

A REGIONAL STUDY OF THE WINNIPEG FORMATION

A Dissertation
Presented to
the Faculty of Graduate Studies
University of Manitoba



In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by

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September 1952.

A REGIONAL STUDY OF THE WINNIPEG FORMATION.

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CHAPTER I.

INTRODUCTION.

Statement of Problem and Outline of Work.

While assisting with the mapping of the Ordovician in Manitoba for the Manitoba Department of Mines and Natural Resources, Mines Branch, during the summer of 1951, the writer had the opportunity to select a Master of Science problem.

Several interesting phenomena not previously known, were observed in the basal sand and shale formation of the Ordovician. Though a paleontologic report on the Winnipeg had been recently completed, it was suggested to the writer that a detailed sedimentologic and stratigraphic study of the Winnipeg formation would constitute an interesting and challenging study.

After considering several topics, the writer decided that because he had assisted in the mapping of the Winnipeg (Ordovician), his field knowledge would aid in a laboratory investigation of this formation.

It was decided to examine this formation and present the work done with the results obtained in a thesis entitled, "A Regional Study of the Winnipeg Formation."

In the early fall of 1951, the investigation included only the area of Manitoba, south and west of the Precambrian shield. Later sufficient subsurface and outcrop information was available to the writer, enabling the inclusion of a much larger area in the study.

The purpose of this regional study is to establish possibly the source (s?), depositional environments, areal distribution, and differences in lithology of the Winnipeg formation. Additions to existing faunal lists, age of the Winnipeg, and correlations are included in this paper.

Many different laboratory techniques were applied in the search for possible solutions to a problem of this nature. Mechanical sieving, textural analysis, heavy mineral separation and identification, thin section examination, X-ray diffraction powder photographs, recently developed mapping techniques, fossil study, insoluble residue preparation and examination, and a thorough search into the literature constitute the work completed and reported on in this paper. Tables, maps, figures and plates are incorporated to elucidate points of interest.

History of Previous Work.

Sir John Richardson in 1825-27 (Whiteaves 1900 P.130)* accompanied Sir John Franklin on an expedition to

* The complete references are listed alphabetically in the bibliography.

the Arctic Sea, and enroute they stopped at many outcrops on Lake Winnipeg. Some of these exposures were the sand and shale beds now known as Winnipeg formation.

A geological survey of the west coast of Lake Winnipeg was made by Hind in 1858 (Whiteaves 1900, p.130). He stated, "Fine exposures of the Chazy formation are said to occur on Punk Island and along the west coast north of Big Grindstone Point as far as Cathead."

In 1878-79, Bell of the Geological Survey of Canada in a report on the Churchill and Nelson Rivers observed a sandstone (Ordovician) overlying the Precambrian along the Portage Chute rapids on the Churchill River.

In the years 1889-90 and 1891, a detailed geological examination of the west shores of Lake Winnipeg was made by Tyrrell and Dowling of the Geological Survey of Canada. Tyrrell (1889) remarked, "that so far no fossils of any kind have been detected in the sandstones which are supposed to be referable to the Chazy (St. Peters) formation." Dowling (1895) subdivided the Winnipeg sandstone and mottled limestones: he placed the sandstones of Punk Island and Deer Islands below the "lower mottled limestones." He named these arenaceous rocks the "Winnipeg Sandstones." Dowling and Tyrrell from 1885 to 1900 mapped the northern fringe of the Paleozoic outcrops from south of Lake Athabaska to Lake Winnipeg. They detected

a sandstone containing Ordovician fossils overlying the Precambrian at Cormorant, Reid, Sturgeon, Cranberry, Simon-house, and Wekusko Lakes.

J.F. Wright (1922) while geologically mapping southeastern Manitoba, placed the Winnipeg sandstone as early Ordovician or possibly equivalent to the Potsdam sandstone of Cambrian age in the St. Lawrence and Ottawa Valleys.

DeLury (1924) in a Geological Survey of Canada Summary Report, described basal sandstones of Ordovician age from Deschambault Lake.

In 1925 Wallace wrote a paper describing geological formations of Manitoba. He included a brief description of the fossils and lithology in the Winnipeg formation and mentioned the correlations with the Black River (mid-Ordovician), and the Cambrian which had been made by earlier workers.

In 1926 Cole and McMahon worked on the clay deposits underlying the Winnipeg sandstone on the northeast side of Punk Island.

A heavy mineral study of the Winnipeg sandstone was made by Wallace and McCartney in 1928.

Wright in 1932 investigated the clay underlying the Winnipeg sands on Punk Island.

In 1949 Kerr used the name Winnipeg formation when referring to the Winnipeg sandstones.

In 1951-52 Nelson of the Geological Survey of Canada made a detailed lithologic and paleontologic investigation of the basal sands of the Ordovician in the Hudson's Bay Lowland.

In 1951 Macauley (Manuscript) made a stratigraphic and detailed paleontologic study of the Winnipeg. Macauley and Leith (1951) established the Winnipeg as a formation.

Acknowledgments

The writer wishes to acknowledge with many thanks the suggestion of this problem, the helpful criticisms and generous opinions rendered by A. D. Baillie of the Manitoba Department of Mines and Natural Resources, Mines Branch.

For sanctioning the study, the many constructive criticisms and ideas, and the patient assistance in the preparation of this dissertation, the writer wishes to express his indebtedness to Professor E. I. Leith of the University of Manitoba.

To Doctor W. O. Kupsch of the Saskatchewan Geological Survey, and to S. J. Nelson of the Geological Survey of Canada, for opinions, specimens, photographs and their valuable time, the writer is extremely grateful.

For permission to examine his manuscript entitled "The Stratigraphy of the Winnipeg formation," the writer is grateful to G. W. Macauley.

Many thanks are rendered the Staff of the Geology Department of The University of Manitoba for their co-operation and helpful advice.

To Mr. D. F. Towse of the North Dakota Geological Survey, gratitude is expressed for his providing much valuable subsurface information.

Gratitude is expressed to Mrs. L. B. Kerr and Mr. R.A.C. Brown of the Manitoba Department of Mines and Natural Resources, Mines Branch for their assistance with the stratigraphic and paleontologic information.

For the numerous and carefully prepared thin sections sincere thanks are offered Mr. K. W. Wilson of The University of Manitoba.

Mr. C. L. Baker of the South Dakota Geological Survey graciously rendered information on the St. Peter and Winnipeg formations.

Mr. V. D. Colcleugh permitted the reproduction of Figure 10.

The writer wishes to acknowledge thanks to Mr. J. D. Dwer of the California Standard Company, Mr. Hart Green Jr., The Imperial Oil Limited, The Shell Oil Company, The Socony Vacuum Exploration Company, The Albercan Oil Company, The Phillips Petroleum Company and the Manitoba Department of Mines and Natural Resources, Mines Branch, for their kind permission allowing the examination of logs, samples and cores.

CHAPTER II

EXTENT AND LITHOLOGY OF THE WINNIPEG FORMATION, AND SOME ASSOCIATED BEDS.

INTRODUCTION.

The Winnipeg formation outcrops on Hecla, Punk, Black, Deer and Little Deer Islands on Lake Winnipeg, Manitoba. It is exposed also at Victoria Beach (only lowest water level), and on the west shore of Lake Winnipeg, in an almost continuous band from Little Grindstone Point north to Limestone Cave Point. (Map VI).

A basal sandstone of the Ordovician which may be Winnipeg formation, outcrops at Deschambault and Amisk Lakes in Saskatchewan, Cranberry, Portage, Simonhouse Lake, Wekusko Lake, Minago River, and along the Churchill and Knife Rivers in the Hudson Bay Lowland, Manitoba. (Map VI).

From the examination of subsurface data the writer extends the distribution of the Winnipeg over central and southern Saskatchewan, the eastern side of Montana, all of North Dakota, and central and southwest Manitoba.

It may possibly occur in the Hudson Bay Lowland, along the northern outcrop fringe of the Paleozoics in Manitoba and Saskatchewan, and in northwest South Dakota.

LITHOLOGY

Field data collected by the writer, personal communications, and various published reports provide sufficient data to clearly indicate the general character of the Winnipeg formation. Several lithologic well logs* and measured outcrop sections of this formation are herewith presented. Included in this chapter are the lithologies of some beds associated with the Winnipeg formation.

SOUTH DAKOTA

Several wells in Northwest South Dakota may contain the Winnipeg formation. The correlation and definite placement of these beds is described in Chapter VII. These wells are listed by counties. Lithologic logs are copied from the South Dakota Geological Survey Report of Investigations 65, 1949.

- * Table 14, page 144 shows well numbers, names, locations, elevations and sources of information.

BUTTE COUNTY

Seyler-Carl Anderson No. 1.
 Section 12, Township 8, Range 5 east.
Elevation 2887.

Interval	Description
	Whitewood?
5280	Trenton? Ordovician?
5310	Limestone light brown, fine sugary silty.
5310-5330	Transition to Black River, limy silt, faintly green.
5330-5400	Black River. Metabentonite, talcose, greasy, flaky, green with small particles of black detrital phosphate. Slakes greatly into thin flakes.
5400-5440	St. Peter sandstone, fine grained some fluoresces, a little glauconite and some marcasite and pyrite cement, interbedded at top with green metabentonite.
5440-5551	Sandstone, a little coarser grained, angular, deep pink.
5510-5570	Deadwood sandstone with detrital glauconite, light green, limy.

HARDING COUNTY

State Royalty Petroleum Company, No. 1.
 SE 1/4, NE 1/4, Section 35, Township 18 N. Range 1 E.
Elevation 3267.5

Interval	Description
	Whitewood?
7720-7730	Middle Ordovician - dark grey limestone, very fine to medium crystalline. Contains oldest known fish scales and Middle Ordovician Graptolites.
7730-7740	Decorah - Platteville shale, dark blue grey, grading down into green chloritic basal limestone, may contain small chert pebbles and fine sand grains.

7740-7745	Shale, chloritic, bentonitic, green with scattered small quartz grains and black phosphate grains some rolled and rounded and fine pebble size.
7781-7783	Some green siltstone.
7781-7785	Green shale, has some sandstone, white, fine to medium, subround to subangular.
7785-7820	Green shale, darker green grey, some sandstone, white coarse angular.
7820-7903	St. Peter (Lower Ordovician*) sandstone, cream, poorly cemented, porous grains, medium to coarse, angular subangular, partly recrystallized. Saturated with light yellow oil at 7820. Angular pink feldspar fragments from 7876 down.
7903-7908	Arkose.

Northern Ordnance Corporation Harding School Land Well.
 Section 1, Township 17 N. Range 1 E.
Elevation 3430.

Interval	Description
	Whitewood?
7760-7890	Dolomite dense, spotted, pink, fine rhombs.
7890-7895	Brachiopod.
7895-7905	Shale, dark Lincoln green, unctuous, flaky and splintery, with some quartz and black phosphate grains (Decorah).
7905-7980	Shale, green and purple, some 7962 is shale, dark green, chloritic, dense, compact, conodont. (Belodus compressus). Cores from 7962-7966, shale, dark grey siltstone, green grey with thin shale lenses, black phosphate and sand grains at 7965-7971 is medium grey bentonite.

* The St. Peter is regarded as Middle Ordovician and not Lower Ordovician.

7980-8000

St. Peter sandstone, pure white, medium to coarse grained, subrounded calcite cement, etched grains, in part recrystallized.

The following wells in northwest South Dakota are thought to contain the Winnipeg formation but they are not described in detail. Names, locations, and elevations of these wells are given.

HUGHES COUNTY

Pierre Airport Well.
Section 35, Township 111 N., Range 79 W.
Elevation 1708.

LAWRENCE COUNTY

F. J. Weller Weisman No. 1.
Section 30, Township 7 N., Range 43.
Elevation 3680.

PERKINS COUNTY

Shell Homme No. 1.
North East 1/4, SE 1/4, Township 20N., Range 12E,
Section 13.

? COUNTY

Phillips Petroleum Company, State School Land No.1.
Section 36, Township 5 N., Range 27 E.

Summary of the Lithology of Possible Winnipeg formation in South Dakota.

Under the Whitewood dolomite in northwestern South Dakota lie sandstone and shale beds which are possibly correlative with the Winnipeg formation. The Shale ranges from zero to ninety feet in thickness, has a green to greyish color, is fissile, splintery, waxy bentonitic and chloritic, it contains black shiny phosphate nodules, sand grains, pyrite

and small fossils. Underlying the shale there is twenty to thirty feet of white to cream, porous, friable, well rounded to subangular, medium grained, well sorted, sometimes petroliferous sandstone. Pink, angular, coarse glauconitic, arkosic and quartzitic sandstone are at the base of the formation.

MONTANA

Pure Oil Company State No. 1.
Section 36, Township 2 N., Range 51 E.

Interval	Description
8630	Whitewood
9050	Winnipeg
9185	Deadwood
10,015	Precambrian
10,018	Total Depth

Carter's Northern Pacific No. 1.
SW 1/4. SE 1/4, Section 19, Township 4 N., Range 63 E.

Interval	Description
8830-9450	Interbedded green sandy shale, sandy shaly limestone, and sandstone with the percentage of sandstone increasing toward the base.

SASKATCHEWAN

Subsurface:

Shell Big Muddy Lake No. 1.

Lsd. 15, Section 12, Township 3, Range 21, W. 2nd. Mer.

Elevation 2,520' KBTotal Depth 10,238'

Interval	Description
9705-9710	Limestone, buff to greyish brown, micro-crystalline, dolomitic, few scattered micro-vugs, trace of grey opaque chert, slightly silty, slight interbedding, grey, fine to medium, grained quartzitic sandstone, dolomitic, no visible porosity, no shows.
	Winnipeg.
9710-9715	Dolomite, grey to greyish brown, fine to micro-crystalline, calcareous in part, slightly silty, no visible porosity, no shows, scattered rounded quartz grains, large and small, slight interbedding grey dense, slightly silty dolomite.
9715-9720	Dolomite, as above with interbedded grey fine-grained quartzitic sandstone, tight, no visible porosity, no shows, slightly dolomitic in part few scattered large frosted rounded quartz grains.
9720-9725	Dolomite, buff to buff grey, fine to micro-crystalline, few scattered quartz grains embedded, slight interbedding grey fine to medium grained, quartzitic sandstone, grey in color, fairly tight, no visible porosity, no shows.
9725-9733	As above with interbedded buff tan, crystalline to dense limestone, dolomitic, no visible porosity, no shows.
9733-9750	Sandstone, grey to white, fine to very fine grained, quartzitic, with scattered large rounded, frosted quartz grains, very pyritic in part, well sorted in part, no visible porosity, no shows, much dolomite assoc. (caving ?) buff brown, fine to micro-sucrose, silty in part, with a few scattered large quartz grains, slight inter-bedding green silty shale.
9750-9755	As above, with slight interbedding buff to brown, micro-crystalline limestone, slightly silty and dolomitic, no visible porosity, no shows.

- 9755-9774 Sandstone, white to grey to brown in part, fine to medium to coarse grained, well sorted in part, siliceous matrix, scattered large sub-rounded frosted quartz grains, fairly pyritic in part, no visible porosity, no shows, much of the above dolomite and red shale assoc. (caving ?).
- 9774-9800 Sandstone, grey to buff brown, to light buff, fine to medium, to coarse grained, with scattered large sub-rounded frosted quartz grains, sandstone is very siliceous in part, no visible porosity, no shows, fairly pyritic, slightly glauconitic at 9780' interbedded green waxy looking shale, (much dolomite and shale cavings.)
- 9800-9810 Sandstone, grey to light buff, fine to medium to coarse grained with scattered large sub-rounded frosted quartz grains, siliceous, no visible porosity, no shows, a few scattered thin laminations of brown argillaceous material, pyritic, interbedded dark green waxy pyritic shale.
- 9810-9860 Sandstone, white to grey, fine to medium grained, well sorted in part, with scattered large rounded frosted quartz grains, argillaceous matrix, very quartzitic, scattered traces of slight porosity, no shows, pyritic, interbedded dark green, waxy, pyritic shale, with scattered embedded quartz grains.
- 9860-9885 Sandstone, white to grey to buff brown, fine to medium to coarse grained with scattered large, rounded, frosted quartz grains, siliceous in part. Traces of slight porosity, no shows, pyritic, interbedded dark green, pyritic, waxy looking shale, with embedded quartz grains. (Shale appears to have scattered black micro-fossils embedded.)
- 9885-9913 Sandstone, white to grey to buff grey, medium to coarse grained, with scattered large frosted, rounded quartz grains, argillaceous matrix, friable in part. No visible porosity, no shows, very pyritic in part.
- 9913-9916 Sandstone, light buff to white, very fine grained, no visible porosity, no shows, few scattered large rounded frosted quartz grains, pyritic.
- 9916-9922 Sandstone, grey with greenish tinge in part, very fine to fine grained, silicified in part, no visible porosity, no shows, very glauconitic, pyritic, slight interbedding, green, waxy looking, glauconitic shale.

9922-9960 Tentative sample top. Cambrian 9916' (-7396')
 Sandstone, white to grey, very fine to fine
 grained, silicified in part. No visible
 porosity, no shows. Very glauconitic, pyritic,
 appears very sl. dolomitic in part. Slight
 interbedding dark green waxy looking shale.
 Trace of interbedded dark maroon shale at 9935'.

Eatonia No. 1.
 Lsd. 4, Section 32, Township 26, Range 21 W. 3rd. Mer.
Elevation 2200.

Interval	Description
5800-5880	Limestone - dolomitic - light buff to pink, slightly sucrosic 5840 - 5850.
	<u>Winnipeg?</u>
5880-5890	Sandstone - glauconitic (40%). Shale - sandy brown (30%). Limestone - dolomitic as above (30%).
5890-5980	Sandstone - as above, but with increasing amounts of grey greenish and some red shale and decreasing amounts of limestone.
5980-6040	Shale - grey (80%). Sandstone - glauconitic (18%). Trace of mauve shales 5990-6400.
6040-6270	Shale - grey (99%). Trace of dolomitic limestone and glauconitic sandstone.
6270-6530	Shale - green grey and mauve (100%), splintery.
6530-6550	Shale - green grey and mauve as above (90%). Sandstone - glauconitic (10%).
6550-6600	Shale - green, grey and mauve (100%).

Hudson's Bay Oil and Gas Company, Gronlid No. 1.
 Lsd. 15, Section 32, Township 47, Range 17 W. 2nd Mer.
 Elevation KB 1420.8 Total Depth 2596

Interval	Description of Cores
<u>Top of Winnipeg.</u>	
2343.9	Light green to dark green claystone. Indurated medium grained frosted quartz sand. Color due to claystone matrix, quartz grains are colorless. Small amount of mauve with above green claystone. There is a one half inch bed of clean grained frosted quartz sand at top of the above two feet four inches.
7.9	Indurated medium grained frosted quartz sand. Color due to claystone matrix as above, fair intergranular porosity. This core had a slightly brackish water taste and slight H ₂ S odor and is very wet. There is some pyrobitumen following boundaries of point of the sandstone which gives the core a mottled effect. Except where above mottling is apparent, the sandstone is very finely wavy and irregularly bedded.
2355-95	#12 Recovery 16.3'.
10.2	Dark greyish green, medium grained quartz sand as above. Partly nodular, indurated generally with fair intergranular porosity. Slightly H ₂ S odor. Brackish to taste, very wet, shows generally a mottled effect due to pyrobitumen forming a cover over irregular shapes of the sandstone and these in turn being surrounded by finer pieces which may also be pyrobitumen stained.
5	
4.0	
2.1	Generally purple with minor light green microscopic colored sandstone. Microscopically the sandstone is medium grained to fine grained frosted quartz. Colorless with good porosity generally slightly indurated. Medium grained frosted quartz sand, brackish. Wet negligible pyrobitumen odor due to quebracho in mud. The original color was slightly greenish due to minute amounts of light green argillaceous material. Note: Biscuits of core show the purple quebracho color invading from the outside. The inside light green very mashed up sand as above and some light green argillaceous sandstone as above probably represents 2.5' of sandstone in above 4.0'.

2395-2400

#13 Recovery 4.4'

Medium grained to coarse grained frosted rounded quartz sandstone. Moderately indurated. Generally with very good porosity and these zones are shown by purple quebracho invasion. Some light green zones are filled with a light green argillaceous material and have suffered no invasion. Microscopically the core is predominately purple with light green bands. Very good porosity. Brackish taste, slightly salty and slight H₂S odor. The last 5' are strongly cross-bedded.

2400-2421

#14 Recovery 14'

One 1-1/2" disc of dark green rubbery shale on top, otherwise core is as above, medium grained, rounded and frosted quartz sand. Slightly indurated, generally good porosity, brackish, slight H₂S odor. Microscopically quebracho purple with light green slightly argillaceous bands throughout strongly cross-bedded.

2421-30

#15 Recovery 7.8'

Continues as above, strongly cross-bedded medium grained to clear grained frosted quartz sandstone. Colors green where clay filled and quebracho red porous.

2590-2594

#16 Recovery 1.5'

Coarse up to 3" very angular white to yellow, clear grained quartz fragments in an indurated resistant bed. Red coarse grained frosted quartz sandstone red color due to hematite.

2594-2596

#17 Recovery 1.3'

As above.

Outcrop:

Deschambault Lake
 Section below measured by Dr. W.O. Kupsch on
the northeast shore of Ballantyne Bay.

- | | | |
|----|---|----|
| 3. | Thin bedded Ordovician dolomite | |
| 2. | Argillaceous sandstone | 1' |
| 1. | Friable, horizontally bedded, pure white quartz
sand | 6' |
- Lake Level

Amisk Lake
 One mile south of Sucker Creek and fifty
 feet east of Amisk Lake road near Flin Flon,
Saskatchewan.

- | | | |
|----|---|-------|
| 3. | Arenaceous dolomite grading to dolomite, pale
red to grey red, mottled to grey orange,
finely crystalline with uneven fracture sur-
face. In beds 3" - 6" the dolomite may be
traced for more than 100 yards and in places
reaches 30' | 30'0" |
| 2. | Consolidated sandstone. Pale red, orange
or yellow, lowest inch containing small clay
pockets | 0'4" |
| 1. | Orangy-brown (ochreous) carbonate cemented
sandstone in beds one foot thick | 1'0" |

Summary of the Lithology of the Winnipeg formation in
 Saskatchewan.

The Shell Oil Company (personal communication)
 places the lower contact of the Winnipeg formation at the
 first appearance of glauconite in the Winnipeg sand. Dr.
 W.O. Kupsch (personal communication) places the lower limit
 of the formation at the first appearance of coarse, angular
 poorly sorted quartz, or glauconitic sand. The following is

a generalized description of the Winnipeg formation occurring in Saskatchewan:

4. Arenaceous iron stained fossiliferous dolomite 10' - 20'
3. Well sorted, rounded, frosted, medium grained, pyritiferous, white to iron stain sandstone and interbedded, dark green, waxy, fissile, splintery, pyritiferous shale 100' - 225'
2. White to rusty, friable, well sorted, rounded, medium grained clear quartz sand 0' - 30'
1. Angular, glauconitic, coarse, poorly sorted sandstone.

MANITOBA

Subsurface:

California Standard Company, Wawanesa No. 1.
Section 3, Township 18, Range 18, W.Prin. Mer.
Elevation 1364.4 KB

Interval	Description
3085-3090	Dolomite, pale yellowish orange. Rose shale fragments.
3090-3095	Pale yellowish orange, arenaceous dolomite. Rose, light pinkish grey sandstone. Light grey green to dark green wavy shale. Small fragments of red brown sandstone.
3095-3100	Grey shale, some sandstone covered by shining brown bituminous looking material.
3100-3105	Light green shale and sandstone.
3105-3135	As above with some red shale and reddish sandstone.
3135-3140	Large angular light green quartz grains and small buff sandstone.
3140-3145	Red shale, grey green sandstone and reddish sandstone.

- 3145-3155 Siliceously cemented sandstone, very irregular fracture, some pinkish quartz and dolomite. Some dark grey green splintery shale.
- 3155-3165 Light greenish grey calcareous sandstone. Little dark grey and reddish shale.
- 3165-3200 Mostly siliceous yellow to greyish orange sandstone, some calcareous, little grey to grey green shale, fissile and splintery.
- 3220-3235 Calcareous yellowish siltstone, and little dark grey shale.
- 3235-3255 Calcareous yellowish siltstone, reddish shale mottled with greenish shale.
- 3255-3260 Sandstone as above, but sometimes interbanded with dark grey shale.
- 3260-3290 Sandstone as above but some very red due to iron oxide. Little reddish and green shale. Reddish color decreases to 3290.

Imperial Madeline No. 1.
 Tsd. 16, Section 18, Township 18, Range 29, W.Prin.Mer.
Elevation 1597 K.B.

Interval	Description
4290-4295	Yellowish grey arenaceous dolomite dominant. Rare red brown waxy shale.
4295-4320	Red brown waxy splintery shale.
4320-4325	Waxy, splintery, green shale with numerous pyrite fragments, crystals, and nodules. Some calcareous cemented sandstone.
4325-4350	Mostly dark green, splintery, waxy, fissile shale. Some red brown, waxy, splintery shale. Rare greenish sandstone.
4350-4390	Mostly dirty grey, to yellowish orange, silty sandstone. Some green black, and reddish brown shale.
4390-4400	As above, but numerous medium sized loose quartz grains.
4400-4420	Splintery, waxy, fissile, pyritiferous green shale, and silty, dirty to greyish white sandstone. Rare brown shale.

- 4420-4435 Mostly greyish silty sandstone. Some green and brown shale.
- 4435-4450 Shale, greyish sandstone, angular quartz, biotite, and granite fragments.

Red River Oil, No. 2.
 Lsd. 2, Section 1, Township 5, Range 1, W.Princ. Mer.
Elevation 795 G.L.

Interval	Description
760-770	Pale yellowish arenaceous dolomite.
770-790	Blue green, fissile, waxy, splintery shale. Abundant pale yellowish orange sandstone fragments with some loose quartz grains. Some brownish shale.
790-860	Fine, rounded quartz sand, frosted and pitted, abundant grey green, and grey olive, splintery, waxy shale. Some sandstone cemented by carbonate matrix.
860-900	Mostly fine, rounded, quartz sand with some red and green shale.
900-940	Mostly olive shale, some red, blue green fissile, splintery, waxy shales. Increasing very fine white quartz sand to 940.
940-950	As above, but mostly fine rounded white quartz sand.
950-952	As above, plus granite fragments.

Hart Green Wakely No. 1.
 Lsd. 13, Section 28, Township 4, Range 4, W.Prin.Mer.
 Elevation 875 contours.

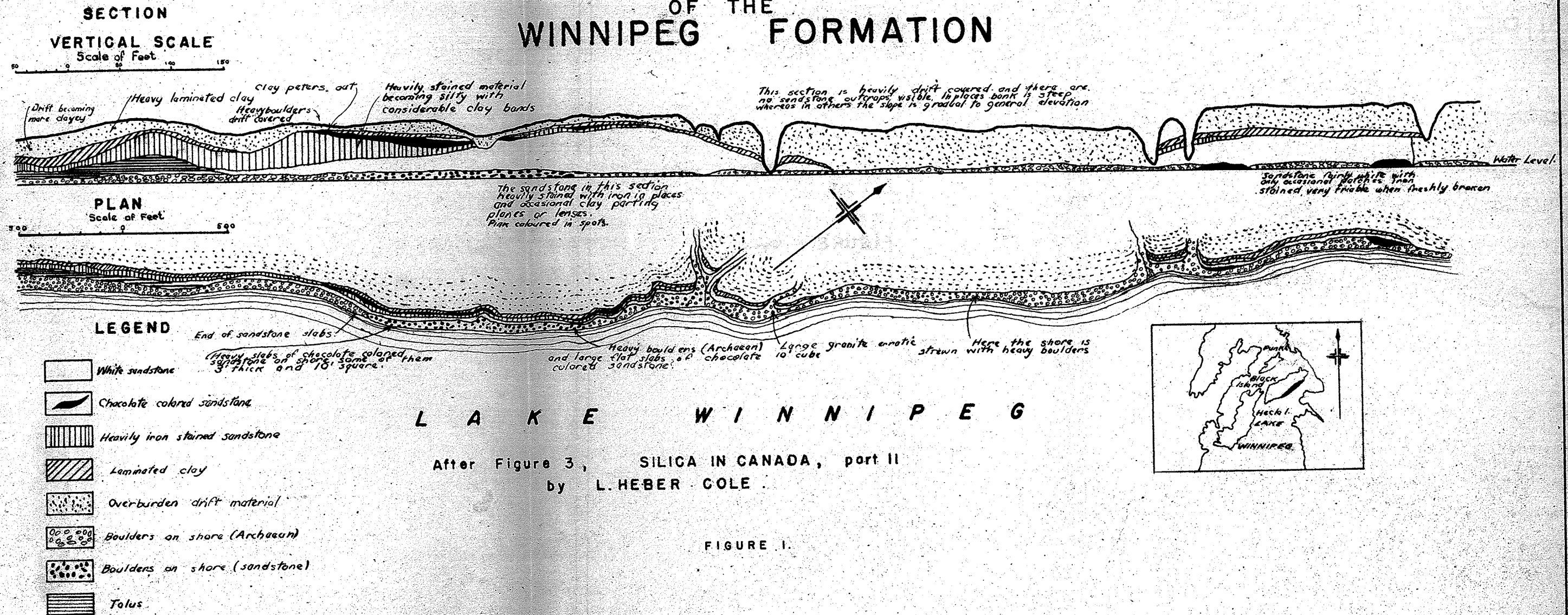
Interval	Description
1250-1280	Clayey material, light brown (5YR6/4*) and greenish shale.
1280-1290	Sand, medium to coarse rounded, frosted quartz and brilliantly iron stain.
1290-1294	Shale, dark greenish grey with some maroon streaks, abundant sand, medium grained rounded and frosted.
1294-1360	Sand, colorless quartz, rounded frosted medium grains of fairly uniform size, quite pure, some orange stain, a few fragments are green maroon streaked shale. 1313-1320. Some clayey shale, orange to reddish shades.
1360-1390	Shale, moderate brown (5YR4/4) and a bit green, soft, clayey.
1370-1380	Considerable sand as above.
1380-1390	Considerable dusky yellow (5Y6/4) shale, soft.
1390-1445	Shale, variegated shade of green, maroon and yellowish brown, soft clayey.
1420-1445	Shale is a little more splintery.
1436-1445	Considerable loose frosted sand.

* These numbers refer to those in the color chart issued by The National Research Council (U.S.A.).

R. J. McGuckin Test Hole, No. 3.
Township 33, Range 1, W. Princ. Mer.
Elevation 760 contours.

Interval	Description
142-155	Shale, light to dark greyish olive, latter contains small rounded bodies composed of iron, fossils probably.
155-165	Shale "storm grey", some dark greyish olive, some fossils as above.
165-178	Sandstone clear quartz, grains rounded from 3 to 5 millimeters.
178-240	Sandstone, pale olive buff grains, two millimeters, clear and rounded.
240	Pink granite gneiss.

BLACK ISLAND, LAKE WINNIPEG. SECTION THROUGH AND PLAN OF THE LOWER SANDSTONE UNIT OF THE WINNIPEG FORMATION



Outcrops:

The descriptions of the Winnipeg formation exposures are compiled from the field notes and from the binocular examination of ninety-four specimens collected from the outcrops. Those sections listed, but not described by the writer are indicated. Numerous sections of the Winnipeg are found in Manitoba, but only some of the most noteworthy are described.

Black Island - Lake Winnipeg.

"On the northwest and southeast side of the island, cliffs of Winnipeg sandstone as much as 60 feet high are exposed.* For the most part this rock is fine grained almost pure silica, white, unconsolidated sand. Parts of it weather a buff to brownish color owing to some iron impurities.

A peculiar feature of this formation is the presence of more highly consolidated, very porous, buff to grey sandstone. This has been noted at the tops of cliffs, underlain by the unconsolidated sand. At one locality on the northwest side of the island, small concretionary-like pyrite or marcasite spheres were found in the grey porous sandstone." (Davies 1951).

A detailed section of the southeast side of Black Island is illustrated in Figure 1.

* Writer's comment: The cliffs of Winnipeg sandstone on Black Island are ^{not} higher than 40 feet.

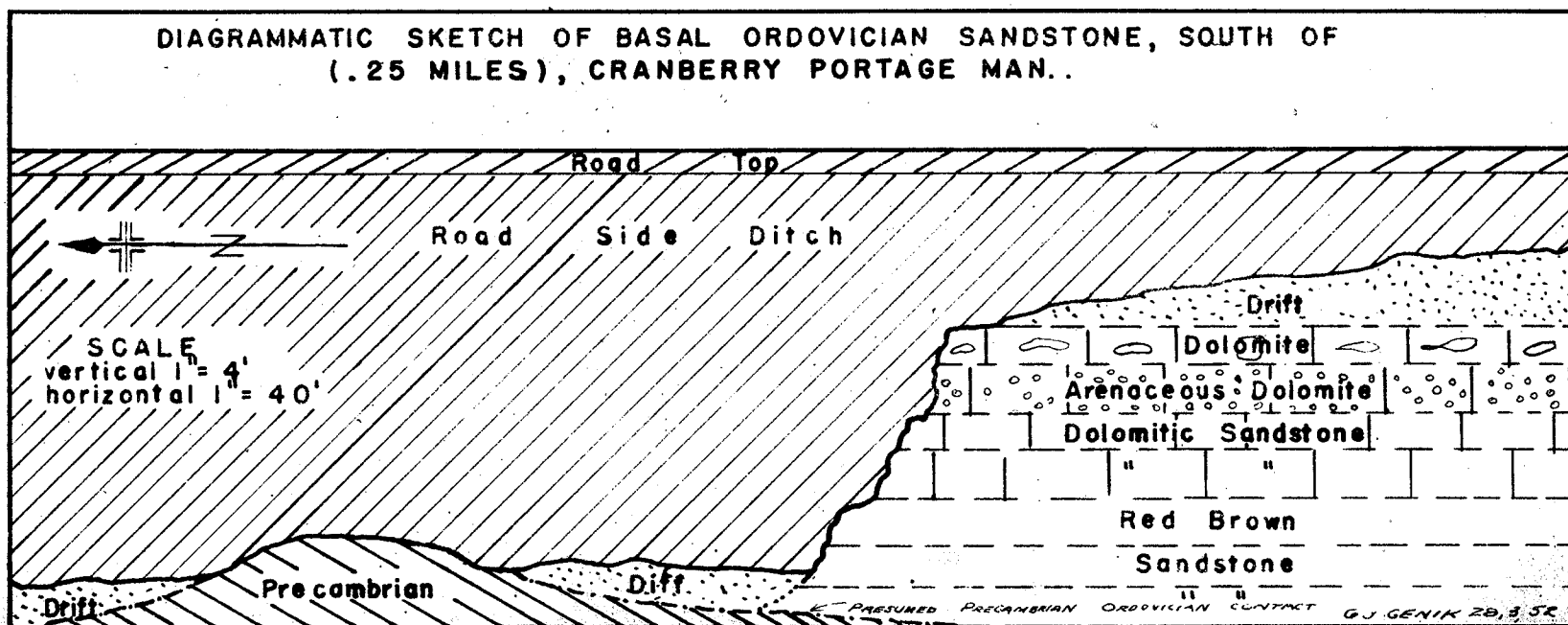


FIGURE 2.

Punk Island - Lake Winnipeg

One hundred yards from the northeast extremity of

Punk Island:

Glacial material	3'
Sandstone, very fine, white, silty, greyish, slightly impure, ripple marked	9'
Total thickness	12'

Most easterly outcrop of Winnipeg on eastern side of Punk Island.

3.	Varved clay	2' - 3'
2.	Sandstone, friable to poorly consolidated, medium to fine grained, white to rusty yellowish brown. Four feet from top of this unit are oxidized iron sulphide nodules, three feet above the base of the unit is abundant iron staining. Close to base of unit at lake level sandstone is moderately well consolidated, white	10'
1.	Lake level.	

First point 1/2 mile west of northwest extremity of Punk Island.

3.	White, iron stained, cross-bedded, variable grain sized, fine friable sandstone containing tubular structures perpendicular to the bedding	5'
2.	Sandstone consolidate in 3" - 4" beds	1'
1.	Sandstone, white unconsolidated friable, little iron staining, structureless	12'

One quarter mile east of most prominent point on north shore
of Punk Island. Composite section

Dog Head member, Red River formation
Winnipeg formation

8.	Dark grey green shale, blocky and semi-conchoidal fracture	8' - 10'
----	---	----------

7.	Very dark brown argillaceous sand	3'
6.	Sandstone, consolidate calcareous	1'
5.	Pyrite nodules 50%, sandstone 50%	1'
4.	Sandstone friable unconsolidated white to yellow to orange brown	24'
3.	Argillaceous sandstones in irregular beds	2'
2.	Pyrite oolites in beds 2" to 3" thick, argillaceous matrix	2'
1.	Lake level	

Deer Island, near north extremity of Island

Dog Head member, Red River formation:

7.	Dolomitic limestone, impure, greyish orange and dark yellowish grey. Granular with many fossil fragments; in beds 4" - 6"	10'
6.	Dolomitic to arenaceous limestone as above with iron sulphide nodules and thin silty partings quartz grains abundant, contains dark grey streaks of disseminated pyrite. Lower 6" is very dark grey and nodular and makes sharp contact with underlying sandstone	4'6"

Winnipeg formation:

5.	Argillaceous sandstone, greenish yellow to greyish orange, friable, poorly cemented with iron oxide, many worm-like tubes of sand in an argillaceous matrix	1'6"
4.	Quartzose, sandstone, fine to medium, poorly consolidated, discoloured by iron oxide nodules	4'5"
3.	Quartzose sandstone with clay partings, 1 inch to 2 inches thick, friable, some beds are well consolidated with a carbonate cement, some pyrite nodules	5'5"
2.	Shale, greyish green, soft and plastic, similar to underlying shale but contains no arenaceous areas	4'3"

1. Shale, dark greenish grey, non calcareous, breaks in laminae 2" - 3", contains many thin bands and nodules and worm like tubes of sandstone with carbonate cement. Iron sulphide nodules and dark brown phosphatic pellets are common. Fossils are present in shale and sandstone 9'7"

Deer Island, 1/2 mile southeast of preceding section.

7. Shale, greyish green (cf. Unit 5, below)..... 5'
6. Sandstone, well consolidated with calcareous cement; contains phosphatic nodules and small masses of pyrite crystals 1'
5. Sandstone, pale brownish red, very soft and friable with clay matrix, contains bands of pockets of clay 6'
4. Shale, dark greyish green, breaks in laminae one quarter inch to one inch, contains many thin partings of sandstone, fossiliferous, brachiopods, gastropods, pelecypods 7'6"
3. Sandstone, contains many pyrite nodules and disseminated pyrite, very resistant beds, upper four inches is softer and contains pockets of soft green clay 1'8"
2. Sandstone, light grey, in thin irregular beds, poorly cemented with a clay matrix 1'
1. Sandstone, greyish yellow, in beds six inches to twelve inches thick, well consolidated with a matrix of quartz silt, iron oxide cement forms a resistant ledge 3'

Cranberry Portage, Manitoba.

One quarter mile south of Cranberry Portage along the sides of the road the sandstone and dolomite section is exposed 80' north of a Precambrian outcrop (Figure 2 p. 27).

Cranberry Portage - (Cont'd.)

4. Arenaceous dolomite to dolomite, irregular weathered surface, mottling yellowish grey to greyish orange, in beds 8" to 10" 2'
3. Dolomitic sandstone to arenaceous dolomite, fossiliferous mottled yellow grey to greyish orange. Lowest bed is seven inches thick others are 3" to 4" 2'
2. Sandstone yellow brown, fairly well cemented, highly fossiliferous in beds 5" - 10" thick. Some sand is red brown and contains few iron oxide nodules 1'6"
1. Precambrian

Minago River, Manitoba.

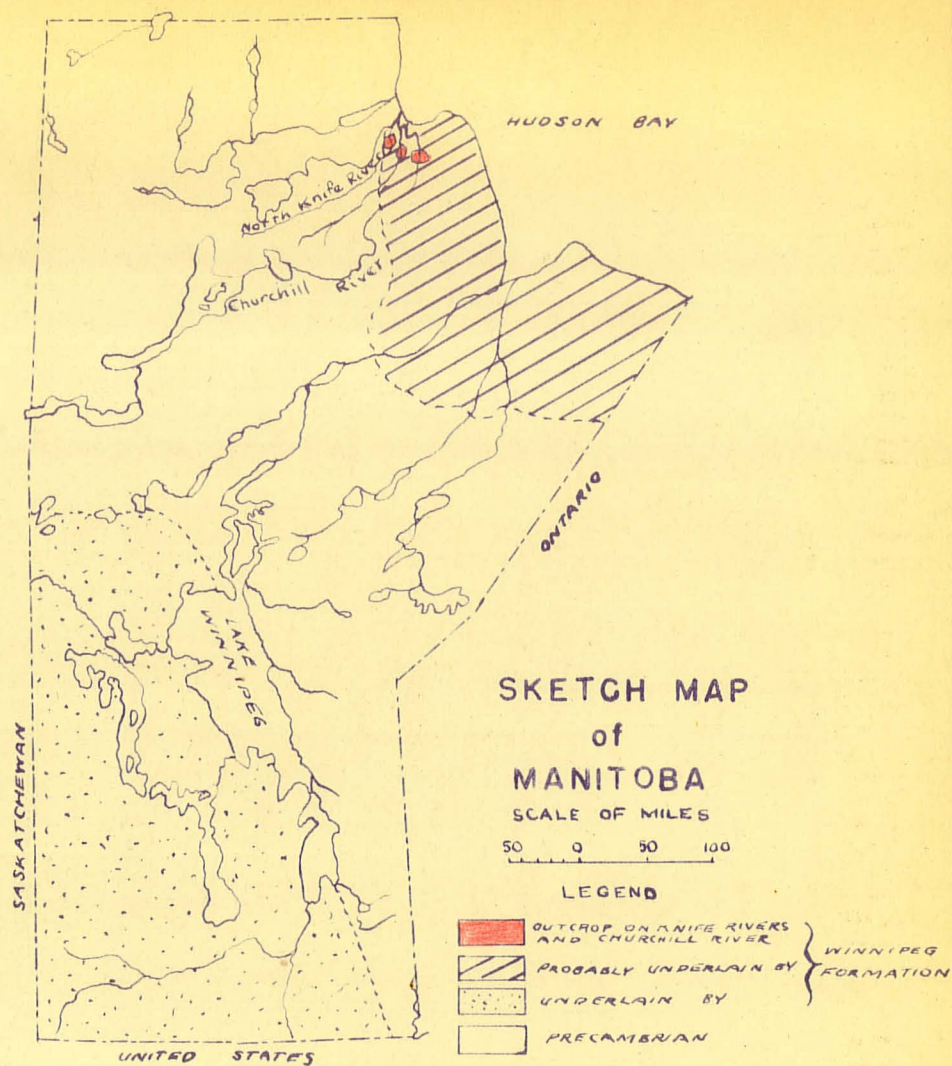
Southend of Hill Lake on Minago River (Tyrrell J.B. 1900).

