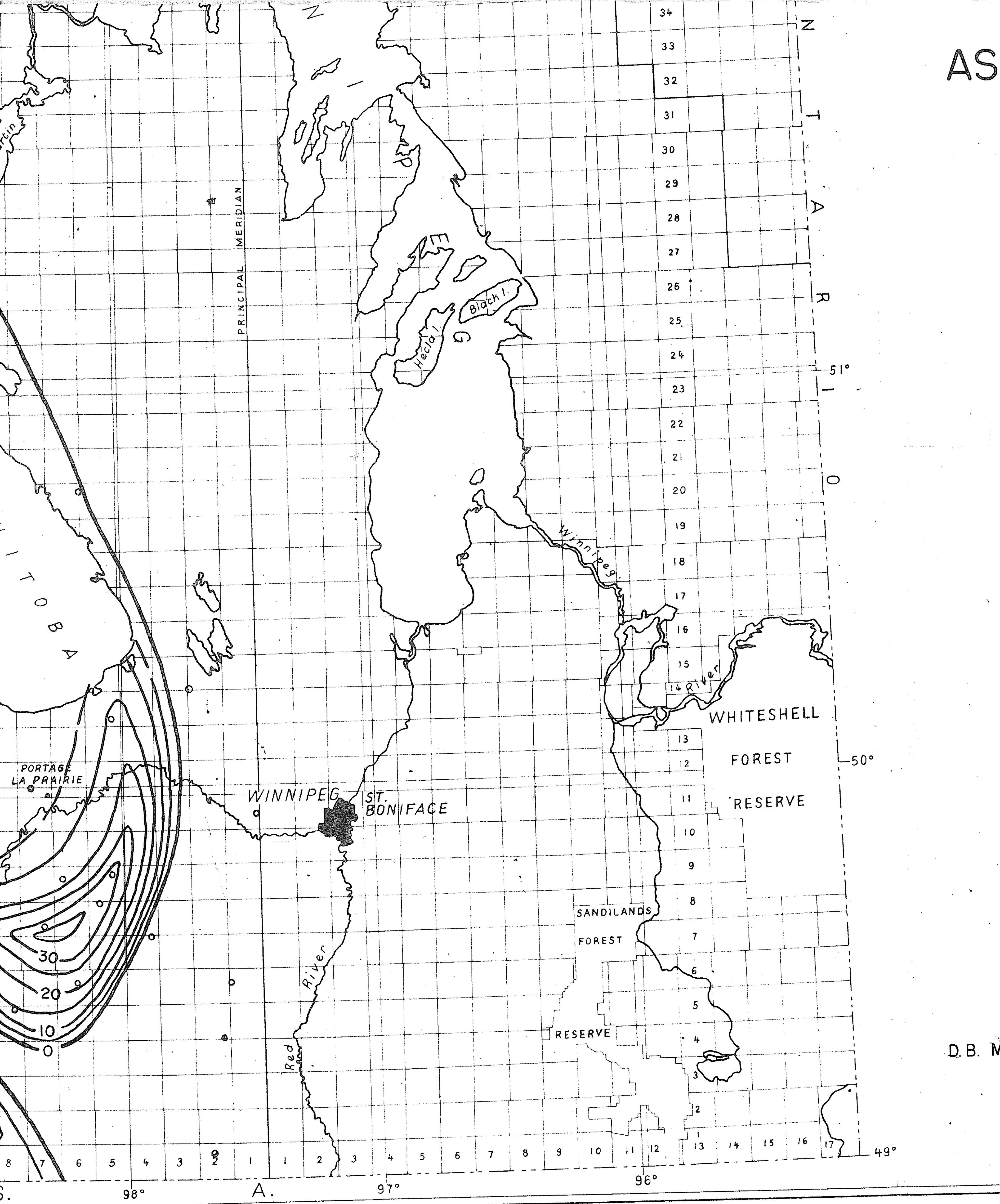
THE ELK POINT GROUP IN

MANITOBA

ISOPACH MAP



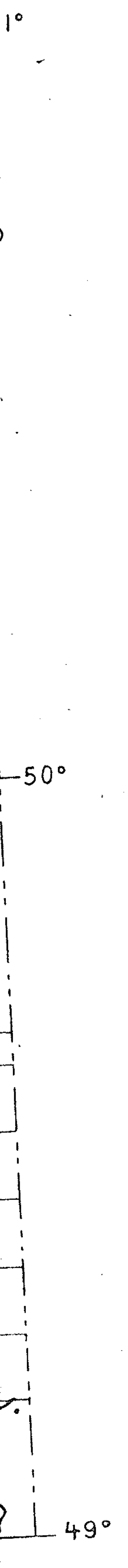
DUCK MOUNTAIN
FOREST
RESERVE
Winnipegosis
LAKE
Dauphin Lake
Dauphin
51°
RIDING MOUNTAIN
FOREST RESERVE
40
30
20
40
30
20
10
50°
Assiniboine
BRANDON
SPRUCE WOODS FOREST RESERVE
60
50
40
30
20
TURTLE MT. FOREST RESERVE
29 28 27 26 25 24 23 22 18 17 16 15 14 13 12 11 10
49°
101°
100°
U.
99°


AS
PRINCIPAL MERIDIAN
Hecla I.
Black I.
Winnipeg
River
WHITESHELL
FOREST
RESERVE
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
SANDILANDS
FOREST
RESERVE
Red River
30
20
10
0
51°
50°
49°
98°
97°
96°
A.
D.B. M

C

ASHERN FORMATION

ISOPACH INTERVAL = 5 ft.

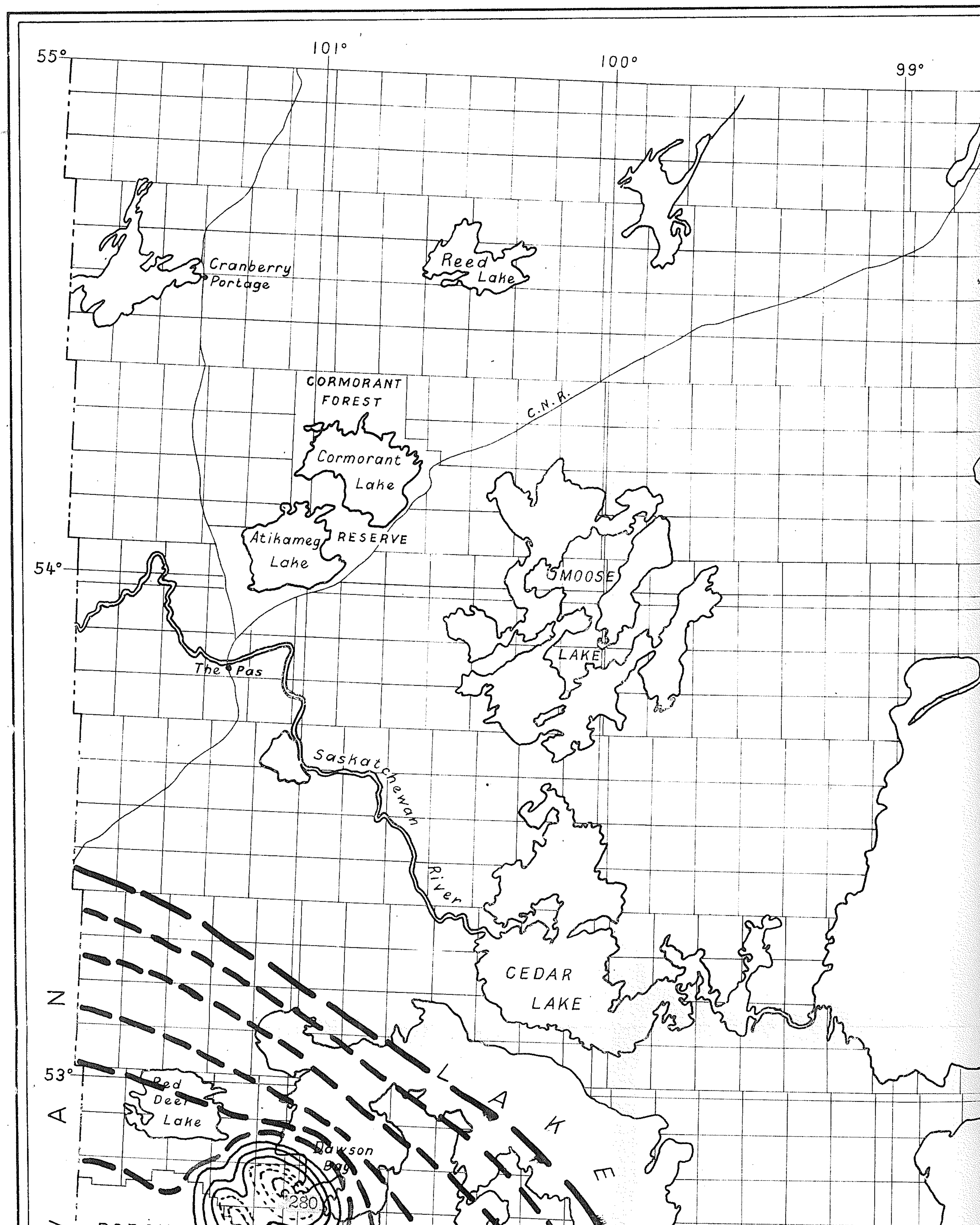


D.B. McKENNITT

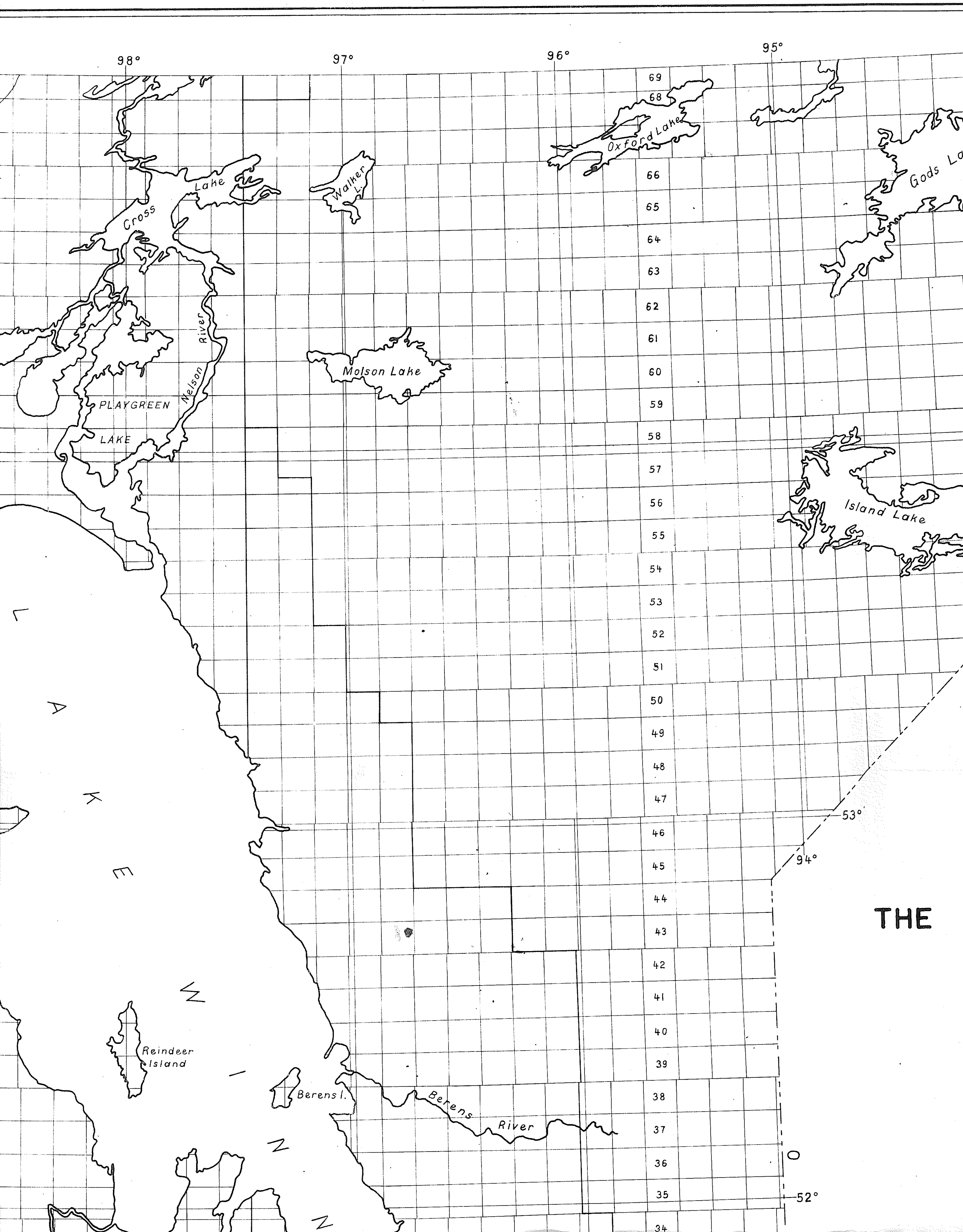
1960

0 8 16

Scale 16 miles to 1 inch

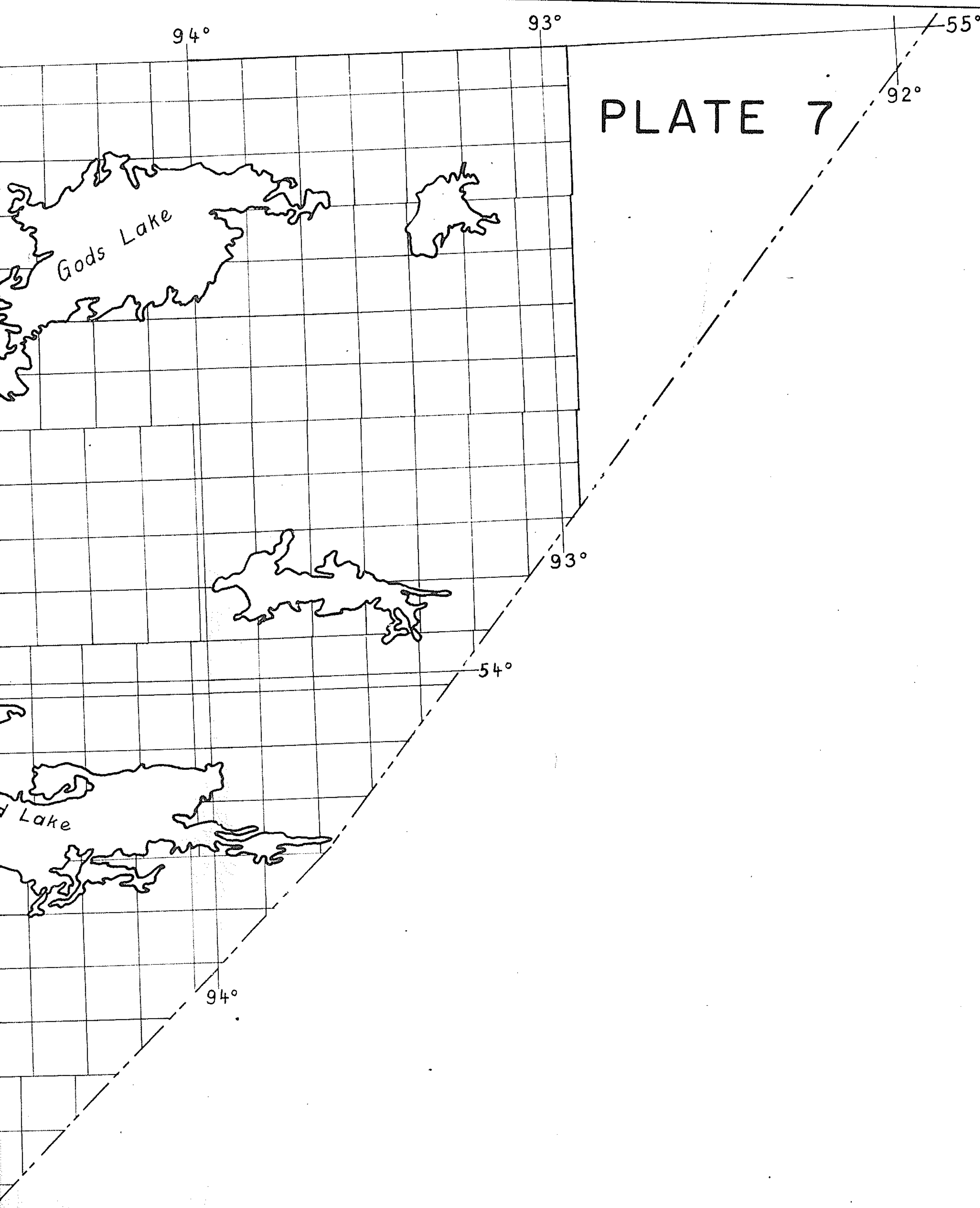


55°
101°
100°
99°
Cranberry Portage
Reed Lake
CORMORANT FOREST
Cormorant Lake
C.N.R.
Atikameg Lake
RESERVE
54°
MOOSE
LAKE
The Pas
Saskatchewan River
CEDAR LAKE
53°
Red Deer Lake
Dawson Bay
280