2. Light yellowish Trenton limestone 15'
1. Light grey fossiliferous, brownish weathering sandstone, thick bedded and rather fine grained 10'

Churchill River, Manitoba (Nelson, S.J. 1952).

Portage Chute, Bad Cache Rapids, Hudson Bay Lowlands.

3. Arenaceous dolomite to dolomite +25'
2. Sandstone, rusty weathering to greyish limy matrix; quartz grains are clear, well rounded mostly less than two millimeters in diameter. Lower foot, grains are larger more angular and Little limy matrix. Top two feet, grains are smaller, more rounded, limy matrix dominant 2'4"
1. Red syenite gneiss one foot below water.



Taken From
The **GEOLOGICAL FORMATIONS of MANITOBA**
By R. C. WALLACE

Modified after WALLACE'S
Plate VIII, p. 36

G. J. GENIK

North Knife River, Manitoba. (Nelson, S.J. 1952)

Section was measured just south of the junction of the North and South Knife Rivers.

- | | | |
|----|---|-----|
| 3. | Limestone, bedded | 3' |
| 2. | Sandstones, bedded, exceedingly fossiliferous | 12' |
| 1. | Precambrian slate | |

Summary of Winnipeg formation in Manitoba:

Red River dolomite

Winnipeg formation:

- | | | |
|----|---|---------|
| 4. | Arenaceous dolomite | 2'-20' |
| 3. | Blue green fissile, splintery, pyritiferous, fossiliferous shale. Sometimes shale is arenaceous and contains phosphatic and pyrite nodules, or interfingering sand layers , , , , , | 0'-100' |
| 2. | Pyritiferous or oolitic, well consolidated siliceous sandstone. Oolites make up more than 50% of this unit | 0' - 2' |
| 1. | Pure white medium grained abundantly iron stained, highly rounded, frosted and pitted, rarely fossiliferous friable unconsolidated quartz sand | 0'-100' |
- Precambrian

NORTH DAKOTA

Subsurface:

Turner Oil Company, No. 1. L.G. Gapp.
Section 7, Township 163 N. Range 55W.
Elevation +825 contour

Interval	Description
742-986	Winnipeg shale
986-1090	Winnipeg sand
1090	Precambrian

Town of Grafton Well
Walsh County Section 13, Township 157 N, Range 53W.,
Elevation 825

Interval	Description
	<u>Winnipeg:</u>
745-785	Grey hard shale
785-880	Green blue shale
880-900	Dark red gritly shale
900-903	White sandstone
	<u>Precambrian:</u>
903-912	Grey granite

Town of Hamilton Well,
Pembina County, Section 25, Township 162N, Range 53W.,
Elevation 824

Interval	Description
	<u>Winnipeg:</u>
762-892	Blue shale (caving)
892-897	White sandstone
	<u>Precambrian:</u>
897-912	Blue and grey granite

Glenfield Oil Company #1,
Foster County, SE1/4, Section 18, Township 146N, Range 62W.,
Elevation 1510

Interval	Description
	<u>Winnipeg formation:</u>
2750-2890	Blue grey shale, reddish brown shale, fragment of a phosphatic linguloid.
2890-2980	Sandy shale.
	Cambrian ? Deadwood ?

2980-3020	Red, green and grey sandstone, glauconite and quartz, the conspicuous minerals, in part fine grained, in part coarse, especially coarse at 3,000 feet.
3020-3030	Dark brown coarse glauconite and micaceous sand.
3030-3050	Dark brown fine glauconite sand.
3050-3060	Red and grey shale.
3065-3100	Dark brown sand.
3100-3150	Olive drab to rusty brown, micaceous sand, mostly very fine grained, some medium grained.
	Precambrian
3150-3160	Granite gneiss.

Continental-Pure Davidson No 1,
Section 6, Township 140N, Range 77W,
Elevation 1909 K.B.

Sample descriptions by D.F. Towse (personal communication).

Interval	Description
6500	<u>Winnipeg formation:</u>
6500-6540	Shale, medium grey to very slightly greenish, slightly sandy with small fine-grained tight sandstone.
6540-6560	Shale, dark greenish grey, splintery, with small amounts of pyrite.
6560-6570	Sandstone, quartzose, medium to coarse grained, rounded, loose, calcareous.
6570-6660	Shale, dark greenish grey, as above, with occasional grey, calcareous silt streaks.
6660-6690	Sandstone, quartzose, medium to coarse grained, poorly sorted, rounded to subrounded, soft to tight with calcite cement and abundant grey chert.
6690-6710	Shale as above with small chalky limestone.

Cambrian:

- 6710-6840 Sandstone, fine to medium grained, angular quartz, porous, calcite cement. Abundant coarse round glauconite grains in top half.
- 6840-6860 Shale as above, slightly micaceous with a trace of pyrite.
- 6860-6949 Sandstone, medium grained porous, much glauconite and shale and some limestone in top part. A few coarse shale and quartz pebbles, small feldspar and muscovite. A few coarse round frosted quartz grains at the base.

Precambrian

- 6949 Light brown medium grained granite.

Union Oil Company, Aanstad #1,
Section 29, Township 158N., Range 62W.,
Elevation 1544' K.B.
Sample descriptions by D.F. Towse.

Interval	Description
3040	<u>Winnipeg formation:</u>
3040-3095	Greyish green, calcareous mudstone, medium hard, with inclusions and bands (up to 4" thick) of light greenish grey argillaceous limestone. Occasional compacted fossiliferous layers.
3095-3210	Greyish green non-calcareous indurated silty mudstone with some olive brown shale; minor amounts of limestone.
3210-3219	Medium to fine subrounded quartz sand.
3219	<u>Precambrian:</u>
3219-3223	Grey granite gneiss, weathered at top.

Summary of the Winnipeg formation in North Dakota.

Red River dolomite

Winnipeg formation:

3. Arenaceous dolomite 2'- 10'
2. Green, waxy, splintery, fissile, blue green, purplish, silty, calcareous or arenaceous, fossiliferous shale, and interbedded minor sandstone 50'-300'
1. Pure white friable, unconsolidated well rounded frosted and pitted quartz sandstone 0'- 50'

Precambrian, Cambrian or Pre-Winnipeg Ordovician.

Definition of the Three Units Comprising the Winnipeg formation.

The information garnered from a thorough study of the lithology in the Winnipeg formation enables the writer to suggest that the Winnipeg consists of three distinct lithological units. Although these lithological components may occur together in a section, it is commonly observed that only one or possibly two of the units occur together. Beginning with the uppermost lithological unit, the three which comprise the Winnipeg formation will now be named.

Deer Island Unit.

The Deer Island unit is named after the type outcrop locality on the northern extremity of Deer Island (Plate III, 1,3). Consisting of from two feet to twenty feet of dolomitic sandstone which from the base, grades upward into an arenaceous dolomite. This unit at the top is dolomitic

limestone. The beds may range in thickness from three inches to ten inches.

Grindstone Point Unit.

The Grindstone Point unit derives its name from a type outcrop section on Grindstone Point. Sections of this unit on Deer Island are just as typical as those on Grindstone Point, but because the name Deer Island has already been applied to the upper unit, the name Grindstone Point, is given the middle component of the Winnipeg formation. (Plate II, 2, 3, and Plate IV, 1,2).

The Grindstone Point unit ranges in thickness from zero feet to three hundred feet. It is composed of green greyish to purplish, waxy, fissile, splintery, pyritic nodular, phosphatic, siliceous to faintly calcareous shale, with interbedded medium grained, well sorted, highly rounded frosted and pitted, sometimes cross-bedded, friable to consolidated (by pyrite or calcium carbonate) sandstone.

Black Island Unit.

The Black Island unit, the lowest one of the Winnipeg formation, gets its name from the type outcrop locality on Black Island (Plate V, 1,2) In thickness this unit ranges from zero feet to more than one hundred feet.

It consists of massive to poor horizontally, thick bedded, white to slightly yellowish orange, pure, well sorted, highly rounded, frosted and pitted, medium to fine grained, poorly consolidated to completely unconsolidated quartz sandstone.

Lithology of Beds Overlying and Underlying The Winnipeg Formation.

All examined records show that the Winnipeg is overlain by an arenaceous dolomite or dolomitic limestone. These arenaceous dolomites or dolomitic limestones are gradational from, and conformable with the beds of the Winnipeg formation (Plate II, 1; Plate III, 1, 2). To show the degree of gradation of sandstone into dolomite, several insoluble residues were prepared from selected samples and the results are listed in Table 1, p. 40 .

TABLE I.

INCREASING PERCENTAGE OF CARBONATE IN WINNIPEG
FORMATION FROM SANDSTONE AT BASE OF SECTION INTO
THE OVERLYING RED RIVER DOLOMITIC LIMESTONE.

AMISK LAKE.

Distance from Base of Section	Total Weight of Sample In Grams	Weight of Insoluble Residue in Grams	Percentage Insoluble Residue	Percentage Dissolved Carbonate
6'4"	37	.11	0.3	99.7
6'4"-1'4"	38	1.51	4.0	96.0
1'4"-1'	40	8.00	20.0	80.0
1' -0'	36	15.5	43.0	57.0

CRANBERRY PORTAGE

6'-4'	36.5	1	Trace	+99
4'-3'	47.6	3.2	7.5	92.5
3'-2'	36.0	12.5	34.0	66.0
2'-1'	47.6	17.20	45.2	54.8
1'-0'	36.5	27.76	65.4	34.6

The contact between the Winnipeg and underlying Precambrian is easily recognized. However, in southern central and western Saskatchewan, eastern Montana, and north-western South Dakota, it is extremely difficult to place with any certainty the contact of the Winnipeg beds with the underlying Ordovician? or Cambrian strata.

Well sections and maps (J. Webb 1952 and Laird 1952) were studied, from which the writer has compiled sufficient information to present his picture (Map III) of the geology which occurs immediately beneath the Winnipeg formation.

EXPLANATION OF PLATE I.

- FIGURE 1. Eolian ? cross-bedding in Recent sandstone at Albert Beach, one and one half miles east of Victoria Beach.
- Figure 2. Aqueous cross-bedding in Recent sandstone at Albert Beach, two miles east of Victoria Beach.
- Figure 3. Recent dune sands, one mile east of Victoria Beach.



PLATE I



1.



2.



3.

EXPLANATION OF PLATE II

- Figure 1. Cross-bedded sand of Deer Island unit underlying Dog Head dolomitic limestone on the northwest side of Deer Island, and slumped blocks of Dog Head along face of outcrop.
- Figure 2. Cross-bedding of sand and shale beds in the Grindstone Point unit on the north side of Deer Island.
- Figure 3. Calcareous (light colored) sandstone bands with interbedded (greyish) shale bands of the Grindstone Point unit, on the northeast side of Deer Island.

PLATE II



1.



2.

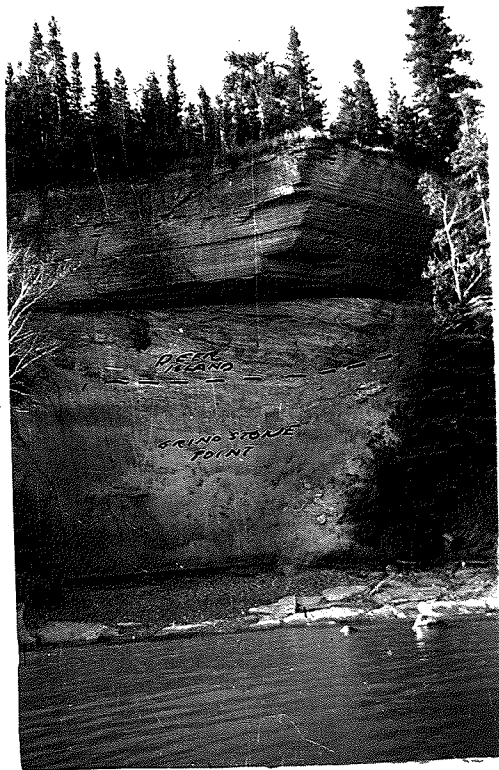


3.

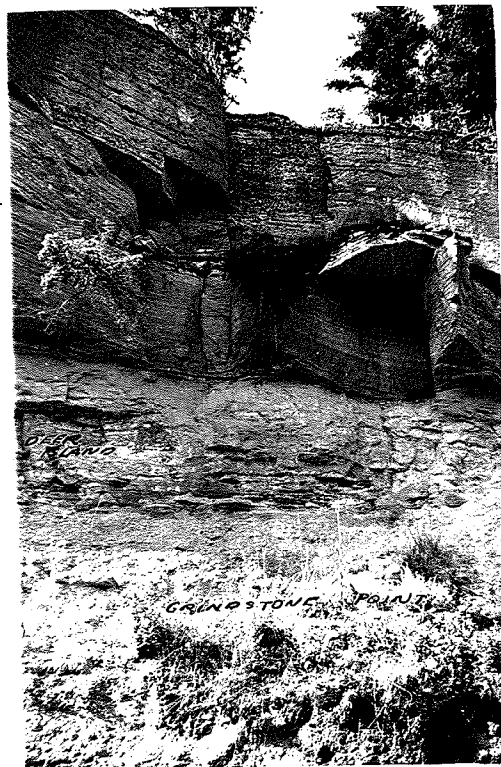
EXPLANATION OF PLATE III.

- Figure 1. Grindstone Point and Deer Island units overlain by Dog Head limestone on the west side of Punk Island.
- Figure 2. Sand of Grindstone Point unit grading into sand-dolomite of the Deer Island unit and overlain by the Dog Head limestone.
- Figure 3. A shale-sandstone contact within the Grindstone Point unit, overlain by thinly bedded dolomitic sandstones of the Deer Island unit, on the northeast side of Deer Island.

PLATE III



1.



2.



3.

EXPLANATION OF PLATE IV.

Figure 1. Outcrop of shale-sand Grindstone Point unit of the Winnipeg formation, on the east side of Little Grindstone Point, west shore of Lake Winnipeg.

Figure 2. Outcrop of sand-shale Grindstone Point unit of the Winnipeg formation, on the north side of Grindstone Point, west shore of Lake Winnipeg.

PLATE IV



1.

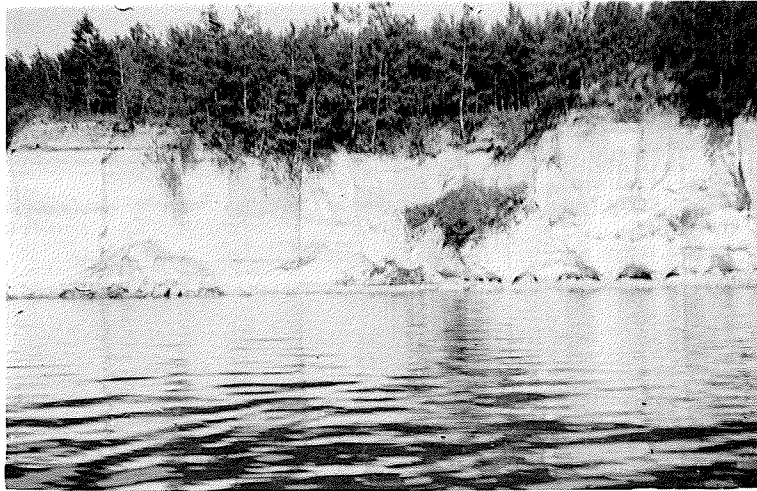


2.

EXPLANATION OF PLATE V.

- Figure 1. Black Island unit with natural bridges at the base of the case hardened sandstone, on the east side of Black Island.
- Figure 2. Black Island Unit, section showing poorly developed horizontal bedding, on the southeast side of Black Island.

PLATE V



1.



2.

EXPLANATION OF PLATE VI.

- Figure 1. * Basal sandstone of the Ordovician (Winnipeg formation - Deer Island unit ?) overlain by Ordovician (Dog Head) arenaceous dolomite on the North Knife River about forty miles from its mouth. The Precambrian is exposed just below water level.
- Figure 2. * Basal sandstone of the Ordovician overlain by the upper dolomitic arenaceous limestone member of the Portage Chute formation (Ordovician). Tape roll (centre bottom) is on contact between the basal sandstone and the underlying Precambrian whereas the head of the hammer (centre left) is on contact between sandstone and the overlying Portage Chute, two and three quarter miles below Portage Chute on the Churchill River.
- Figure 3. ** Basal sandstone of the Ordovician and the overlying (hand is on the contact) Red River dolomitic arenaceous limestone, on the northeast shore of Ballantyne Bay, Deschambault Lake Saskatchewan.

* By S. J. Nelson 1951.

** By Dr. W. O. Kupsch 1951.

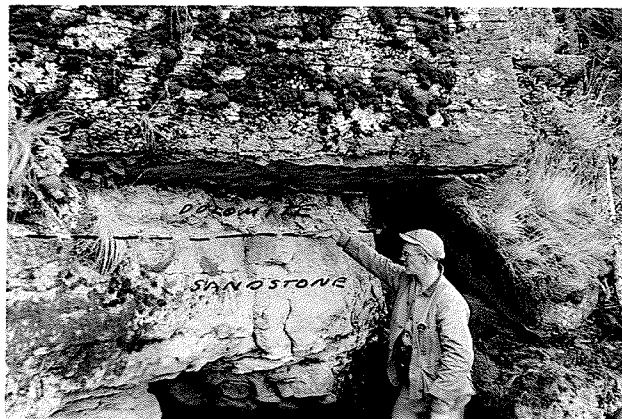
PLATE VI



1.



2.



3.

CHAPTER III.

STRUCTURAL, TEXTURAL, PETROGRAPHIC, COMPOSITIONAL AND FORMATIVE FEATURES OF THE WINNIPEG FORMATION.

INTRODUCTION:

This chapter is a detailed report on the structural, textural and compositional features in the Winnipeg. The origin and formation of certain features in the formation is discussed.

STRUCTURAL FEATURES

Bedding

Horizontal beds from two inches to three inches up to two feet are observed in the Winnipeg formation. This feature is apparent in all three units, but is not as well defined in the Black Island unit as in the Grindstone Point or Deer Island units. (Plate III, 2,3; Plate IV, 1; Plate V, 1).

Cross-bedding may be seen within the Winnipeg formation. This feature is not well developed but it is exhibited in the Deer Island (Plate II, 1), and the Grindstone Point units (Plate II, 2). Cross-bedding is confined to the upper twenty feet of the Winnipeg. According to Schrock's (1948) classification, the cross-bedding in the Winnipeg is of the aqueous type.

For purposes of comparison with the Winnipeg cross-bedding of eolian and aqueous origin (Plate I, 1,2,3) in Recent

sands at Albert Beach near Victoria Beach are illustrated.

Ripple marks

In a section on the northeast side of Punk Island ripple marks are present in the Black Island unit of the Winnipeg. The ripple marks appear as an undulating band on the upper surface of a greyish sandstone with the base of a white sandstone.

Nodules and Concretions with the Exception of Oolites

In the Winnipeg there are nodules and concretions composed of several different materials.

These nodules and concretions occur in the Deer Island and Grindstone Point units, and with the exception of rare fulgerite-like, calcareous cemented, irregularly shaped sand structures, are absent from the Black Island unit.

Iron sulphide and iron oxide nodules are present throughout the sand-shale of the Grindstone Point unit. The structures range in size from six millimetres in diameter to more than six centimetres in diameter. They may be spherical, ellipsoidal, cylindrical or irregular in shape. (plate VII, 1,4).

Sand and pyrite, and or sand and limonite nodules are present in the Grindstone Point unit as spherical, tubular,

or ellipsoidal, well-consolidated resistant aggregates of pyrite or limonite cemented quartz grains.

Principally towards the base of the Grindstone Point unit, ^{are} exist irregularly shaped, highly rounded and polished, black, shiny, phosphatic nodules, ranging from less than one millimetre to more than five millimetres in diameter.

Oolites

Iron sulphide oolites

Iron sulphide, concentrically laminated oolites, form a rock which is cemented by about twenty-five percent to fifty percent of grey siliceous material. (Plate VII, 2; Plate VIII, 3).

These oolites occur at the contact between the upper limit of the Black Island unit and lower limit of the Grindstone Point unit, in beds ranging in thickness from four inches to eighteen inches. On Punk Island, the thicker beds are made up of several three to four inch layers. Their occurrence is noted, "At one locality on the northwest side of the (Black) island small concretionary like pyrite or marcasite spheres were found in the grey porous sandstone. These have been noted at the tops of cliffs underlain by unconsolidated sand." (Davies 1952). The oolites are brassy yellow and composed of tiny granules (.001 millimetres) of

shiny iron sulphide. These oolites range in size from .10 millimetres to 1.75 millimetres; the average being between .5 millimetres to .75 millimetres. A single lamina is less than .03 millimetres wide. (Plate VIII, 3).

Iron Oxide Oolites

These have been noted from subsurface samples and were reported in lithologic logs (Plate VII, 3). The following Wells contain iron oxide oolites.

California Standard Daly 15-18	at 5,230 feet
California Standard Hartney 16-33	4,195 feet
Imperial Birtle	at 4,165 feet
Red River Oil No. 1	at 250 feet
R.J. McGuckin Test Hole #3	at 160 feet

A dark, chocolate², shiny brown color is seen in these structures. They are flattened ellipsoids, crumbly, soft, thin and concentrically laminated. When pulverized they form a yellow powder. They range in size from .25 millimetres to 1.5 millimetres, the mean being about .75 millimetres. Laminae are approximately .03 millimetres in width and contain numerous tiny (.001 millimetres) iron sulphide grains.

Resistant Beds

Some beds of the Winnipeg seem more resistant than others due to consolidation by cementing material which may be of a carbonate or of ferruginous character. (Plate XI, 2).

In other localities case hardening has been responsible for the resistance of the beds to weathering. On Black Island the wave action of Lake Winnipeg has formed natural bridges at the base of the case hardened sandstone cliffs. (Plate V,1).

Fossils

Generally, fossils are rare in the Winnipeg formation. Some beds on Deer Island, at Victoria Beach, Little Grindstone and Grindstone Points are fossiliferous (Chapter VI). The Winnipeg? dolomitic sandstone beds of Deschambault and Amisk Lakes and Cranberry Portage are rich in poorly preserved fossil remains.

Intrastratal Solution

There are several features within the Winnipeg formation which strongly suggest intrastratal solution.

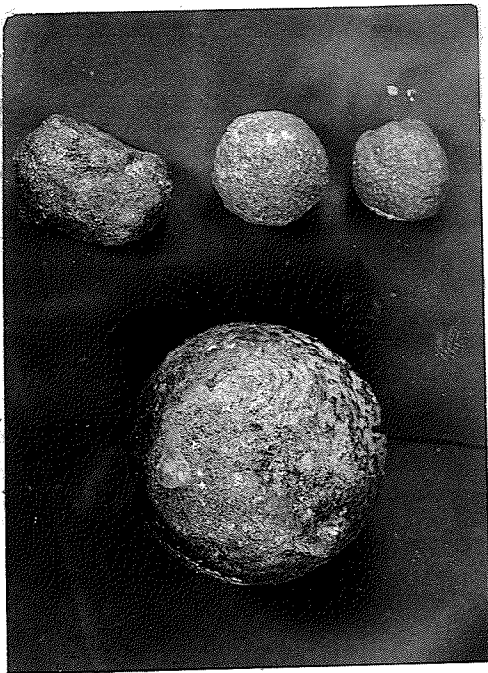
These are:

1. The lack of calcite fossils.
2. The calcite fossils have been dissolved of their calcite, the voids were filled in by sand grains and recemented by a ferruginous carbonate, dolomite, or impure calcite cement.
3. The presence of rare, not easily soluble phosphatic fossils and phosphatic nodules are associated with the dissolved carbonate fossils.
4. The presence of iron oxide staining or discoloration on sand grains.
5. Pyritized fossils.
6. Oxidized iron sulfide nodules.
7. Lack of unstable heavy minerals.

EXPLANATION OF PLATE VII.

- Figure 1. Pyrite concretion and nodules x.75 from the Grindstone Point unit on the north side of Deer Island.
- Figure 2. Pyrite oolites x 15, polished section, from the pyrite beds at the base of the Grindstone Point unit on the west side of Punk Island.
- Figure 3. Goethite oolites x 15, from the green shale of the Grindstone Point unit in the Winnipeg formation, found in the (core at the bottom of the) Hartney well.
- Figure 4. Pyrite concretion x 1.5, polished section, showing euhedral pyrite nucleus surrounded by a pyrite-quartz mass, location as for figure 1., Plate VII.

PLATE VII



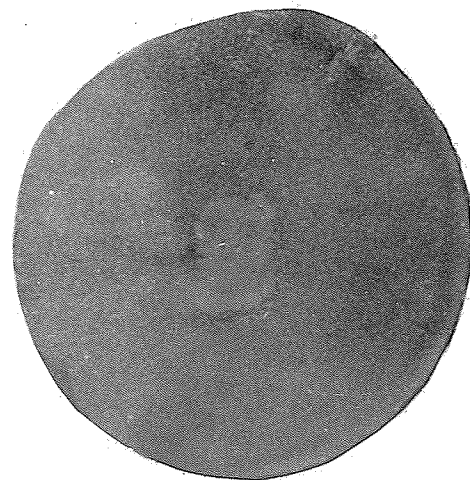
1.



2.



3.



4.

Textural Features

Most specimens of the Winnipeg were collected by the writer except for those from Ballantyne Bay collected by Dr. W. O. Kupsch, from Lake Athabaska collected by Saskatchewan Department of Natural Resources and from Knife River and Portage Chute collected by S. J. Nelson of the Geological Survey of Canada.

Consolidated samples were disaggregated in a strong solution of hydrochloric acid. Boiling was sometimes necessary and where this was not effective the specimens were crushed between softwood blocks. Several washings in running water were required to remove the acid and wood chips.

A hot air bath* which proved rapid was used to dry the samples. Each specimen was separately and thoroughly mixed then divided into forty gram samples. A set of Tyler Standard V2 Screen Scale Sieves was utilized in the screening of the sands.

* The writer improvised a hot air bath which consisted of a jet of air blowing through the flame of a Meeker burner. This hot air jet was directed against a supported, covered beaker, containing the wet sand. Five to ten minutes were required in drying a forty gram sample. This hot air bath does not cause spitting and thereby loss of sample.

Size of Grain

Grade Size Distribution

Of the eighteen Winnipeg sandstone sievings made, ten showed that more than fifty percent of the sample was retained on the 100 mesh or .147 millimetre screen. Only in three samples were there any grains remaining on the 2.362 millimetre screen (8) mesh, and this amounted to less than 0.9 percent in each. The very fine mesh of .074 millimetres had retained on it from three to twenty-five percent.

Table 2, gives the average weights of eighteen sievings retained on the screens. The column on the left shows the number of individual samples (from a possible eighteen), which were retained (middle column) on a particular mesh size. The column on the right of the page shows the average weight in percent, of the eighteen specimens having a particular mesh size. For example the upper line of Table 2 is read in the following manner: 3 samples out of a possible eighteen contained material on the 8 mesh Tyler screen. From the right column it is found that only .081 percent of the total weight of the 18 samples is retained on the 8 mesh sieve.

TABLE 2.
AVERAGE WEIGHTS OF EIGHTEEN SIEVINGS RETAINED
ON SCREENS

No. of samples from a total of 18.	Tyler Mesh	Average of 18 samples in weight percent retained on individual screens
3	8	.081
12	14	2.3
17	28	8.36
18	48	23.55
18	100	46.21
18	200	17.67
17	-200	2.19

Cumulative Logarithmic Diagrams and Their Statistical Parameters.

Cumulative logarithmic diagrams for several sievings of the Winnipeg sands and one for the Athabaska sandstone are given (Figures 3-9). The complete information regarding the construction of cumulative logarithmic diagrams and the computation of statistical parameters may be found in any standard work on Sedimentary Petrology, as in the Manual of Sedimentary Petrography by W. C. Krumbein and F. J. Pettijohn. It is thought advisable to give brief descriptions of some of the statistical parameters such as median diameter (M_d), Symmetry or Skewness (Sk) and the Kurtosis (K). Percentiles (P_{90} , P_{10}) and Quartiles (Q_3 , Q_1) are not described.

The median diameter (M_d) represents the average grain size of a sediment.

The degree of sorting is the extent to which grains

spread on either side of the average grain diameter and it is represented by the sorting coefficient (S_o).

The Symmetry or Skewness (SK), of a curve shows whether the sediment has a predominance of coarse or fine material. If the calculated SK value for a sediment is positive (+), then coarse material exceeds fine, but if the SK value is negative (-), fine admixtures exceed coarse.

The Kurtosis (K) of a curve is a mathematical value which indicates the peakedness of a curve.

An interpretation of these various parameters may assist in providing information which can be utilized in the reconstruction of the sedimentological processes. The median diameter of a clastic sediment may provide clues as to the strength of current (water or wind) which moved the material to its place of deposition. From the coefficient of sorting, some conception may be had of the distance of transportation (or duration of transport) and the range of conditions (Krumbein and Sloss 1951, p. 75) such as velocities or degrees of turbulence in the transporting media which the sediment has undergone.

The Tyler Standard Screen Scale

Form No. L-6
Please mention it
when ordering

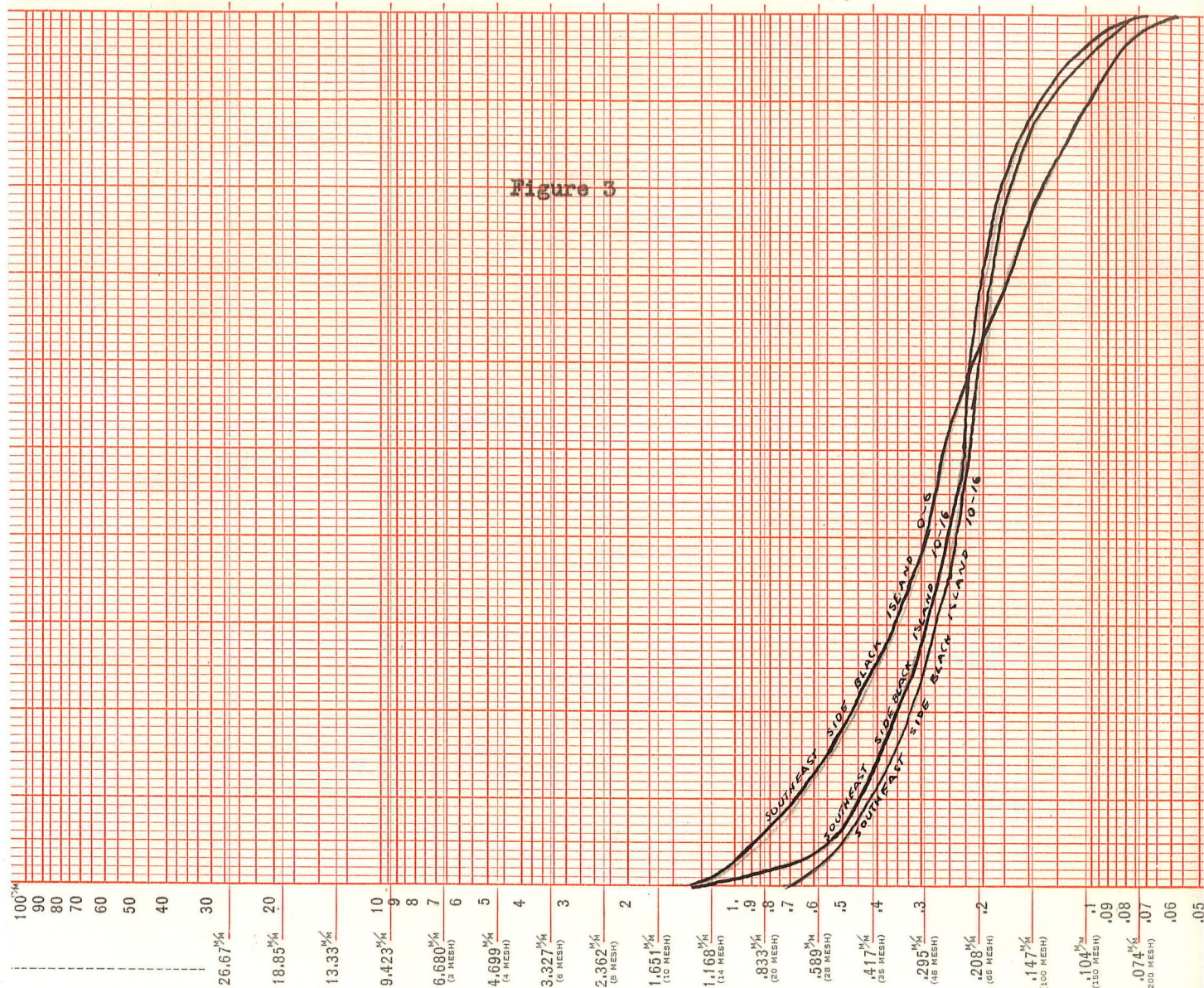
Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg sands

Name Black Island, 0'-6', 6'-10', 10'-16'

Date January, 1952

64

Figure 3



SCREEN SCALE RATIO 1.414				Black Island 0'-6'			Black Island 6'-10'			Black Island 10'-16'		
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
26.67	1.060											
18.85	.742											
13.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8									
1.651	.065	10	12									
1.168	.046	14	16	.2097	.534	.534				.0085	.022	.022
.833	.0328	20	20									
.589	.0232	28	30	2.6728	6.700	7.234	.3962	1.40	1.40	1.2422	3.1820	3.204
.417	.0164	35	40									
.295	.0116	48	50	12.437	37.23	38.454	8.645	22.26	23.66	9.5583	24.58	27.784
.208	.0082	65	70									
.147	.0058	100	100	15.977	40.20	78.654	24.437	64.10	87.76	23.5807	60.25	88.034
.104	.0041	150	140									
.074	.0029	200	200	7.903	19.7	98.354	4.7318	12.31	100.07	4.4770	11.43	99.464
.074	.0029	200	200	.068	.021	98.375	1.866	.485	100.55	.2045	.318	99.78
Totals,				39.208	98.385	98.375	38.396	100.55	100.55	39.07	99.782	99.78

The Tyler Standard Screen Scale

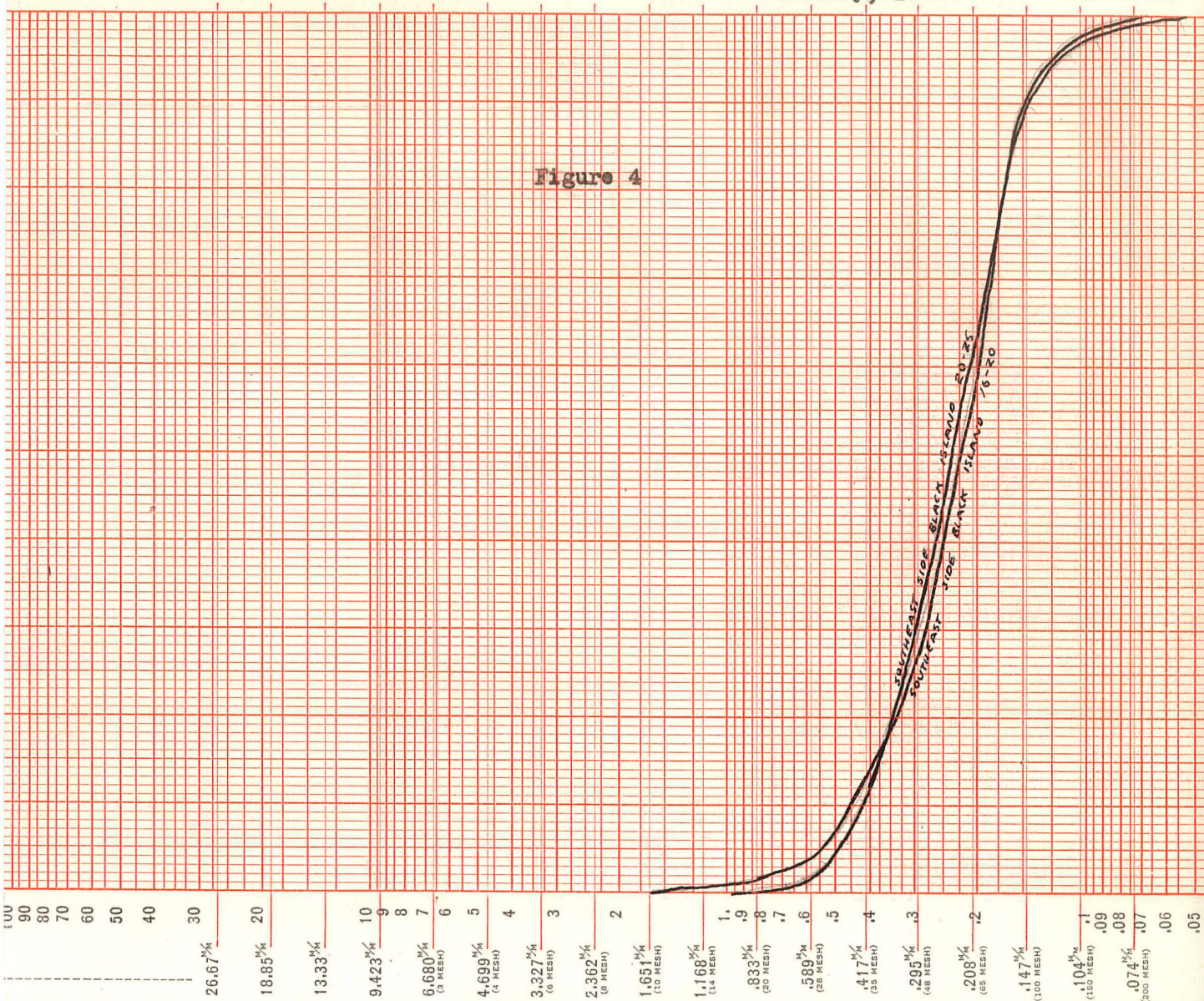
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Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg sands

name Black Island, 16'-20', 20'-26',

Date January, 1952

65



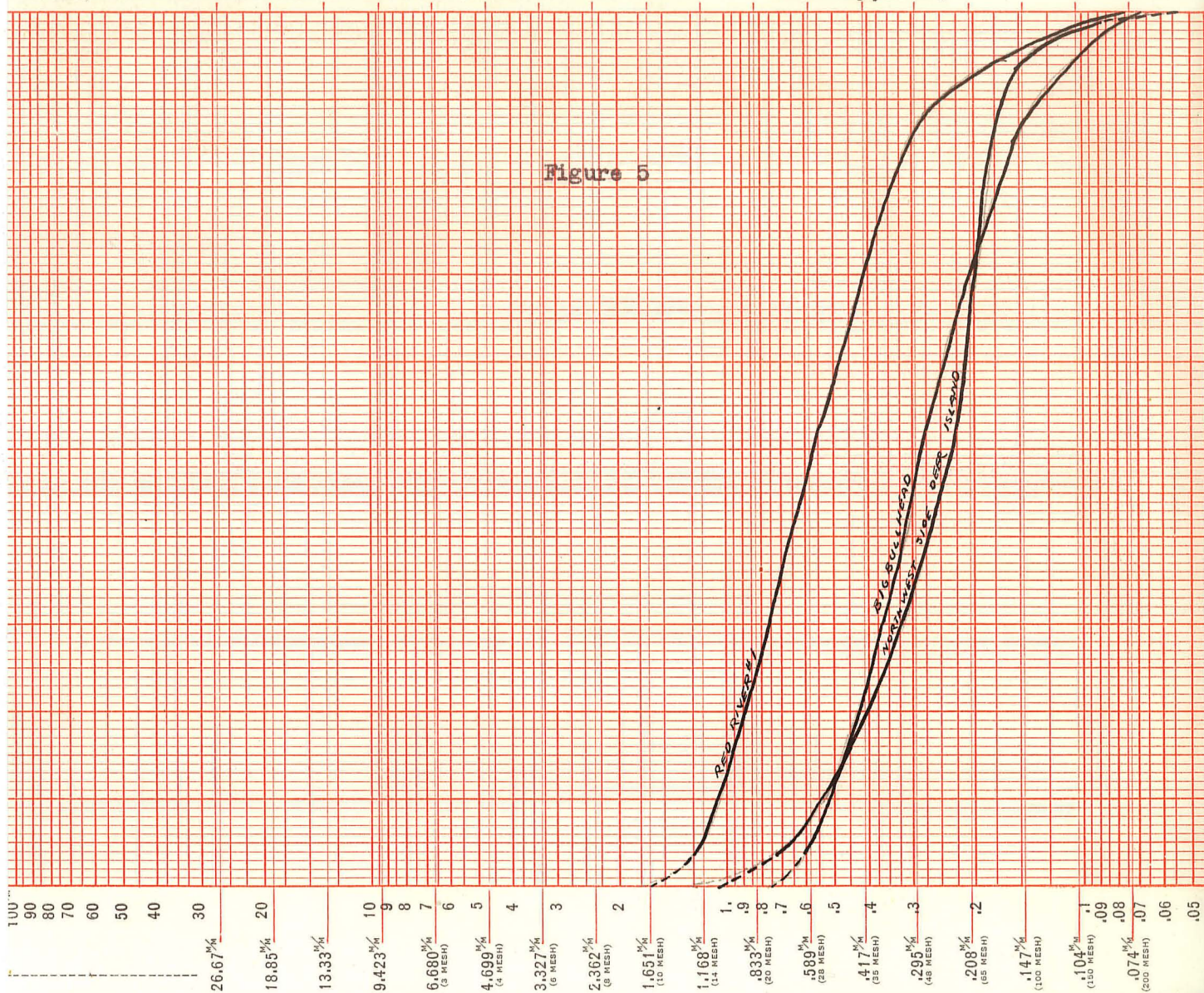
SCREEN SCALE RATIO 1.414				Black Island, 16'-20'			Black Island 20'-26'					
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
36.67	1.050											
18.85	.742											
13.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8									
1.651	.065	10	12									
1.168	.046	14	16	.127	.321	.321	.099	.252	.252			
.833	.0328	20	20									
.589	.0232	28	30	1.305	3.299	3.620	1.107	2.820	1.359			
.417	.0164	35	40									
.295	.0116	48	50	9.864	24.820	28.440	11.893	30.000	31.359			
.208	.0082	65	70									
.147	.0058	100	100	24.917	62.900	91.340	23.318	58.700	90.059			
.104	.0041	150	140									
.074	.0029	200	200	3.074	7.740	99.088	3.128	7.880	98.539			
.074	.0029	200	200	.345	.619	99.699	.154	.368	98.927			
Totals				39.632	99.699	99.699	39.699	100.040	100.040			