270
PORCUPINE
FOREST
RESERVE
Swan Lake
LAKE WINNIPEGOS
INSUFFICIENT
350
52°
SASKATCHEWAN



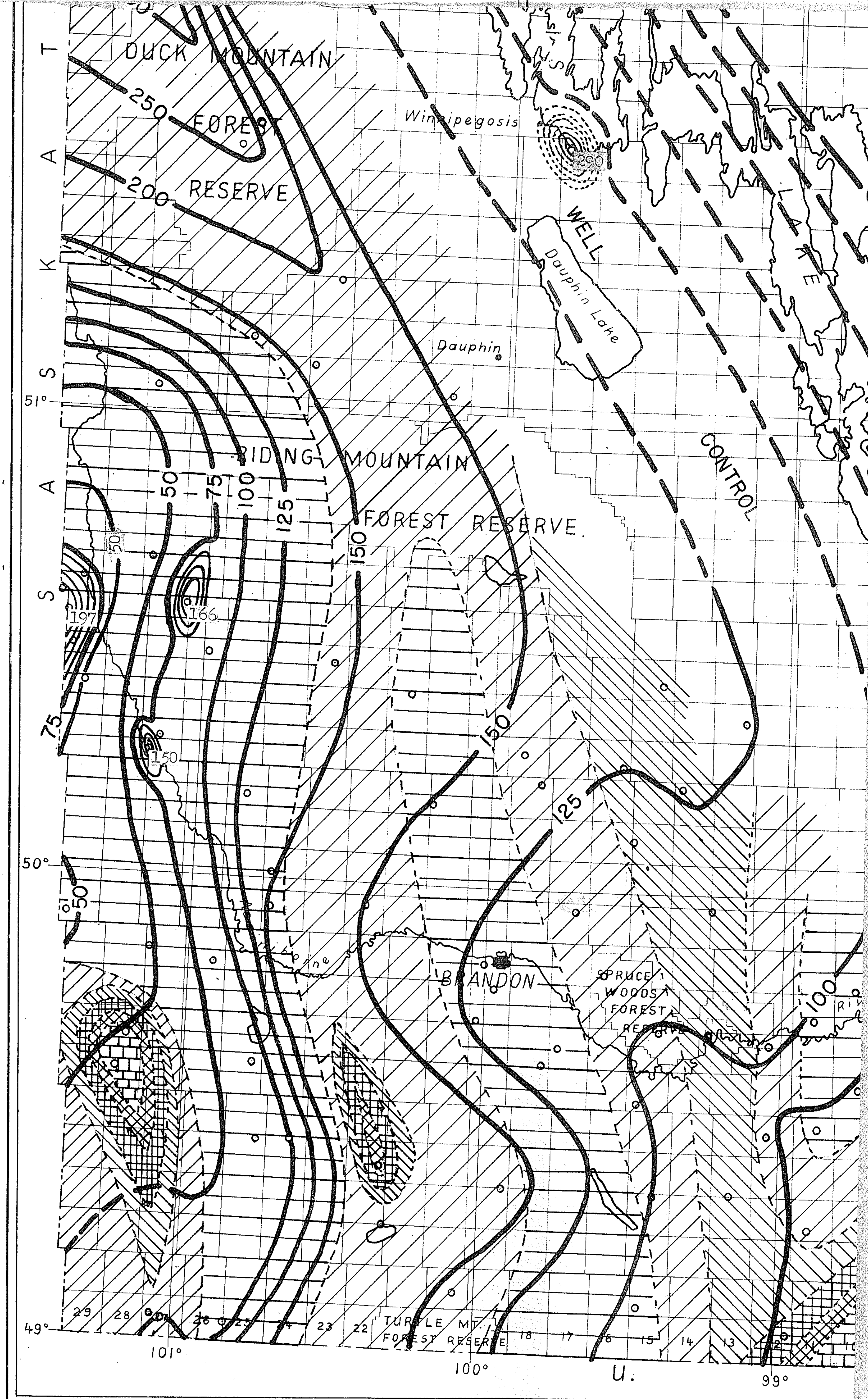
98°
97°
96°
95°
69
68
Oxford Lake
Gods La
Walker L.
Cross
Lake
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
Nelson
River
Molson Lake
PLAYGREEN
LAKE
Island Lake
L
A
K
E
W
I
N
N
53°
94°
THE
Reindeer Island
Berens I.
Berens
River
O
52°

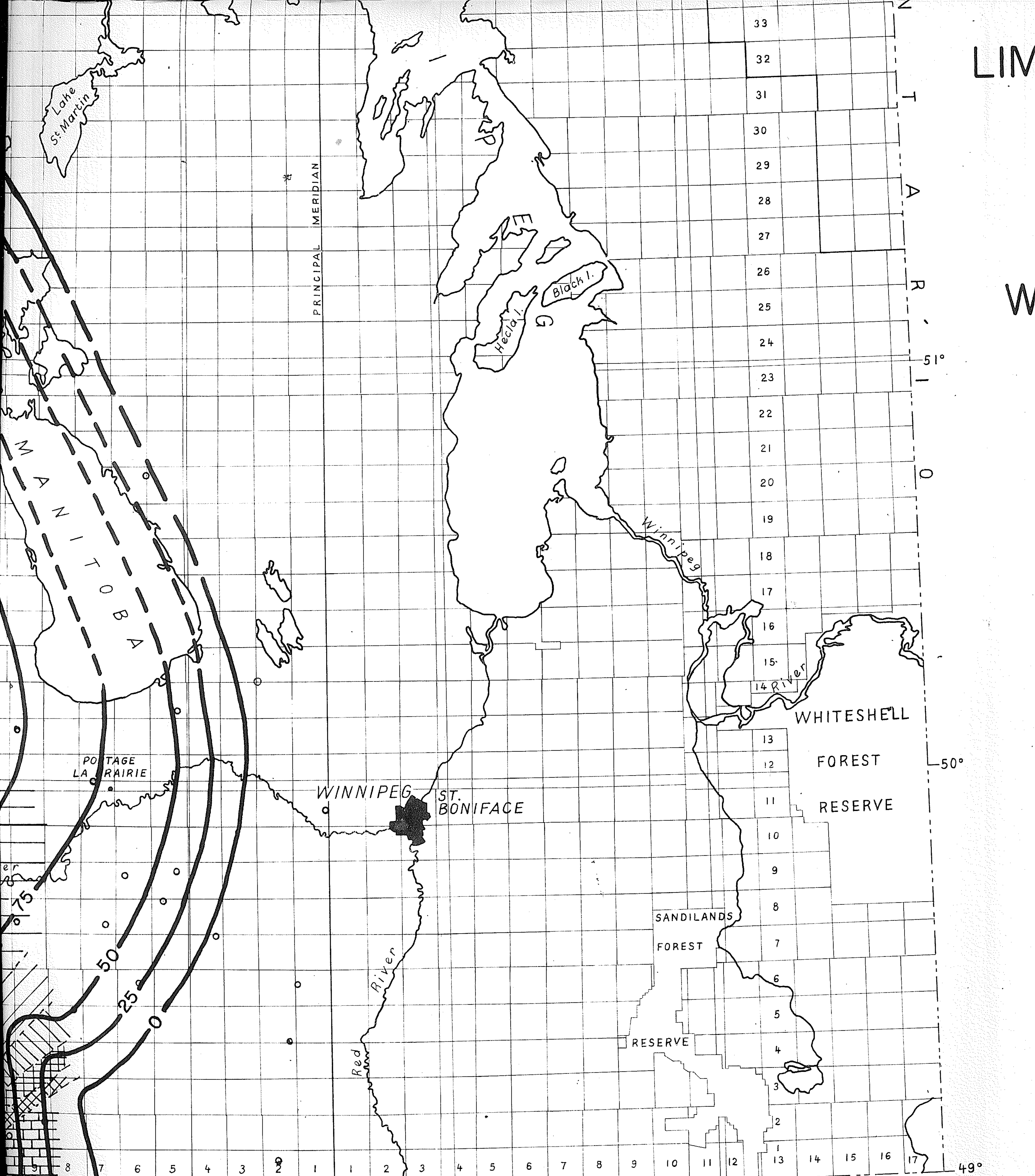
PLATE 7



HE ELK POINT GROUP IN
MANITOBA

ISOPACH AND

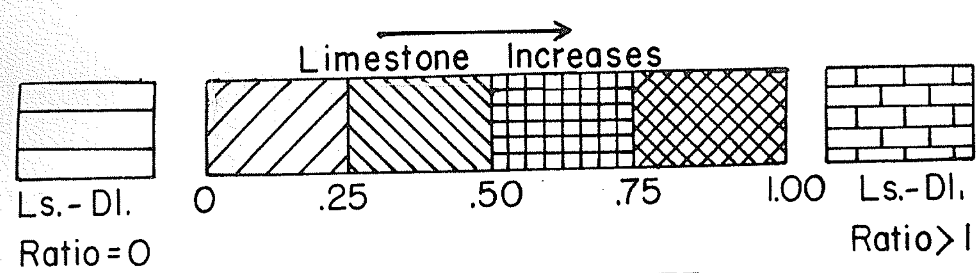

DUCK MOUNTAIN
FOREST
RESERVE
Winnipegosis
290
WELL
CONTROL
LAKE
Dauphin Lake
Dauphin
RIDING MOUNTAIN
FOREST RESERVE
S
A
S
K
A
T
51°
50°
49°
250
200
150
125
100
75
50
197
166
BRANDON
SPRUCE WOODS FOREST RESERVE
TURTLE MT. FOREST RESERVE
29
28
27
26
25
24
23
22
18
17
16
15
14
13
12
101°
100°
99°
U.



LIM
W
Lake St. Martin
PRINCIPAL MERIDIAN
MANITOBA
Hecla I.
Black I.
Winnipeg
WHITESHELL
FOREST
RESERVE
14 River
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
Red River
SANDILANDS
FOREST
RESERVE
75
50
25
0
51°
50°
49°
98°
97°
96°
S.
A.