The Tyler Standard Screen Scale

Form No. L-5
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Cumulative Logarithmic Diagram of Screen Analysis on Sample of **Winnipeg sands.**
Name **Red River #1, NW. Deer Island, Big Bull Head.** Date **January, 1952.**

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SCREEN SCALE RATIO 1.414				Red River # I.			NW. Deer Island			Big Bull Head		
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
26.67	1.050											
18.85	.742											
13.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8									
1.651	.065	10	12									
1.168	.046	14	16	1.244	4.96	4.96						
.833	.0328	20	20	10.966	44.00	48.96	1.774	7.00	7.00	1.093	4.20	4.20
.589	.0232	28	30									
.417	.0164	35	40	9.599	38.40	87.36	6.853	27.20	34.20	11.688	44.60	48.80
.295	.0116	48	50									
.208	.0082	65	70	2.273	9.10	96.46	15.442	61.00	95.20	9.939	38.30	87.36
.147	.0058	100	100									
.104	.0041	150	140									
.074	.0029	200	200	.753	3.00	99.46	1.284	5.05	100.25	3.212	12.00	99.10
.074	.0029	200	200	.121	.48	99.94				.132	.50	99.60
Totals,				24.956	99.94	99.94	25.354	100.25	100.25	25.985	99.60	99.60

The Tyler Standard Screen Scale

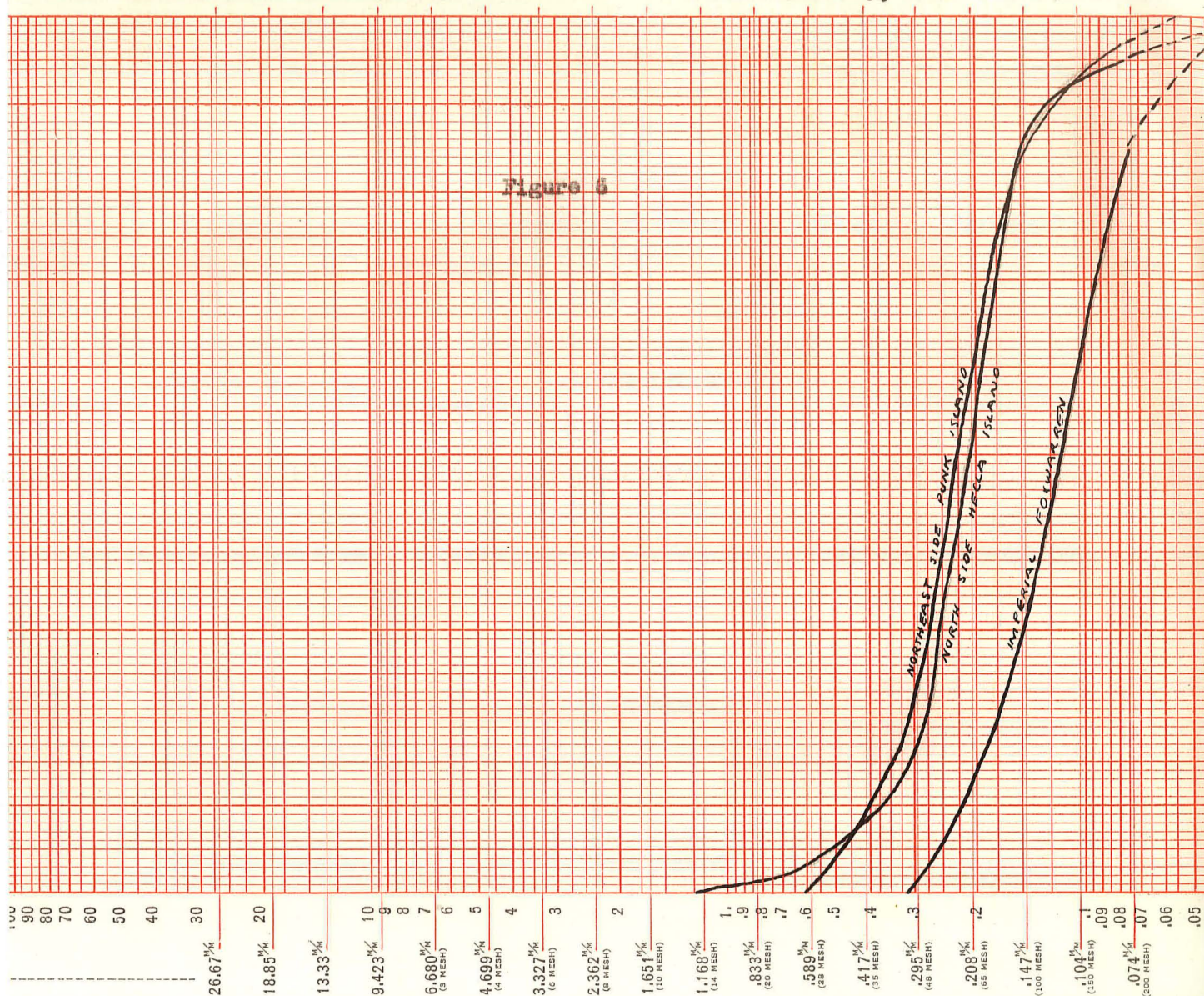
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Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg sands.

Sample Punk Island, Hecla Island, Imp. Foxwarren.

Date January, 1952

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SCREEN SCALE RATIO 1.414				NE. Side Punk Island			N. Side Hecla Island			Imp. Foxwarren		
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
26.67	1.050											
18.85	.742											
13.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8									
1.651	.065	10	12									
1.168	.046	14	16				.018	.046	.046			
.833	.0328	20	20									
.589	.0232	28	30	.876	.212	.212	1.266	3.24	3.29			
.417	.0164	35	40									
.295	.0116	48	50	8.578	21.64	21.852	5.278	13.52	16.81	.340	.870	.870
.208	.0082	65	70	25.290	64.00	85.852	27.220	70.00	86.81	11.466	29.40	30.27
.147	.0058	100	100									
.104	.0041	150	140									
.074	.0029	200	200	4.637	11.40	97.252	3.445	8.86	95.67	21.718	55.50	85.77
.074	.0029	200	200	.267	.67	97.922	1.707	4.38	100.05	5.612	14.65	100.42
Totals,				39.648	97.922	97.922	38.923	100.05	100.05	39.137	100.42	100.42

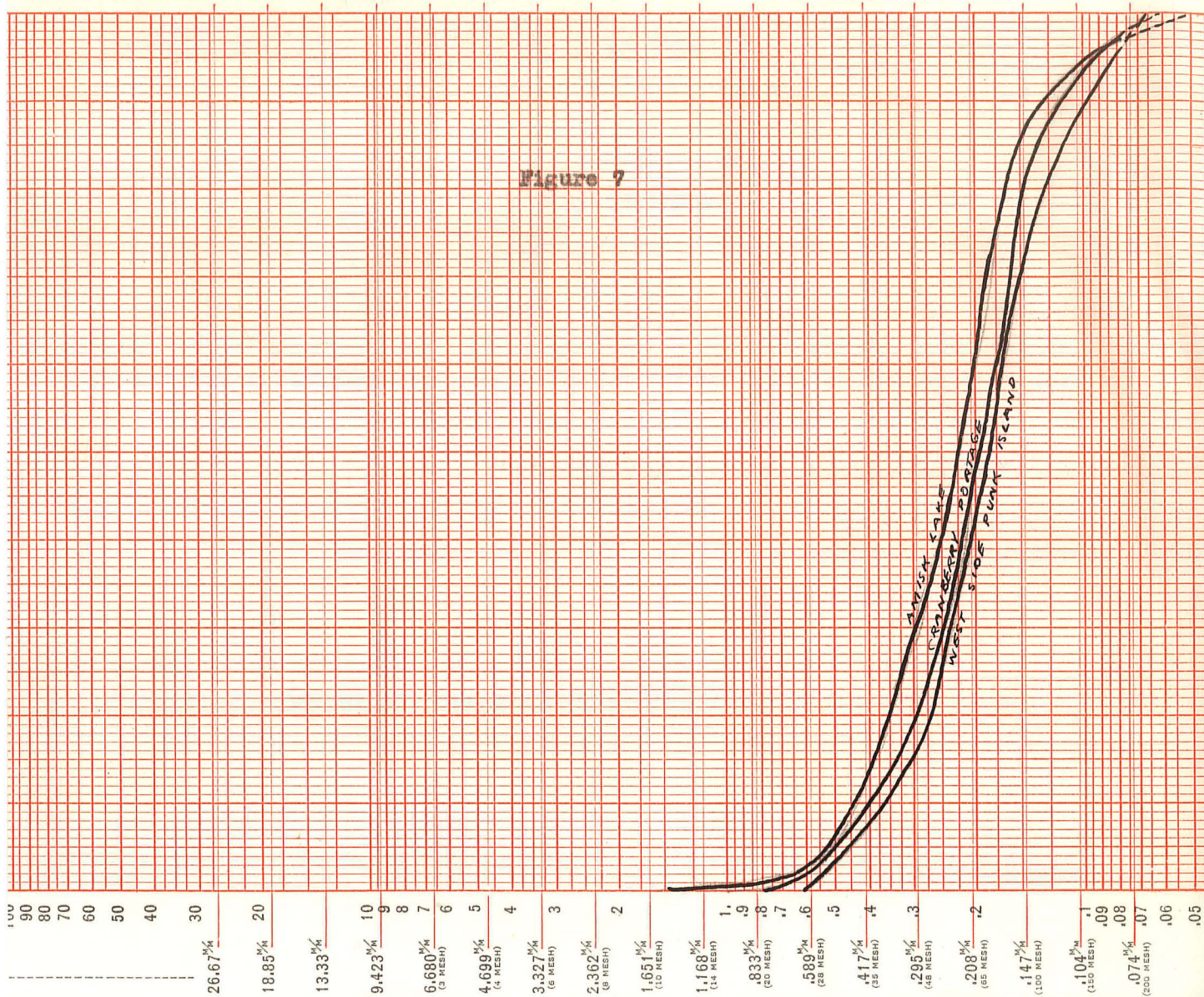
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Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg sands.

from Amisk Lake, Cranberry Portage, Punk Island. Date January, 1952

68



SCREEN SCALE RATIO 1.414				Amisk Lake			Cranberry Portage			W. Side Punk Island		
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
16.67	1.050											
8.85	.742											
3.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8									
1.651	.065	10	12									
1.168	.046	14	16	.650	.69	.69	.019	.05	.05			
.833	.0328	20	20									
.589	.0232	28	30	1.10	2.46	3.15	1.514	2.31	2.36	.129	.434	.434
.417	.0164	35	40									
.295	.0116	48	50	12.216	27.40	30.55	9.942	20.01	22.37	4.579	15.60	16.03
.208	.0082	65	70									
.147	.0058	100	100	25.406	57.00	87.55	29.642	59.80	82.17	16.573	55.05	71.08
.104	.0041	150	140									
.074	.0029	200	200	4.993	11.20	98.85	8.124	16.34	98.52	8.020	26.80	97.88
.074	.0029	200	200	.345	.77	99.52	.426	.88	99.40	1.020	3.41	101.29
Totals,				44.71	99.52	99.52	49.670	99.40	99.40	30.321	101.29	101.29

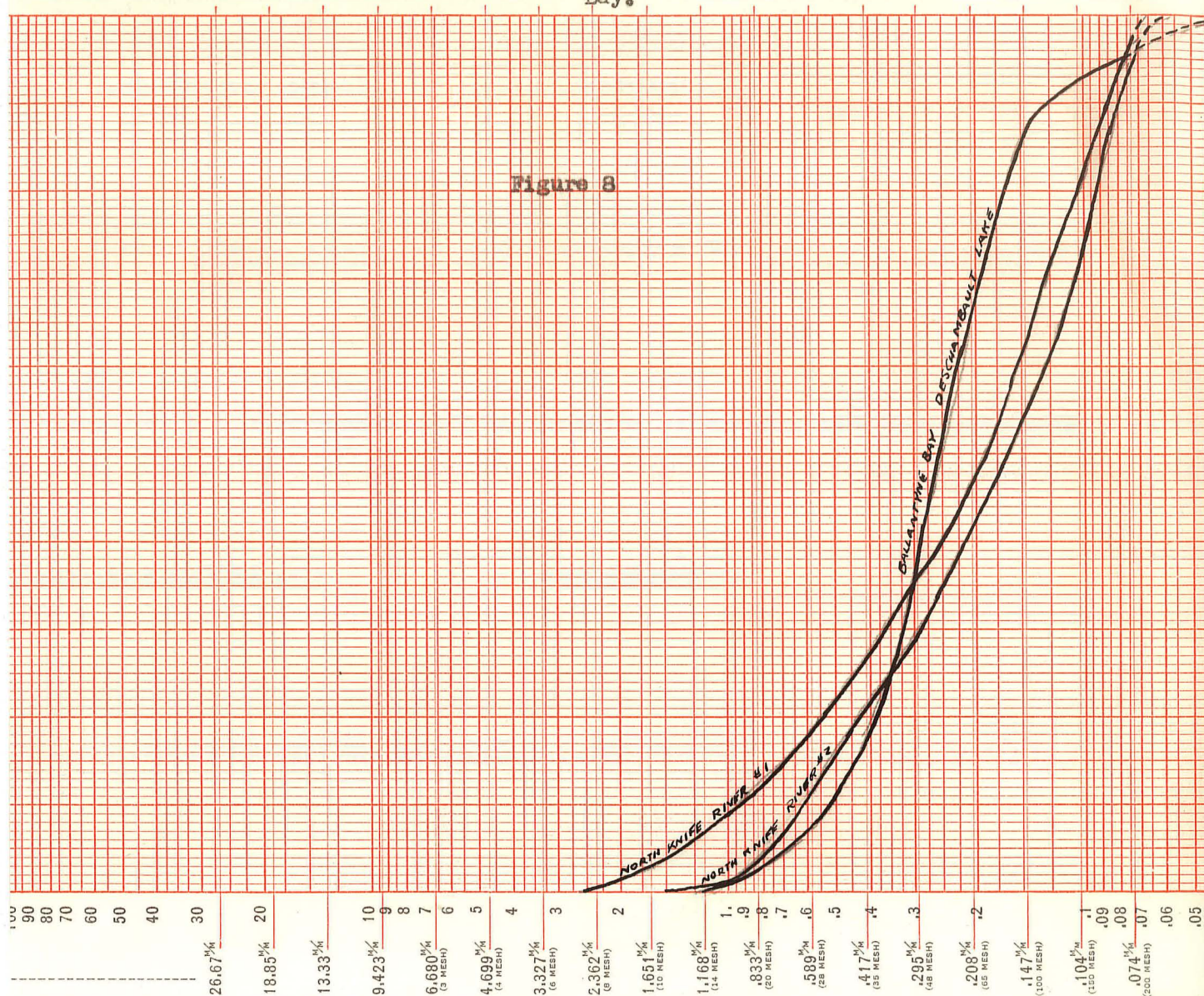
The Tyler Standard Screen Scale

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Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg sands.

Sample N. Knife Riv. #1, N. Knife Riv. #2, Ballantyne Bay, Date January, 1952

69



SCREEN SCALE RATIO 1.414				N. Knife River # 1			N. Knife River #2			Ballantyne Bay		
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
26.67	1.050											
18.85	.742											
13.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8	.093	.260	.260	.175	.298	.298			
1.651	.065	10	12									
1.168	.046	14	16	2.038	6.150	6.410	.861	.218	.516	.320	.602	.602
.833	.0328	20	20									
.589	.0232	28	30	4.254	13.00	19.410	4.946	12.55	13.066	2.697	6.757	7.560
.417	.0164	35	40									
.295	.0116	48	50	5.282	16.21	35.62	6.548	17.55	30.61	12.384	31.00	38.560
.208	.0082	65	70									
.147	.0058	100	100	8.394	25.80	61.42	9.640	25.20	55.81	17.371	43.61	82.069
.104	.0041	150	140									
.074	.0029	200	200	11.417	35.12	96.54	16.294	41.20	97.81	5.409	13.58	95.649
.074	.0029	200	200	1.142	3.50	100.54	1.049	2.80	99.81	1.665	4.20	99.849
Totals,				32.620	100.54	100.54	39.513	99.81	99.81	39.846	99.849	99.849

The Tyler Standard Screen Scale

Form No. L-6
Please mention above
when ordering

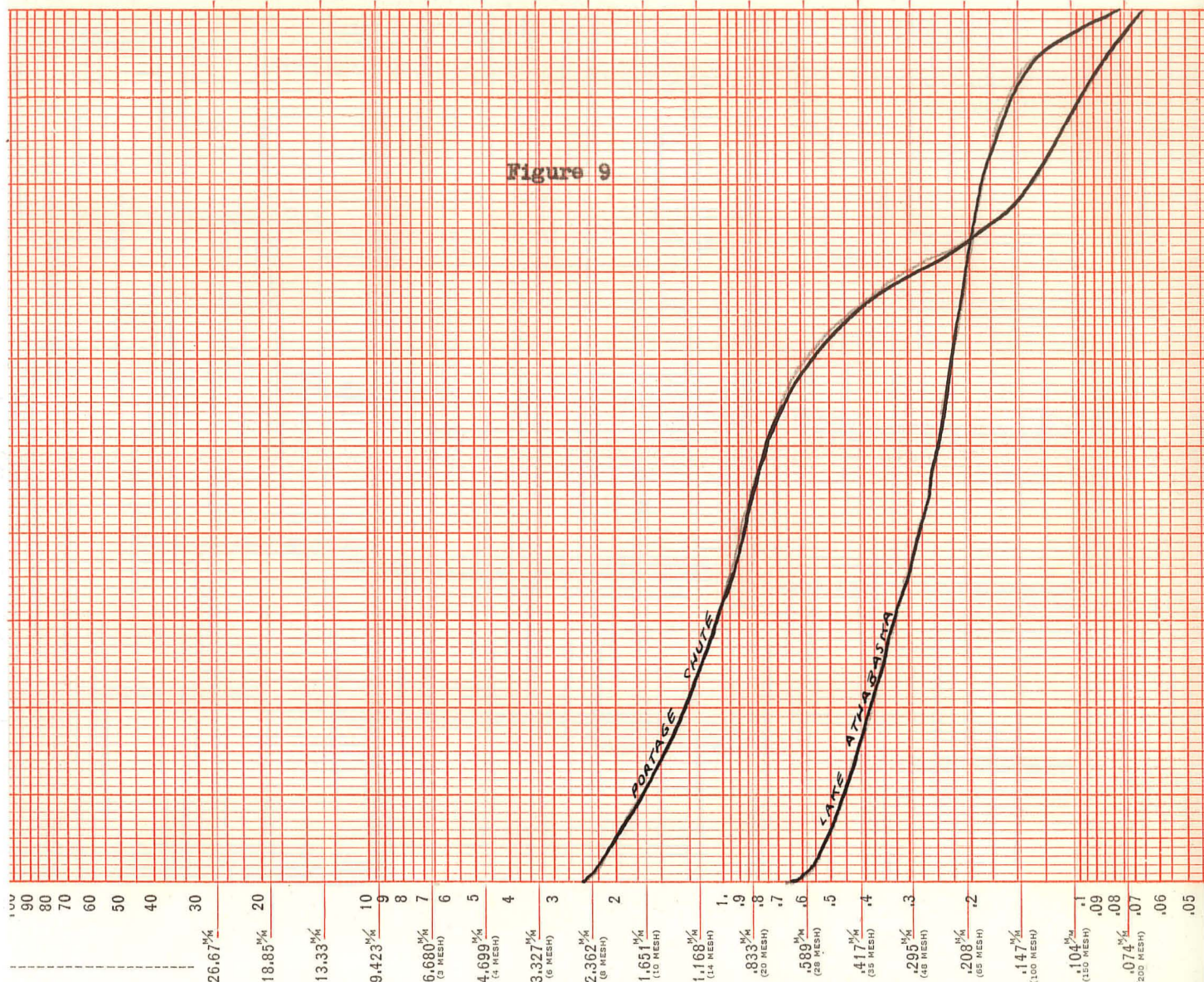
Cumulative Logarithmic Diagram of Screen Analysis on Sample of Winnipeg & Athabaska sands.

from Portage Chute, Lake Athabaska;

Date January, 1952.

70

Figure 9



SCREEN SCALE RATIO 1.414				Portage Chute			Lake Athabaska					
Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
Milli-meters	Inches											
16.67	1.050											
8.85	.742											
8.33	.525											
9.423	.371											
6.680	.263	3										
4.699	.185	4	4									
3.327	.131	6	6									
2.362	.093	8	8	.178	.905	.905						
1.651	.065	10	12									
1.168	.046	14	16	4.854	24.50	25.20						
.833	.0328	20	20									
.589	.0232	28	30	6.951	35.00	60.20	.155	.49	.49			
.417	.0164	35	40									
.295	.0116	48	50	2.100	11.00	71.20	11.786	37.80	38.29			
.208	.0082	65	70									
.147	.0058	100	100	1.523	7.55	78.75	17.23	54.35	92.64			
.104	.0041	150	140									
.074	.0029	200	200	4.047	20.04	98.00	2.496	7.88	100.52			
.074	.0029	200	200	.277	1.35	100.05	.099	.31	100.83			
Totals,				19.930	100.14	100.14	31.775	100.83	100.83			

TABLE 3.
STATISTICAL PARAMETERS

SAMPLE	Md	Q3	Q1	P90	P10	So	Sk	Kurtosis
Amisk Lake	.170	.210	.150	.115	.410	1.34	1.40	.102
Cranberry Portage	.178	.248	.135	.098	.370	1.35	1.02	.220
Imperial Foxwarren	.215	.265	.168	.113	.370	1.25	.995	.197
Red River #1	.600	.825	.375	.250	1.08	1.48	.835	.270
North Knife #1	.185	.450	.113	.085	.950	1.86	1.34	.195
North Knife River #2	.163	.365	.096	.080	.640	1.95	1.36	.240
Ballantyne Bay	.250	.358	.175	.125	.525	1.45	1.00	.229
Portage Chute	.750	1.168	.175	.095	.175	2.58	5.19	.620
Big Bullhead	.287	.400	.188	.132	.520	1.46	.102	.620
Deer Island, N.W. side	.230	.360	.188	.160	.540	1.39	1.27	.227
Punk Island, West side	.220	.320	.148	.124	.435	1.47	.980	.216
Hecla Island, North side	.225	.280	.174	.125	.390	1.27	.970	.200
Punk Island, N.E. side	.113	.160	.085	.069	.220	1.37	1.06	.250
Black Island, S.E. side*								
" " 0' - 6'	.250	.180	.390	.138	.650	.680	1.25	.244
" " 6' -10'	.230	.176	.320	.136	.440	.742	1.12	.231
" " 10' -16'	.210	.155	.295	.104	.420	.724	1.03	.222
" " 16' -20'	.235	.178	.315	.155	.450	.752	1.00	.232
" " 20' -26'	.225	.178	.315	.147	.430	.752	1.11	.242
Lake Athabaska (Cambrian-Precambrian)	.250	.360	.195	.116	.435	1.320	1.12	.300

* This section is 0' at the top, 26' at the base.

Interpretation of Logarithmic Cumulative Diagrams and Parameters.

Considering now the cumulative logarithmic diagrams (Figures 3-9) and statistical parameters (Table 3) computed for specimens of the Winnipeg formation, a high degree of uniformity among both diagrams and parameters may be discerned. The diagram and data for the Athabaska sandstone compares closely to most of the Winnipeg diagrams and parameters. In the Winnipeg material there exists a high degree of uniformity with but few exceptions. Noticeable differences show in diagrams and parameters for the samples from Portage Chute and the Red River No. 1 well. The Portage Chute material is a sand of normal sorting (So value equals 2.58) and possesses considerably more coarse admixture than fine. Its average diameter of grain is .75 millimetres and is considerably larger than most of the Winnipeg samples. In the Red River No. 1 sample the average diameter of .60 millimetres is closer to that of the Portage Chute median diameter, than to the median diameter of any of the others. It is well sorted, possesses a slightly higher percentage of fine admixtures than coarse, but conforms to the general uniformity among the remaining samples.

As the cumulative logarithmic diagrams and statistical parameters for samples of the Winnipeg formation are generally uniform, it seems reasonable to suppose that conditions prevailing during their transportation and deposition were essentially similar. The average diameter of Winnipeg sand

is of a high degree and thereby implies transportation over long distances (or of long duration), and also implies much reworking of the sand. The Skewness values being similar, provide further evidence to substantiate the idea of lengthy transportation and reworking of the sediment.

Sphericity

Applying Waddell's method of determining sphericity, the sphericities of 180 grains of Winnipeg sand of .589 millimetre size were calculated (Table 4 p. 77). The sphericities of every sample are similar and show an average of .84. As the value 1.0 represents a perfect sphere the sands of the Winnipeg are highly spherical (Plate IX, 1-4; X, 1). The Athabaska sand whose computed sphericity is .80 compares closely to the .84 value for the Winnipeg.

Roundness

Roundnesses of more than one hundred sievings of sand from the Winnipeg formation are computed. Table 5, page 78, shows the roundness values for each of the 14, 28, 48, 100, 200 and pan sievings of six specimens from the Winnipeg. Computation was effected by a comparison of the grains roundness with those roundnesses shown by the Visual Roundness Chart (Krumbein W.C. 1941). In the fourteen mesh sievings, twenty percent have a .1 to .3 roundness, thirty-nine percent have a .4 to .6 roundness and forty-one percent have a roundness value of .7 to .9. The value 1.0 represents perfect roundness, and

it can be seen that the fourteen mesh grains exhibit a high degree of roundness. The 28 mesh grains also show a high degree of roundness but the 48 mesh grains show considerable angularity. Roundness in the sand of the Winnipeg is best developed in the coarser fractions and angularity is highest in the finest fractions (Plates VIII, 4: IX, 1-4; X, 1).

In Table 6, page 79, the columns entitled Roundness show the degree of rounding developed into what the writer has classified in two groups for each sample. Group A consists of the 14, 28, and 48 mesh fractions of the specimen and Group B is made up of the 100, 200, and pan fractions. It is readily observed that the group A representing the coarser fractions, possesses the highest degree of roundness.

Frosting

The sands of the Winnipeg formation, especially in the coarser grades are highly frosted. A careful binocular examination of one hundred and twenty-five sievings enabled the writer to notice with a fair degree of accuracy the relative proportions and degree of frosting. These data are presented in Table 6, page 79, (Plate X).

Frosting may be caused by wind action or attrition in water. Dake (1921) suggests that wind is of more importance in frosting than the wet blast action. Roth postulated that as hydrofluoric acid etched glass so the

prolonged action by natural solvents might produce a "ground glass" or "mat surface" i.e. frosting.

The columns entitled Frosting in Table 6, page 79, illustrate the range in the degree of frosting discerned in the sand grains of the Winnipeg. Each sample is divided into Group A (14, 28 and 48 mesh fractions) and Group B (100, 200 and pan fractions). The degrees of frosting are explained by the words "intense" (extremely dull surface of grain,) "moderate" (dull surface of grain,) "slight" (dull to shiny grain surface,) and "none" (shiny grain surface). The percentage value for on intensity of frosting in a group indicates what portion of the total sample has a particular frosting. For example in the sample of Black Island south side sand, Group A, forty percent of the sample is "intensely" frosted, fifty percent is "moderately" frosted ten percent is slightly frosted and zero percent is "none" frosted.

The rounding in the sand of the Winnipeg is best developed in the coarser fractions (Group A).

Pitting

A visual investigation was adopted for the detection of pitting on the sand grains of the Winnipeg and the results are tabulated in Table 6, page 79. Just as for roundness and frosting the results of examination for pitting are listed under Group A and Group B, each group being comprised of samples having mesh sizes formerly described (page 75) "Intense"

pitting is characterized by deep pits covering from fifty percent to seventy-five percent of the grains surface, "moderate" pitting indicates deep pits covering from twenty-five to fifty percent of the grains surface, "slight" pitting is typified by shallower pits than previously described covering from one percent to twenty-five percent of the grains surface and "none" pitting as the term suggests refers to grains which show no such indentations.

Pitting may be the result of physical impact or chemical solution. Pitting is best exhibited in the Group A portion (coarser fractions) of the sample of sands from the Winnipeg formation. (Plate X).

Significance of Sphericity, Roundness, Frosting and Pitting.

The sand of the Winnipeg formation is highly spherical, well rounded, thoroughly frosted and deeply pitted. Definite causes which could result in these textural features in a sand are not certainly known. It is commonly believed by the foremost sedimentologists that the action of wind and water may have contributed to forming of rounding, frosting and pitting in a sand grain.

Although textural characteristics alone are insufficient bases on which to state the manner of sand deposition, other features shown within the sand, together

T A B L E 4.

STATISTICAL DATA FOR THE DETERMINATION OF SPHERICITY IN
 TWENTY SAMPLES (OF+.589 MILLIMETRE SIZE) OF SAND GRAINS
 FROM THE WINNIPEG FORMATION.

Sample (9 grains)	Area mms.	Area ins.	dc*	Dc**	dc/ Dc***
Black Island south side					
0' - 6'	115.5	.20	12.4	15.8	.82
6' - 10'	124	.18	12.5	14.6	.85
10' - 16'	82	.14	9.5	12.0	.87
16' - 20'	198	.32	16.1	19.2	.85
20' - 26'	121	.19	13.0	14.0	.84
Black Island north side	109	.14	11.4	14.0	.83
Victoria Beach	114	.18	11.0	14.0	.81
Big Bull Head	98	.17	10.5	13.0	.82
Punk Island NW side	67	.10	8.5	11.0	.80
Hecle Island north side	190	.328	16.0	19.6	.81
Deer Island	164	.250	14.5	18.0	.83
Grindstone Point	74.6	.12	9.6	10.8	.86
Punk Island NE side	105	.16	11.2	13.0	.88
Red River No. 1 well	209	.35	17.0	20.0	.83
Amisk Lake	92	.14	11.3	13.0	.88
Cranberry Portage	90	.16	10.0	13.0	.77
North Knife River No. 1	180	.24	15.0	18.0	.80
North Knife River No. 2	153	.29	14.8	16.0	.80
Bad Cache Rapids	205	.316	16.1	19.0	.85
Gronlid well		.16	11.5	13.0	.88

* dc equals diameter of a circle in millimetres which has an area equal to the area of the projected grain.

** Dc equals diameter in millimetres of the smallest circle circumscribing a grain.

*** dc/Dc equals the sphericity of the grain, the value 1 represents perfect sphericity.

T A B L E 5.

THE PERCENTAGES, OF THREE DEGREES OF ROUNDING, EXHIBITED BY QUARTZ GRAINS OF 14, 28, 48, 100, 200 AND PAN SIZES, IN THE WINNIPEG FORMATION.

SAMPLE	Roundness 14 Mesh			Roundness 28 Mesh			Roundness 48 Mesh		
	.1-.3	.4-.6	.7-.9	.1-.3	.4-.6	.7-.9	.1-.3	.4-.6	.7-.9
Black Island, S. Side*	10	20	70	5	15	80	20	20	60
Red River No. 1 Well	10	30	60	30	30	40	60	20	20
Amisk Lake	40	40	20	10	30	60	10	30	60
Cranberry Portage	10	20	70	10	30	60	10	30	60
Ballantyne Bay	30	50	20	10	60	30	50	30	20
Bad Cache Rapids	20	70	10	20	60	20	60	20	10
<u>TOTAL</u>	120	230	250	85	225	240	210	160	230
AVERAGE	20	39	41	14	38	48	35	27	38

SAMPLE	Roundness 100 Mesh			Roundness 200 Mesh			Roundness Pan		
	.1-.3	.4-.6	.7-.9	.1-.3	.4-.6	.7-.9	.1-.2	.3-.6	.7-.9
Black Island, S. Side	20	50	30	30	60	10	90	10	0
Red River No. 1 Well	50	30	20	80	20	0	90	10	0
Amisk Lake	40	30	30	85	10	5	95	5	0
Cranberry Portage	20	50	30	60	30	10	90	10	0
Ballantyne Bay	70	20	10	70	30	0	90	10	0
Bad Cache Rapids	80	20	0	90	10	0	90	10	0
<u>TOTAL</u>	280	200	120	415	160	25	545	55	0
AVERAGE	47	33	20	70	26	4	90	10	0

* Example:

10% of sample retained on the size 14 mesh has a roundness of .1-.3

20% of sample retained on the size 14 mesh has a roundness of .4-.6

70% of sample retained on the size 14 mesh has a roundness of .7-.9

TABLE 6.

STATISTICAL DATA ON ROUNDING, FROSTING AND PITTING OF QUARTZ GRAINS IN THE WINNIPEG FORMATION.

Results For Each Sample Are Tabulated in Two Groups, Group A and Group B. Group A Is Comprised of 14, 28, and 48 Mesh Sizes, Whereas Group B Is Comprised of 100, 200 and Pan Sizes. Values Represent Percentage Amounts Of Each Group.

Sample	Group	Roundness			Frosting				Pitting			
		.1-.3	.4-.6	.7-.9	Intense Moderate	Slight None			Intense Moderate	Slight None		
Black Island, S.Side	A	10	25	65	40	50	10	0	5	25	0	70
No. 1	B	60	30	10	0	3	12	85	0	0	10	95
Black Island, S.Side	A	12	23	65	60	30	10	0	10	40	15	35
No. 2	B	50	35	15	0	15	40	45	0	0	10	90
Black Island, S.Side	A	13	22	65	40	25	22	13	+1	7	6	86
No. 3	B	65	20	15	5	10	20	65	0	0	0	100
Black Island, S.Side	A	12	25	63	50	35	15	0	20	15	10	55
No. 4	B	60	30	10	0	10	30	60	0	5	10	85
Black Island, S.Side	A	20	50	30	20	40	30	0	5	15	0	80
No. 5	B	40	45	15	0	10	40	60	0	5	0	95
	A	10	40	50	0	15	50	35	0	0	10	90
Victoria Beach	B	15	60	25	0	5	20	75	0	5	0	95
	A	5	25	70	20	70	10	0	10	15	30	45
Big Bull Head	B	50	40	10	0	10	70	20	0	0	0	100
	A	5	20	75	20	70	10	0	10	15	30	45
Black Island N.Side	B	50	40	10	0	10	70	20	0	5	10	85
	A	10	20	70	15	40	45	0	5	10	0	85
Punk Island N.W.Side	B	55	30	15	0	0	15	85	0	0	5	95
	A	5	20	75	40	40	20	0	0	20	0	80
Hecla Island N.Side	B	35	30	25	0	20	30	50	0	10	0	90
	A	20	60	20	20	40	60	0	0	0	10	90
Deer Island	B	60	30	10	0	15	45	40	0	0	0	100
	A	5	45	50	5	20	70	5	5	10	0	85
Grindstone Point	B	40	50	10	0	10	45	45	0	0	0	100

TABLE 6. CONTINUED

STATISTICAL DATA ON ROUNDING, FROSTING AND PITTING OF QUARTZ GRAINS IN THE
WINNIPEG FORMATION.

Results For Each Sample Are Tabulated in Two Groups, Group A and Group B. Group A Is Comprised Of 14, 28, and 48 Mesh Sizes Whereas Group B Is Comprised of 100, 200 and Pan Sizes. Values Represent Percentage Amounts of Each Group.

Sample	Group	Roundness			Frosting				Pitting			
		.1-.3	.4-.6	.7-.9	Intense		Slight	Intense		Slight		
					Moderate		None	Moderate		None		
Punk Island	A	10	30	60	20	60	20	0	5	20	10	65
N.E. Side	B	55	30	15	0	20	50	30	0	0	0	100
Imperial	A	20	20	60	60	20	20	0	10	0	30	60
Foxwarren	B	55	30	15	0	20	30	50	0	10	0	90
Red River	A	30	35	35	5	35	60	0	20	20	15	35
No. 1	B	80	15	5	0	5	20	75	0	0	0	100
Ballantyne	A	30	30	40	10	50	40	0	10	15	0	75
Bay	B	80	20	0	15	10	70	5	0	0	0	100
	A	20	35	45	20	50	30	0	5	10	10	75
Amisk Lake	B	75	15	10	0	10	40	50	0	0	0	100
	A	10	25	65	35	50	15	0	5	5	30	60
Cranberry Portage	B	60	30	10	0	5	15	80	0	0	5	95
	A	35	55	10	25	35	25	15	10	55	5	30
North Knife River #1	B	60	30	10	0	15	35	50	0	15	0	85
	A	30	40	30	20	60	20	0	35	40	10	15
North Knife River #1	B	80	15	5	30	15	5	50	0	20	0	80
	A	20	70	10	5	15	40	40	5	10	10	75
Bad Cache Rapids	B	85	10	5	0	10	20	70	0	0	0	100
Pine Point Lake*	A	90	10	0	0	20	30	50	0	0	5	95
Athabaska	B	95	5	0	0	0	10	90	0	0	0	100

* This sample is not Winnipeg formation, but a Cambrian ? Precambrian ? specimen which is given for a comparison with the Winnipeg.

with its texture, may be utilized in suggesting modes and environments of emplacement. Because of its widespread distribution, uniformity, content of marine fossils uniform size of grain, rounding, frosting and pitting, the Winnipeg formation was deposited in marine conditions. Chemical weathering, mechanical weathering, transportation by wind, streams, rivers, lakes and seas, may all have been important factors in the formation and deposition of the sands in the Winnipeg.

Composition

Cement

Twenty-five thin sections of specimens from different outcrops of the Winnipeg were prepared. These showed limonite, pyrite, marcasite, calcium carbonate, calcium carbonate and iron oxide, silica, and dolomite cements. Calcium carbonate and iron oxide are the dominant cements. Plate XII, 2). Limonite, pyrite and silica are less abundant cements.

Replacement, Authigenesis, and Petrography of the Quartz Grains.

Quartz grains appear to show partial replacement by the cement in cracks and fractures. In many places pyrite partially replaces the quartz grains. (Plate XII, 1).

Little authigenic growth was observed on the quartz grains from the Winnipeg sand. Some appeared on the samples from the Lake Winnipeg localities. Macauley (1951) stated he observed double authigenic growth on one or two grains. This phenomenon of double authigenesis was not observed by the writer. When single authigenic growth is observed it is distinguished from the rounded nuclear grain by a zone of cloudy material about .01 millimetres wide separating the nucleus from the secondary overgrowth.

Authigenesis tends to make rounded grains angular. The thin section of a sample of Athabaska sandstone shows authigenic growth on most of the grains (Plate XIII, 2).

Microcline when present is always surrounded by authigenic feldspar which is probably orthoclase. (Plate XIII, 1).

Only rare quartz showed strain shadows. These appeared especially in thin sections of rock from Cranberry Portage, Amisk Lake, Churchill River and North Knife River. Quartz grains are usually clear, but some have inclusions of bubbles, biotite, magnetite, tourmaline and rutile needles. The inclusions are often aligned in a parallel fashion within the grain.

Authigenic growth upon quartz grains may furnish some idea as to the number of sedimentological processes through which the sand has passed. If a grain possesses two layers of authigenic growth it may be assumed that this particular grain has been exposed to at least two cycles of sedimentation. Double authigenesis has been mentioned to exist on grains of Winnipeg sand. Because of this feature the Winnipeg may have been deposited after the re-working of a primary cycle sand.

Strain shadows in quartz grains may also be utilized as an evidence to provide information for the source of a sand. Considerably more strain shadows were found in the sand grains from the northern Manitoba exposures of the Winnipeg (Knife Rivers and Portage Chute) than from the south central Manitoba (Deer Island, Punk Island, Black Island, Grindstone Point) exposures of the Winnipeg formation. In the northern areas of the Winnipeg, metamorphic rocks may have provided more material for the formation of the sands than they did in the southern areas.