LIMESTONE – DOLOMITE RATIO MAP

WINNIPEGOSIS FORMATION



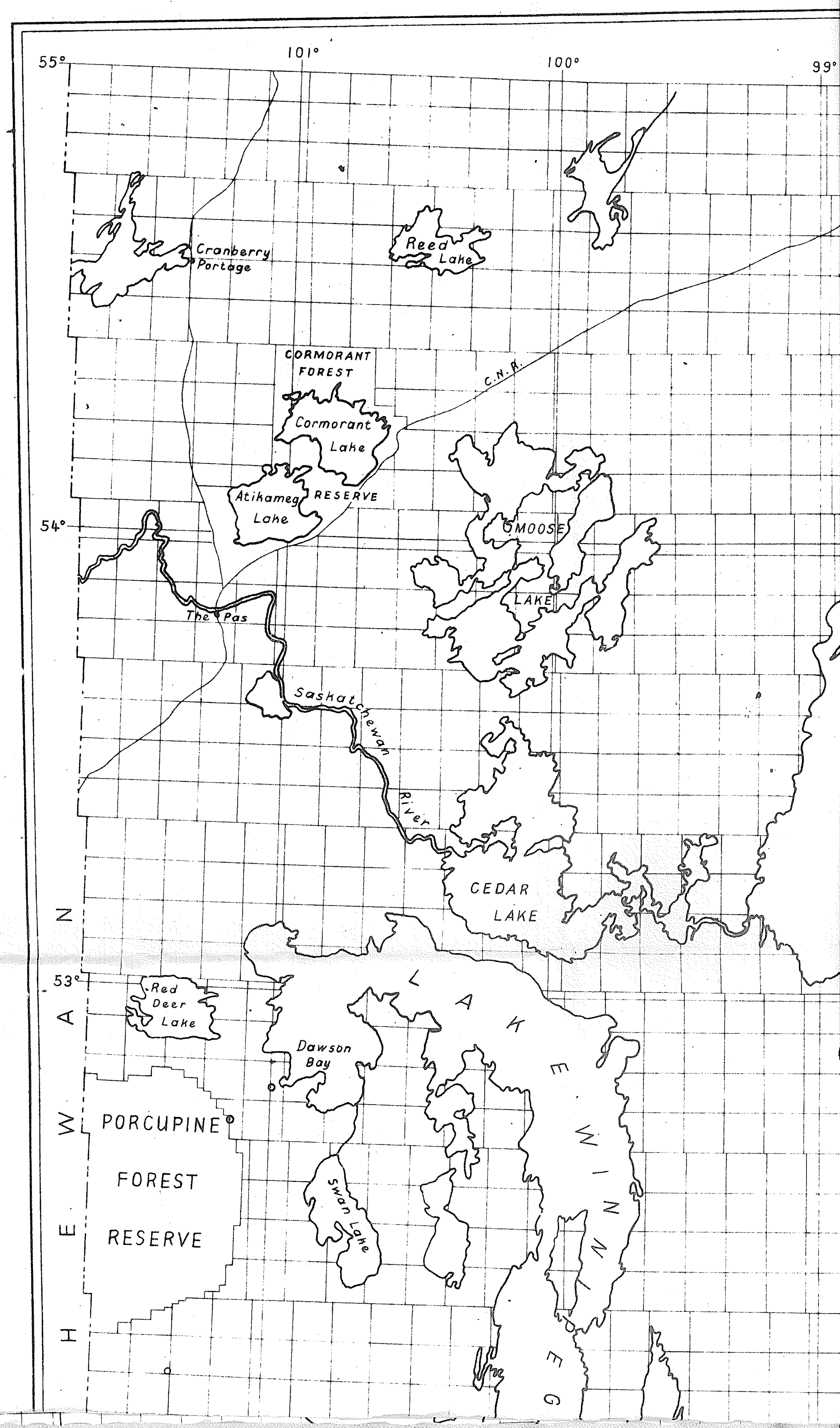
LIMESTONE – DOLOMITE RATIO

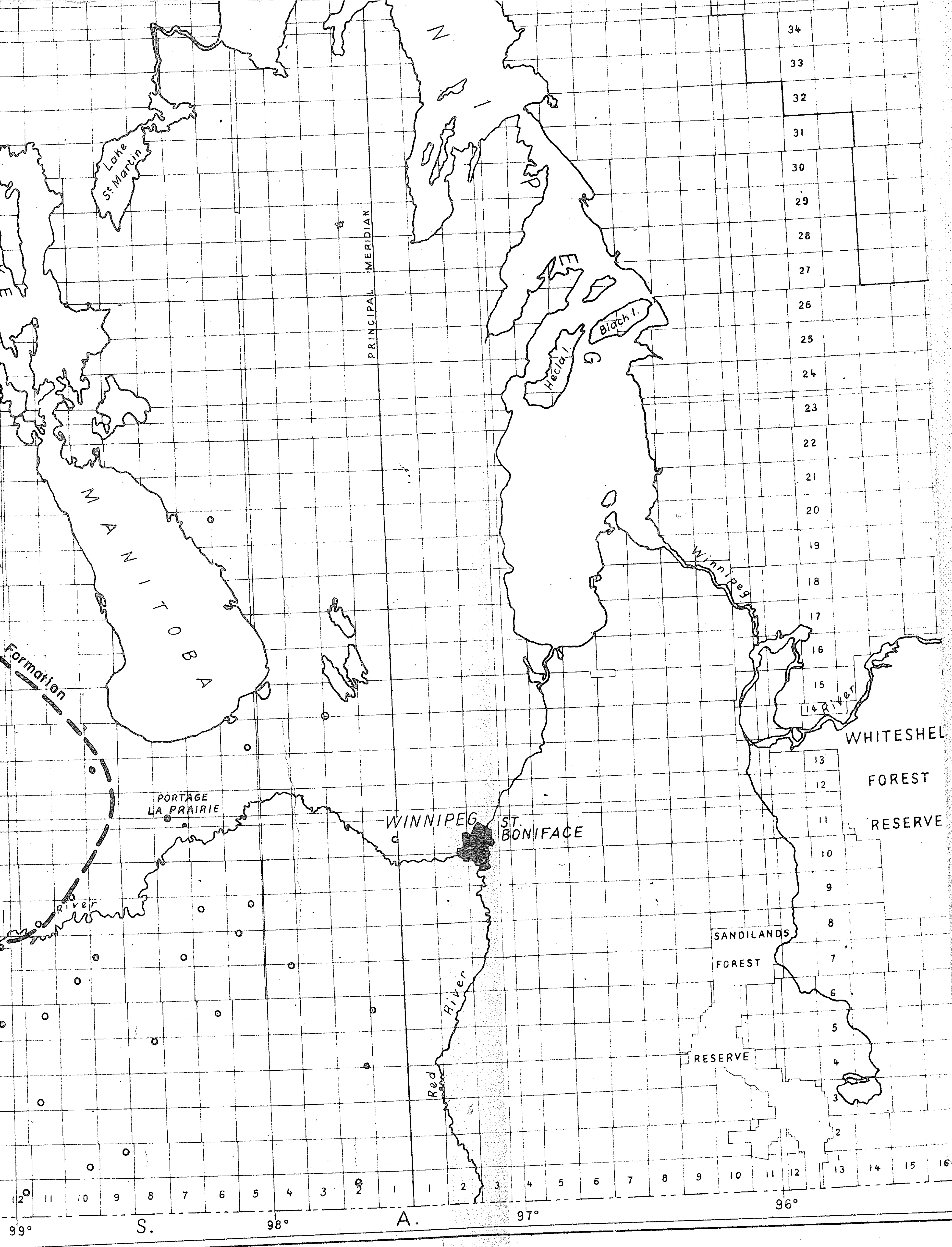
ISOPACH INTERVAL = 25 ft.

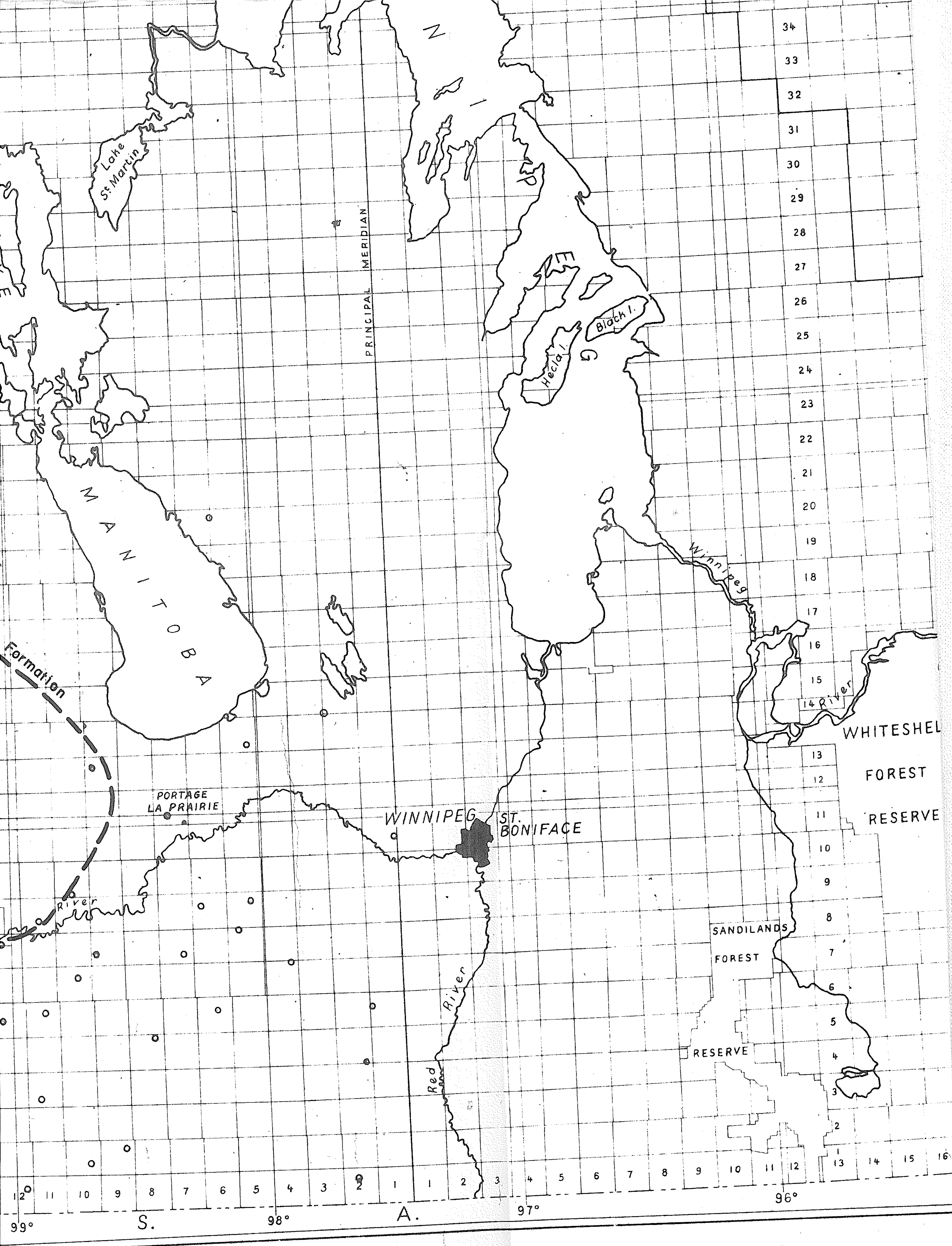
D. B. McKENNITT 1960

0 8 16

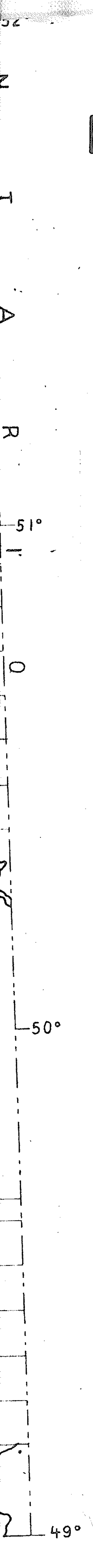
Scale 16 miles to 1 inch


55°
101°
100°
99°
54°
53°
Cranberry Portage
Reed Lake
CORMORANT FOREST
C.N.R.
Cormorant Lake
Atikameg Lake
RESERVE
MOOSE
LAKE
The Pas
Saskatchewan
River
CEDAR LAKE
Red Deer Lake
Dawson Bay
PORCUPINE
FOREST
RESERVE
Swan Lake
LAKE WINNIPEG
SASKATCHEWAN