Composition of Oolites and Nodules

Composition of Oolites

X-ray powder diffraction photographs were taken of oolites from the oolitic beds on Punk Island. These oolites were found to be composed of pyrite. The crystalline form of

limonite, goethite, represents the composition of the oolites in the Hartney Well (Plate XIII, 3).

Composition of Nodules.

Some of the nodules are pyrite and quartz, others are dolomite and quartz, some are ferruginous calcite (siderite) and quartz, and some identified by Macauley (Manuscript 1951) are "sedimentary apatite."

Composition of the Fossils.

Composition of the fossils may vary in the different outcrops of the formation. At Deschambault and Amisk Lakes, and at Cranberry Portage the fossils are made up of arenaceous dolomite. From the Lake Winnipeg localities fossils are formed of pyrite, arenaceous calcite or dolomite, and black-brown chitinous phosphatic material. Aragonite fossils are present in a sample of Winnipeg shale from the Aanstadt Well, North Dakota. (Plate XIII, 4).

Composition of Shale.

Samples of Winnipeg shale from the Hartney Well, Victoria Beach, and the Aanstadt Well were x-rayed. In these three specimens the shale was determined to be Malliss clay. Malliss clay is composed of various proportions of quartz, calcite, halloisite and nacrite. (Nagelschmidt 1935).

The powder photographs of these particular shales provided only very weak lines, from which the identifications

could be made. Lines partially comparable to montmorillonite were obtained in the photograph of the shale from the Aanstadt Well.

Insoluble Residues.

Several insoluble residues from seven samples of approximately forty grams each were prepared. The data compiled from a study of the insoluble residues are presented in the table following.

TABLE 7.

INSOLUBLE RESIDUES

	Weight of Sample	Weight of Insoluble Residues	Percentage Insoluble Residue	Composi- tion of Insoluble Residues
Amisk Lake	37	.11	0.3	Quartz sand
Cranberry Portage	36.5	27.76	65.4	" "
North Knife River #1	37.30	16.55	44.5	" "
North Knife River #2	47.3	40.76	85.2	" "
Portage Chute, Churchill	43.0	20.2	46.5	" "
Ballantyne Bay	37.3	33.9	90.0	" "
Lake Athabaska	33.7	33.3	98.72	" "

Purity of the Black Island Unit *

The lowest beds of the Winnipeg formation consist of a sand which has a composition of almost 100% silica. Two analyses of these sands are presented immediately following:

Analyses

Copy of Analyses** Report from J.T. Donald & Company, Limited, Montreal.

1.	Silica	99.42
	Iron oxide	0.02
	Aluminum	0.31
	Lime	0.10
	Magnesia	0.12
	Soda	-
	Potash	-
	Less on ignition	0.14
2.	Black Island Sand	(Quinn 1928)
	Silica	98.0
	Aluminum & Iron	1.5
	Calcium	1.2
	Moisture	0.8

* For locations see lithologic sections of Black and Punk Islands pp. 25 and 28 .

** One sample of silica sand from Red Clif Factory, Lake Bar Sand & Gravel Company, Winnipeg. Marked #2538 (no. 1), August 4, 1933. Received analyses from Dominion Glass Company Limited. (This reference received from Manitoba Mines Branch.)

3.

TABLE 8.

CHEMICAL ANALYSES OF DIFFERENT GRAIN SIZES FROM BLACK ISLAND
(QUINN, 1928).

Elements	28	35	48	65	100	150	200 & over
	Mesh	Mesh					
Silica	97.4	98.1	98.5	98.5	98.1	98.5	90.2
Aluminum & Iron	1.3	1.6	1.3	1.3	1.7	1.5	4.47
Calcium	1.4	1.2	.8	.8	1.0	1.0	2.93

HEAVY MINERALS IN THE WINNIPEG FORMATION.

INTRODUCTION

From different layers and localities of the Winnipeg formation, seventeen, forty grams samples were sieved, and from these, heavy mineral separations were carried out. A cursory binocular examination of the various fractions showed that the heavies were nearly absent from every sieving but the 100 and 200 mesh size.

The usual manner of heavy mineral separation was performed utilizing Bromoform (CBr_4 , S.G.2.89) (Krumbein and Pettijohn 1938).

Amounts of heavy minerals separated from the various 40 gram samples, ranged from twenty-five to one hundred grains. In no sample did they equal or exceed more than a trace* of the total sample.

* Trace equals less than one percent of total sample.

Description of Heavy Minerals

A chart showing the types and relative amounts of heavy minerals in some sand specimens of the Winnipeg formation is shown in Table 10, page 94 , following the descriptions. Also included in this chart for purposes of comparison are heavy minerals from localities not in the Winnipeg formation. A Table of heavy minerals from the St. Peter sandstone is shown to illustrate similarities and differences with the Winnipeg heavy mineral suite. (Table 9, page 93).

GARNET - Mostly pink, some clear to yellowish. Few grains are rounded, especially from Lake Winnipeg localities. Generally very irregular and sharply edged with irregular to conchoidal fracture. Some grains show marked pittings. (Plate XIII, 1,3).

GALENA - A steel blue cubic fragment may be tarnished pyrite grain. Galena from Grindstone Point reported by F.D. Shepherd (personal communication.) Outcrop at Grindstone Point has some steely blue cubic crystal aggregates, may be galena.

HORNBIENDE - Grains prismatic, fairly smooth sides, irregularly fractured ends. Pleochroic from light to dark green.

BIOTITE - Shreds, fractured prisms and platelets, and prism like fragments, from light to dark brown greenish and yellowish brown to almost black. Pleochroic halos. Irregularly fracturing ends and parallel to sub parallel sides.

This mineral is not found in the Winnipeg formation sands but is found in the sample from Lake Athabaska and in the sample of probably contaminated Winnipeg sandstone. (Plate XI, 4).

IRON OXIDE - Reddish brown yellow to orange or purplish stains or as irregular fragments.

MAGNETITE - Rounded to subrounded. Bluish black to black. Some show small fracture surfaces having limonite. (Plate XI, 2, 3).

MARCASITE - Acicular, arrowhead, cruciform-like, bronzy to brassy yellow crystals and aggregates. Rare.

PYRITE - Octahedrons, pyritohedrons, cubic crystals and aggregates are of brassy yellow color. Sometimes occur as oolities. (Plate XIII, 2).

ZIRCON - Prisms, terminated by rounded, subrounded or cubic pyramids. Some stubby pyramidal irregular or fractured

fragments. Fracture, irregular to conchoidal. Prismatic forms frequently contain many inclusions and are often zoned. Inclusions in other forms vary from none to many. Colors from clear, pink to brownish dusky grey. Some are pitted. (Plate XIII, 1, 2, 3). A chart of the various zircons and their distribution within the Winnipeg is given in Table II, page 95 .

STAUROLITE - Very pale lemon to amber yellow. Rare greenish or brownish pleochroic. Some of the irregular grains show distinct hackly fractured terminations. Others show "concertina" like pattern on sides of grain. (Plate XIII, 1).

TOURMALINE - Violet pearly blue, (indicolite Na-Fe-Li), black brown (schorlite Fe) yellow, pistachio green-clear (Cr tourmaline), clear, pink-mauve (rubellite Li), yellow green (elbaite or schorlite Ca Na, Fe, Li), well rounded, rounded prismatic and rare euhedral prisms, lens like grains. Pleochroism high in lighter colored grains. Some grains broken. Biotite, rutile, magnetite and bubble inclusions are common. Darker colors predominate. (Plate XIII, 1, 2, 3). Some are peculiarly colored, mottled blue and yellow. The Sohio Plunkett samples contain only deep red tormaline. A chart showing the types of tourmalines and zircons is presented in Table II, page 95 .

RUTILE - Foxy red to brown red in irregular grains.
One specimen of geniculate twins.

MONAZITE - Reported by Macauley, 1951 not seen by
the writer.

UNKNOWN - Green brown in transmitted light, irregular
shape, slightly rounded. Pale yellowish cream to very
light green in reflected light. R.I. more than 1.54.
Isotropic or very weakly anisotropic.

Not enough material was available for an X-ray powder
diffraction photo.

MELANTERITE - Crystals "in the overlying shale on the
north side of Black Islands", (reported by F. D. Shepherd,
personal communication.)

Significance of Heavy Minerals.

The heavy detrital minerals (other than quartz)
detected in the Winnipeg formation represent a stable suite
of heavies not unlike those found in many other basal sand-
stones. No distinguishing variations are shown by the heavy
minerals from different localities of the Winnipeg formation.
Only traces of unstable heavy minerals are found within the
Winnipeg. The ferromagnesians with the exception of rare
hornblende are absent.

As the heavy mineral suite of the Winnipeg is represented by the stablest forms it is suggested that chemical and physical eradication of the unstable accessories has occurred from reworking of the sands and from intrastratal solution.

According to Krynine (1946) certain types of tourmalines are characteristic of particular parent rocks. The tourmalines in the Winnipeg show its sands to have been derived from granites, pegmatites, and metamorphosed sediments.

T A B L E 9.

HEAVY MINERAL CONTENT IN THE ST. PETER SANDSTONE*

Sample Number	Estimated per- cent of Major Constituents		Ana- tase	Spin- el	Garnet	Epidote(?)	Pyrite	Marcasite	Limonite	Gram of Heavy Minerals in Ten Pounds of St. Peter
	Zircon	Tour- ma- line								
1	45	45	10		R	R	R			0.07
8	55	45	R	R	R		C			1.62
9	55	45	R						A	1.26
11	50	50	R						R	1.51
13	65	35	R					C	C	1.27
18	45	55	C	R				C		1.33
25	65	35	R	R				R		3.19
33	50	50	R							2.40
36	80	20	R	R						2.60
43	50	45	5	R			C	C	C	1.14
45	50	50	R	R			R		R	0.95
47	70	30	R	R						2.78
51	35	30	35							3.60
54	50	50	R	R			R		R	1.93
60-61	30	70	R				R		R	0.18

A= Abundant

C= Common

R= Rare

* After Table 3, Bulletin No. 53, Illinois State Geological Survey, "Geology and Economic Resources of the St. Peter Sandstone, by F. J. Lamaar, 1927.

T A B L E 10.

HEAVY MINERALS IN THE WINNIPEG FORMATION AND SOME ASSOCIATED BEDS

Sample	Biotite	Galena (?)	Garnet	Hornblende	Iron oxide	Magnetite	Marcasite	Pyrite	Rutile	Staurolite	Tourmaline	Unknown	Zircon
WINNIPEG FORMATION:													
Black Island S. side #1*	T				T	C		R		P	D		R
Black Island S. side #2					T	R				R	D		A
Black Island N. side				T	T	A		T		P	A		D
Victoria Beach						P		D		R	P		P
Deer Island				T	T	A		A		P	C		P
Big Bull Head				R	T	A	R	D		R	A	R	P
Grindstone Point	T	T			R	C		P	T	R	D		P
Hecla Island				T	T	P	R	D		P	A		P
Red River #1			R	T		A	A	D	T	R	P		C
Red River #2		T	R		T	C	P	D		R	C		P
Red River Hepner #2					T		A			T	A	T	D
Imperial Foxwarren				R	T		P	T			D		
Punk Island			T	T	T	A		R	T	C	D		P
Ballantyne Bay			R		P	A	?	A	T	R	C		C
Amisk Lake			A		T	P	P	D		R	C		R
North Knife River			R		R	P	P	D		T	A		P
Bad Cache Rapids			R		T	A	D	P		T	A		P
RECENT SANDS													
Traverse Bay			C	P		A		A			P		P
CAMBRIAN, ALBERTA													
Sohio Plunkett well						P	D	P			C		C
CAMBRIAN(?), PRECAMBRIAN (?)													
Athabaska Sandstone	D	T	T		P			P	R	R			R

D = Dominant, more than 50%

A = Abundant, more than 25% up to 50%

C = Common, more than 10% up to 25%

P = Present, more than 5% up to 10%

R = Rare, more than 1% up to 5%

T = Trace, less than 1%

* This sample contaminated with Recent sand.

T A B L E 11.

TOURMALINE & ZIRCON TYPES IN THE WINNIPEG FORMATION
AND ASSOCIATED BEDS.

Location	Pink Tourmaline	Brown Tourmaline	Green Tourmaline	Blue Tourmaline	Black Tourmaline	Mottled * Tourmaline	Prismatic Pyramidal Zircon	Fragmental Irregular Zircon	Stubby Pyramidal Zircon	Clear Tourmaline
WINNIPEG FORMATION										
Black Is. S. side		X	X		X		X			
Black Is. SE side		X	X	X	X		X			
Black Is. N. side		X	X	X	X		X	X	X	
Victoria Beach		X	X		X		X		X	
Deer Island		X	X	X	X		X	X	X	
Big Bull Head		X	X	X						
Grindstone Point	X	X	X	X	X		X	X	X	
Hecla Island		X	X		X		X			
Red River #1 well		X	X		X		X	X	X	
Red River #2 well		X	X		X			X	X	
Red River Hepner #2 well	X	X	X		X		X	X	X	
Imperial Foxwarren		X								
Punk Island		X	X	X			X	X	X	
Ballantyne Bay	X	X	X	X	X	X	X	X	X	X
Amisk Lake	X	X	X	X	X					
North Knife River		X	X		X		X		X	
Bad Cache Rapids		X	X	X	X	X	X	X	X	X
RECENT SANDS										
Traverse Bay		X	X		X		X	X	X	
CAMBRIAN SANDS										
Alberta		X	X		X		X		X	
Sohio Plunkett Well		X	X		X		X		X	
CAMBRIAN(?) PRECAMB.										
Athabaska Sands		X						X		

* Mottled Tourmaline is a mixture of blue and yellow.

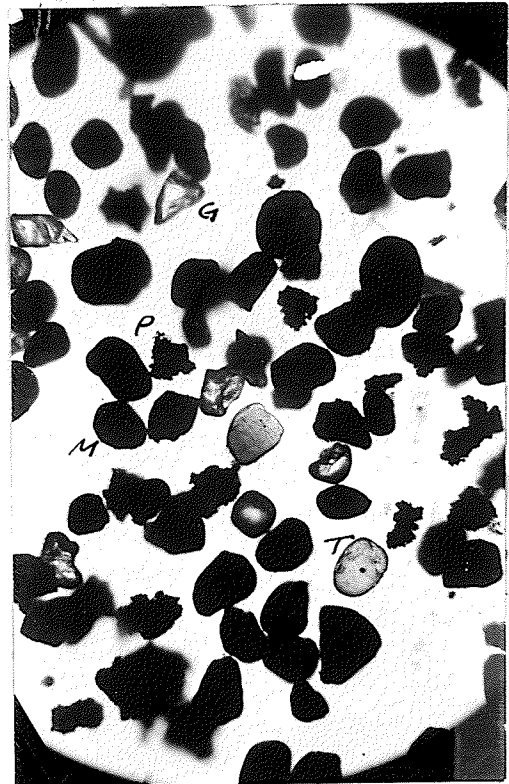
EXPLANATION OF PLATE VIII

- Figure 1. Heavy minerals x 25, Tourmaline (T), Zircon (Z), Garnet (G), and Magnetite (M), from the basal sandstone of the Ordovician (Deer Island unit ?) on the northeast side of Ballantyne Bay, Deschambault Lake, Saskatchewan.
- Figure 2. Heavy minerals x 25, Tourmaline (T), Garnet (G), Magnetite (M), and Pyrite (P), from the basal sandstone of the Ordovician at the Bad Cache Rapids on the Churchill River.
- Figure 3. Pyrite oolites x 10, from the base of the Grindstone Point unit on the west side of Punk Island.
- Figure 4. Quartz grains x 20, from the Winnipeg sand at the twenty-five hundred foot mark in the Gronlid well.

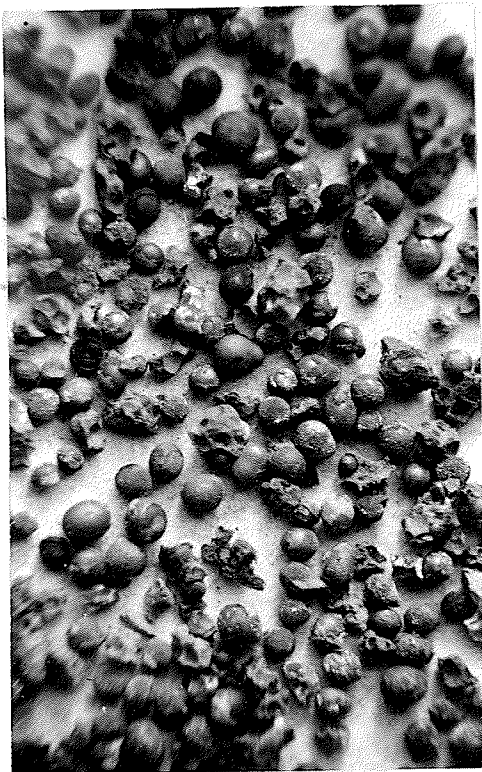
PLATE VIII



1.



2.



3.

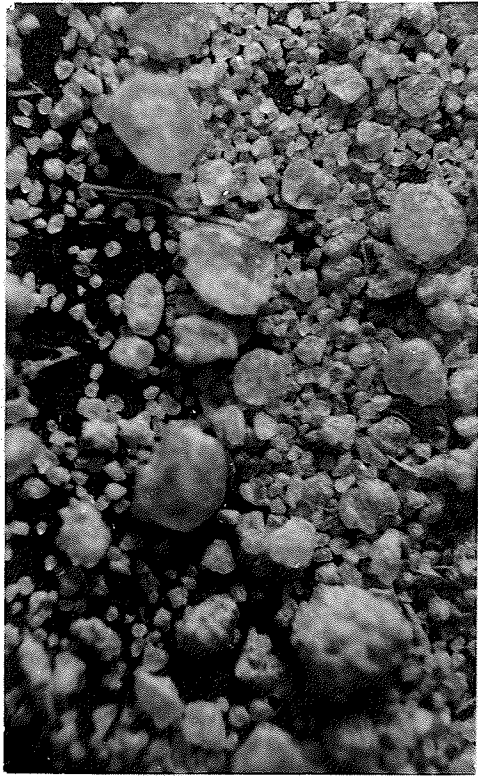


4.

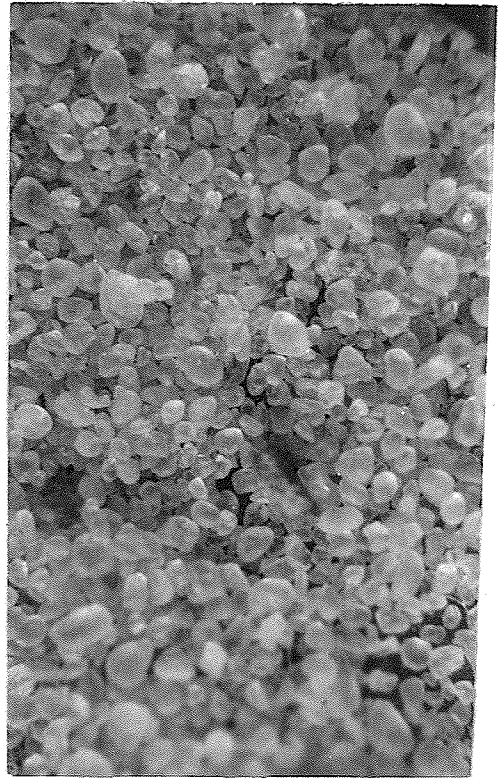
EXPLANATION OF PLATE IX

- Figure 1. Quartz sand x 20, from the basal sandstone of the Ordovician (Deer Island unit ?) at the Portage Chute Rapids on the Churchill River.
- Figure 2. Quartz sand x 20, from the Grindstone Point Unit on the north side of Hecla Island.
- Figure 3. Quartz sand x 20, from the basal sandstone of the Ordovician (Deer Island unit ?) at Cranberry Portage.
- Figure 4. Quartz sand x 20, from the Black Island unit on the south side of Black Island.

PLATE IX



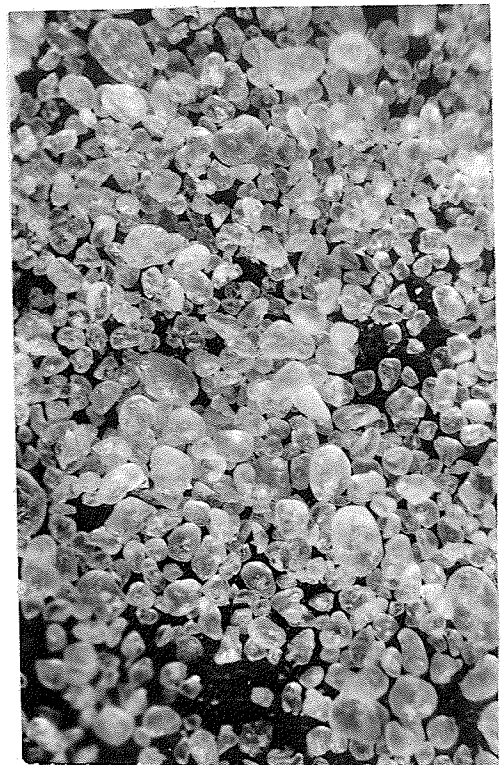
1.



2.



3.



4.

EXPLANATION OF PLATE X

Figure 1. Typical rounding, frosting and pitting, as seen in the sands of the Winnipeg formation. This sample is from the Grindstone Point on the west side of Punk Island.

PLATE X



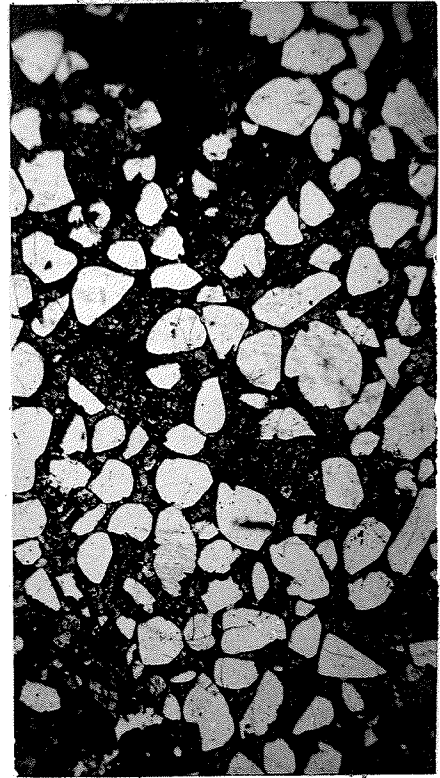
EXPLANATION OF PLATE XI

- Figure 1. Sandstone x 10, cemented by pyrite, from the Grindstone Point unit on the northwest side of Hecla Island.
- Figure 2. Sandstone x 10, cemented by a ferruginous carbonate, from the basal sandstone of the Ordovician (Deer Island unit ?) at Cranberry Portage.
- Figure 3. Pebble conglomerate x 10, from the basal sandstone of the Ordovician (Deer Island unit ?) at Portage Chute on the Churchill River.
- Figure 4. Argillaceous dolomitic limestone x 10, from ten feet above base of Portage Chute formation, same location as figure 3, plate XI.

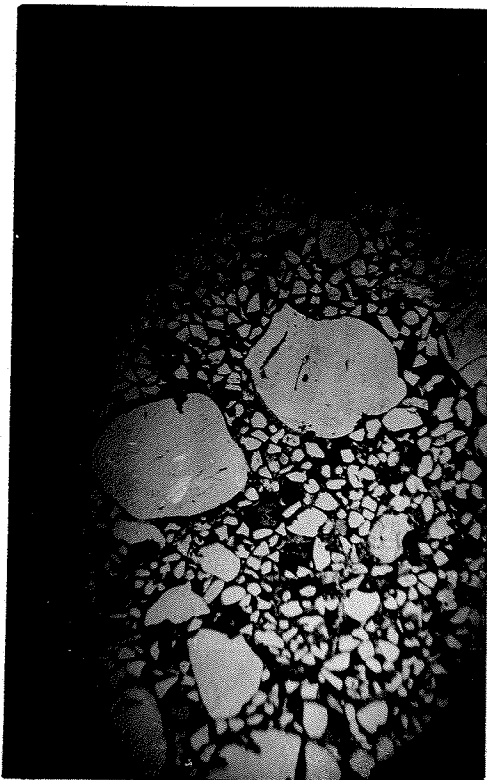
PLATE XI



1.



2.



3.



4.

EXPLANATION OF PLATE XII

- Figure 1. Authigenic microcline (M) x 100, in sandstone from the Grindstone Point unit at Victoria Beach.
- Figure 2. Authigenic quartz x 10, in Athabaska sandstone from Pine Point, Lake Athabaska.
- Figure 3. Goethite oolites x 10, in shale of Grindstone Point unit from a core sample of the Hartney well.
- Figure 4. Aragonite fossils (thin sections) x 10 in shale on Grindstone Point unit, from a core sample of the Union Oil Aanstadt well.

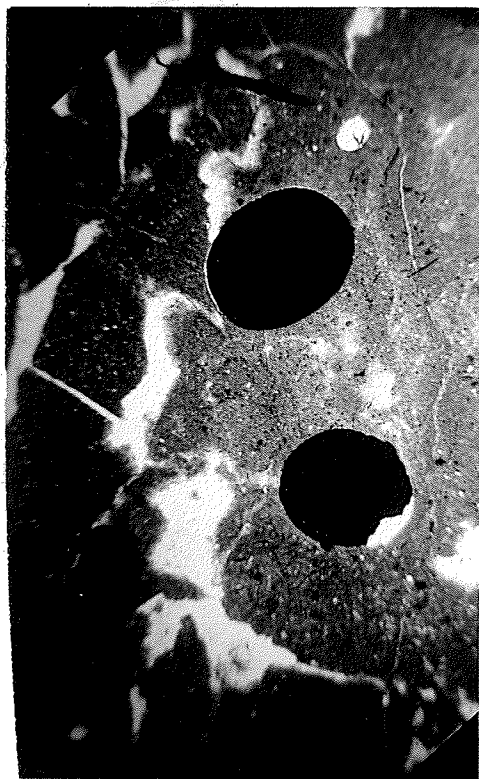
PLATE XII



1.



2.



3.

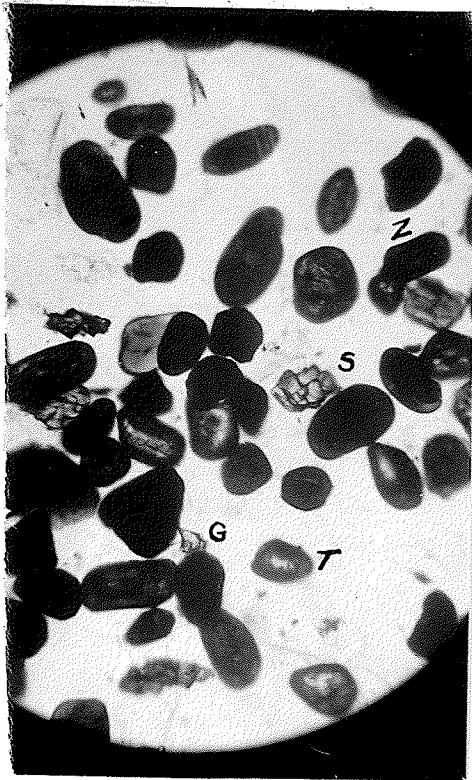


4.

EXPLANATION OF PLATE XIII

- Figure 1. Heavy minerals x 45, Staurolite (S), Tourmaline (T), Garnet (G), and Zircon (Z), from the Grindstone Point unit on the west side of Punk Island.
- Figure 2. Heavy minerals x 10, Tourmaline (T), Zircon (Z), Dolomite (D), Magnetite (M), and Pyrite (P), from the Grindstone Point unit on Grindstone Point.
- Figure 3. Heavy minerals x 10, Tourmaline (T), Garnet (G), Zircon (Z), and Magnetite (M), from a contaminated sample of the Black Island unit on the northwest side of Black Island.
- Figure 4. Heavy minerals x 10, Garnet (G), Biotite (B), from the Athabaska sandstone, Pine Point Lake, Athabaska.

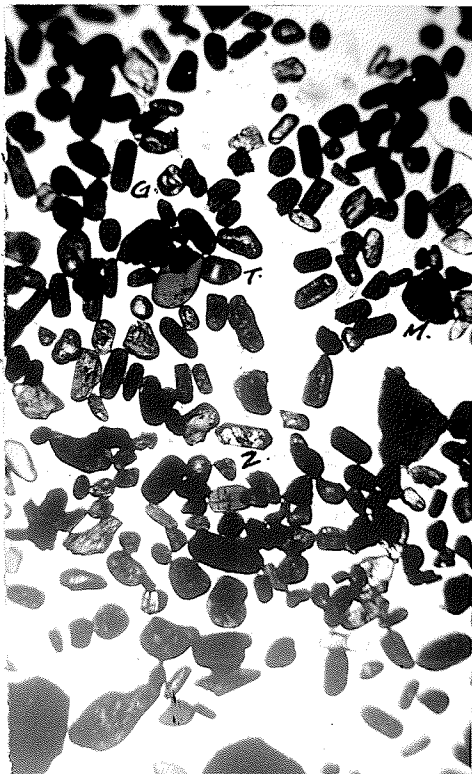
PLATE XIII



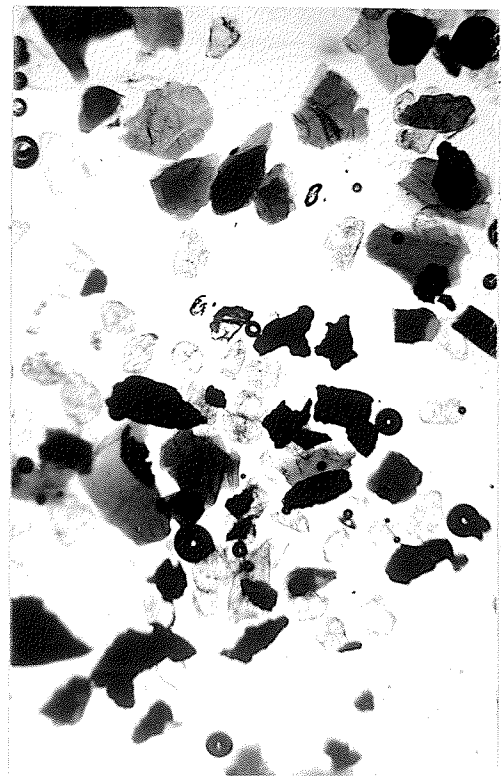
1.



2.



3.



4.

ON THE ORIGIN AND FORMATION OF PYRITE, IRON OXIDE, CALCIUM CARBONATE, PHOSPHATE NODULES AND OOLITES WITHIN THE WINNIPEG FORMATION.

INTRODUCTION.

The material in this chapter was assembled to provide information that would aid with the reconstruction of paleographic conditions which existed during the deposition of the Winnipeg formation.

SEDIMENTARY PYRITE

According to Mathias (1928) sedimentary pyrite maybe formed in many ways, by reduction of iron sulphate in solution by organic matter, or by sulphate reducing bacteria, or by the action of hydrogen sulphide on iron sulphates or carbonates in solution. Krumbein and Garrels (1952) believe the hydrogen ion concentration pH, and the oxidation reduction Eh, provide two basic controls which largely determine the kinds of chemical end members produced by inorganic and, or biochemical reactions. In sea water, where iron is present together with other elements, the existence of particular iron compounds as e.g. pyrite, siderite, or hematite, depends on definite physical chemical conditions. Pyrite deposits independently of pH, but it is stable only within certain limits of Eh, i.e. from Eh -0.4 to Eh -0.125. If the Eh changes, siderite or hematite which are stable within the new Eh values may preferentially exist.

The amount of one mineral, however, e.g. pyrite

which will precipitate, is dependent on the amount of its constituents available.

These stability limits Eh and pH, function according to Krumbein and Garrels (1952, p. 13) essentially independent of temperature, pressure and composition of the sea water system from which they precipitate.

Sedimentary Pyrite in the Winnipeg formation.

This pyrite occurs in nodules, oolites, as irregular grains, as fossil replacements and as cement throughout nearly all beds of the Winnipeg formation. There is little if any pyrite in the beds immediately overlying the Winnipeg, nor is there any pyrite except for a few detrital grains within the basal (Black Island) unit of the formation.

Several features are exhibited by the pyrite within the Winnipeg. The writer suggests that as there are organic remains (phosphatic fossils) associated with the iron sulphide, reduction of iron sulphate by organic matter has partially formed the pyrite. Krumbein and Garrels (1952) have proven the effect exerted by Eh and pH on chemical deposition, it is suggested here that some of the pyrite is primary and was formed in an environment with an Eh of from -0.4 to Eh-0.125, that is in reducing conditions. Fossils in the Winnipeg are often pyritized and this would indicate some

pyrite is post-depositional or of secondary (epigenetic) formation.

Iron Oxide

Weathering has caused the formation of iron oxide. Iron oxide is observed at times, closely associated with rusty pyrite. Powdery yellowy sulphurous material is often found with the iron oxide.

Calcium Carbonate

In the Black Island unit no carbonate is present. In the Grindstone Point unit a few limy bands up to one foot thick may be detected. The writer suggests these limy bands resulted from intrastratal solution. From the base of the Deer Island unit to its top, the carbonate increases from a trace to nearly pure carbonate.

The nature of occurrence of the carbonate in the Deer Island unit may indicate that a change of conditions took place. Conditions in which principally sand was deposited may have been followed by a change to those conditions in which predominantly carbonate formed. The sea water existing at the time of the carbonate deposition may have been slightly alkaline with a pH value above plus or minus 7.8 (Krumbein and Garrels, 1952).

Phosphate Nodules in the Winnipeg

The deposition of the phosphate ion is dependent upon pH, but is independent of Eh fluctuations. Phosphate will precipitate in a physico - chemical environment similar to that of the carbonates. The Grindstone Point unit of the Winnipeg formation contains many black shiny phosphatic nodules.

Phosphatic or sedimentary apatite nodules similar to those of the Winnipeg are found in rock types from Precambrian to Recent.

Pettijohn (1926) did considerable work on phosphatic nodules in the Platteville limestone overlying the St. Peter sandstone. The writer thinks their manner of formation may furnish some data which could be applied to the explanation of the formation of the phosphate nodules in the Winnipeg.

Phosphatic nodules in the Platteville, according to Pettijohn (1926 pp 372), have been formed on the division planes of formations due to non-deposition and solution, and therefore may be used as a criterion in the determination of unconformities.

Phosphatic nodules are characterized by dark, brown, shiny, black surface. According to Pettijohn (1926) a hard

fine grained amorphous material which is an inherent property of the nodule precipitated under favorable conditions, may cause the glaze or polish. Other workers believe this shiny surface or polish on phosphatic nodules may result from the movement of these structures by currents and waves.

The phosphatic nodules of the Winnipeg exhibit the following features. They are from 1 mms. to 5 mms. in diameter, shiny dark brown to black on the surface, and dark brown and soft in the centre. Microscopically they are composed of a dark brownish amorphous looking material. They are isotropic, have a fine grained darker amorphous material forming the periphery of the nodule, and occur throughout the Grindstone Point unit.

Macroscopic and microscopic similarities are noticeable between the phosphatic nodules from the Platteville limestones and those from the Winnipeg formation. The noticeable similarities in the nodules are in size, color, hardness, texture, composition isotropism, and the shiny hardness of the surface, and their occurrence in comparable lithologic sequences.

As phosphatic nodules similar to those in the Winnipeg are claimed to represent depositional irregularities

or even depositional breaks, the presence of phosphatic nodules in the Grindstone Point unit of the Winnipeg suggests that similar conditions prevailed during their formation.

Origin and Formation of Oolites in the Winnipeg

Many ideas are prevalent today on the manner in which oolites form. Bucher (1918) believes oolites were formed generally in suspension, by a substance changing from an emulsoid state to a solid, that the spherical shape of the grains is due to the tendency of the droplets forming during the process of separation to coalesce, and that the difference between radial and concentric structure depends on the impure substances discarded or retained in the growing structure.

Other writers ascribe organic as well as inorganic origins. Organically formed oolites do not contain concentric or radial structures as do the inorganically formed ones.

Bucher (1918) claims oolites are either primary or secondary. If secondary, oolites have practically no binding matrix, they are uniform in grain size thus indicating sorting, the oolites may be laid down as cross-beds, or else the secondary oolite may have incorporated within it material which is foreign to the surrounding matrix.

Pyrite Oolites

The petrographic description, the stratigraphic position and the location of oolite occurrences have been discussed previously in this report (pp. 55, 84). Some aspects of the origin and formation of sedimentary pyrite have also been discussed. It is not possible to state the actual formative processes operating to produce pyrite oolites in the Winnipeg. However, a few suggestions on their formation are offered by the writer. The pyrite oolites are primary because they are cemented by an abundant silty matrix and because they possess none of the other features such as cross-bedding or lack of cement that are characteristic of secondary oolites. Pyrite oolites of the Winnipeg exhibit a spherical shape. This is so because they were formed either as solid structures, or else as gel structures which hardened before the deposition of superincumbent beds.

Graptolites which were planktonic organisms are associated with the oolites. Many writers believe pyrite oolites are a good criterion to use in the detection of an unconformity. If this is so, then there is the possibility of an unconformity between the top of the Black Island unit and the base of the Grindstone Point unit. The pyrite oolites in the Winnipeg are always composed of concentric laminations which are characteristic of inorganically formed oolites (Bucher, 1918).

These spherulitic structures are associated with marine planktonic fossils and it is therefore suggested these oolites were formed in a body of water connected to an open, freely circulating marine environment. The oolites being pyrite have likely had their origin in reducing conditions.

Goethite Oolites

The structure and petrographic characters of the Goethite oolites have been described on pages 56 and 84.

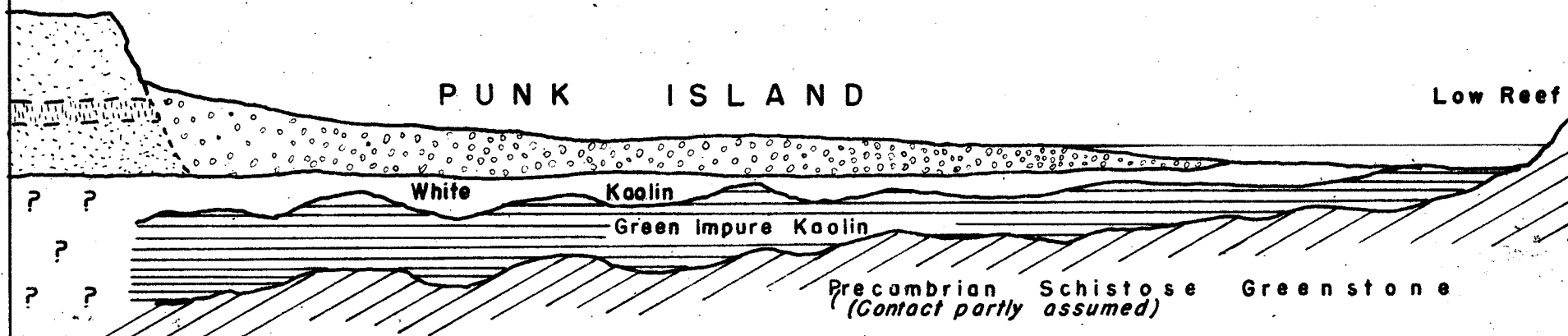
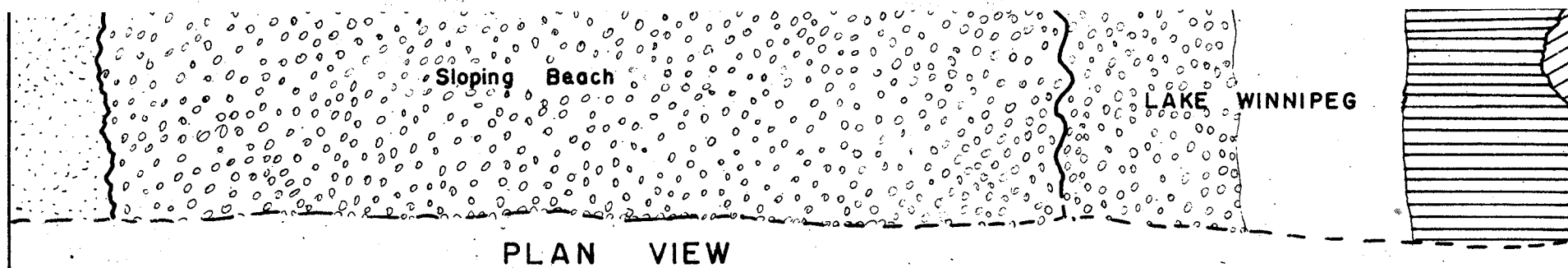
Many of the goethite oolites of the Winnipeg formation contain granules of pyrite disseminate through, or forming part of the goethite laminae. The presence of pyrite in the hydrated iron oxide suggests the possibility that the original oolite was pyrite which was changed to iron oxide by subsequent oxidation and hydration. This chemical activity may have removed nearly all the pyrite, leaving only a few grains in the crystalline limonite.

The goethite oolites are flattened ellipsoids whereas the pyrite ones are principally spherical. This feature may be explained by the idea that the latter originated as a structure of solid pyrite crystals and the former as a soft gel which has been flattened by the overlying beds.

The goethite oolites are not uniformly disposed within the containing shale and tend to be arranged in groups of closely spaced oolites. They occur within the shale and it is not positively known if they occur at the base of the Grindstone Point unit as do the pyrite oolites. The upper limits of the goethite oolites may possibly be used to determine the base of the Grindstone Point unit when doing subsurface work.

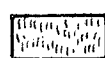
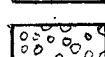
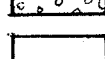
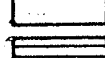
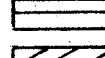
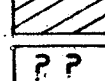
These oolites seem to have been formed from original pyrite oolites. The presence of pyrite with goethite also suggests a physico-chemical environment which would be amenable to both these compounds, i.e. one in which the Eh's range from -0.125 to -0.225.

The goethite oolites are secondary if they resulted from the original pyrite oolites. Their disorderly arrangement and lack of intervening cement favors the idea that they were moved after being formed. Their flattened ellipsoidal shapes indicate them to have been deposited as rounded bodies prior to the deposition of overlying strata which subsequently caused their flattening. Their presence near the base of the Grindstone Point unit may have some significance towards the possibility of an unconformity at the base of the Grindstone Point unit.



SCALE
Vertical lin. = approx 12 ft.
Horizontal lin. = approx 40 ft.

LEGEND

-  Sandstone
-  Hard Sandstone
-  Recent Sand Beach
-  White Kaolin
-  Green Impure Kaolin
-  Precambrian Greenstone
-  Unknown

SECTION SOMEWHAT IDEALIZED

*THIS SECTION SLIGHTLY MODIFIED
AFTER "A SAMPLE SECTION BY
RECONSTRUCTION OF OLD FIELD
NOTES" by V. D. COLCLEUGH 1951.*

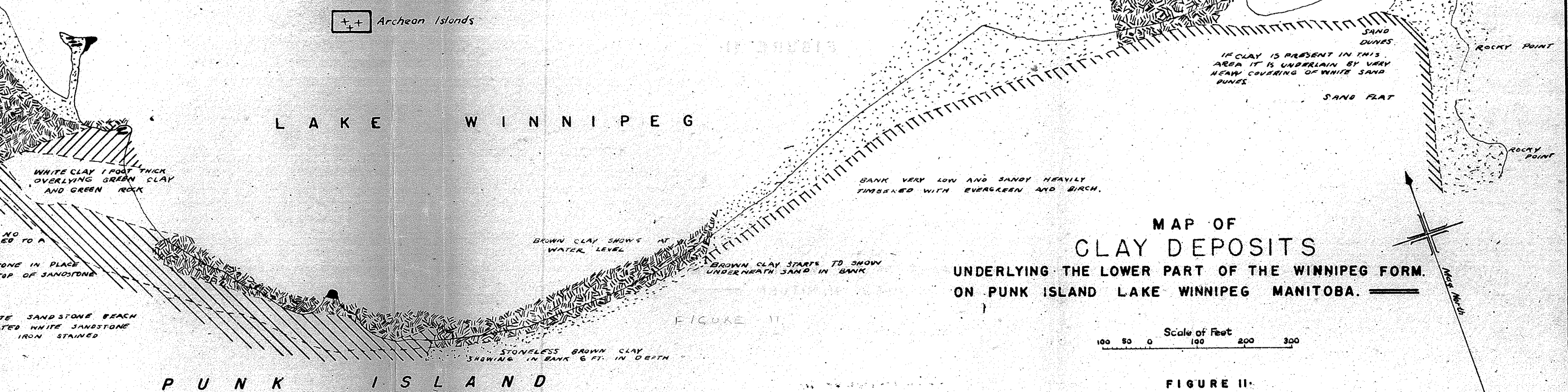
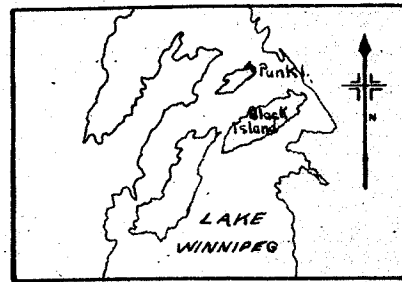
REPRODUCED WITH PERMISSION OF
V. D. COLCLEUGH.

WEATHERED PRECAMBRIAN.
KAOLIN BETWEEN PRECAMBRIAN
AND WINNIPEG FORMATION ON
NORTHEAST CORNER PUNK ISLAND
LAKE WINNIPEG, MANITOBA.

FIGURE 10.

LEGEND

-  White clay
-  Green clay
-  Brown plastic stoneless clay
-  White sandstone and sand
-  Other sand (recent)
-  Rock outcrops (Archean)
-  Archean Islands



MAP OF
CLAY DEPOSITS
UNDERLYING THE LOWER PART OF THE WINNIPEG FORM.
ON PUNK ISLAND LAKE WINNIPEG MANITOBA.

Scale of Feet
100 50 0 100 200 300

FIGURE II.

Taken from "INVESTIGATIONS IN CERAMICS AND ROAD MATERIALS" part V, page 26, after figure I
(slightly modified) by L.H. COLE and J.F. McMAHON, No. 690, 1926

G.J. GENIK 28,3,52

CHAPTER IV

ON THE NATURE OF THE PRECAMBRIAN LAND MASS BELOW THE WINNIPEG FORMATION

Over an extensive area, the Precambrian immediately underlies the Winnipeg formation (Map III). Within this area the features noted on the Precambrian - Winnipeg contact are herein described. Included in this chapter is a brief description of the contacts between Precambrian and overlying Paleozoic rocks at localities other than those where Winnipeg overlies the Precambrian.

Relief

The Precambrian surface underlying the Winnipeg formation is believed by many to have been a peneplain with gentle undulations. In Manitoba, northeastern Saskatchewan, and eastern North Dakota the structure contours on the top of the Precambrian show no particular topographic features, only a general steepening of the basin as its centre is approached. The well information indicates that the steepening is more rapid in eastern North Dakota than in Manitoba. A list of elevations on top of the Precambrian immediately under the Winnipeg, is given in Table 15, page 145.

The upper limit of the surface of the pre-Paleozoic land mass in Manitoba dips on an average of fifteen feet per mile to the southwest.

Contact of Precambrian and Winnipeg formation

Outcrop

The contact between the base of the Winnipeg and the Precambrian has not been seen by the writer, but Bell (1895) and Nelson (1952) have seen it on the Churchill River (Plate VI, 1,2).

Though the Precambrian Winnipeg contact is not observed in the outcrops on Lake Winnipeg, at Black and Punk Islands the Black Island unit outcrops with 300 feet of Precambrian. (Figures 10, 11). At Cranberry Portage the Precambrian is exposed 80 feet south of the Winnipeg formation. (Figure 2).

On Punk Island, Cole and McMahon (1926) observed kaolin associated with the Winnipeg sandstone. Along the northeast shore of Punk Island overlying the Precambrian and below the Winnipeg there are several feet of Kaolin. The kaolin here shows a definite relationship to the Precambrian greenish grey, schistose, metasediment as it grades upward from unaltered greenish grey schistose metasediment, to green impure kaolin, to pure white kaolin. J. F. Wright (1932) and V. D. Colcleugh (1951) also worked on the kaolins on Punk Island. (Figures 10, 11). As the kaolin underlies the Winnipeg, weathering of the Precambrian must have been operative preceding the deposition of the Winnipeg.

The variable nature of the subsurface contact of the Winnipeg formation and Precambrian is shown in Table 12, page 123.

Contact of Paleozoics and Precambrian Other Than the Contacts of the Winnipeg and Precambrian.

The Paleozoic Precambrian contacts other than those contacts of the Precambrian with the Winnipeg show several interesting features. When studied these features show similarities and differences with the Winnipeg - Precambrian contact. In Chapter VII, when the origin of the Winnipeg shall be discussed the Paleozoic - Precambrian contact features will be considered in relation to the Winnipeg - Precambrian contact.

In the Sawatch range of Colorado, the Upper Cambrian Sawatch quartzite rests directly upon the eroded surface of the Precambrian rocks. The contact from Gilman to Brush Creek is clean cut; a thick basal conglomerate of well-rounded pebbles rests on a relatively smooth surface of pre-Cambrian granitic rocks. Farther south in the Aspen district the Precambrian granite was deeply weathered before the deposition of the Cambrian beds so that the lower beds of the Sawatch consist of arkosic grit only slightly reworked before deposition. (Johnson, J.H., 1944).

Near Manitou, Colorado a granite sedimentary con-

tact is practically a plane for the entire area. A coarse greyish white sandstone, rarely conglomeratic but sometimes enclosing a few small pebbles overlies a coarse red biotite granite. (Crosby, W.O., 1899).

In the Lake Simcoe area of Canada, Lowville limestone rests directly on Precambrian crystalline rocks. (Deane, 1950, pp 9 and 10).

In the Lake St. John district of Saguenay, Quebec, there occurs at two places, small remnants of limestone resting on the granitic (Precambrian) gneisses. (Hume, G. S., 1925).

TABLE 12

SHOWING THE NATURE OF THE PRECAMBRIAN WINNIPEG-CONTACT

<u>W E L L</u>	<u>LOCATION</u>	<u>TYPE OF PRECAMBRIAN</u>
Imperial Birtle	1-27-17-26WP	Pink granite
Imperial Madeline	16-18-18-29WP	Biotite granite
Imperial Foxwarren	16-22-19-22WP	Granite
Cal. Stan. Hartney	16-33-5-20WP	Biotite granite gneiss
Red River Oil #1	13-6-13-6EP	Granite
Red River Oil #2	2-1-5-1WP	Granite
Red River Hepner #2	3-1-5-2WP	Granite
Hart Green Wakeley #1	1-28-4-4WP	Pink, feldspar granite
McGuckin Test Holes	33-1WP	Pink granite gneiss
Commonwealth Manitou #2	8-26-9WP	Rusty decomposed and weathered granite
Stony Mountain	29-12-2EP	Light grey igneous rock
Winnipegosis #4	29-30-17EP	Weathered grey granite
Lilyfield D.D. Hole	Near Lilyfield	200' of weathered granite
Black Is. D.D. Hole	SE side Black Island	80'-100' highly weathered green phyllite
Mafeking #3	12-12-43-26W1	Weathered disintegrated red granite.

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CHAPTER V.

PALEONTOLOGY

INTRODUCTION.

This chapter is intended primarily for the purpose of stating the identifications and to show the illustrations made of the fossils collected from the Deer Island unit outcropping at Cranberry Portage and Amisk Lake. Other faunal lists for several localities of the Winnipeg are given in this chapter. A faunal list for all of the Winnipeg, showing distribution in units and general localities, is given here. (Table 13).

AMISK LAKE

One quarter mile south of Sucker Creek on Beaver Lake Road Fossils collected by A. D. Baillie, Dr. W. O. Kupsch and G. J. Genik.

1. Endoceras sp.
2. Actinoceras sp.
3. Kochoceras sp. *
4. Cyrtogomphoceras? sp.*
5. Maclurites? cf. manitobensis, Whiteaves *
6. Liospira sp.
7. Solenospira sp.
8. Sinuites cancellatus, (Hall)
9. Hormotoma sp., (a small form)
10. Zygospira? sp.
11. Sowerbyella sp.
12. Rhynchotrema? sp.
13. Diceromyonia? cf. storeya, Okulitch *
14. Réceptaculites sp.
15. Cyclocrinites cf. globosus, Billings

* These were collected by Dr. W. O. Kupsch of the Department of Natural Resources, Saskatchewan and were identified by Dr. R. A. C. Brown, Paleontologist, Manitoba Mines Branch.

CRANBERRY PORTAGE

One quarter mile south of Cranberry Portage in roadcut along the main highway. Fossils were collected by A. D. Baillie and G. J. Genik, and identified by the writer.

1. *Endoceras* sp.
2. *Streptelasma* sp.
3. *Clinopistha*? cf. *antiqua*, Whiteaves
4. *Halysites* cf. *gracilis*, (Hall)
5. *Archinacella instabilis* var. *incurva*, Ulrich & Scofield
6. *Maclurites*-operculum fragments
7. *Scolecodont* sp.
8. *Ctenodonta*? sp.
9. *Salpingostoma* cf. *buelli*, Whitfield
10. *Narthecoceras*? sp.
11. *Maclurites* sp.
12. *Diestoceras* sp.
13. Cephalopod, brachiopod and gastropod fragments

HILL LAKE, MANITOBA

South end of lake where Minago River flows in.
Collection by J. B. Tyrrell (1892).

1. *Ctenodonta subnasuta*
2. *Pleurotomaria* sp.
3. *Murchisonia* or *Loxomema* (large sp.)
4. *Helicotoma* sp.
5. *Salpingostoma buelli*, Whitefield
6. *Bellerophon* sp.
7. *Juvellania semiplanatum*, Whiteaves; or *Triptero-ceras planoconvexum*, Hall
8. *Narthecoceras crassiphonatum*, (Whiteaves)

STURGEON LAKE, SASKATCHEWAN

On east side of Sturgeon Lake, fossils collected by
J. B. Tyrrell (1892)

1. *Endoceras annulatum*, Hall
2. *Actinoceras* sp.
3. *Maclurites manitobensis*, Whiteaves
4. *Conradella* sp.

LAKE WINNIPEG

Fossils collected from Victoria Beach, Black Island, Deer Island, Punk Island and Grindstone Point. List compiled by G. W. Macauley (1951.)

COELENTERATA

1. *Climacograptus typicalis*, Hall
2. *Conularia formosa*, Miller and Dyer
3. *Conularia* sp.
4. *Climacoconus* cf. *clarki*, Sinclair
5. *Streptelasma* n.sp. Macauley Mss.
6. *Streptelasma* n.sp. Macauley Mss.

ANNELIDA

1. *Scolithus* sp.
2. *Serpulites dissolutus*, Billings

BRYOZOA

1. *Hallopora multitabulata*, (Ulrich)
2. *Rhinidictya mutabilis*, Ulrich
3. *Escharopora* sp. Ulrich

BRACHIOPODA

1. *Lingula* sp.
2. *Platystrophia reversata*, (Foerste)
3. *Plectorthis plicatella*, (Hall)
4. *Rhynchotrema inaequivalvis*, (Castlenau)
5. *Rhynchotrema inaequivalvis*, var. *laticostata*
Winchell & Schuchert
6. *Trematis* sp.
7. *Orthis* (*Hesperorthis*) *triceneria*, (Conrad)
8. *Cyclospira bisulcata*, (Emmons)
9. *Sowerbyella* sp.
10. *Strophomena* sp.
11. *Dalmanella* sp.

PELECYPODA

1. *Cyrtodonta* sp.
2. *Modiolodon patulus*, Ulrich

GASTROPODA

1. *Sinuities cancellatus*, (Hall)
2. *Salpingostoma* sp.
3. *Hormotoma gracilis*, Whitfield
4. *Hormotoma* sp. ind. (cf. *winnipegensis* or *major*)
5. *Solenospira pagoda* var. *occidentalis*, (Salter)

CEPHALOPODA

1. Endoceras sp.
2. Ehippiorthoceras formosum, Foerste
3. Spyroceras sp.
4. Westonoceras manitobense, (Whiteaves)

TRILOBITA

1. Ceraurinus icarus, (Billings)

OSTRACODA

1. Leperditia sp.

CRINOIDEA

1. Grinoid columnals
2. Glyptocrinus sp.

ALGAE

1. Licrophycus
2. Palaeophycus

From the Lake Winnipeg outcrops some fossils not previously found within the Winnipeg formation. Collected by A. D. Baillie - G. J. Genik, and identified by the writer.

1. Trematis sp.
2. Palaeacmea cf. orphyne?, Billings
3. Ozarkodina? sp.
4. Graptolites? sp.
5. Clidophorous? cf. stoningtonensis, (Billings)

A complete fossil list of the Winnipeg formation is presented in Table 13, page 128.

TABLE 13.

FOSSILS AND THEIR OCCURRENCE IN THE WINNIPEG FORMATION

Fossil Name	Deer Island Unit, at Cranberry Portage, Amisk, Sturgeon, and Hill Lakes	Grindstone Point Unit, at South End of Lake Winnipeg
<u>CEPHALOPODS</u>		
<i>Tripteroceras planconvexum</i> , (Hall) or	X	
<i>Jovellania semiplanata</i> , (Whiteaves)		
<i>Nartheoceras crassiphonatum</i> , (Whiteaves)	X	
<i>Actinoceras</i> sp.	X	
<i>Kochoceras</i> sp.	X	
<i>Cyclendoceras annulatum</i> , (Grabau and Shimer)	X	
<i>Diestoceras</i> sp.	X	
<i>Endoceras</i> sp.	X	X
<i>Ephippiorthoceras formosum</i> , Foerste		X
<i>Spyroceras</i> sp.		X
<i>Westonoceras manitobense</i> , (Whiteaves)		X
<i>Cyrtogomphoceras</i> sp.	X	X
<u>COELENTERATES</u>		
<i>Streptelasma</i> sp.	X	
<i>Halysites</i> cf. <i>gracilis</i> , Hall	X	
<i>Climacograptus typicalis</i> , Hall		X
<i>Conularia formosa</i> , Miller and Dyer		X
<i>Conularia</i> sp.		X
<i>Climacoconus</i> cf. <i>clarki</i> , Sinclair		X
<i>Streptelasma</i> n. sp., Macauley Mss.		X
<i>Streptelasma</i> n. sp., Macauley Mss.		X

TABLE 13 - CONT'D.

FOSSILS AND THEIR OCCURRENCE IN THE WINNIPEG FORMATION

Fossil Name	Deer Island Unit, at Cranberry Portage, Amisk, Sturgeon and Hill Lakes	Grindstone Point Unit, at South End of Lake Winnipeg
<u>BRACHIOPODS</u>		
Lingula sp.		X
Platystrophia reversata, (Foerste)		X
Plectorthis plicatella, (Hall)		X
Rhynchotrema inaequivalvis, (Castelnau)		X
Rhynchotrema inaequivalvis var. laticostata, Winchell and Schubert		
Rhynchotrema sp.	X	X
Sowerbyella cf. sericea, Jones	X	
Sowerbyella sp.	X	X
Trematis sp.		X
Orthis (Hesperorthis) tricenaria, Conrad		X
Cyclospira bisulcata, Emmons)		X
Diceromyonia cf. storeya, Okulitch	X	
Zygospira ? sp.	X	
Strophomena sp.		X
Dalmanella sp.		X
<u>CONODONTS</u>		
Stereoconus (iden. by Youngquist Univ. of Idaho)	X	
Chirognathus(" " " ")	X	
Microcollodus(" " " ")	X	
Ozarkodina sp.		X
<u>ANNELIDS</u>		
Scolecodont	X	
Scolithus sp.		X
Serpulites dissolutus, Billings		X

TABLE 13 - CONT'D.

FOSSILS AND THEIR OCCURRENCE IN THE WINNIPEG FORMATION

Fossil Name	Deer Island Unit, at Cranberry Portage, Amisk, Sturgeon, and Hill Lakes	Grindstone Point Unit, at South End of Lake Winnipeg
<u>PELECYPODS</u>		
Cyrtodonta sp.		X
Modiolodon patulus, Ulrich		X
Clidophorous? cf. stoningtonensis, Billings		X
Ctenodonta subnasuta, Ulrich	X	
Ctenodonta sp.	X	
Clinopistha cf. antiqua, Whiteaves	X	
<u>GASTROPODS</u>		
Sinuities cancellatus, Hall	X	X
Salpingostoma sp.	X	X
Hormotoma gracilis, Whitfield	X ?	X
Hormotoma sp. ind. (cf. winnipegensis or major)		X
Hormotoma sp. (small)	X	
Solenospira pagoda var. occidentalis, (Salter)	X ?	X
Paleacmea cf. orphyne ?, Billings		X
Maclurites manitobensis, Whiteaves	X	
Maclurites sp.	X	
Maclurites' opercula ?	X	
Murchisonia or Loxonema sp. (large)	X	
Helicotoma sp.	X	
Salpingostoma buelli, Whitfield	X	
Salpingostoma cf. buelli, Whitfield	X	X ?
Bellerophon sp.	X	
Solenospira sp.	X	
Liospira sp.	X	
Archinacella var. incurva, Ulrich and Schofield	X	
Conradella sp.	X	

TABLE 13 - CONT'D.

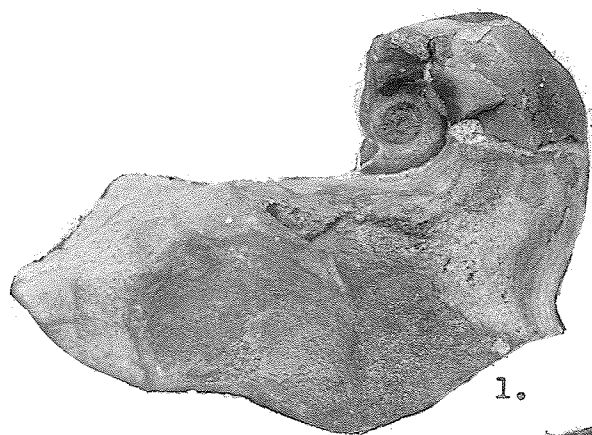
FOSSILS AND THEIR OCCURRENCE IN THE WINNIPEG FORMATION

Fossil Name	Deer Island Unit at Cranberry Portage, Amisk, Sturgeon, and Hill Lakes.	Grindstone Point Unit, at South End of Lake Winnipeg.
<u>BRYOZOANS</u>		
Hallopore multitabulata, (Ulrich)		X
Rhiniidictya mutabilis, Ulrich		X
Escharopora sp., Ulrich		X
SPONGES		
Cyclocrinites cf. globosus, Billings	X	
TRILOBITES		
Ceraurinus icarus, (Billings)		X
OSTRACODS		
Leperditiasp.		X
CRINOIDS		
Glyptocrinus sp.		X
Crinoid columnals	X ?	X
ALGAE		
Licropheycus sp.		X
Paleopheycus sp.		X
INCERTAE CEDIS		
Receptaculites sp.	X	

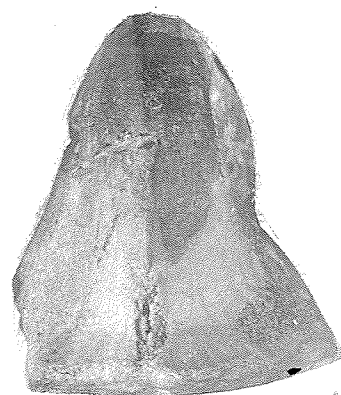
EXPLANATION OF PLATE XIV

- Figs. 1-2. *Salpingostoma* cf. *buelli*. 1, side view of internal and external mold with portion of replaced shell material, x 1; 2, posterior view of same x 1.25; from Deer Island unit one-half mile south of Sucker Creek on Beaver Lake Road, Saskatchewan.
- Figs. 3-4. *Palaeacmea* cf. *orphyne*, Billings 3, side view, 4, dorsal view, both of external mold, x 1; from Grindstone Point unit on north side of Deer Island.
- Fig. 5. *Liospira* sp. Dorsal view of internal mold, x 7.5 from Deer Island unit on roadcut one-half mile south of Cranberry Portage.
- Fig. 6. *Maclurites* sp. side view of inner and outer molds with fragments of replaced shell, x 1; from same location as 5.
- Fig. 7. *Hormotoma* sp. Portion of internal mold, x 1.5; from same horizon and location as 5.
- Figs. 8-9. *Sinuities cancellatus*, Hall, 8, apertural view, 9, lateral view, both of internal mold, x 1; from same location and horizon as 5.
- Figs. 10-11. *Maclurites* sp. fragments of operculum, x 1; from same horizon and location as 1-2 and 5.
- Fig. 12. *Solenospira* sp. Portion of internal mold, 7.5; from same horizon and location as 1-2 and 5.

PLATE XIV.



1.



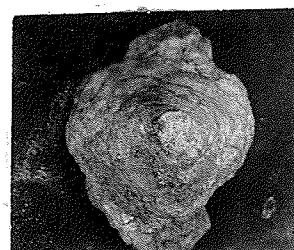
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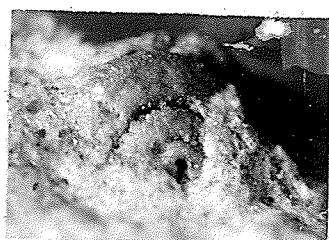
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4.



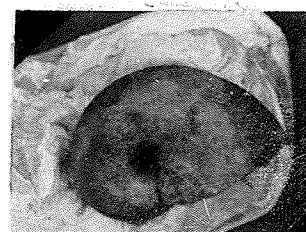
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7.



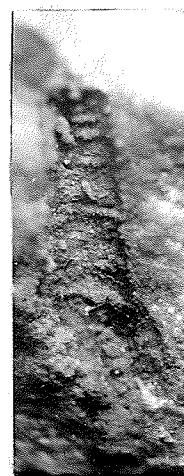
8.



9.



10, 11.



12.

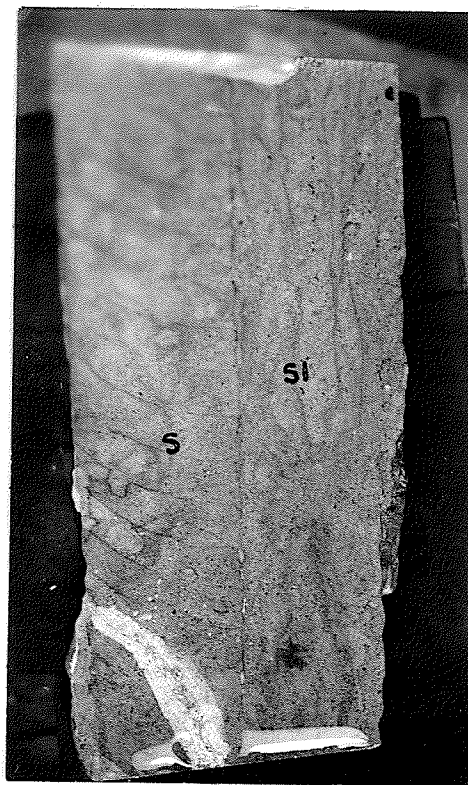
EXPLANATION OF PLATE XV

- Figure 1. Diestoceras sp. Dorsal view of internal mold, x 1; from Deer Island unit on roadcut one half mile south of Cranberry Portage.
- Figure 2. Endoceras sp. Transverse section showing septa (S), and siphuncle (SI), x .33; from same horizon and location as 1.
- Figure 3. Endoceras sp. Sagittal section showing white calcite and dark sandy carbonate endocones, x 1; from Deer Island unit on roadcut one-half mile south of Sucker Creek on Beaver Lake Road, Saskatchewan.
- Figure 4. Actinoceras sp. Poorly preserved portion of internal mold, x .33; from same horizon and location as 3.

PLATE XV.



1.



2.



3.

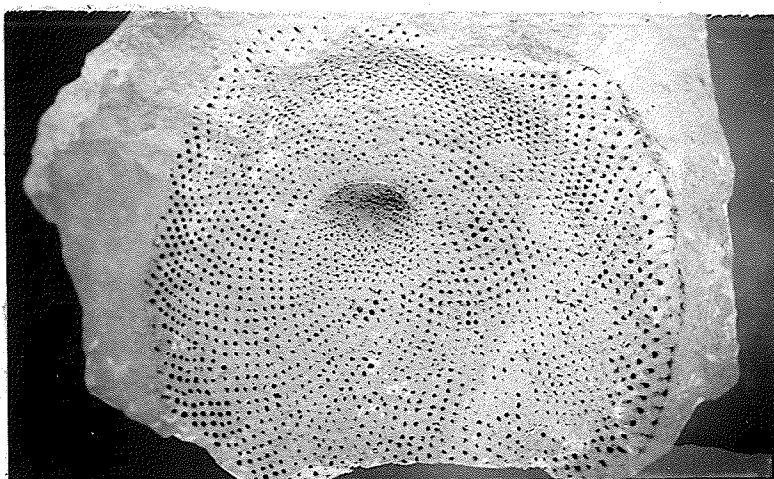


4.

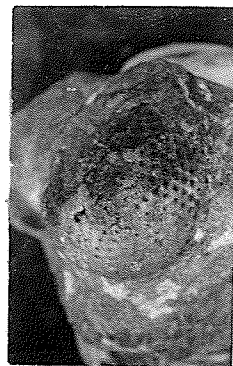
EXPLANATION OF PLATE XVI

- Fig. 1. *Receptaculites* sp. Portion of external mold of base?, x .25; from Deer Island unit on roadcut one half mile south of Sucker Creek on Beaver Lake Road, Saskatchewan.
- Fig. 2 . *Cyclocrinites* cf. *globosus*, Billings. External mold, x 1; from Deer Island unit on roadcut one half mile south of Cranberry Portage.
- Fig. 3. *Trematis* sp. Phosphatic cast, x 5; from Grindstone Point unit on northwest side Deer Island.
- Figs. 4-5. *Sowerbyella* cf. *sericea*, (Jones). 4, internal mold, 5, external mold, x 4; from same horizon and location as 2.
- Fig. 6. *Rhynchotrema* ? sp. Portion of external mold, x 2; from same horizon and location as 2.
- Fig. 7. *Streptelasma* sp. Portion of internal mold, x 1; from same horizon and location as 2.
- Fig. 8. *Endoceras* sp. Portion of siphuncle, x 15; from same horizon and location as 1.
- Fig. 9. *Ozarkodina* sp. A pearly calcite cast, x 15; from same horizon and location as 3.
- Fig. 10. *Scolecodont*. A black fragment, x 25; from same horizon and locality as 2.
- Fig. 11. Graptolite? sp. Phosphatic imprint or mold, x 7.5; from same horizon and location as 3.

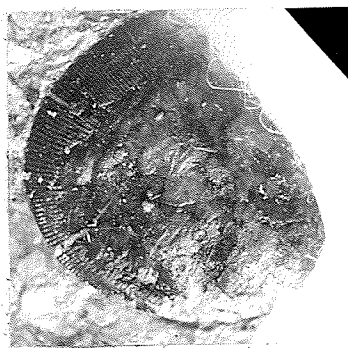
PLATE XVI



1.



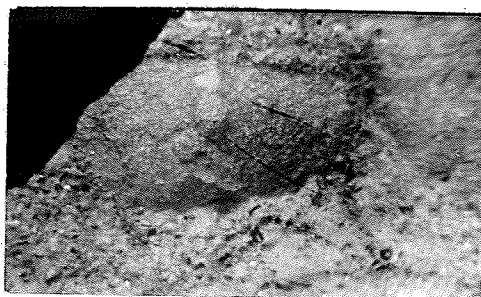
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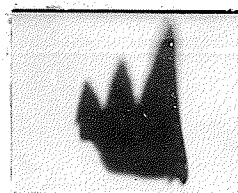
8.



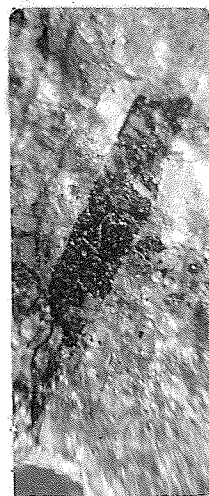
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9.



10.



11.

EXPLANATION OF PLATE XVII

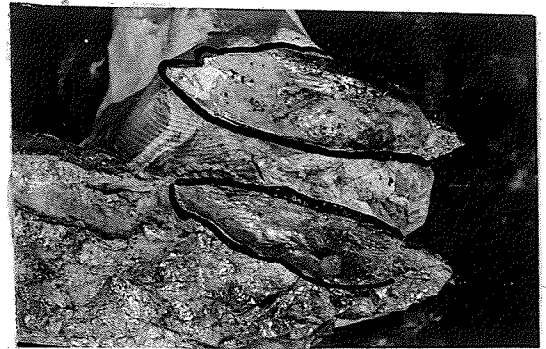
- Fig. 1. *Clinopistha* cf. *antiqua*, Whiteaves. Internal mold of right valve, x 1.5; from Deer Island unit on roadcut one half mile south of Cranberry Portage.
- Fig. 2. *Clidophorous* cf. *stoningtonensis*, Billings. Portions of external molds of right and left valves, x 1; from Grindstone Point unit on north side Deer Island.
- Fig. 3-6. *Ctenodonta* sp. 3.6, side view of left valve, 5, side view of right? valve, 4, dorsal view right? valve, all are internal molds x 7.5, except 6 which is x 1.5; from same horizon and location as 1.
- Fig. 7* *Maclurites* sp. Internal mold, x approximately .10; from Deer Island unit on roadcut one half mile south of Beaver Lake Road, Saskatchewan.

* By Dr. W. O. Kupsch 1951.

PLATE XVII.



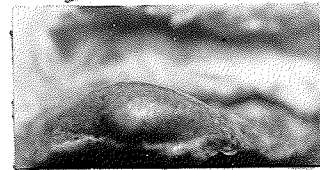
1.



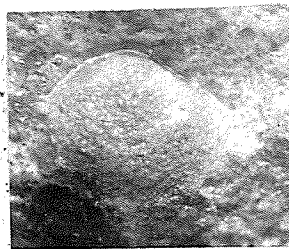
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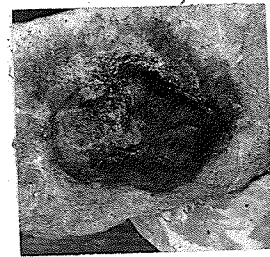
3.



4.



5.



6.



7.

CHAPTER VI

STRATIGRAPHIC MAPS

INTRODUCTION

An attempt has been made in this chapter to compile the existing subsurface and outcrop data on the Winnipeg formation so that stratigraphic maps i.e. geology, isolith, isopach, lithofacies and structure contour maps could be constructed.

These maps are merely a preliminary attempt utilizing existing, but incomplete information. Within two or three years additional subsurface data may completely alter the present maps.

According to Krumbein and Sloss (1951, p. 393) individual maps may show the areal distribution of structural, lithologic, or stratigraphic characteristics which could provide a basis for reconstruction of the paleogeography, paleogeology, structural history, and historical geology of a unit (e.g. the Winnipeg formation).

It is with this in mind that the writer prepared the stratigraphic maps accompanying this report. The significance of the information interpreted from these maps will be discussed in Chapter VII.

Compilation of Data

Well cuttings and cores from ten Manitoba wells were examined. Lithologic logs and sections from sixty wells containing Winnipeg formation were studied. These data have been assembled into tables and represent the newest cumulative data on the Winnipeg. Table 14 gives well numbers, names, locations, elevations and source of information. Table 15 furnishes depth of top, depth and type of beds underlying the Winnipeg, total thickness, thickness of sand, shale thickness and the sand shale ratios. No attempt has been made to restore the eroded edges of the formation. Where a datum was required the plane for the maps was sea level.

Structure Contour map on the base of the Winnipeg and the Paleogeology of the pre-Winnipeg. (Map III in pocket).

The contours show a bowl shaped basin, oval in outline. The long axis trends northwest and the short axis northeast. The deepest part of the structure lies in the vicinity of central western North Dakota. The sides of the basin tend to flatten at the rim of the structure in Manitoba and North Dakota. A description of the geology of the beds underlying the Winnipeg formation has been discussed previously on pages 39 and 40.

Structure Contour map on top of the Winnipeg

An oval, bowl shaped basin whose long axis trends northwest and whose minor axis trends northeast occupies the position of the Williston depression and has a pattern almost identical to the structure on the base of the Winnipeg. (Map II in pocket).

Sand Isoloth of Winnipeg Formation

Lateral and vertical variations in the extent and thickness of the sand are readily observed in the sand isolith. (Map IV in pocket). There is abundant subsurface information for North Dakota and for Manitoba. Not much doubt was entertained by the writer while contouring these areas. However, for remaining areas, incomplete information necessitated considerable inference in the construction of this map, as well as in some of the other stratigraphic maps.

The thickest sand sections are present in the vicinity of the Gronlid Well in north central Saskatchewan and in the vicinity of the Turner Gapp Well in northeastern North Dakota. No sand is present over a large area of central North Dakota. It begins to form, and thickens outwards from this area into Montana, South Dakota, Saskatchewan, Manitoba and Eastern North Dakota.

Shale Isolith of Winnipeg Formation

Little shale is encountered in the Winnipeg formation other than in central eastern North Dakota and southeastern Manitoba which are the localities of greatest thickness of shale. (Map V in pocket).

Isopach of Winnipeg Formation

Thickest accumulations of Winnipeg formation are shown in central northwest Saskatchewan around the Gronlid Well in southeast Manitoba and in northeast North Dakota around the Turner Gapp Well, and in central North Dakota around the Semling Well. (Map VI in pocket).

Lithofacies Map of Winnipeg Formation (Map VI in pocket).

The lithofacies pattern shows the greatest sand shale ratio to follow the outer limits of the basin. The lowest sand to shale ratio is in central and northeastern North Dakota.

T A B L E 14

Location of Wells and Source of Information

Well No.	Elevation	Name	Location	Source of Information
1	2451	Norcanols Pennant	4-14-18-16W3	Manitoba Mines Branch - Unpublished Litholog
2	2884	Imperial Swift Current	11-20-13-13W3	Manitoba Mines Branch - Unpublished Litholog
2a		Tidewater Braddock	5-7-14-10W3	Confidential
2b		Quintana Melaval	2-14-18-4W3	Confidential
3	2332 G.L.	Imperial Morse	1-6-18-7W3	Manitoba Mines Branch - Unpublished Litholog
4	2410 G.L.	Norcanols Ogema	4-24-7-23W2	Manitoba Mines Branch - Unpublished Litholog
4a	2511 G.L.	Shell Big Muddy Lake No. 1.	15-12-3-21W2	Shell Oil Company Litholog
5	2541	Norcanals Parry	16-8-9-21W2	Manitoba Mines Branch - Unpublished Litholog
5a		Sohio Socony Avonlea	15-7-12-21W2	Confidential
6	2206 G.L.	Imperial Lawson	16-13-21-6W3	Manitoba Mines Branch - Unpublished Litholog
7	1949	Imperial Elbow	12-25-23-6W3	Manitoba Mines Branch - Unpublished Litholog
7a		Tidewater Birsay Crown	13-4-25-8W3	Confidential
7b	2200	Husky Phillips Eatonia	4-32-26-24W3	Confidential
8	2206	Albercan Crown #1	13-22-45-11W3	Saskatchewan Government Schedule of Wells 1951
8a		Albercan Mayfair #1	13-32-35-3W3	Dr. W. O. Kupsch - Saskatchewan Geol. Survey
8b	1631	Saskatchewan Big River No. 1	5-10-55-7W3	Saskatchewan Government Schedule of Wells 1951

T A B L E 14. - CONT'D.

LOCATION OF WELLS AND SOURCE OF INFORMATION

Well				
No	Elevation	Name	Location	Source of Information
8c	1862	Husky Jet Monnerey	1-16-53-24W3	Confidential
9	1420.8	Hudson's Bay Gronlid	15-32-47-17W2	Manitoba Mines Branch - Riley's Reproduction.
10	1575	Peesane Strat.Test #1	9-22-45-12-W2	Saskatchewan Government Schedule of Wells 1951
10a	1240±	Hudsons Bay Strat. Test No. 1	12-20-47-2W2	Confidential
10b		Sohio Plunkett	1-15-34-25W2	Confidential
10c	1600±	Husky Phillips Fitzmaurice	16-18-27-8W2	
11	1265	Zenon Park No. 1	1-10-47-13W2	Saskatchewan Government Schedule of Wells 1951.
12	1220	Petrolcan No. 2	16-35-50-15W2	Saskatchewan Government Schedule of Wells 1951
13	1140	Mafeking Diamond Drill No. 3	12-12-43-26W1	Manitoba Mines Branch - Publication 49-1
14	1140±	Mafeking No. 2	2-45-26W2	Manitoba Mines Branch - Publication 49-1
15	760±	McGuckin Test Holes	33-1WP	Manitoba Mines Branch - Miscellaneous Logs
16	840±	Winnipegosis No. 1	29-30-17WP	Manitoba Mines Branch - Publication 49-1
17	1812 G.L.	Imperial Foxwarren	16-22-19-22WP	Litholog by G. J. Genik
18	1588	Imperial Madeline	16-18-18-29WP	Litholog by G. J. Genik
19	1775 G.L.	Imperial Birtle	1-27-17-26WP	Litholog by G. J. Genik
20	1140	Langford No. 1	5-29-14-14WP	Manitoba Mines Branch - Publication 49-1
21	1608	California Standard Daly 15-18	15-18-10-27WP	Litholog by G. J. Genik

T A B L E 14 - CONT'D.

Location of Wells and Source of Information

Well No.	Elevation	Name	Location	Source of Information
22	1410	California Standard Hartney 16-33	16-33-5-20WP	Litholog by G. J. Genik
23	1355	California Standard Wawanesa	3-18-18WP	Litholog by G. J. Genik
24	1305 G.L.	Brandon Coutts No.2	14-16-10-19WP	Manitoba Mines Branch - Publication 49-1
25	850	Portage la Prairie	3-9-12-7WP	Manitoba Mines Branch - Publication 49-1
26	800	Stony Mountain	29-12-2EP	Manitoba Mines Branch - Publication 49-1
27	780	Red River No. 1	13-6-13-6EP	Litholog by G. J. Genik
28	1244±	Whiteside No. 1	13-5-3-12EP	Litholog by G. J. Genik
29	795	Red River No. 2	2-1-5-1WP	Litholog by G. J. Genik
30	797	Red River Hepner #2	3-1-5-2WP	Manitoba Mines Branch - Logged by L. B. Kerr
31	875±	Hart Green Wakeley #1	1-28-4-4WP	Manitoba Mines Branch - Logged by L. B. Kerr
32	1270	Commonwealth Manitou #1	8-26N-9WP	Manitoba Mines Branch - Publication 49-1
32a	825±	Turner Oil Gapp #1	7-163N-55W	North Dakota Geological Survey - Report of Investigation No. 2
32b	824	Town of Hamilton Well	35-162N-53W	Manitoba Mines Branch - Files
33	1600 G.L.	Wohlitz No. 1	32-160N-60W	Manitoba Mines Branch - Files
34	1555 G.L.	Skjervheim No. 1	28-159N-60W	Manitoba Mines Branch - Files
35	1535	Union Oil, Aanstadt	29-158N-62W	Manitoba Mines Branch - Files
36	825	Town of Grafton	13-157N-53W	Manitoba Mines Branch - Files
37	825	Univ. of North Dakota	5-151N-50W	D.F. Towse, N.D.G.S., Pers. Comm.
37a	844	R.R. Dev., Edgar Berg No. 1	35-152N-51W	Rept. of Invest. No. 2, N.D.G.S.
38	1510	Glenfield Oil Company	18-146N-62W	Manitoba Mines Branch - Files

T A B L E 14 - CONT'D.