Lake St. Martin
PRINCIPAL MERIDIAN
MANITOBA
Formation
Black I.
Hecla I.
Winnipeg
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
River
Red River
14 River
WHITESHEL
FOREST
RESERVE
SANDILANDS
FOREST
RESERVE
99°
S.
98°
A.
97°
96°



Lake St. Martin
M A N I T O B A
Formation
PRINCIPAL MERIDIAN
Black I.
Hecla I.
Winnipeg
River
WHITESHEL
FOREST
RESERVE
PORTAGE LA PRAIRIE
WINNIPEG
ST. BONIFACE
River
Red River
SANDILANDS
FOREST
RESERVE
99°
98°
97°
96°
S.
A.



PRAIRIE EVAPORITE FORMATION

0 - 100 ft. ISOPACH = MAINLY ANHYDRITE

100 - 400+ ft. ISOPACH = MAINLY HALITE

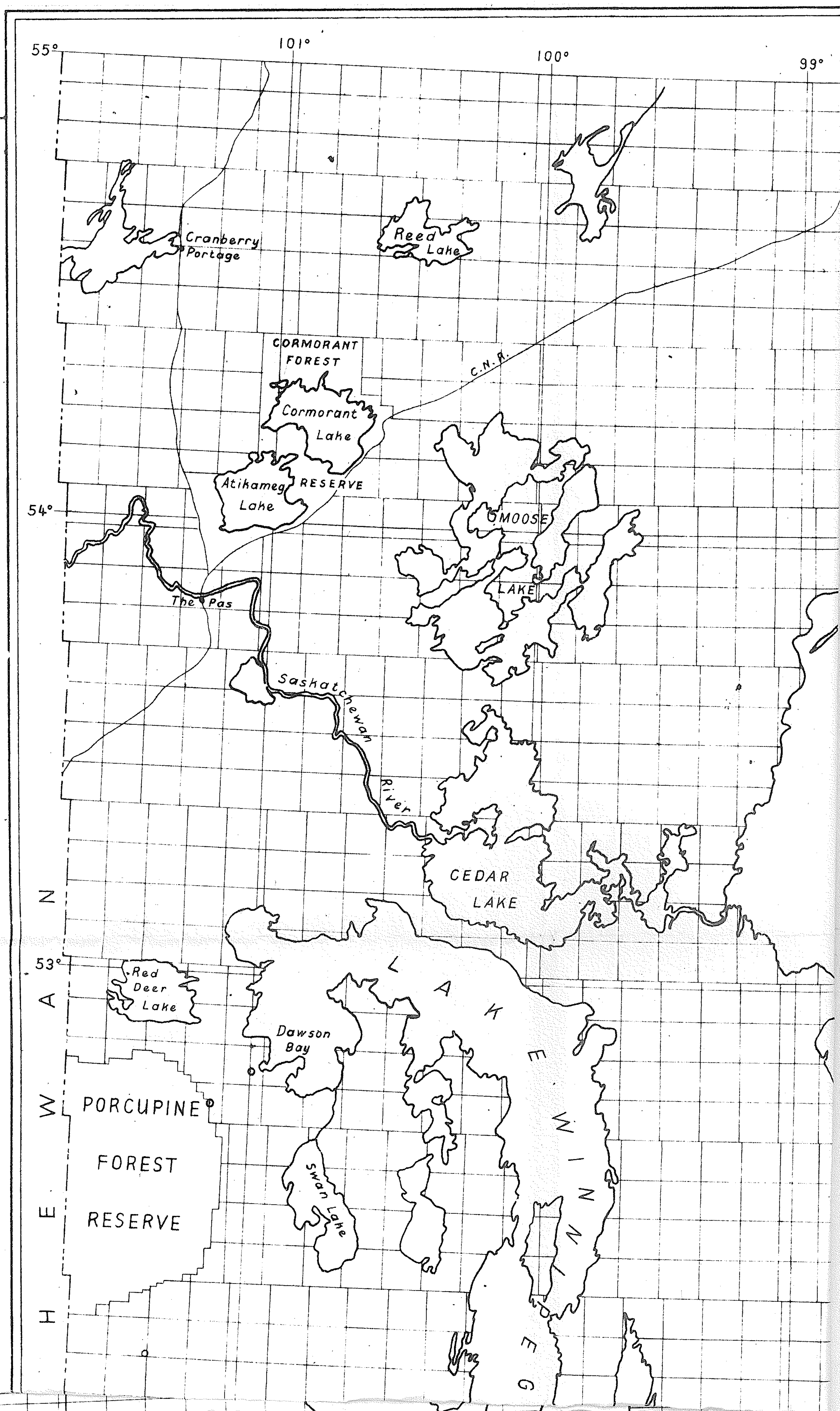
ISOPACH INTERVAL = 100 ft.