Location of Wells and Source of Information

Well No.	Elevation	Name	Location	Source of Information
39	923	U.S.G.S. Test Holes	4-139N-51W	D.F. Towse, N.D.G.S. Pers. Comm.
40	955	Ruddy Bros. No. 1	11-132N-48W	D.F. Towse, N.D.G.S. Pers. Comm.
41	605±	Soldiers' Home	11-134N-56W	D.F. Towse, N.D.G.S. Pers. Comm.
42	2025	Franklin Invest. No.1.	35-133N-75W	Manitoba Mines Branch - Files
42a	2012	Rosser Pendleton	35-133N-76W	Tops of Signif. Wells, N.D.G.S. Well Data
43	1900	Cont. Pure Oil Dav. No. 1	6-140N-77W	D.F. Towse, N.D.G.S., Pers. Comm.
44	1805	Prairie Oil Armstrong	2-140N-73W	Manitoba Mines Branch - Files
44a	1869	Gaier No. 1	11-141N-67W	Tops of Signif. Wells, N.D.G.S. Well Data
45	1963	Magnolia State	36-141N-73W	G.W. Macauley, Master of Science Manuscript, 1951
46	2025 G.L.	Emma L. Semling	18-141N-81W	Manitoba Mines Branch - Files
46a	2284	Fritz Leutz	28-142N-89W	Tops of Signif. Wells, N.D.G.S. Well Data
47	2000±	Samedan Vaughan Hanson	10-146N-81W	G.W. Macauley, Master of Science Manuscript, 1951.
48	3000±	Pure Oil Co.'s State #1	36-2N-51E	Litholog, Montana School of Mines
49		No. 1 Carter's North Pacific	19-4N-62E	Mines Branch (Manitoba) - Files
50	3267.5	State Royalty No. 1	35-18N-1E	Rept. of Inves. 65, S.D.G.S., 1949
51	3430	N. Ordn. Harding Shoel	1-17N-1E	Rept. of Inves. 65, S.D.G.S., 1949
52	3322	N. Ordn. Government No. 1	32-15N-2E	Rept. of Inves. 65, S.D.G.S., 1949

T A B L E 15.

THICKNESS AND LITHOLOGIC DATA FOR THE WINNIPEG FORMATION

All Elevations are Below Sea Level, Except When Identified by a + Sign Before an Elevation, Which Signifies Above Sea Level.

Well No.	Top of Winnipeg	Bottom on Ordovician	Bottom on Cambrian	Bottom On Pre-cambrian	Total Thickness	Feet of Sand	Feet of Shale	<u>Sand</u> <u>Shale</u>	Ratio
1	4019		4109		100	25	75	1/3	
2	4206		4216		10	10?		1/1	?
2a		Winnipeg Reported							
2b		Winnipeg Reported							
3	4400	4464 in Winnipeg?			65	50?	15	3/1	?
4	6195		6385	6980	190	170	20	8/1	
4a	7204		7405?		190	140	50	3/1	
5	6013		6097		100	80	20	4/1	
5a		Winnipeg Reported							
6	4179		4204?						
7	3516								
7a		Winnipeg Reported							
7b	3675		4564						
8	1709		1719		20	20?	?	?	
8a		Winnipeg Reported							
8b	324		344		20	20		20/1	
8c		Winnipeg Reported							
9	923			1175	250	245	5	49/1	
10	930			985	55	50	5	10/1	
10a	240			350					
10b		Winnipeg Reported							
10c	3070			3270?	200?				
11	843			941	98	98		98/1	
12	450			550	100±	100		100/1	
13	380			430	52	50	2	25/1	
14	360			422	50	50		50/1	
15	620±			520±	100	70	30	2.13/1	

T A B L E 15 - CONT'D.

THICKNESS AND LITHOLOGIC DATA FOR THE WINNIPEG FORMATION

All elevations are below seal level, except when identified by a + sign before an elevation, which signifies below sea level.

Well No.	Top of Winnipeg	Bottom on Ordovician	Bottom on Cambrian	Bottom on Pre Cambrian	Total Thickness	Feet of Sand	Feet of Shale	<u>Sand</u> <u>Shale</u>	Ratio
16	500			620	120	50	70	.71/1	
17	2218			2358	140	80	60	1.25/1	
18	2702			2852	150	90	60	1.50/1	
19	2330			2481	150	70	80	.88/1	
20	1240			1365	125		125	125/1	
21	3612			3762	150	50	100	.50/1	
22	3540			3720	180	35	145	.25/1	
23	1730			1935	205	150	50	3/1	
24	2260								
25	510			640	130	10	120	.083/1	
26	+190			+92	98	13	85	.166/1	
27	+530			+430	130	10	120	.083/1	
28	+784?			+490	30	30		30/1 ?	
29	25			155	130	80	50	1.60/1	
30	118			245	115	100	15	7/1	
31	375			575	200	100	100	1/1	
32	1210			1340	130	10	120	.083/1	
32a	+83			165	348	104	244	.400/1	
32b	+62			73	135	130	5	26/1	
33	1145								
34	1645			1849					
35	1505			1685	180	20	160	.125/1	
36	+80			78	158	3	155	.021/1	
37	+418	+410?			10?				
37a	+414			+344	70				
38	1240			1380	140		140	.007/1	

TABLE 15 - CONT'D.

THICKNESS AND LITHOLOGIC DATA FOR THE WINNIPEG FORMATION

All elevations are below sealevel, except when identified by a + sign before an elevation, which signifies below sea level.

Well No.	Top of Winnipeg	Bottom on Ordovician	Bottom on Cambrian	Bottom on Pre-Cambrian	Total Thickness	Feet of Sand	Feet of Shale	<u>Sand</u> Shale Ratio
39		N O W I N N I P E G						
40		N O W I N N I P E G						
41	230			300	70?	60?		
42	2855			3055	200	120	80	1.5/1
42a	3038	3288?			250 _±			
43	4600	4810?		5050?	210	50	160	.33/1
44	1800	2014?			215	10	205	.05/1
44a	2106	2276?			170			
45	3212	3529?			315	65	250	.25/1
46	6285	6635?						
46a			10,059					
47	6720	7020?			300	50	250	.20/1
48	6050	6185?			135			
49	6233?	6368?			100			
50	4460	4606			146	66	80	.75/1
51	4465	4570			105	35	70	.50/1
52	3608	3716?			108	50	58	1/1

CHAPTER VII

THE SOURCE AND DEPOSITION OF THE WINNIPEG FORMATION

Several authors have suggested that the Winnipeg was derived from the reworking of the weathered Precambrian and the resulting sand was layed down as a blanket deposit. From his study of the Winnipeg the writer strongly believes that the source and deposition of the Winnipeg was a result of several phenomena and not merely from the reworking of an old land mass and simple deposition, as was previously believed. Those sources which have possibly contributed to the formation are now discussed.

SOURCE OF SAND IN THE WINNIPEG.

CAMBRIAN? - PRECAMBRIAN OF NORTHWEST TERRITORIES.

Precambrian or Cambrian sandstone covers a large area south of Lake Athabaska and is known as the Athabaska sandstone. As this sandstone outcrops only about two hundred miles north of the 250 foot thick section of Winnipeg sand in the Gronlid Well area some relationship between the Winnipeg and Athabaska sandstones is not illogical. A sample of the Athabaska sandstone was studied thoroughly, and it has several lithologic features similar to the Winnipeg. The Athabaska is pure quartz sandstone, highly cemented and the grains are almost completely surrounded by authigenic (secondary) quartz. Biotite and minor tourmalines are the only heavy minerals of any prominence.

Transportation and reworking of this Athabaska sand could have removed the unstable biotite, concentrated the stable heavy minerals to a suite such as is found in the Winnipeg, and could have removed most of the authigenic overgrowths of the sand.

As the Athabaska sandstone is so close to the great thickness of Winnipeg sand around the Gronlid Well, and because of the lithologic similarities between the Winnipeg and Athabaska sandstones, it is suggested here that the Cambrian?-Precambrian? sandstones in the Lake Athabaska area be considered as a source of the sand in the Winnipeg formation.

CAMBRIAN OF WESTERN CANADA

Because the Cambrian of Saskatchewan contains glauconite, poorly sorted, angular, sometimes pink sand, or dolomite, it may be differentiated from the Winnipeg. The texture and heavy minerals of the Cambrian are nearly identical with those of the Winnipeg. The Cambrian lies directly beneath the Winnipeg in central, eastern and southern Saskatchewan.

Geologists examining subsurface sandstones and subsurface data, experience much doubt and considerable difficulty in separating the closely associated Winnipeg and Cambrian sands in Saskatchewan.

As there are so many similarities between the Winnipeg sands and the Cambrian sands of Saskatchewan, the Cambrian sands may well have been a source of the Winnipeg.

ARCTIC AREA

Basal conglomerate in a sand indicates that transportation of the sand has not been as lengthy as for a sand which contains no basal conglomerate. Small amounts of basal pebble conglomerate are found in some localities of the Winnipeg formation? of the Hudson Bay Lowland. (Plate XI, 3). Basal pebble conglomerate is not found in the Winnipeg formation to the south. The sands in the Winnipeg? in the Hudson Bay Lowland have therefore not been transported as long or as far as those sands in the Winnipeg formation to the south. With this idea, the writer believes some sand of the Winnipeg formation might have had an Arctic area as its source.

PRECAMBRIAN OF SIOUX ARCH

Baker (personal communication) believes that the red quartzite of the Sioux Arch has been the source for the St. Peter sandstone. This Precambrian quartzite, as it is composed of highly indurated quartz grains, could, if broken down by the incessant pounding of a stormy epeiric sea, be a contributing factor to the formation of the

Winnipeg sand. However, as the sand isolith shows no sand just north of the Sioux uplift the contribution of this rock to the formation of the Winnipeg is doubtful. But there is a further possibility that currents might have swept away the sand formed from the Sioux quartzite into other localities. There is then a possibility that the Sioux Arch was attacked by agitated seas and the quartzite was broken down into sand grains which might have been subsequently deposited as part of the Winnipeg formation.

PRECAMBRIAN OF CENTRAL AND SOUTHWEST MANITOBA

Underlying the Winnipeg in Manitoba the Precambrian commonly shows a high degree of weathering (Table 12, p.123). It appears questionable for the Winnipeg formation to have been derived principally and directly from the reworking of underlying weathered Precambrian beds because of this existing abundance of weathered material.

If the Winnipeg is not derived from the reworking of the old Precambrian land mass then, there should normally be a conglomerate at the base of the Winnipeg or in the weathered Precambrian material. However, this has been reported only on rare occasions. This objection is actually weak, because it has been pointed out that sandstones, and even limestones may be deposited on the Pre-

cambrian without either an intervening basal conglomerate or highly weathered surface. (page 121).

It seems then, that most of the Winnipeg formation has been emplaced on, and not directly derived from the underlying weathered Precambrian.

The sand of the Winnipeg possesses a high degree of roundness, sphericity, and exhibits abundant frosting and marked pitting. In the sands only the very stable heavy minerals occur. These features are typical of a long transported, well sorted, and much reworked sand. Marine fossils establish the depositional environment of the Grindstone Point and Deer Island units as marine. In the Black Island unit we have no such positive evidence, however, the sand in this unit contains a horizontal bedding some possible worm tubes, has an extremely wide occurrence, and possess a high degree of uniformity. These features are indicative of sands deposited in marine conditions.

Winds, rivers and streams, may have all functioned as integral factors in the pouring of the sands of the Winnipeg formation into their depositional sites.

TECTONIC ENVIRONMENT

The tectonic depositional site of the Winnipeg may be deduced from its lithologic association. Lithologic association according to Krumbein and Sloss, is a concept derived from the principle that sedimentary properties are related to the tectonic intensity which prevailed during their deposition. The degree of tectonism, and the kind of tectonic element present during the deposition of a unit, may be determined by its lithologic association.

The Winnipeg formation because it consists of a pure quartz sand and green shale, is placed in the category of a unit which has formed on the stable shelf of a craton. (Krumbein and Sloss, 1951, pp 336-338). This tectonic category seems to be a reasonable deduction as the structure contour maps of the Winnipeg show a shallow, extensive basin. The lithology of the Winnipeg is an association exemplifying extremely slight tectonism.

SOURCE OF SHALE IN THE WINNIPEG

As for the source of the sand, the shale is also believed to be derived from many parent sources.

Although X-ray diffraction photos show the clay to be composed of material generally found as the normal weathering of rocks, there are reasons to believe that the shales of the Winnipeg formation were derived from volcanic sources.

Kay (1935) and Baker (personal communication) gives several evidences to support the idea that continentally spread middle Ordovician clays are the result of widespread volcanism. Clays of northwest South Dakota possibly correlated to the Winnipeg formation contain bentonite or metabentonite (altered original volcanic ash fall), according to Baker. If this is so then the clays of the Winnipeg in North Dakota, Manitoba and Saskatchewan may also be of volcanic origin. In the Winnipeg shales are present small, angular, poorly sorted quartz grains, and shardy, glassy like materials, suggestive of deposition relatively soon after their formation from a parent rock. These corroborate the volcanic theory of origin.

Even though this evidence seems strong, the writer believes that if volcanism was so widespread there should be more lavas and volcanic ejectementa than are known. Because these volcanics are rare, the suggestion is put forth that the clays of the Winnipeg are not due entirely to a volcanic source but have resulted from an other possible source such as weathering.

Pettijohn (1950, p. 281) believes that abrasion - forming mechanical clays, weathering - forming residual clays, and chemical reactions - forming chemical clays are important causal processes in clay formation.

Both volcanic and non-volcanic processes seem to have been important factors in the production of clay within the Winnipeg formation. These clays were transported as particles by wind, or as colloidal material in suspension, or as materials in solution. They were ultimately deposited in seas where conditions were favorable.

SEQUENCE OF EVENTS IN THE DEPOSITION OF THE WINNIPEG FORMATION.

Sands formed by many agents and from diverse sources were carried by rivers, streams, currents and winds to the depositional site (an epeiric sea) of the Black Island unit of the Winnipeg formation. The Black Island unit is spread over much of central western Canada and over the northern portion of the central United States.

After deposition of the Black Island unit ceased, pyrite oolites and phosphatic nodules which suggest an unconformity, were formed on the top of the Black Island unit. This change in conditions was accompanied by the influx of sand like that in the Black Island unit. The seas were alive with dominantly small animal forms such as brachiopods, bryozoans, conodonts, coelenterates and cephalopods. Conditions favoring pyrite deposition and possibly the deposition of some lime existed. These effects, beginning after the cessation of deposition of the Black Island unit caused the formation of the shale-sand Grindstone Point unit.

An extreme, though gradual change effected the formation of the very limy and dolomitic Deer Island unit. The unit of dolomitic sandstone and arenaceous dolomite is highly fossiliferous, the fauna representing generally large forms. Sand was still being deposited but lime deposition was predominant. Perhaps cooler waters from the north encroached southward upon the seas with the resulting change in temperature and composition of the sea waters being responsible for the mass deaths of the then existant animals.

CHAPTER VIII

CORRELATION AND AGE

INTRODUCTION

The age and correlation of the Winnipeg formation is discussed within this chapter.

The presence of the Winnipeg has been definitely established over most of Manitoba, eastern Saskatchewan southwestern Montana and all of North Dakota. Its occurrence has been questioned however, in northwest South Dakota, western Saskatchewan, along the Paleozoic escarpment in northern Manitoba and Saskatchewan, and in the Hudson Bay Lowland area of Manitoba. Arguments are advanced to show that it is the Winnipeg formation which exists at these localities.

CORRELATION

South Dakota

According to the Montana Geological Survey (personal communication) there is Winnipeg formation in the Carter's Northern Pacific Well and Pure Oil State No. 1 Well in southeastern Montana. In South Dakota about seventy miles southeast of these Montanan Wells, in the State Royalty No. 1 and the Northern Ordnance Government Wells, a sand-shale unit directly below Whitewood* dolomite.

* The Whitewood dolomite is equal to the Red River formation.

mite has been correlated by C. L. Baker (personal communication) with the St. Peter sandstone or Winnipeg formation.

Because of their stratigraphic position, their general similarities in lithology and their proximity to known Winnipeg formation the sandshale section in north-west South Dakota underlying the Whitewood dolomite and above the Cambrian or Precambrian is placed by the writer as the southern extension of the Winnipeg formation.

Western Saskatchewan

Many writers have pointed out the difficulty in determining the lower limit of the Winnipeg from the Cambrian in Saskatchewan. The isopach map indicates a thinning of the Winnipeg towards the western border of Saskatchewan. (Map VI in pocket).

Many features occurring singly or together may be utilized to assist in the determination of the bottom of the Winnipeg from the top of the Cambrian. Features which are never observed in the known Winnipeg formation are as follows:

1. Presence of glauconite
2. " angular sand grains (abundant angular)
3. " poorly sorted sand grains
4. " pink quartz sand

5. Presence of dolomite beds within the sand beds
6. Presence of micaceous shales
7. Presence of Cambrian fossils

Northern Manitoba and Saskatchewan

To facilitate discussion, the basal sand beds of the Ordovician in northern Manitoba and Saskatchewan have been referred to as the Deer Island unit of the Winnipeg formation. These beds are stratigraphically equal to those of known Winnipeg, they are lithologically and paleontologically similar to the Deer Island unit of the known Winnipeg, and they have been called Winnipeg sandstone by Wallace (1925). This evidence now warrants the placing of these basal sands (on the fringe of the Paleozoics from Deschambault Lake eastward to the Minage^c River) with the Deer Island unit of the Winnipeg formation.

Hudson Bay Lowland

Stratigraphically and lithologically the Hudson Bay Lowland basal sand of the Ordovician is identical to the Deer Island unit to the southwest along the northern outcrops of the Paleozoics. This conclusive information enables the writer to establish the basal sand of the Ordovician in the Hudson Bay Lowland as a northern extension of the Deer Island unit of the Winnipeg formation.

AGE OF THE WINNIPEG FORMATION

INTRODUCTION

Sufficient reason to believe that, although parts of the Winnipeg formation are of lower Upper Ordovician, (Macauley 1951), the Winnipeg may represent several ages.

Until the age of the Red River beds overlying the Winnipeg formation is definitely established as either Upper or Middle Ordovician there will always be the problem of definitely dating the Winnipeg.

Age of the Red River Beds

Suffice it to say here that there are three prevailing schools of thought regarding the age of the Red River formation. These are, that the Red River is Upper Ordovician, that the Red River is Middle (Trenton) Ordovician, or that the Red River may be Middle and or Upper Ordovician.

Age of the Winnipeg Formation

(Personal Communication)

C. L. Baker of the South Dakota Geological Survey favors placing the sand-shale beds (Grindstone Point unit) in northwest South Dakota as Black River, Middle Ordovician, and the Black Island unit as Chazy of lower Middle Ordovician. His concept is based in

part, on the occurrence in the sand-shale beds (Grindstone Point unit) of Diplograptus and Callograptus which are characteristic of the lower part of the Viola limestone of the lower Trenton. However, Foerste (1932, p. 53) pointed out that the Viola limestone is Cincinnati and is overlain by the Fernvale member of the Richmond.

Furnish, Barragy and Miller (1936, p. 1341) consider the shale and siltstone beds (Winnipeg formation) to be equal to the lower Whitewood of the Upper Ordovician. Ballard (1942) proposed that the shale in the Winnipeg may be partly equivalent to the Black River. Even a Cambrian age (J. F. Wright, 1922) for the Winnipeg formation has been suggested.

In the Black Island unit no diagnostic fossils have yet been found. In the Grindstone Point unit Macauley points out that several forms introductory to the Red River forms are present. In the Deer Island unit fossils seem to be typical of the Red River.

The writer's conviction, from arguments presented, is that the Winnipeg formation may range in age from as early as St. Peter or Chazy time up into Red River time.

CORRELATION OF THE WINNIPEG TO OTHER TIME ROCK UNITS

Deer Island Unit and the Lander Sandstone

A. K. Miller (1930 p. 196) places the Dog Head limestone (Lower Mottled) as equivalent to the Lander sandstone which is the basal member of the Bighorn formation of Upper Ordovician age.

The top beds of the Winnipeg, that is the Deer Island unit, because they grade conformably into the overlying Dog Head limestone (Upper Ordovician) must be closely associated with the Upper Ordovician, Red River formation. This association with the Dog Head, and the same stratigraphic position of the Lander sandstone with the Dog Head, strongly indicate that the Deer Island unit of the Winnipeg formation may be correlated to the Lander sandstone of Wyoming.

The Grindstone Point Unit and the Red River Formation

As the Grindstone Point member contains fauna introductory to the Red River forms, and as the Grindstone Point unit is gradational into the overlying Deer Island unit, the Grindstone Point unit might actually represent the lowest part of the Red River formation.

The St. Peter and the Black Island Unit

Lack of diagnostic fossils in the Black Island

unit, and the possible existence of an unconformity between this unit and the overlying Grindstone Point unit suggest (especially if the Red River is Trenton age), that the Black Island unit could probably be correlated with the St. Peter sandstone.

Red River Formation and the Winnipeg Formation

Another possible correlation is suggested by Foerste (1935, p. 3). He stated although he had no definite faunal evidence that the basal part of the Red River formation may be represented by the Winnipeg formation.

A. D. Baillie, Dr. W. O. Kupsch and the writer, in the summer of 1951, collected several fossils from the Deer Island or upper unit of the Winnipeg formation. These fossils by their gross appearance are readily compared with some of those forms occurring in the Dog Head and other Red River limestones.

This new faunal evidence though by no means conclusive, corroborates Foerste's idea that the Winnipeg sandstone immediately beneath the Dog Head limestone may be the lowest part of the Red River formation.

POSSIBLE DISAPPEARANCE OF THE NAME WINNIPEG
FORMATION

The Deer Island and Grindstone Point units were shown to be possible basal portions of the Red River formation. The Black Island unit was shown to be a possible correlative of the St. Peter sandstone. If these situations could be definitely proven, then the existence of the Winnipeg formation as such is impossible.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The Winnipeg formation has a maximum thickness of about 350 feet and occurs over all the Paleozoic area in Manitoba, North Dakota, eastern and northeastern Saskatchewan, eastern Montana and northwestern South Dakota.

The Winnipeg formation consists of three units. The top one called the Deer Island unit is composed of five feet to fifteen feet of sandstone grading upwards from its base, into an arenaceous dolomite. This unit has within it a fauna similar to some of the fossils in the Red River formation.

The middle unit called the Grindstone Point, consists of nearly three hundred feet of predominantly green, to minor purplish, fissile, fossiliferous, splintery, waxy, pyrite bearing shale, infrequent calcareous sandstone bands, and abundant interbedded (iron stains) poorly consolidated sandstone. Fossils in this unit are small ^a brachiopods, pelecypods, bryozoans, gastropods, cephalopods and corals, some of which are introductory to Red River ^{fauna} fossils.

At the base of the Winnipeg comprising the lowest unit of the formation, is the Black Island unit which ranges up to one hundred feet in thickness. Its upper limit is

sometimes marked by a bed of oolitic pyrite or possibly by accumulations of goethite oolites. The Black Island unit has no? fossils, consists of highly rounded, frosted, pitted, pure, medium grained quartz sand, and has few accessory detrital minerals.

Overlying the Winnipeg in all reported areas is an arenaceous dolomite or dolomitic limestone of Upper Ordovician? age. Underlying the Winnipeg may be Cambrian sands and shales, older Ordovician sands and shales or Precambrian rocks. Whereas the Precambrian-Winnipeg contact is readily determined, much difficulty has been experienced in attempting to separate the base of the Winnipeg from the top of the Cambrian. The Cambrian may contain pink, angular, or poorly sorted quartz grains, glauconite, dolomite beds interbedded with sand beds, greyish micaceous shales and Cambrian fossils. The Winnipeg exhibits none of these features.

Texturally, the sand of the Winnipeg has an average grain diameter of .20 millimetres, it is well sorted, highly spherical, much rounded, and markedly frosted and pitted. Winnipeg sand contains only a trace of the stable accessory detrital minerals such as zircon, tourmaline and magnetite.

Features, such as textural ones just described and structural features such as cross-bedding, horizontal

bedding, wide areal extent, oolites, nodules, and marine fossils, indicate a marine, depositional environment. The texture and heavy mineral content of the sand suggest deposition after much reworking and transport.

Formation of the Winnipeg was inaugurated by the deposition of the Black Island unit in probably a marine environment. Following this an unconformity? identified by pyrite oolites, goethite oolites, and phosphatic nodules was produced on the top of the Black Island unit. Later the Grindstone Point unit of inter-bedded sand and shale was emplaced, followed finally by a gradual chemical-physical variation which effected the sandy dolomitic or dolomitic limestone deposition of the Deer Island unit.

Tourmalines within the Winnipeg are indicative of certain parent source rocks. Metamorphic, igneous and sedimentary rocks were contributors to the sands of the Winnipeg.

The lithologic association (sand-shale) in the Winnipeg is the result of deposition in an area disturbed only mildly by tectonic pulsations. Structure contours on the top and base of the Winnipeg reveal a wide, shallow, elliptical, basin into which the Winnipeg was poured.

A sand map, or sand isoloth, shows two main areas of thick sand accumulation, one in the Gronlid well district of central Saskatchewan, and the other around the Turner Gapp well of northeastern North Dakota and southeastern Manitoba. Several source areas may have been contributors to the Winnipeg formation:

1. Cambrian?-Precambrian? Athabaska sandstone. It is close to and similar lithologically to the Winnipeg.
2. Cambrian sands of western Canada. They are lithologically similar and lie immediately beneath the Winnipeg in Saskatchewan.
3. Precambrian of the Arctic. The Winnipeg in the Hudson Bay Lowland area contains more poorly sorted grains, more coarse grains and also grains with more strain shadows, than are found in the Winnipeg to the south.
4. Precambrian of southern and western Manitoba. The Winnipeg directly overlies the weathered Precambrian.
5. Precambrian quartzite of the Sioux Arch.

A shale map or shale isolith of the Winnipeg formation discloses the greatest thickness of shale to be in southwestern Manitoba and northern central, and eastern North Dakota. Some volcanic like material in the Winnipeg's shale and the evidence of widespread volcanic clays throughout the Middle Ordovician, tend to suggest the shale of the Winnipeg may be partially from a volcanic source. The study of X-ray powder diffraction photographs does not substantiate an entirely volcanic source for the shale in the Winnipeg. It indicates that chemical and physical disintegration and decomposition, or normal rock weathering,

had provided much of the clay for the shales in the Winnipeg.

From the isopach map there are seen three basins or areas of noticeable thickening within the formation. They occur about the Gronlid well area of north central Saskatchewan, around the Turner Gapp well area of northeastern North Dakota and southeastern Manitoba, and in the vicinity of the Semling well in central North Dakota.

A lithofacies map shows that the percentage of shale increases generally towards the deepest part of the basin.

It was not believed that the basal sands of the Ordovician in the Hudson Bay Lowland, or the same type of sands along the northern fringe of the Paleozoics in Manitoba and eastern Saskatchewan are Winnipeg formation. Sand-shale sections underlying Red River beds in southwestern Saskatchewan and northwestern South Dakota were also not believed to be Winnipeg strata. Lithologic, paleontologic and close stratigraphic similarities indicate that these once questionable Winnipeg beds are definitely Winnipeg formation.

In age the Winnipeg formation may represent times

ranging from Chazyan of lower Middle Ordovician to Richmond of lower Upper Ordovician. Baker on rather inconclusive faunal evidence favors placing the Black Island unit of northwestern South Dakota (he calls it St. Peter) as equivalent in age to the lower part of the Trenton. Furnish, Barragy and Miller (1936, p. 1341) consider the Winnipeg to be Upper Ordovician. Ballard (1942) designates a Black River age for the Winnipeg and Wright (1922) even considered a Cambrian age.

The Deer Island unit may be a correlative of the Lander sandstone in Wyoming because they possess close faunal, lithologic and stratigraphic similarities with one another.

The Grindstone Point unit may represent the basal portion of the Red River formation as the former has introductory faunal forms to, and grades into the Red River beds.

An extremely close lithologic similarity is shown between the Black Island unit and the St. Peter of Chazyan age. Lack of any definite faunal evidence in, and the possibility of an unconformity above the lowermost unit of the Winnipeg formation strongly support the suggestion that the Black Island unit may be a correlative of the St. Peter sandstone.

Foerste's idea (1935) that the uppermost beds of the Winnipeg formation (Deer Island unit) may represent the

lowest part of the Red River formation is corroborated by paleontologic evidence collected in the summer of 1951 and shown in Chapter VII.

If the Deer Island and Grindstone Point units are proven to be the lowermost parts of the Red River formation, and the Black Island unit is proven to be Chazyan, then the Winnipeg as a formation may possibly not exist.

BIBLIOGRAPHY.

- ALCOCK, F. J. (1916), Lower Churchill River Region,
Manitoba, Geol. Sur. of Can.
Summ. Rept., (1916), pp. 133-136.
- ALLEN, D. M. (1939), Stratigraphic Study of Baker
Glendive Anticline Eastern
Montana, Bull. Amer. Assoc. Petrol
Geol., Vol. 23, No. 8, pp. 1246-
1250.
- BALLARD, W. N. (1942), Regional Geology of Dakota Basin,
Bull. Amer. Assoc. Petrol. Geol.,
Vol. 26, No. 10 PP. 1557-1584.
- BASSLER, R. S., Bibliographic Index of America
Ordovician and Silurian Fossils,
Parts I and II, U.S. Nat. Mus.
Bull. 92.
- BELL, R. (1879), Report on Explorations on the
Churchill and Nelson Rivers and
Around God's and Island Lakes,
Geol. Sur. Can. Rept. of Progress
(1878) pp. 1C - 44C.
- BILLINGS, (1865), Paleozoic Fossils, Geol. Sur. of
Can. Vol. I.
- BROWNELL, G. M. and Kliske, A. E. (1945), The Hematite
on Black Island, Lake Winnipeg,
Manitoba, Can. Inst. of Min. and
Met. Transactions, Vol. XLVIII,
pp. 284-293.
- BUCHER, W. H. (1918), On oolites and Pherulites, Jour.
Geol., Vol. 26, 1918, pp. 593-
609.

- COLE, L. H., McMahon, F. J. (1926), Kaolin and Associated Clays of Punk Island, Can. Dept. of Mines, Inves. in Ceramics and Road Materials Branch No. 690 Part V, p. 26.
- COLE, L. Heber, (1928), Silica in Canada, Part II Western Canada, Its Occurrence, Exploitation and Uses, Geol. Sur. Can. Mem. 686, p. 17.
- COUSER, C. W. (1935), Paleozoic Structure and Stratigraphy in Minnesota River Valley, Iowa Univ. Studies in Nat. Hist. Vol. 16, No. 6, pp. 451 - 472.
- CROSBY, W. O. (1899), Archean-Cambrian Contact Near Manitou, Colorado, Bull. Geol. Soc. Amer., Vol. 10, pp. 141 - 164.
- DAKE, C. L. (1921), The Problem of the St. Peter Sandstone, School of Mines and Met. Univ. of Missouri, Published 1921.
- DAPPLES, E.C., KRUMBEIN, W.C., and SLOSS, L.L., (1948), Tectonic Control of Lithologic Associations, Bull. Amer. Assoc. Petrol Geol., Vol. 32, No. 10, pp. 1924 - 1947.
-
- (1950), The Organization of Sedimentary Rocks, Jour. Sed. Pet., Vol. 20, No. 1, pp. 3 - 20.
- DAWSON, G. M. (1886), On Certain Borings in Manitoba and the Northwest Territories, Trans. Royal Society of Canada, Vol. IV, Part IV.

- DEANE, R. E. (1950), Pleistocene Geology of the Simcoe Area, Geol. Sur. Can. Mem. 256, pp. 9-10.
- DECKER, C. E. (1942), Viola Well Core from South Dakota, Bull. Amer. Assoc. Petrol. Geol. Vol. 26, No. 1, pp. 123-126.
- DELURY, J. S. (1924), Wapawekka and Deschambault Lakes Area, Saskatchewan, Geol. Sur. of Can. Summ. Rept. 1924, pt.B, pp. 43B-44B.
- DE WOLF, F. W. and West, W. W. (1939), Stratigraphic Studies of Baker Glendive Anticline, Eastern Montana, Bull. Amer. Assoc. Petrol. Geol., Vol. 23, No. 7, pp. 461-475.
- DONALD, J. T. Analysis Report from Manitoba Mines Branch, Winnipeg, Manitoba.
- DOWLING, D. B. (1895), Notes on the Cambro-Silurian Rocks of Eastern Manitoba, The Ottawa Naturalist, Vol. IX, No. 3, pp.66-68.
- _____ (1898), Report on the West Shore of Lake Winnipeg, Geol. Surv. Can. Ann. Rept. (1901), Vol. XI, Part F, pp. 54F-63F.
- _____ (1900), Report on Geological Exploration in Athabaska, Saskatchewan and Keewatin Districts, Geol. Sur. Can. Ann. Rept. (1903) Vol. XIII, Part 6.
- EHLERS, A. (1943), Williston Basin Wildcat Test Oliver County, North Dakota, Bull. Amer. Assoc. Petrol. Geol., Vol. 27, No. 12, pp. 1618-1622.

- FOERSTE, A. F. (1929), The Cephalopods of the Red River Formation of Southern Manitoba, Reprinted from Denison Univ. Bull., Jour. Sci. Lab., Vol. XXIV.
- _____ (1932), Black River and Other Cephalopods from Minnesota, Wisconsin, Michigan and Ontario Reprinted from Denison Univ. Bull., Jour. of Sci. Lab., Vol. XXVII, Part I and Part II.
- _____ (1935), The Cephalopods of the Maquoketa Shale of Iowa. Reprinted from Denison Univ. Bull., Jour. of Sci., Lab., Vol. XXX.
- FURNISH, W. M., Barragy, E.J., and Miller, A. K. (1936), Ordovician Fossils and Upper Part of Type Section of Deadwood Formation, South Dakota, Bull. Amer. Assoc. Petrol. Geol., Vol. 20, No. 10, pp. 1329-1341.
- GRABAU, A. W. (1913), Principles of Stratigraphy, A. G. Seiler and Co., New York.
- GRAHAM, W. A. P. (1929), Heavy Minerals of the Upper Cambrian Formations of Minnesota, Bull. Geol. Soc. Amer., Vol. 40, No. 1, p. 183.
- _____ (1930), A Textural and Petrographic Study of the Cambrian Sandstone of Minnesota, Jour. Geol., Vol. 38, No. 8, pp. 696-716.
- _____ (1933), Petrology of the Cambro-Ordovician Contact in Minnesota, Jour. Geol., Vol. 41, No. 5, pp. 468-486.

- HAYES, A. O. (1915), Wabana Iron Ore in Newfoundland, Geol. Sur. Can. Mem. 78, pp. 89-94.
- HUME, G. S. (1925), The Paleozoic Outlier of Lake Timiskaming, Ontario and Quebec, Geol. Sur. Can. Mem., 1945.
- _____ (1933), Oil and Gas in Western Canada (second edition), Geol. Surv. Can. Econ. Geol. Ser., No. 5, P. 257.
- HUSSEY, R. C. (1926), The Richmond Formation of Michigan, Contributions from the Museum of Geology, Univ. of Michigan, Vol. II, No. 8, pp. 113-187.
- HUTT, G. M. and Seibert, V. J. (1936), Industrial and Fuel Minerals of Manitoba, Can. Min. Met. Bull. 266, pp. 316-332.
- JOHNSON, J. H. (1944), Paleozoic Stratigraphy of the Sawatch Range Colorado, Bull. Amer. Assoc. Petrol. Geol., Vol. 55, No. 3, p. 311.
- KAY, G. Marshall (1935), Ordovician Stewartville-Dubuque Problems, Jour. Geol. Vol. XLIII, No. 6.
- _____ (1929), Stratigraphy of the Decorah Formation, Jour. Geol., Vol. XXXVII, No. 7.
- _____ (1935a), Ordovician Altered Volcanic Materials and Related Clays, Bull. Geol. Soc. Amer., Vol. 46, pp. 238.
- KERR, L. B. (1951), The Stratigraphy of Manitoba with Reference to Oil and Natural Gas Possibilities, Man. Dept. of Mines & Nat. Res., Manitoba Mines Branch, Publication 49-1.

- KIRK, E. (1936), The Harding Sandstone of Colorado, Amer. Jour. Sci., Fifth Series, Vol. XX, pp. 456 - 461.
- KLINE, V. H. (1942), Stratigraphy of North Dakota, Bull. Amer. Assoc. Petrol. Geol. Vol. 26, No. 3, pp. 336 - 379.
- KRUMBEIN, W. C. (1941), Measurement and Geological Significance of Shape and Roundness of Sedimentary Particles, Jour. Sed. Petrol., Vol. II, No. 2, pp. 64-72.
- KRUMBEIN, W.C. and GARRELLS, R.M. (1952), Origin and Classification of Chemical Sediments in terms of pH and Oxidation Reduction Potentials, Jour. Geol. Vol. 60, No. 1, pp. 1 - 33.
- _____ (1948), Lithofacies Maps and Regional Sedimentary Stratigraphic Analysis, Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 10, pp. 1909 - 1923.
- KRUMBEIN, W.C., DAPPLES, E.C., SLOSS, L.L. (1949), Sedimentary Tectonics and Sedimentary Environments, Bull. Amer. Assoc. Pet. Geol., Vol. 33, No. 11, pp. 1859-1891.
- KRUMBEIN, W.C., SLOSS, L.L. (1951), Stratigraphy and Sedimentation, W. C. Freeman and Co., San Francisco, Calif.
- KRYNINE, P. D. (1946), The Tourmaline Group in Sediments, Jour. Geol. Vol. LIV, no. 2, pp. 65 - 87.
- LAIRD, W. M. (1941), Selected Deep Well Records, North Dakota Geol. Sur., Bull. 12.
- _____ (1944), Stratigraphy and Structure of North Dakota, Nat. Oil, North Dakota Geol. Sur., Bull. 18.

- LAIRD, W. M. (1946), The Subsurface Stratigraphy of the Nesson Anticline, North Dakota Geol. Sur. Bull. 21, pp. 11-25.
- LAMAR, J. E. (1927), Geology and Economic Resources of the St. Peter Sandstone of Illinois, Ill. State Geol. Sur., Bull., 53.
- MACAULEY, G. W. (1951), The Stratigraphy of the Winnipeg formation, University of Manitoba, Master of Science, Manuscript, 1951.
- MATHIAS, H. E. (1925), Syngenetic Origin of Pyrite Concretions in the Pennsylvanian Shales of North Central Missouri, Jour. Geol., Vol. 36, pp. 440-450.
- MCINESS, W. (1913), The Basins of the Nelson and Churchill Rivers, Geol. Sur. of Can. Mem. 30, p. 61.
- MILLER, A. K. (1930), The Age and Correlation of the Big-horn Formation of Northwestern United States, Am. Jour. of Sci., Vol. 20, pp. 195-213.
- MOSS, R. G. (1936), Buried Precambrian in U.S.A., Bull. Geol. Soc. Amer., Vol. 47, pp. 935 - 966.
- NAGELSCHMIDT, G. (1935) Rontgenographische Untersuchungen an Tonen II, Der Mineralbestand des Malliser Tones, Groth Zeitschrift Fur Kristallogra Band 87, pp. 136 - 144. Geol. Sur. Can. Lib. Ottawa, Canada.

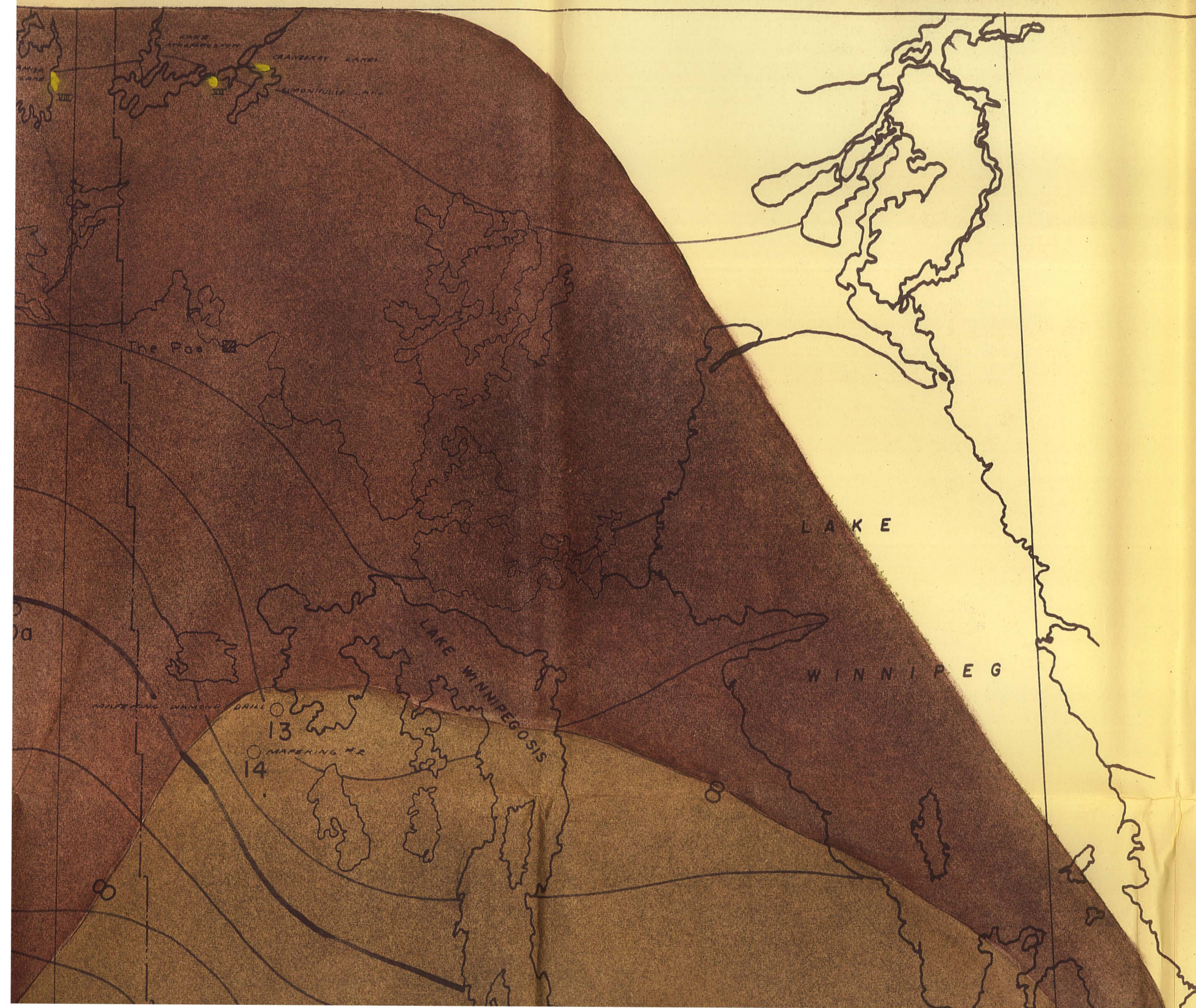
- NELSON, S. J. (1951), Preliminary Report on the Paleozoic Stratigraphy of the Churchill River, Department of Mines and Technical Surveys (Geology) Ottawa, Canada.
- PAYNE, T. G. (1942), Stratigraphical Analysis and Environmental Reconstruction, Bull. Amer. Assoc. Pet. Geol., Vol. 26, No. 11, p. 1697.
- PETTIJOHN, F. J. (1926), Intraformational Phosphate Pebbles of the Twin City Ordovician, Jour. Geol., Vol. 34, pp. 361 - 373.
- _____ (1949), Sedimentary Rocks, Harper and Brothers N.Y.
- QUINN, R. C. (1928), An Investigation of the Physical and Chemical Properties of Manitoba and Saskatchewan Sands, University of Manitoba, Unpublished Master of Science Thesis, 1928.
- ROSS, C. Sand, KERR, P. F. (1931), The Clay Minerals and Their Identity, Jour. of Sed. Petrol., Vol. 1, No. 1, pp. 55 - 65.
- SANDERSON, F. W. (1932), St. Peter Group of Minnesota, Pan-American Geologist, Vol. 58, No. 3, pp. 191 - 196.
- SEAGER, O. A. (1942), Test on Cedar Creek Anticline, Southwest Montana, Bull. Amer. Assoc. Pet. Geol., Vol. 26, No. 5, pp. 861 - 864.
- _____ (1942), Stratigraphy of North Dakota, Bull. Amer. Assoc. Pet. Geol. Vol. 26, No. 10, p. 1673.

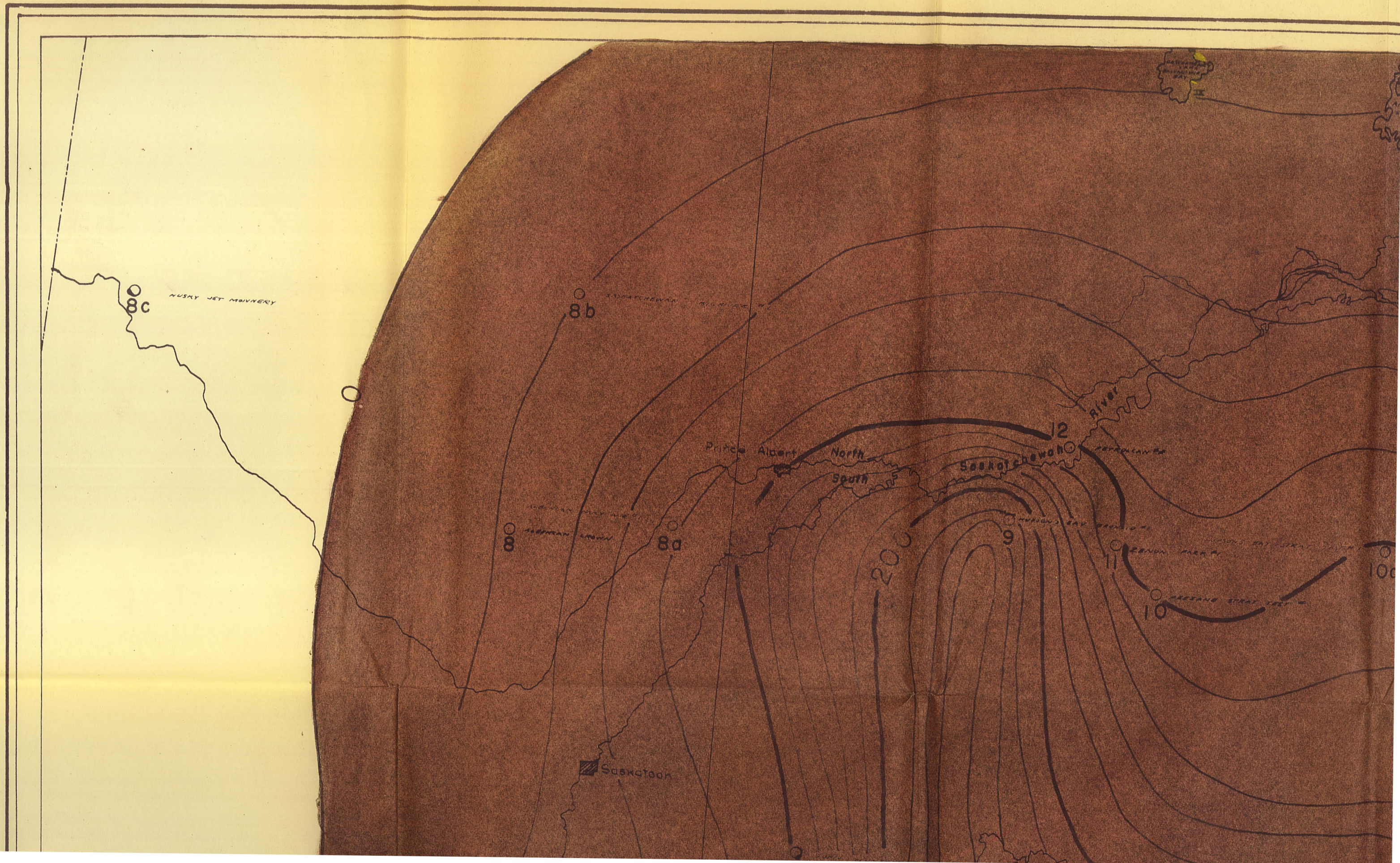
- SHROCK, R. R. (1948), Sequence in Layered Rocks, McGraw-Hill Book Co., Inc., New York.
- STAUFFER, C. R. (1930), Conodonts from the Decorah Shale, Jour. of Paleo., Vol. 4, No. 2, pp. 121 - 128.
- _____ (1935), The Conodont Fauna of the Decorah Shale (Ordovician) Jour. of Paleo., Vol. 9, No. 7, pp. 596 - 620.
- SWAIN, E. (1944), Gas and Oil Development in Saskatchewan, Precambrian Magazine, July 1944, pp. 1 - 12.
- THIEL, G. A. (1935), Sedimentary and Petrographic Analysis of the St. Peter Sandstone, Bull. Geol. Soc. Amer., Vol. 46, No. 4, pp. 559 - 614.
- _____ (1941), Subsurface Structure of the Paleozoic Rocks of Southeast Minnesota, Bull. Geol. Soc. Amer., Vol. 52, No. 1, pp. 49 - 60.
- TYRRELL, J. B. (1892), Report on Northwestern Manitoba, etc., Can. Geol. Sur. Ann. Rept., 5, No. 325, pp. 5 - 232.
- _____ (1896), Report on the Doobaunt, Kazan and Ferguson Rivers and the Northwest Coast of Hudson's Bay, Can. Geol. Sur. Ann. Rept., Vol. IX (1896), p. 101-T.
- _____ (1900), Report on the Northeastern Portion of the District of Saskatchewan and Adjacent Parts of the District of Keewatin, Can. Geol. Sur. Ann. Rept. (New Series), Vol. XIII, 1900.
- TYRRELL, J.B., DOWLING, D.B (1895), Report on the Country Between Athabaska Lake and Churchill River, Can. Geol. Sur. Ann. Rept., New Series, Vol. VIII, Part D.

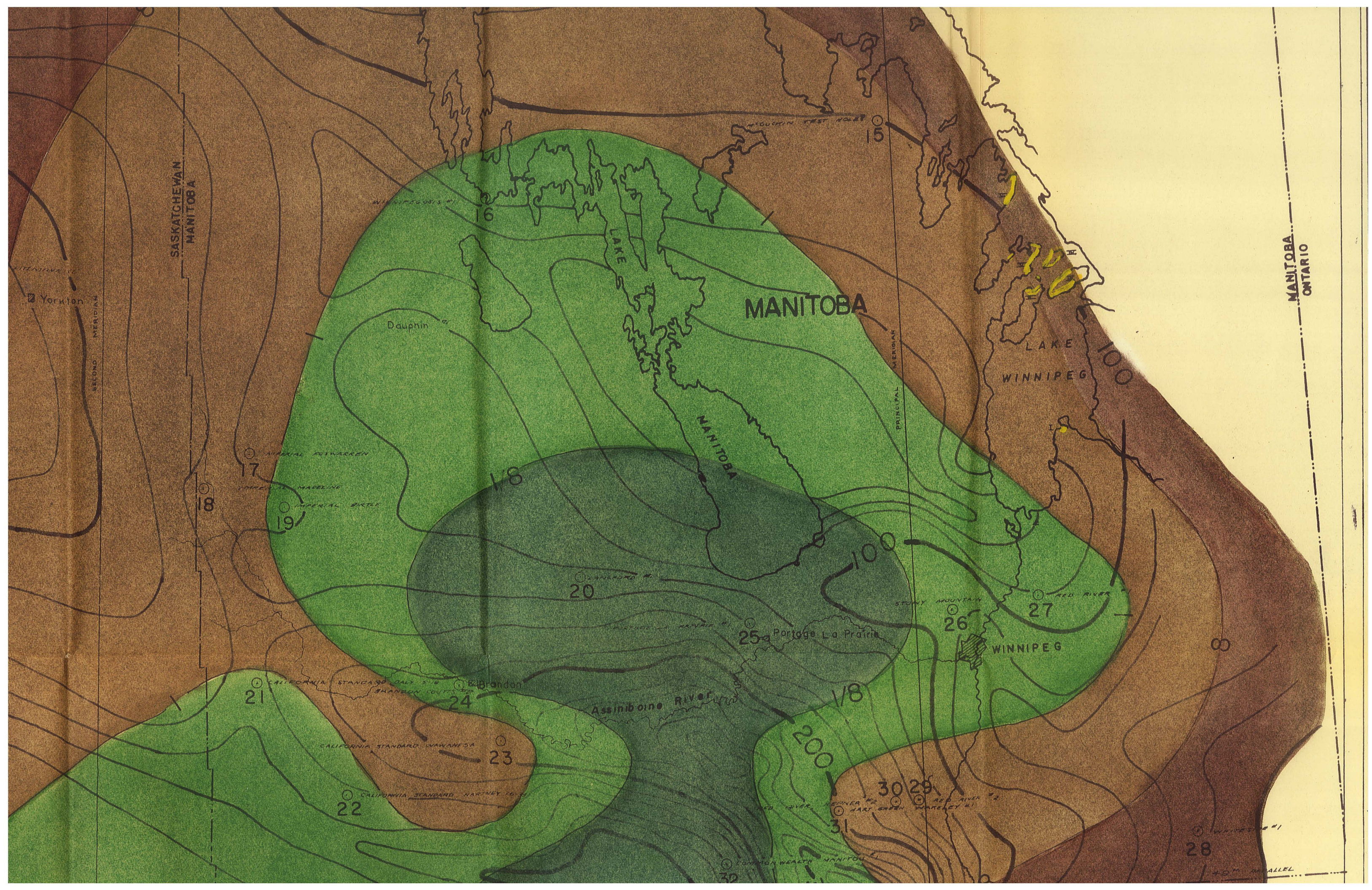
- ULRICH, E.O., CLARKE, J.M., SCHOFIELD, W.H., and WINCHELL, N.H.
(1892-1896), The Geological and
Natural History Society of Minnesota,
Vol. III, Part I and Part II,
Paleontology.
- WALLACE, R.C. (1925), The Geological Formations of Manitoba,
The Natural History Society of
Manitoba, (1925) P. 36.
- WALLACE, R.C., MCCARTNEY, G.C. (1928), Heavy Minerals in
Sand Horizons in Manitoba and
Eastern Saskatchewan, Roy. Soc.
Can.-Trans., Vol. XXII, Sec. IV, p. 199.
- WAYLAND, R.G. (1939), Optical Orientation in Elongate
Clastic Quartz Amer. Jour. Sci.,
(1939), pp. 99 - 109.
- WEBB, J. B. (1951), Geological History of Plains of
Western Canada, Bull. Amer. Assoc.
Pet. Geol., Vol. 35, No. 11, pp. 2291 -
2315.
- WHITEAVES, J.F. (1884-1906), Paleozoic Fossils, Can. Geol.
Sur. Part. 3, Vol. 3.
- WICKENDEN, R.T.D. (1932), Notes on Some Deep Wells in
Saskatchewan, Roy. Soc. Can. Trans.,
Third Series, Vol. 26, Sec. 4,
pp. 177 - 196.
- WRIGHT, J. F. (1932), Geology and Mineral Deposits of a
Part of Southeastern Manitoba, Can.
Geol. Sur. Mem. 169, p. 150.

WRIGHT, J. F. (1933), Amisk Lake Area, Saskatchewan,
Can. Geol. Sur. Sum. Rept. 1932,
Part C, Pub. 2332, pp. 73-110.

————— (1934), West Half Amisk Lake Area
Saskatchewan, Can. Geol. Sur.
Sum. Rept. 1933, Part C, Pub.
2347, pp. 12-22.







7b

HUSKY PHILLIPS EATONIA

MORCANUS BENNANT

1

5

2

2a

QUINTANA MELVAL

2b 100

3

IMPERIAL MORSE

7

SASKATCHEWAN

IMPERIAL LAWSON

6

7a

Saskatoon

THIRD MERIDIAN

10b

Moose Jaw

Regina

5a

MORCANUS ARMY

51

4

MORCANUS OSEMA

10c

HUSKY PHILLIPS EATONIA

8

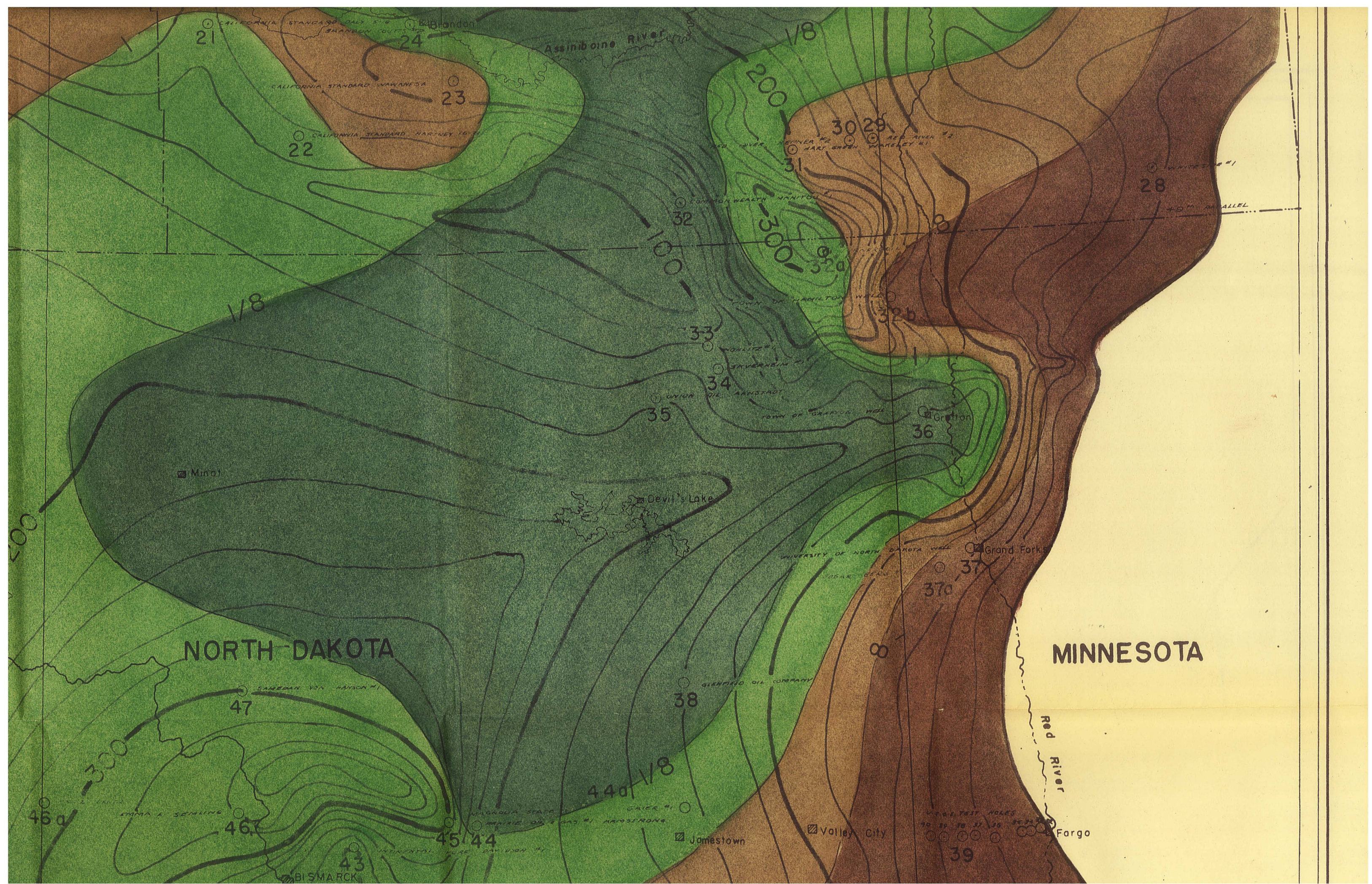
Yorkton

SECOND MERIDIAN

200

CANADA

UNITED STATES



ISOPACH
AND
LITHOFACIES
OF THE
WINNIPEG
FORMATION

SCALE

CONTOUR INTERVAL

MONTANA

Missouri River

Williston

Missouri River

CANADA
UNITED STATES OF AMERICA

260
10

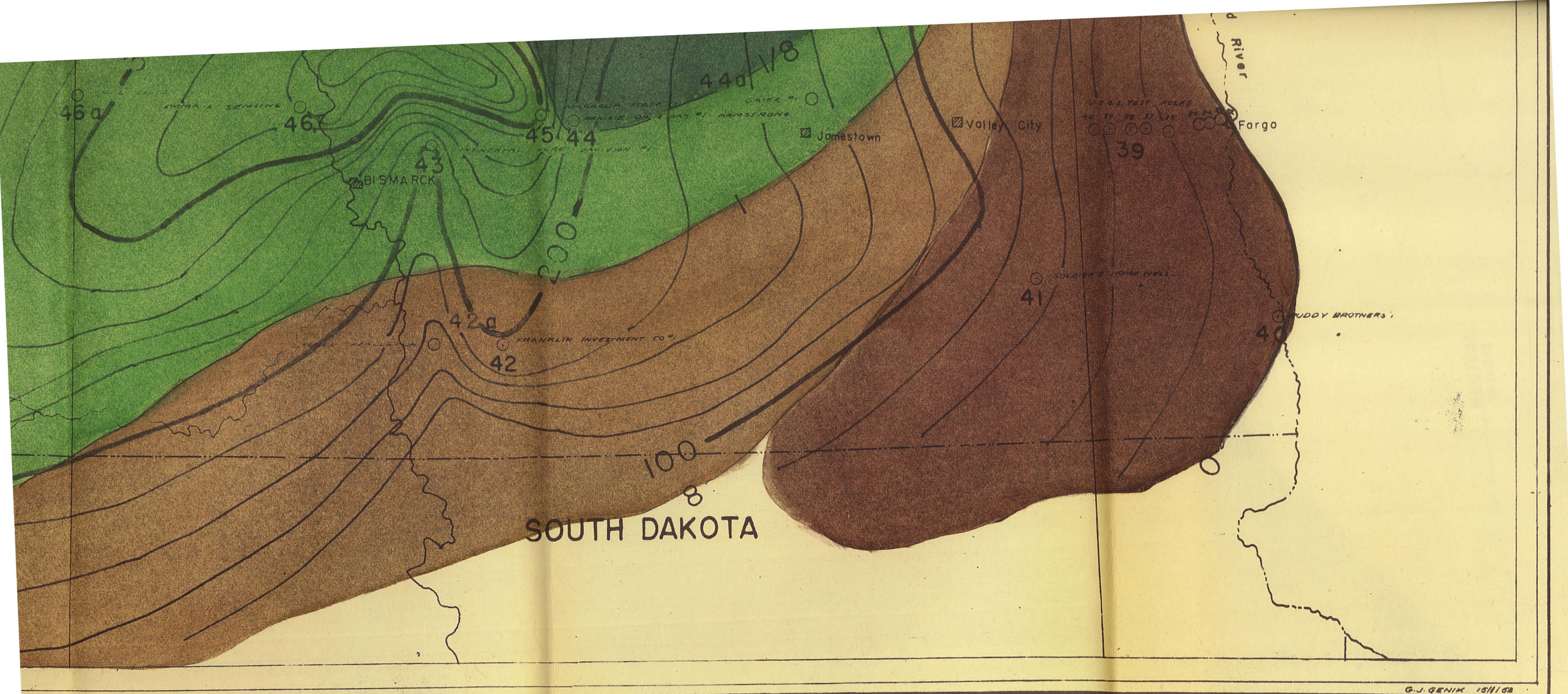
4

4a

00

200

46a



FORMATION

SCALE
ONE Inch = 20 Miles

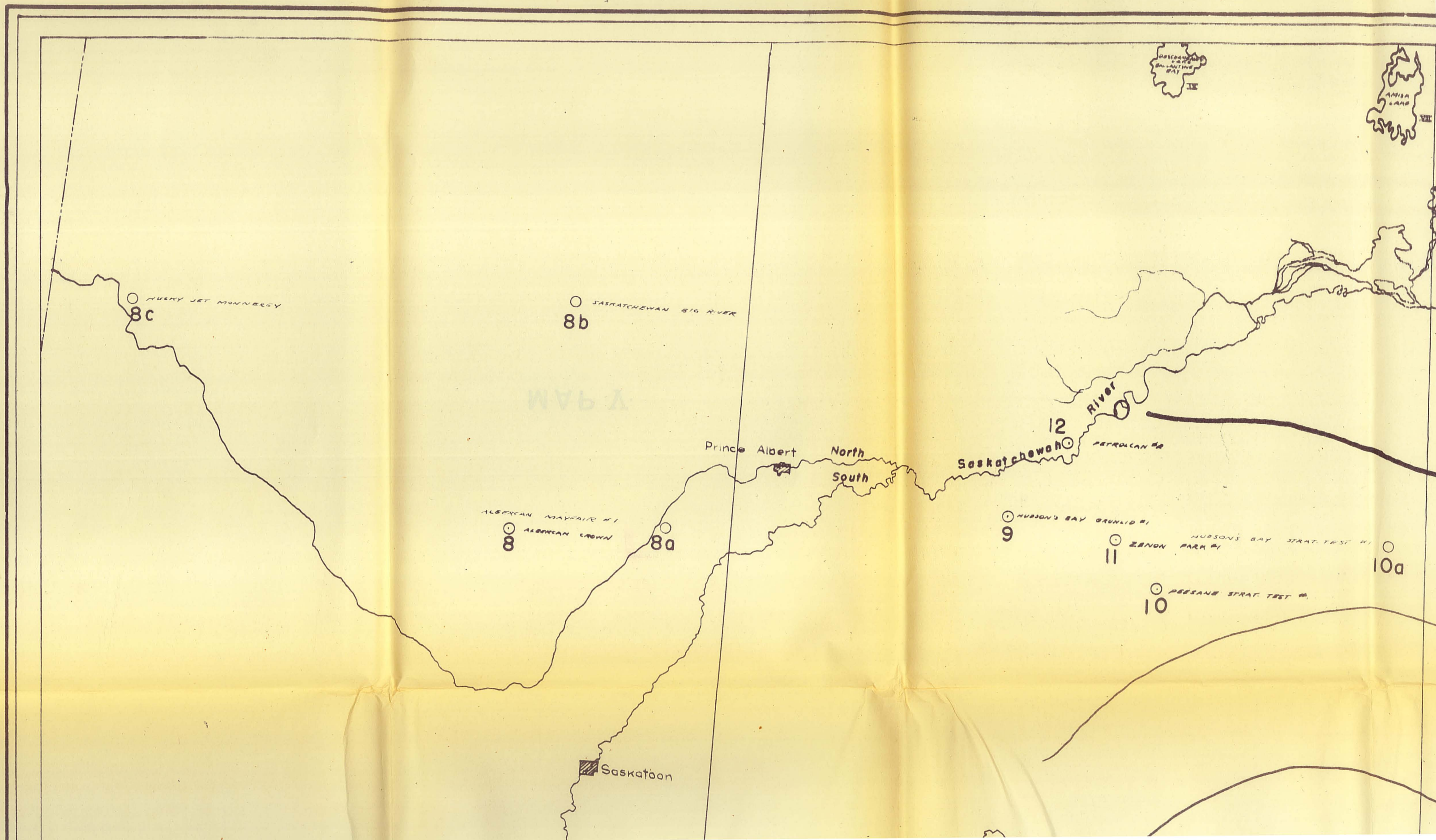
CONTOUR INTERVAL
20 Feet

LEGEND

	20 FOOT ISOPACH CONTOUR
	100 FOOT ISOPACH CONTOUR
	CITY or TOWN
	WELL SITE
	OUTCROP
	SAND SHALE RATIO GREATER THAN 8/1
	SAND SHALE RATIO 8/1
	SAND SHALE RATIO 1 — 1/8
	SAND SHALE RATIO LESS THAN 1/8







5 NORCANOLS ARRY

4 NORCANOLS ODEMA

4a SHELL BIG MUDDY LAKE

CANADA
UNITED STATES OF AMERICA

Missouri River

Williston

100

200

MONTANA

ouri River

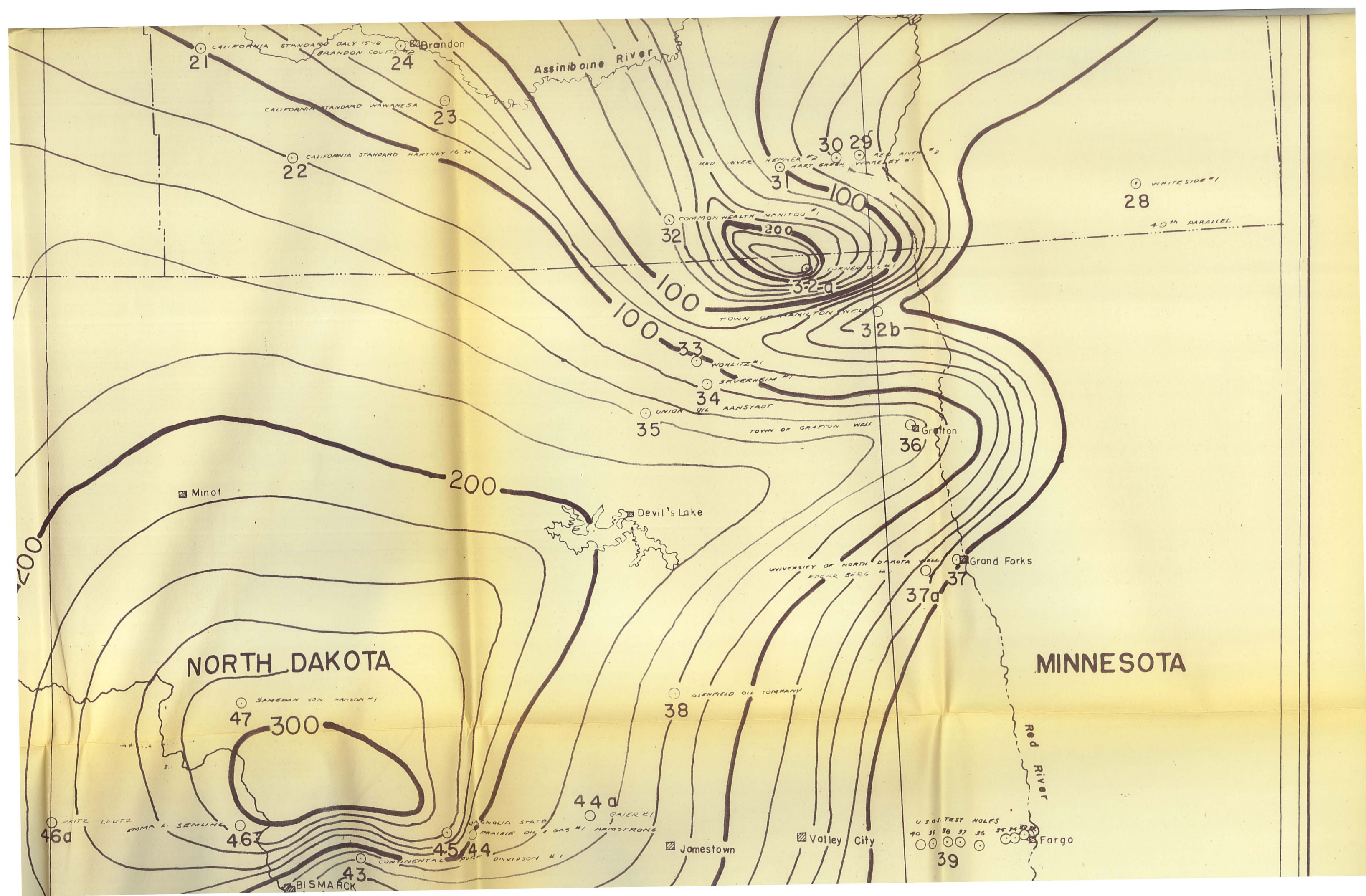
46a

SHALE ISOLITH

OF THE

WINNIPEG

FORMATION

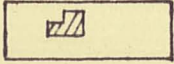
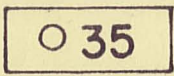
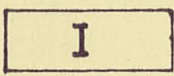