D. B. McKENNITT

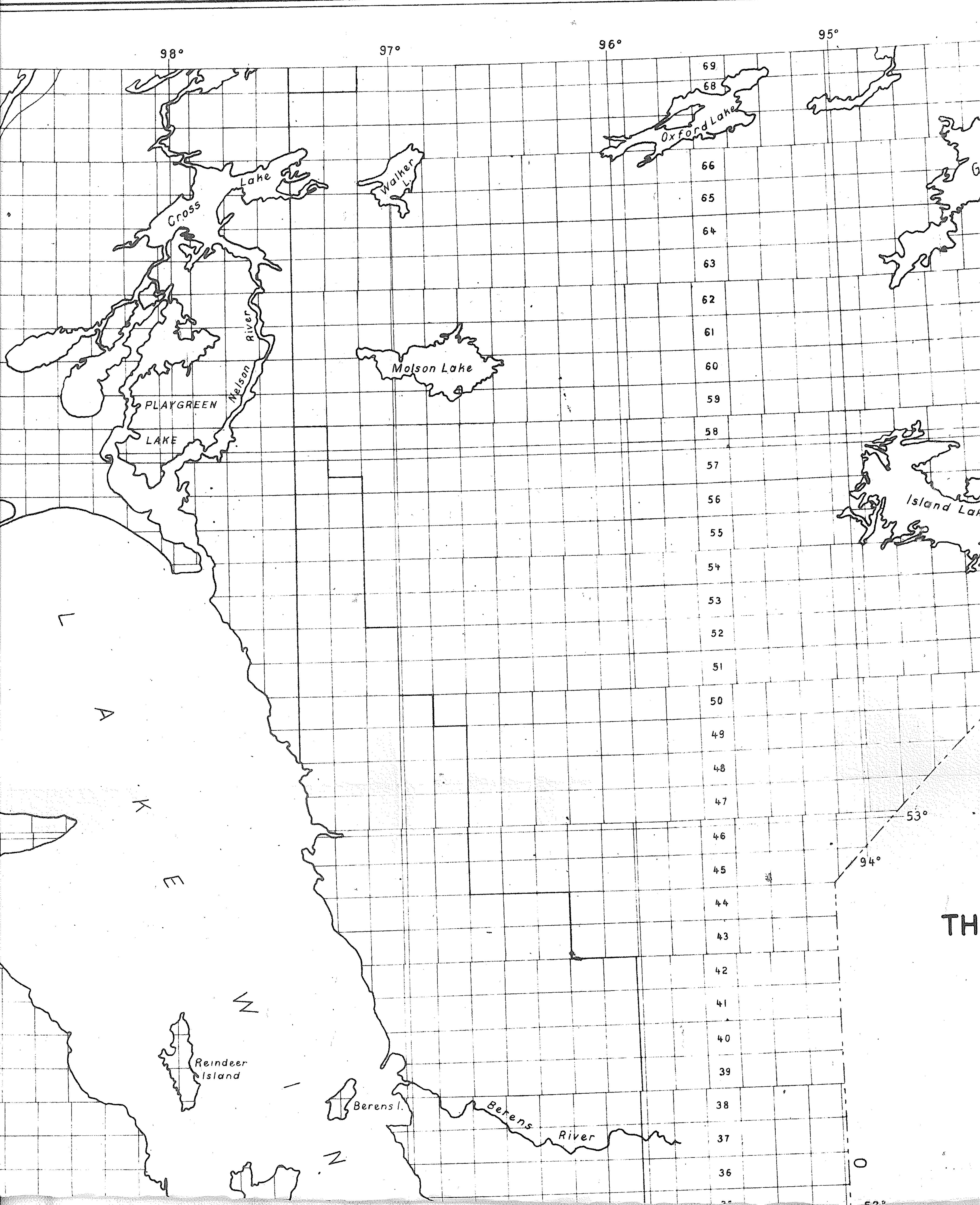
1960

0 8 16

Scale 16 miles to 1 inch



55°
101°
100°
99°
Cranberry Portage
Reed Lake
CORMORANT FOREST
Cormorant Lake
C.N.R.
Atikameg Lake
RESERVE
54°
MOOSE
LAKE
The Pas
Saskatchewan River
CEDAR LAKE
53°
Red Deer Lake
LAKE WINNIPEG
Dawson Bay
PORCUPINE FOREST RESERVE
Swan Lake
HEWAN


98°
97°
96°
95°
94°
53°
Oxford Lake
Walker L.
Cross Lake
Molson Lake
Nelson River
PLAYGREEN LAKE
Island Lake
L A K E W I N
Reindeer Island
Berens I.
Berens River
TH
69
68
66
65
64
63
62
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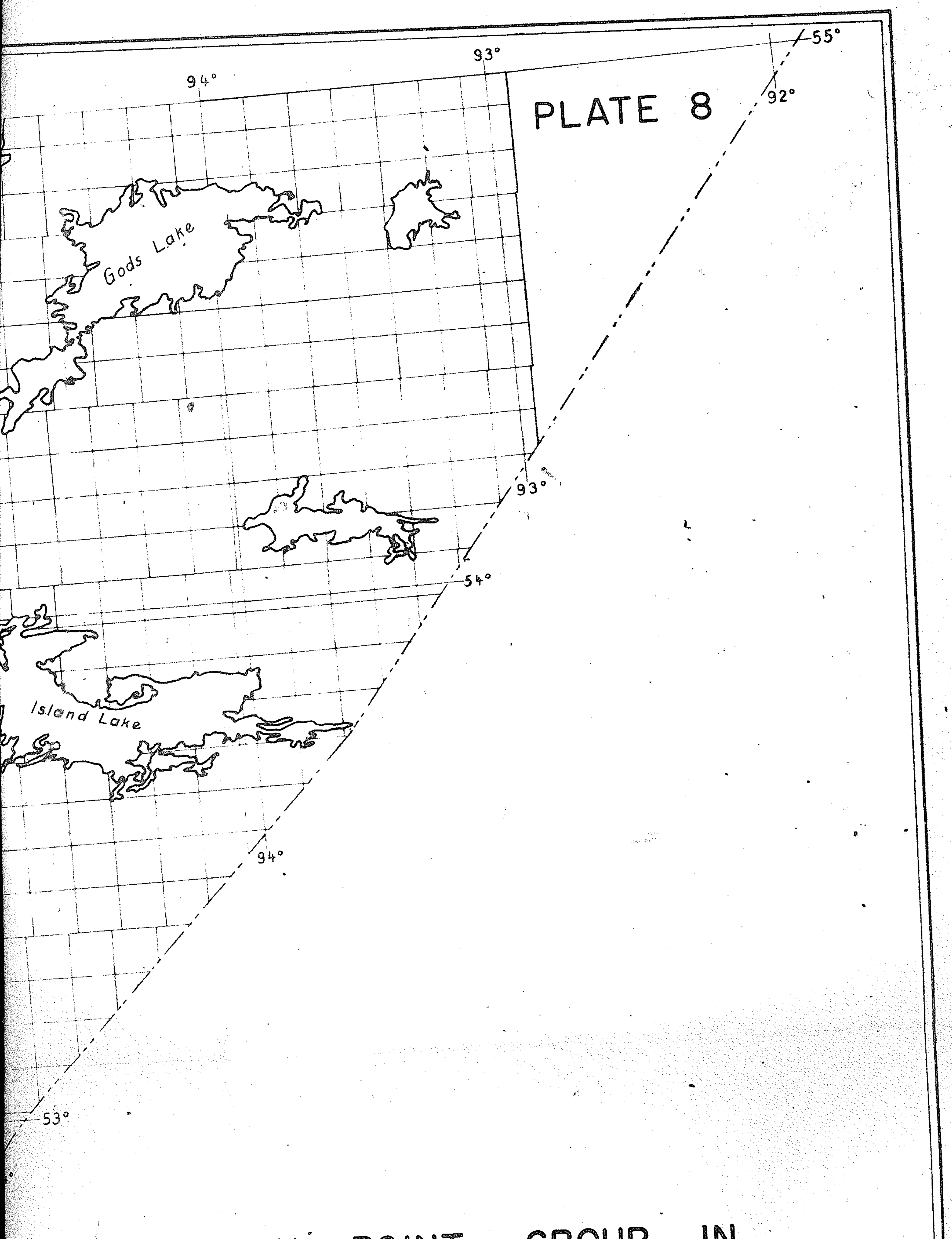
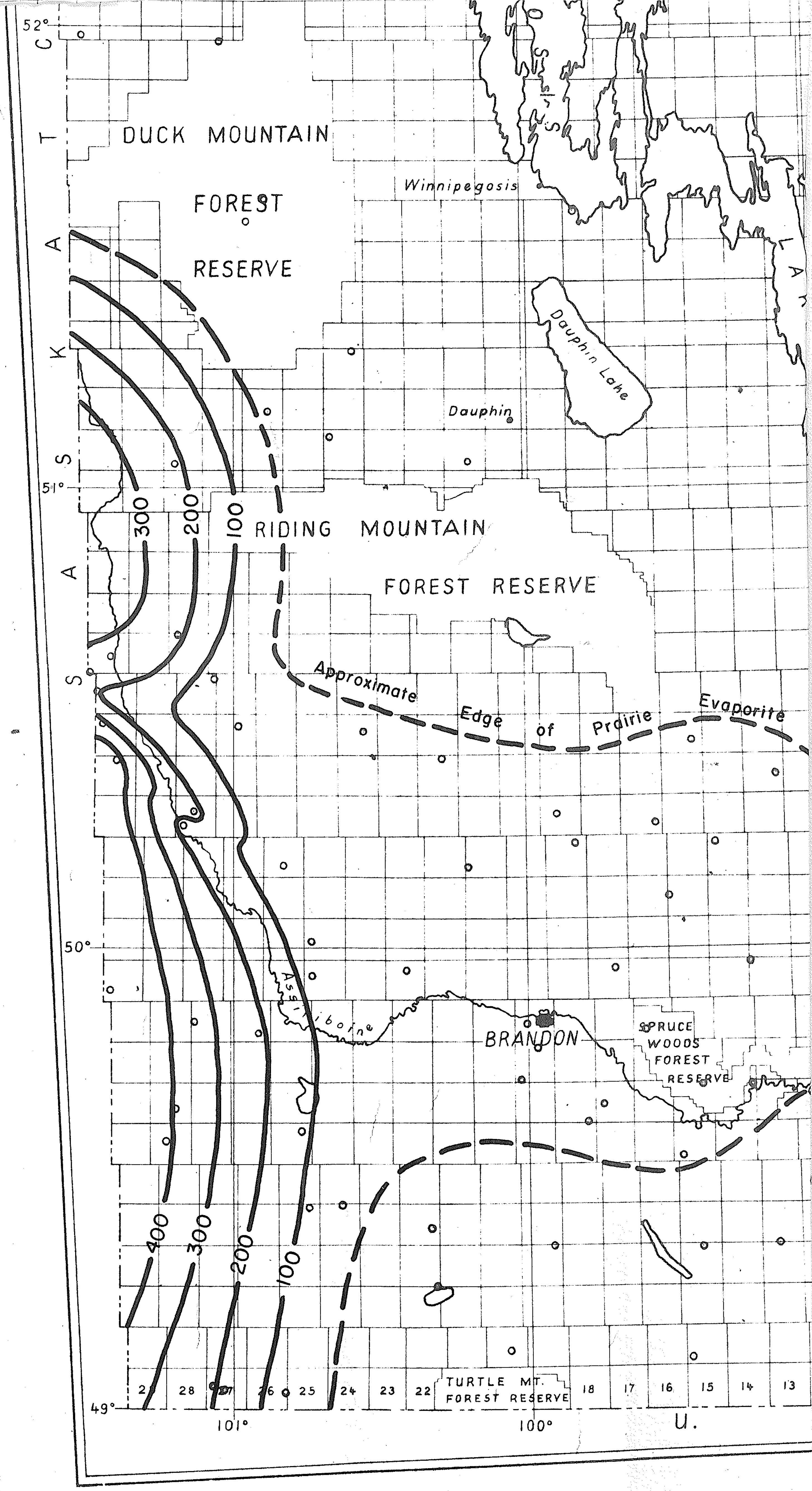
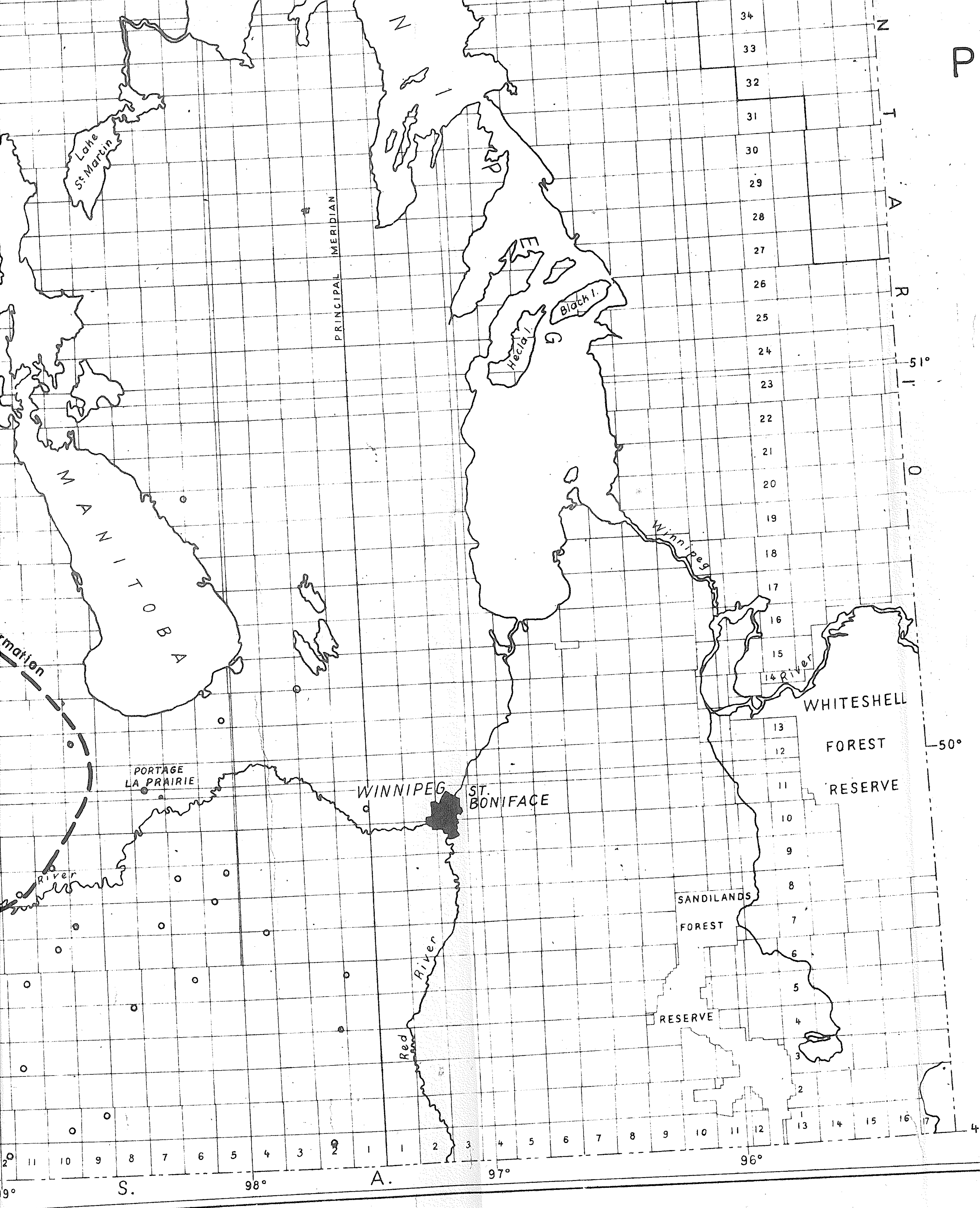
37
36