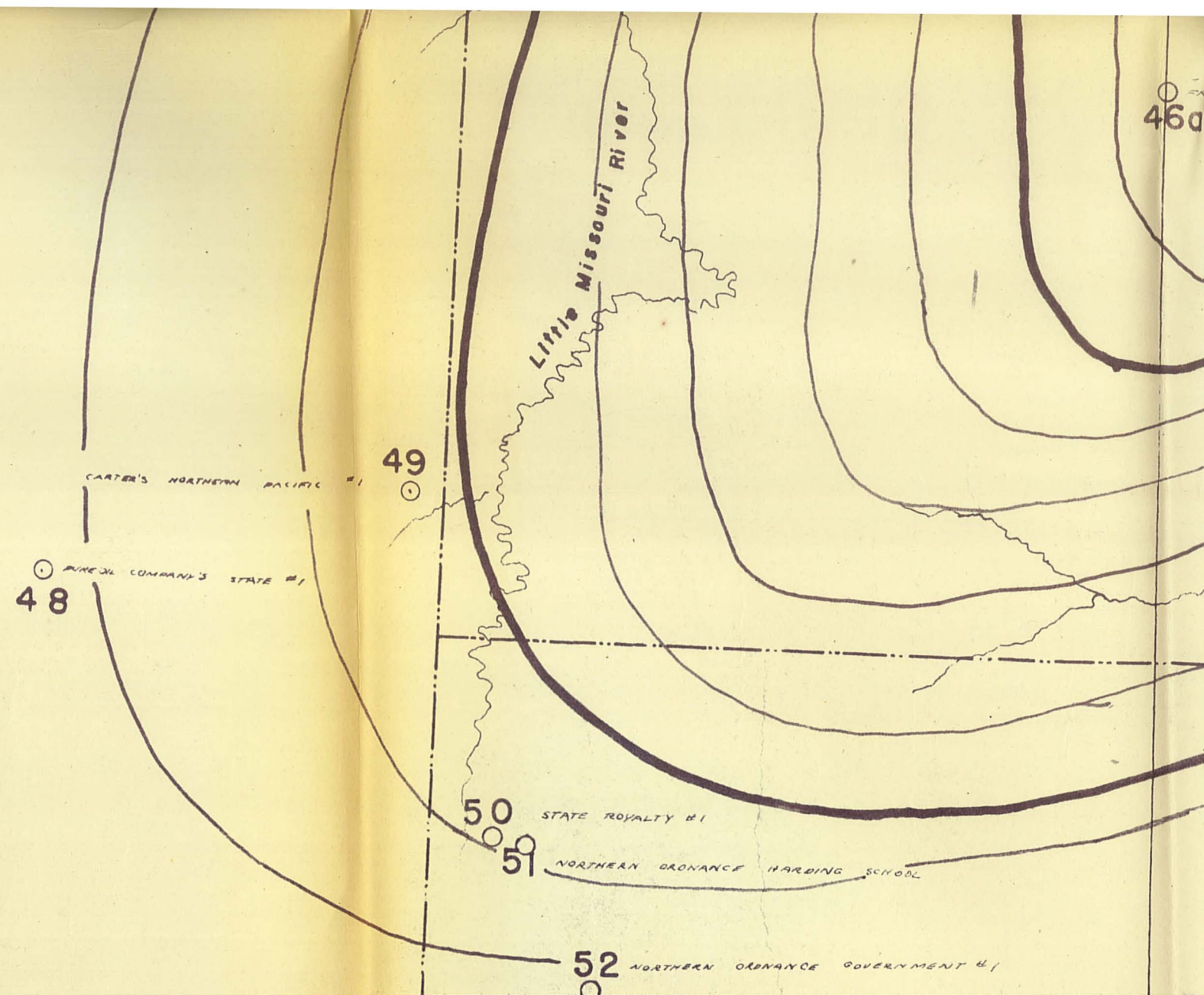
WINNIPEG FORMATION

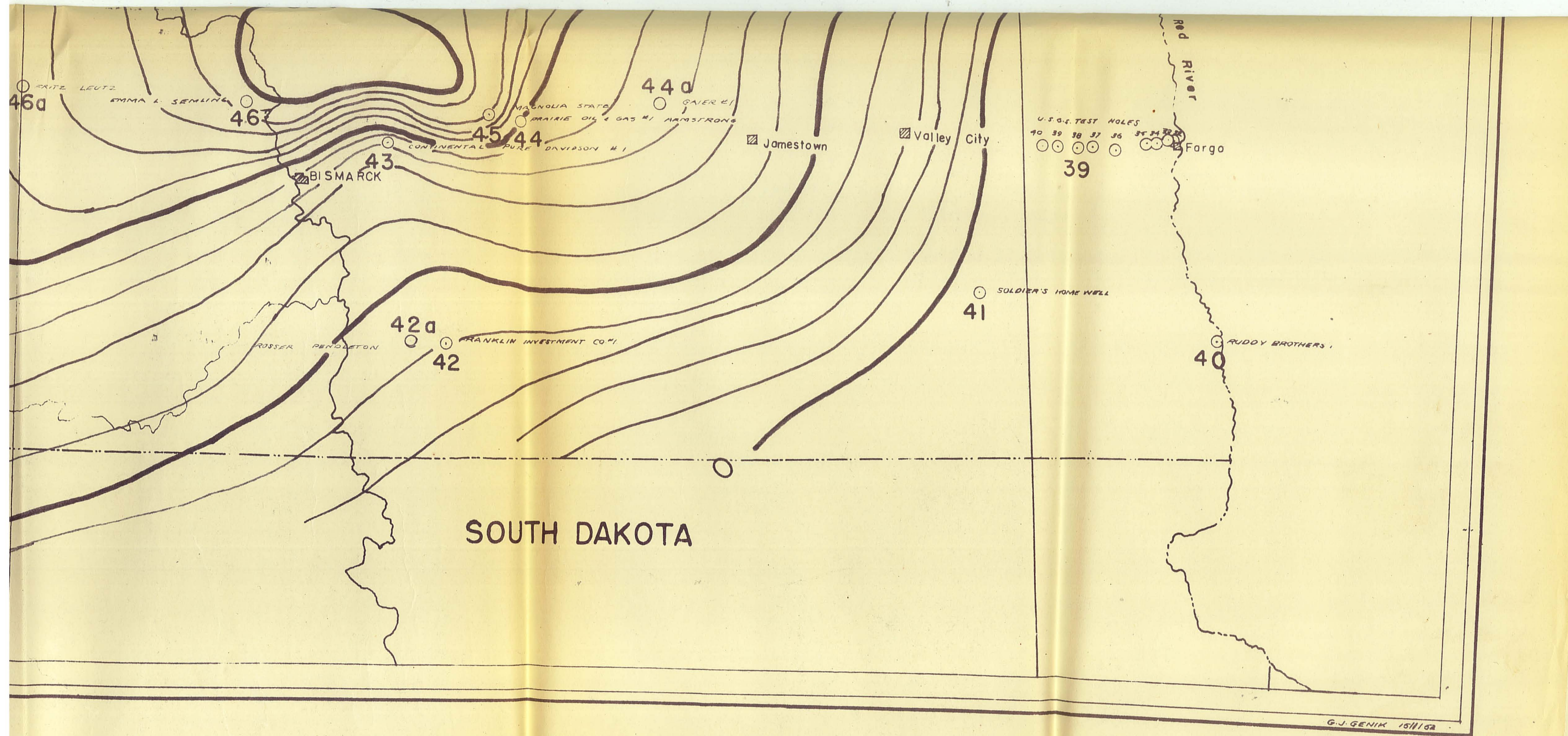
SCALE
ONE Inch = TWENTY Miles

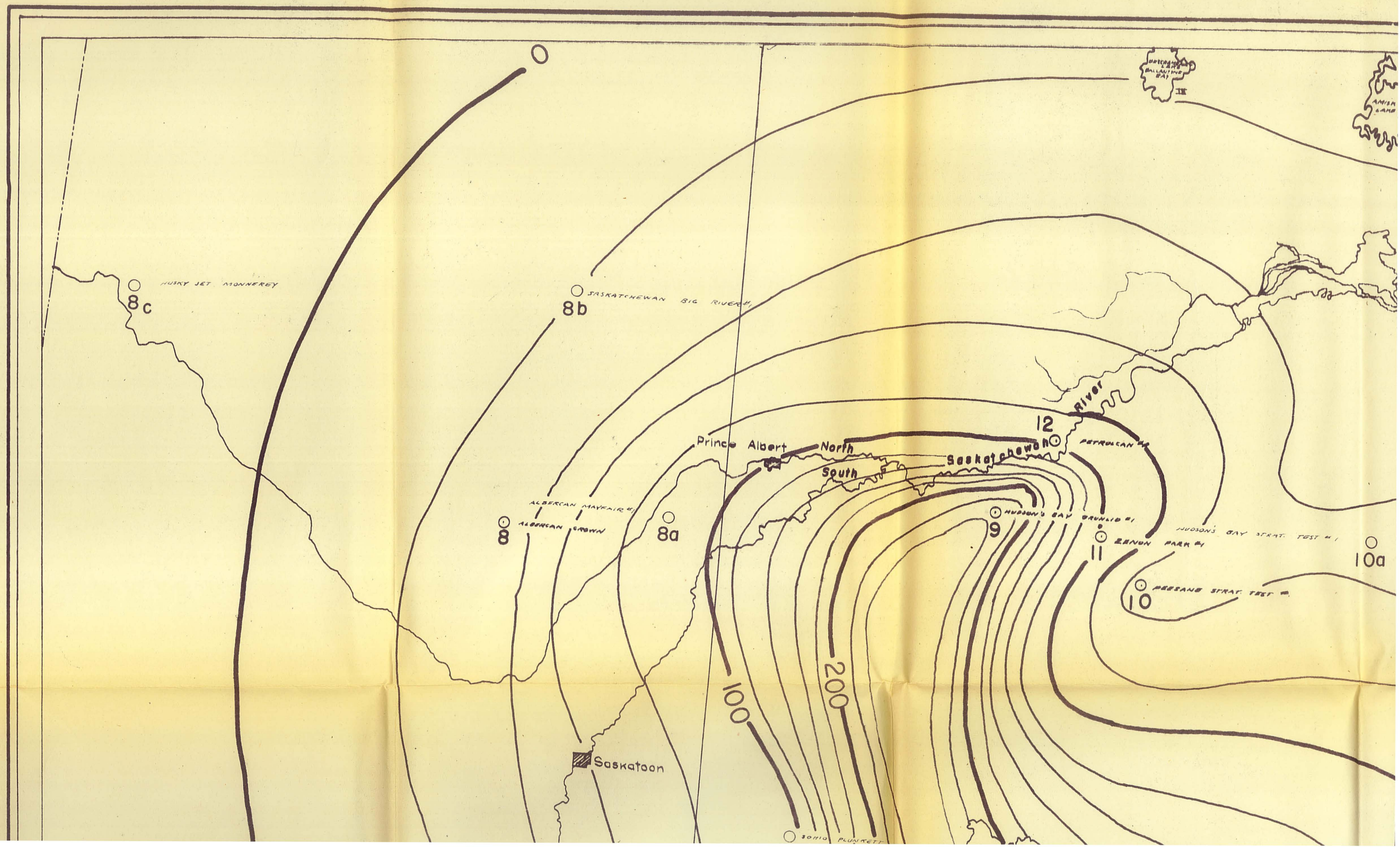
CONTOUR
INTERVAL 20 Feet

LEGEND

-  100 FOOT CONTOUR
-  20 FOOT CONTOUR
-  CITY or TOWN
-  WELL SITE
-  OUTCROP









○ HUSKY PHILLIPS EATONIA
7b

TIDEWATER BIRSA CROWN

7a

IMPERIAL ELBOW

7

SASKATCHEWAN

IMPERIAL LAWSON

6

IMPERIAL MORSE

3

IMPERIAL SWIFT CURRENT

2

TIDEWATER BRADDOCK

2a

QUINTANA MELVAL

2b

100

THIRD MERIDIAN

Moose Jaw

Regina

5a

JOHN SCONY AVONLEA

5

NORCANOLS MARY

4

NORCANOLS OREMA

4a

SHELL BIL MUDDY LAKE

HUSKY PHILLIPS FITZMAURICE

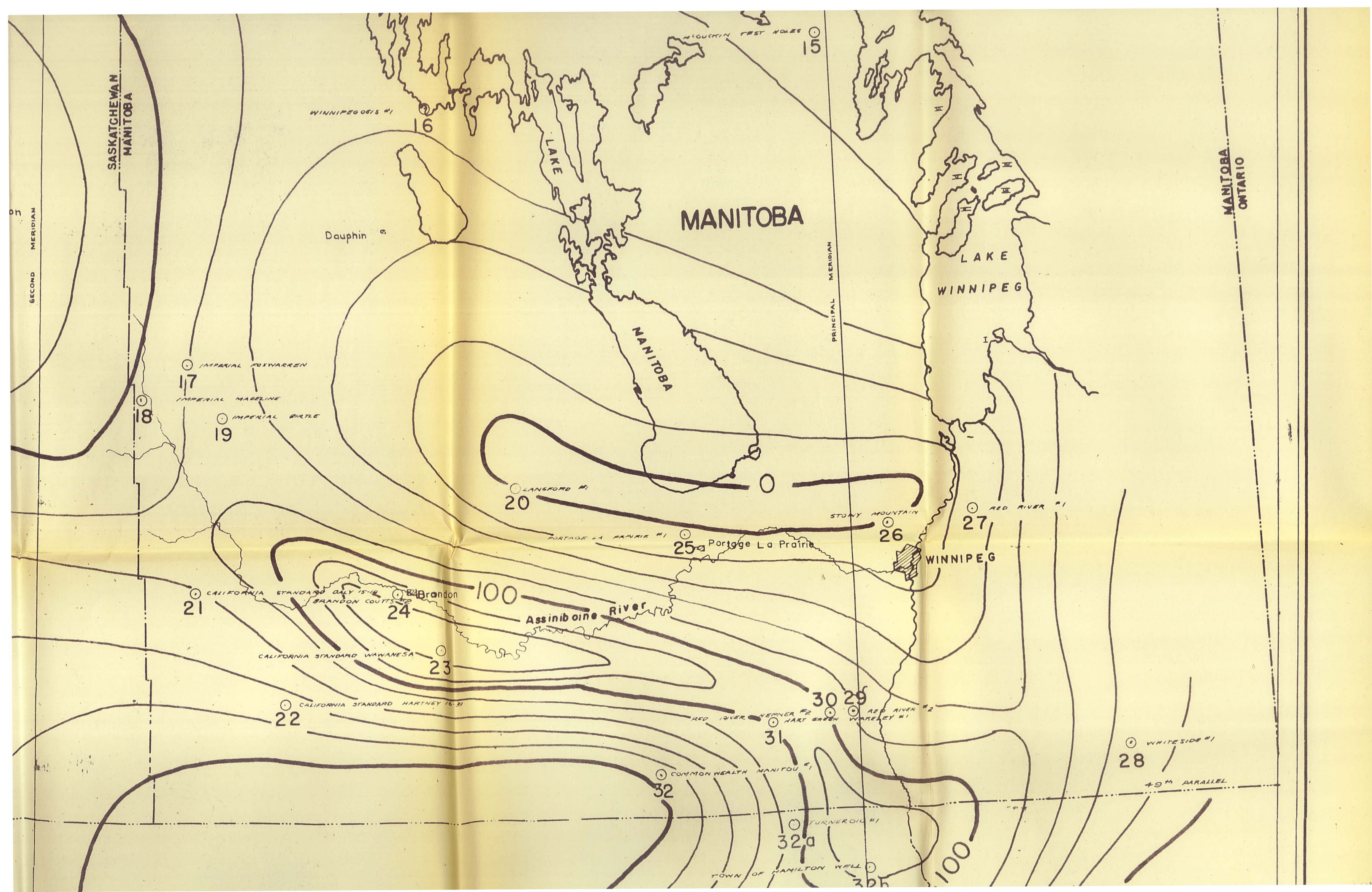
10c

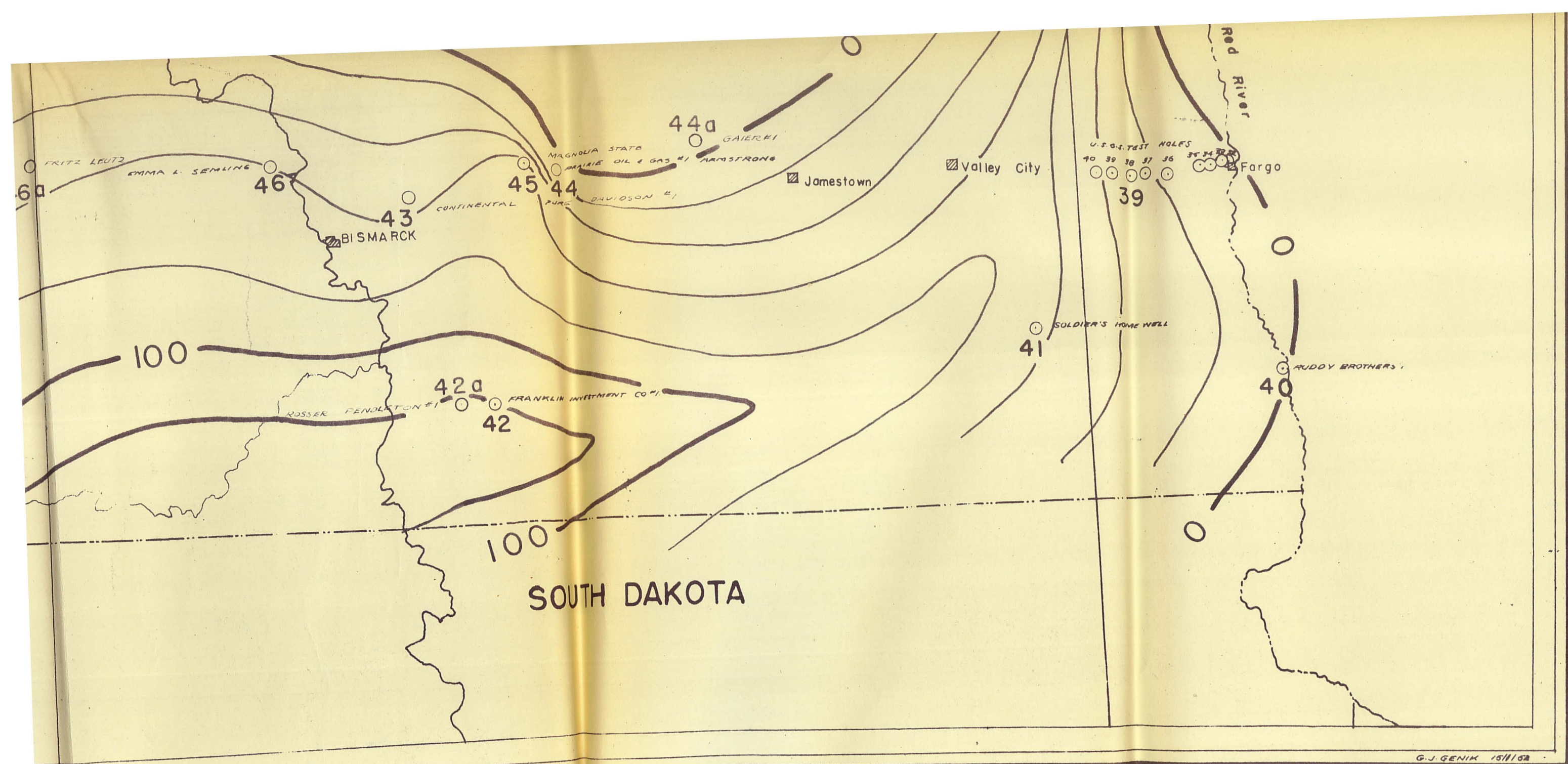
Yorkton

SECOND MERIDIAN

CANADA

UNITED STATES OF AMERICA



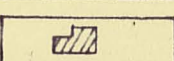
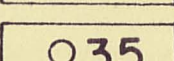
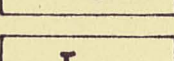


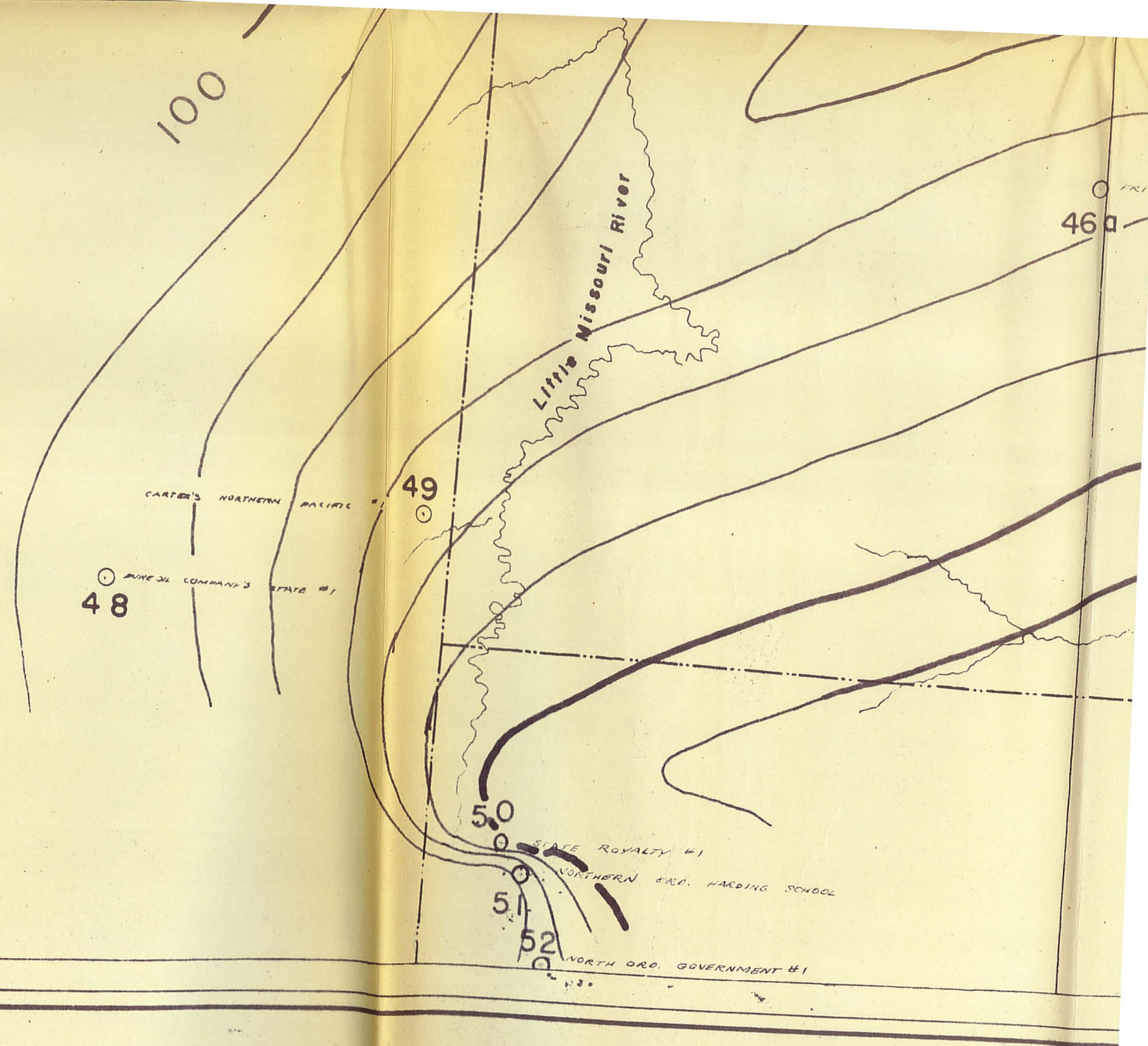
OF THE

WINNIPEG FORMATION

SCALE CONTOUR INTERVAL
ONE Inch = TWENTY Feet 20 Feet

LEGEND

	100 FOOT CONTOUR
	20 FOOT CONTOUR
	CITY or TOWN
	WELL SITE
	OUTCROP









7b

TIDEWATER BRASSY CROWN

7a

7

IMPERIAL ELBOW

SASKATCHEWAN

6

IMPERIAL LAWSON

THIRD MERIDIAN

10c

Yorkton

SECOND MERIDIAN

WOLANUS PENNANT

1

3

IMPERIAL MORDE

Moose Jaw

Regina

2

IMPERIAL SWIFT CURRENT

2a

TIDEWATER BRADDOCK

2b

QUINTANA MELVAL

5a

SUNU SUCONY AVONLEA

5

NORCANOLS MARY

4

NORCANOLS ODEMA

4a

SHELL BIS MUDDY LAKE

CANADA

UNITED STATES OF AMERICA

-3000

-4000

-5000

000

000

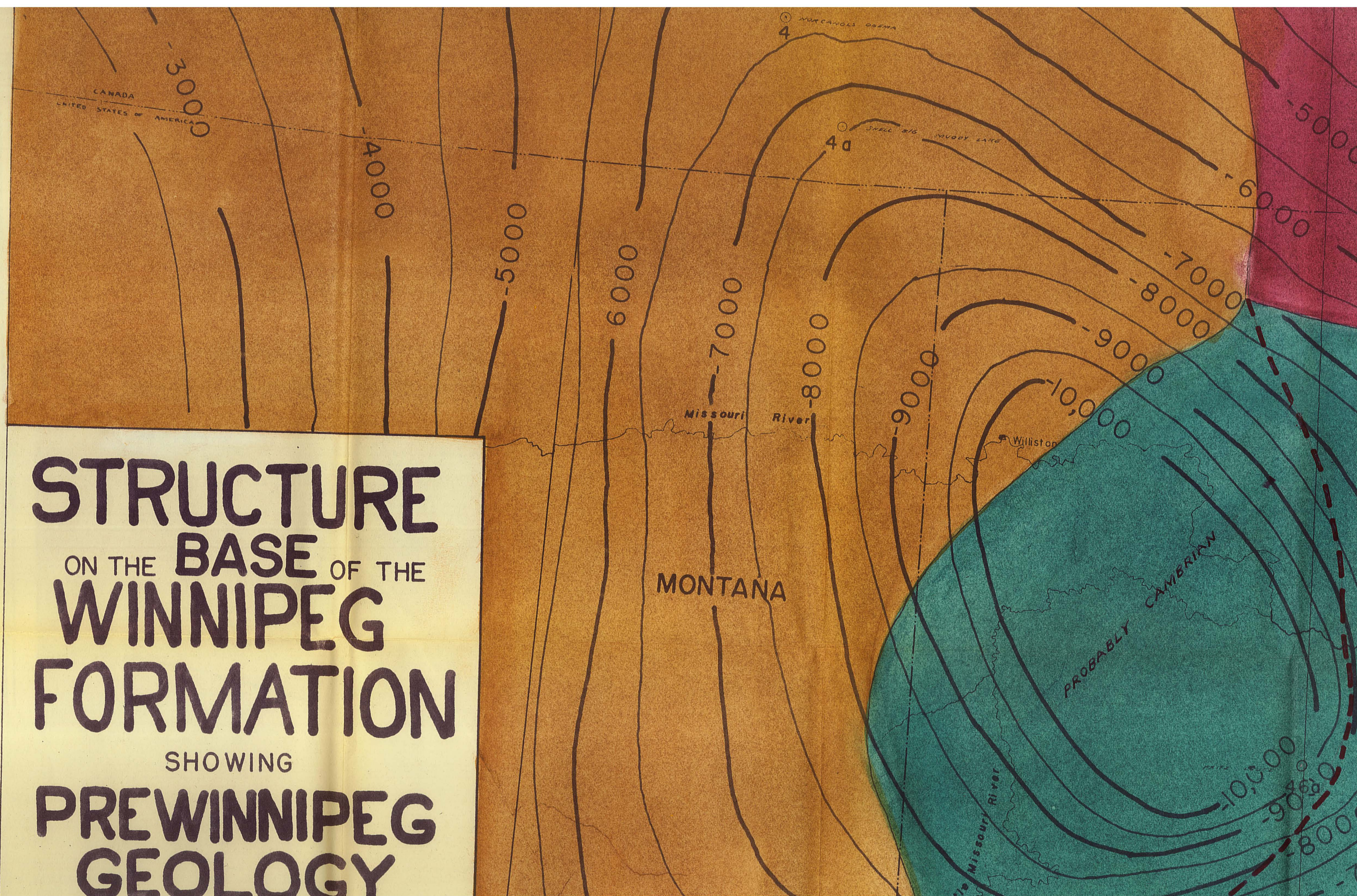
-7000

-8000

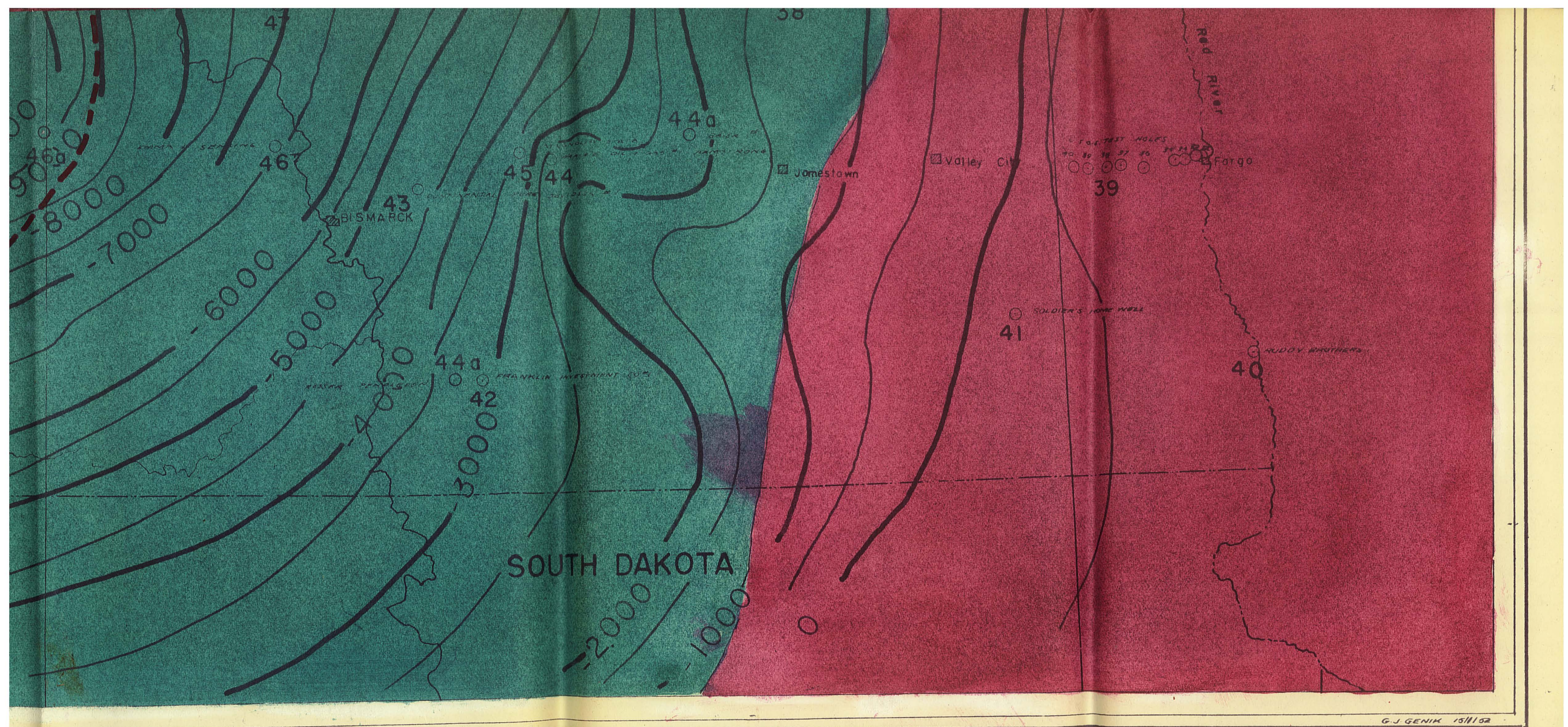
-5000

-6000

STRUCTURE
ON THE BASE OF THE
WINNIPEG
FORMATION
SHOWING
PREWINNIPEG
GEOLOGY





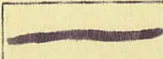
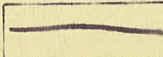
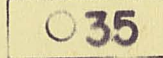


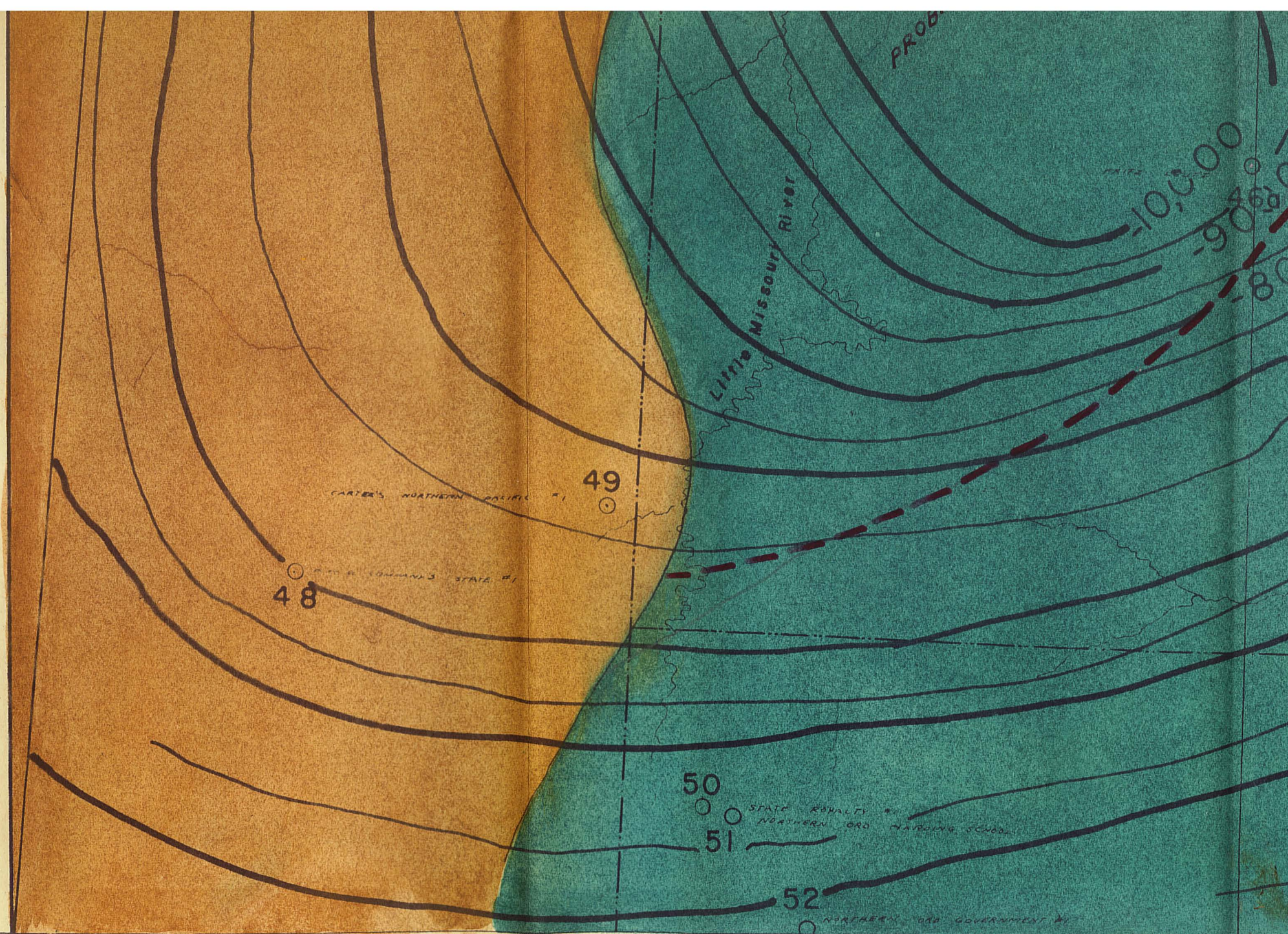
FORMATION

SHOWING

PREWINNIPEG GEOLOGY

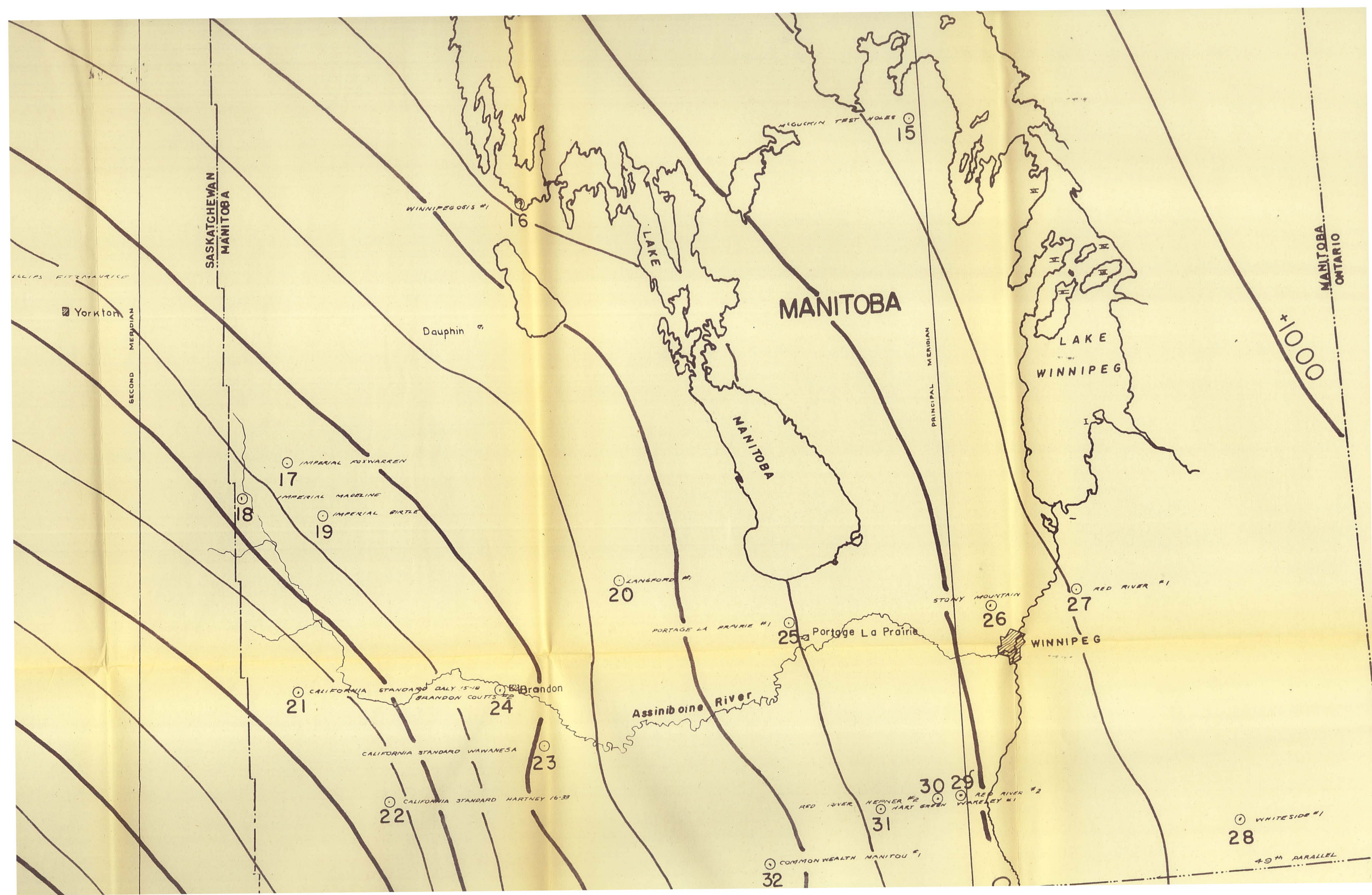
SCALE CONTOUR INTERVAL
ONE Inch = TWENTY Miles 500 Feet
LEGEND

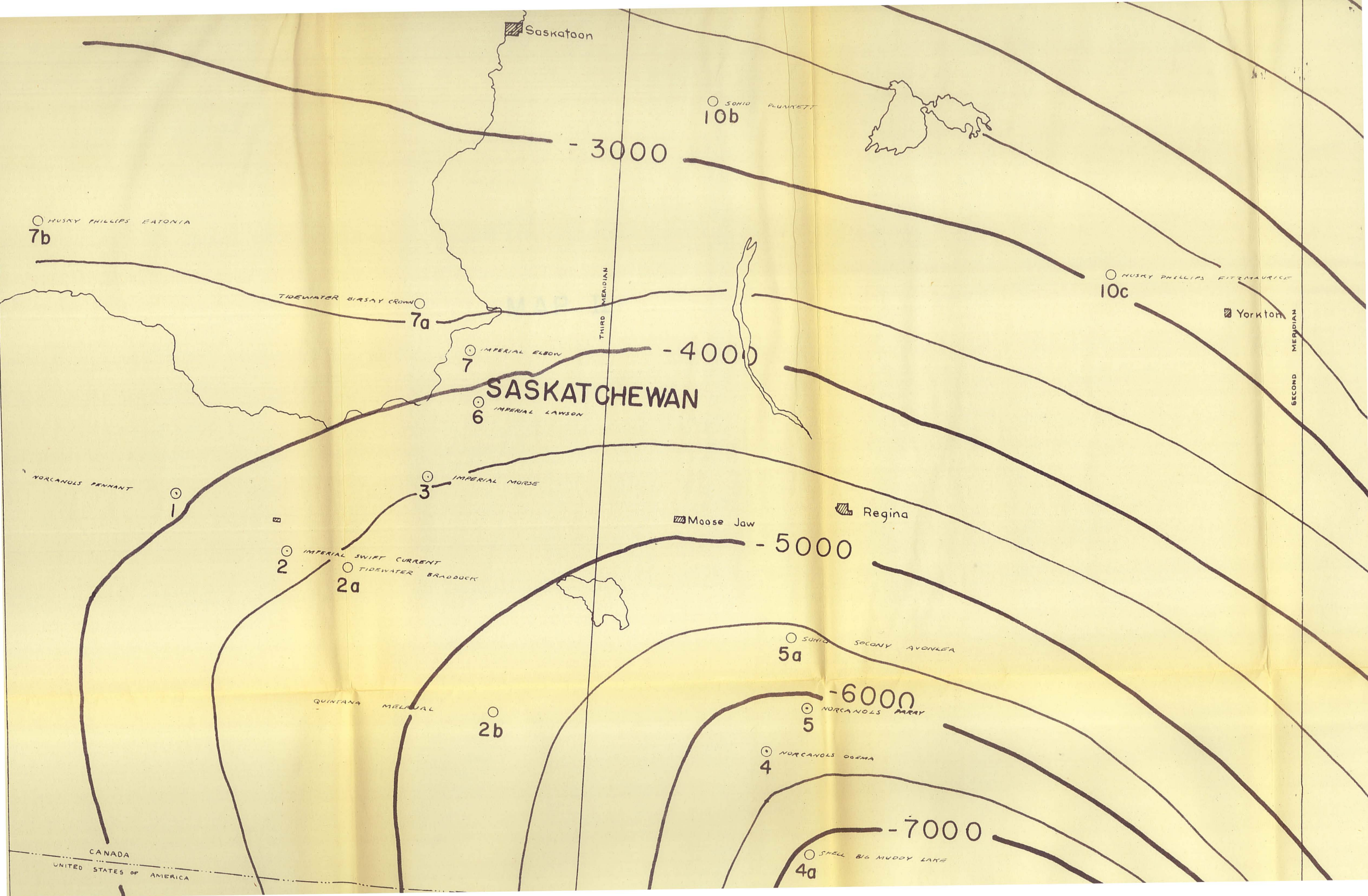
-  1000 FOOT CONTOUR
-  500 FOOT CONTOUR
-  CITY or TOWN
-  WELL SITE
-  OUTCROP
-  PREWINNIPEG ORDOVICIAN
-  CAMBRIAN
-  PRECAMBRIAN

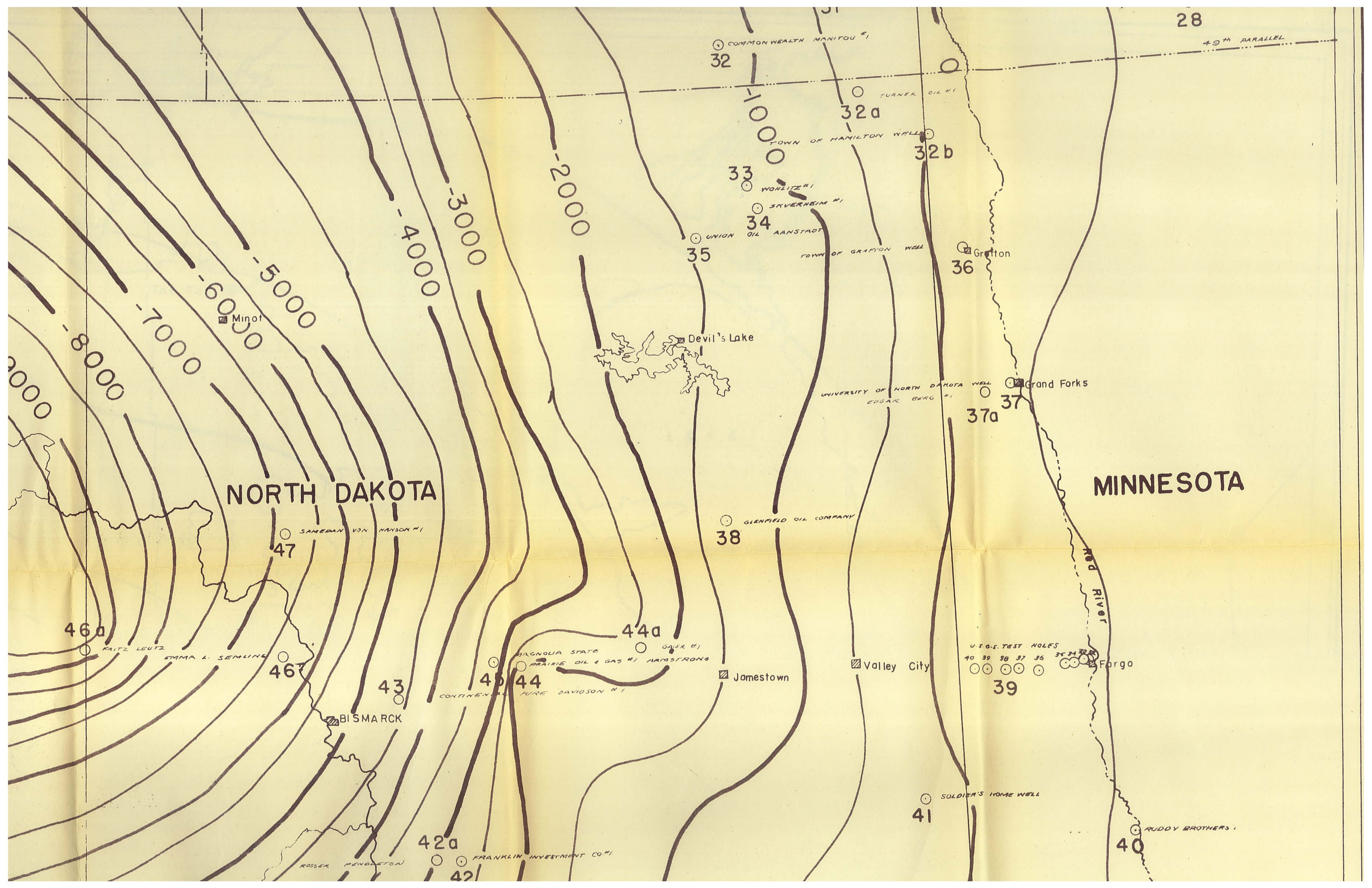








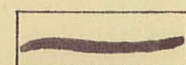




STRUCTURE ON THE TOP OF THE WINNIPEG FORMATION

SCALE CONTOUR INTERVAL
ONE Inch = TWENTY Feet 500 Feet

LEGEND



1000 FOOT CONTOUR



500 FOOT CONTOUR

MONTANA

Missouri River

Winston

4a

SHELL BIG MUDDY LAKE

-7000

-8000

-9000

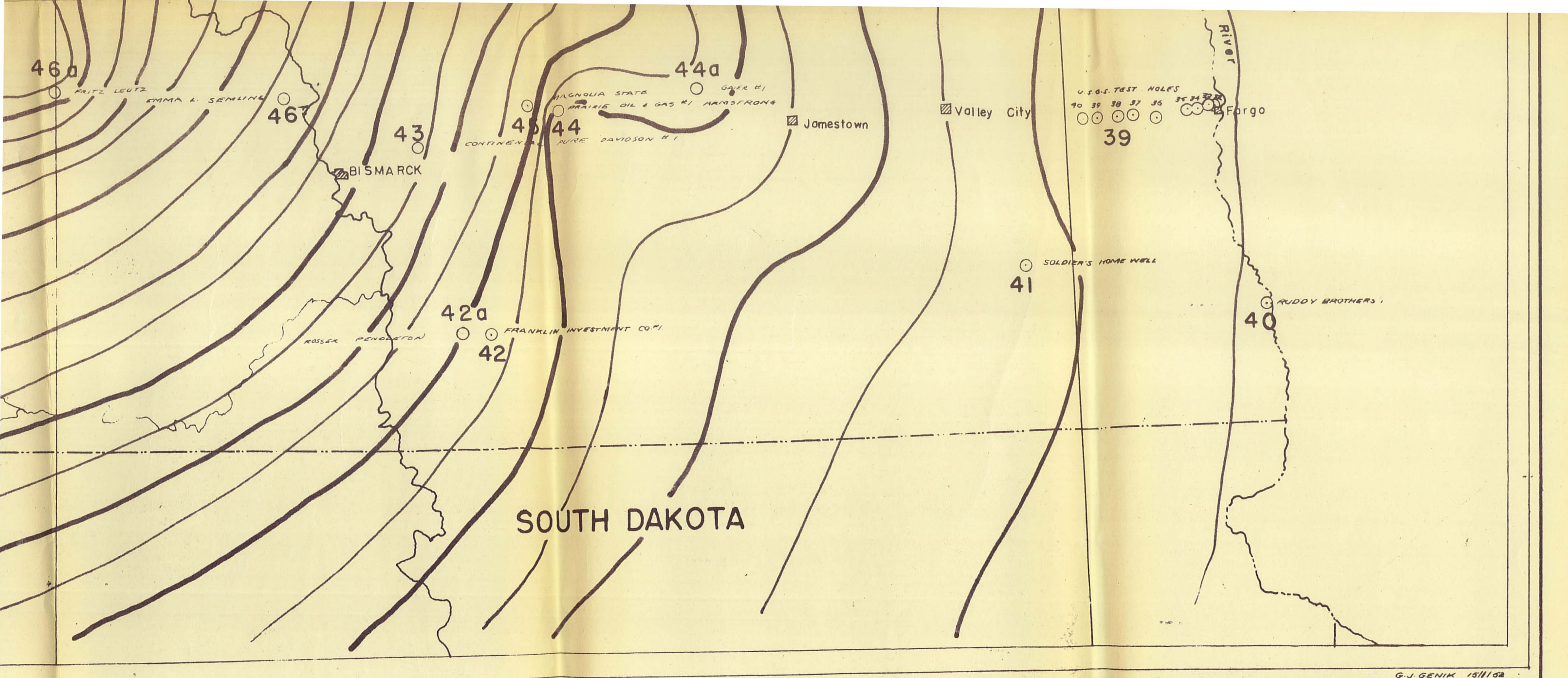
-9000

-9000

-8000

-7000

46a

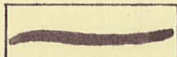
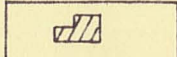
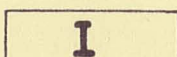


SOUTH DAKOTA

FORMATION

SCALE CONTOUR INTERVAL
ONE Inch = TWENTY Feet 500 Feet

LEGEND

- | | |
|---|-------------------|
|  | 1000 FOOT CONTOUR |
|  | 500 FOOT CONTOUR |
|  | CITY or TOWN |
|  | WELL SITE |
|  | OUTCROP |