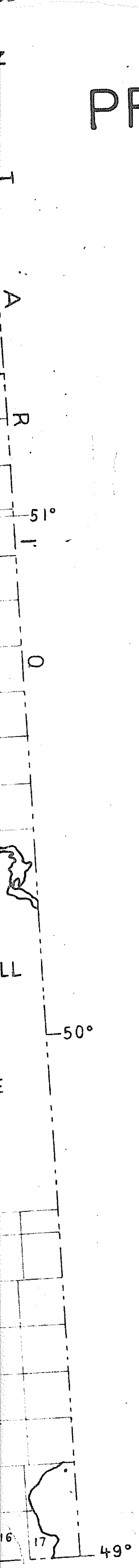
THE ELK POINT GROUP IN MANITOBA

ISOPACH MAP


52°
51°
50°
49°
DUCK MOUNTAIN
FOREST
RESERVE
Winnipegosis
Dauphin Lake
Dauphin
RIDING MOUNTAIN
FOREST RESERVE
Approximate Edge of Prairie Evaporite
300
200
100
400
300
200
100
Assiniboine
BRANDON
SPRUCE
WOODS
FOREST
RESERVE
TURTLE MT.
FOREST RESERVE
28
27
26
25
24
23
22
18
17
16
15
14
13
101°
100°
U.
S A S K A T C



O N T A R I O
P
W I N N I P E G
Black I.
Hecla I.
Winnipeg
River
WHITESHELL FOREST RESERVE
SANDILANDS FOREST RESERVE
WINNIPEG
ST. BONIFACE
Red River
PORTAGE LA PRAIRIE
River
M A N I T O B A
Lake St. Martin
PRINCIPAL MERIDIAN
U. S. A.
51°
50°
49°
96°
97°
98°
99°
rmation



PRAIRIE EVAPORITE FORMATION

0 - 100 ft. ISOPACH = MAINLY ANHYDRITE

100 - 400+ft. ISOPACH = MAINLY HALITE

ISOPACH INTERVAL = 100 ft.

D. B. McKENNITT

1960

0 8 16

Scale 16 miles to 1 inch