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# CRETACEOUS SHALES OF MANITOBA AND SASKATCHEWAN. THEIR ECONOMIC VALUE AS A POSSIBLE SOURCE OF CRUDE PETROLEUM.

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## Introductory.

During recent years, attention has been directed to reported occurrences of oil shale in the provinces of Manitoba and Saskatchewan. The shales referred to are exposed along the escarpment of the Pembina, Riding, Duck, and Porcupine mountains, which border the lake plain and Red river valley of Manitoba. They are also in the escarpment of the Pasquia Hills, a northern extension of the same series. These hills, dignified by the name of mountains, constitute the erosion escarpment of the Cretaceous beds which form the first prairie step. The eastern edge is indented by drainage valleys of varying importance, which separate the hill features into groups. The Pasquia Hills, and Porcupine, Duck, and Riding mountains occupy an area which is bounded toward the north and northwest by the Carrot river, and toward the east by waterways, which include Moose lake, Cedar lake, and Lake Winnipegosis. Broad, low-lying, slightly undulating, lacustral plains, which formed the bed of glacial Lake Agassiz, stretch away from the various waterways to the lower slopes of the hills. These lower slopes are marked by a series of old lake beaches, and rise by easy gradients, through some five or six hundred feet, to the more abrupt escarpment of the main ridge.

The whole area is well watered by numerous small streams, few of which have a width greater than 60 feet. In descending from the table lands, these streams, for the most part, flow with rapid current along boulder-strewn channels, deeply entrenched in precipitous valleys and ravines, where active erosion and landslides are much in evidence. On reaching the lower slopes of the hills, the current slackens, and many excellent geological sections are exposed in cut banks at concave bends. Through the low-lying alluvial lands, the banks, as a rule, are low, and the channels of the meandering type.

Outcrops of shales examined on Birch river, Favel river, Sclater river, Pine river, Vermillion river, and Ochre river, are all near the Hudson Bay branch of the Canadian National Railways, and may be easily reached by highway roads. Outcrops examined on the Tee river - a branch of Pasquia river, Man river, Cracking river, and Papikwan river in the Pasquia Hills, are somewhat remote from rail transportation.

Toward the east and northeast, the slopes of the Pasquia Hills are marked by somewhat sharp gradients. In passing westward, however, the slopes become more gentle, and rock exposures along the various streams less frequent. The elevation of the summit has not been accurately determined, but apparently ranges from 2,000 - 2,300 feet above sea level datum. The area throughout is densely wooded. Apart from a number of comparatively limited areas reserved as timber berths, the forest growth consists, principally, of large poplar and birch. Much of the land is of excellent quality, and, when cleared should prove well adapted to agricultural development.

Outcrops of shale along streams which drain the northeastern slopes of the hills (as on Tee river and Man river) can best be reached from the Pas. From Mountain cabin on Carrot river, some 60 miles W.S.W. from the Pas, a good summer trail, approximately 2 1/2 miles in length, leads south to Tee river. From Camp No.6 on Carrot river, some 90 miles from the Pas, a fair bush road, approximately 17 miles in length, leads to Man river.

Papikwan and Cracking rivers can best be reached from McDonald's Siding, 2 1/2 miles west of Mistatim station, on the Canadian National Railways. From McDonald's Siding, a fair wagon road, some 24 miles in length, leads to Connell Cabin. From Connell Cabin to Papikwan Cabin - a distance of approximately 12 miles - a fair pack trail is available; but between Papikwan Cabin and the shale outcrops at the forks of Cracking river, the trail is wet and difficult. Other trails indicated on the accompanying map are, for the most part, poor, and in many instances, difficult to follow.

## Geology.

The general geology of the area was worked out many years ago by Tyrrell, Dowling, and McInnes, and the reports then issued [1] remain authoritative. The general geological features are simple, and may be very briefly summarized as follows.

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1 Report on Northwestern Manitoba with portions of the adjacent districts of Assiniboia and Saskatchewan, J. B. Tyrrell and D. B. Dowling, Geol. Surv. of Canada, 1892.
The Basins of Nelson and Churchill Rivers, Wm. McInnes, Geol. Surv. of Canada, Mem. 30, 1913.

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The Pasquia Hills, and Porcupine, Duck, and Riding Mountains, are built up of Cretaceous sediments, resting unconformably on limestones of Palaeozoic age. Apart from type fossils, which are found at many localities, the principal subdivisions of the Cretaceous, within the area under consideration, may frequently be recognized by lithological characteristics.

A marker band of impure limestone, averaging some four feet thick, and containing typical fossils, occurs near the top of the Niobrara, and apparently extends over a wide area. Other marker bands are of local significance only. In the following general section, estimated thicknesses are given, but, pending the collection of further data, these must be considered as approximations.

| | | | | |
|---|---|---|---|---|
| Cretaceous | Montana | Pierre (upper) | Odanah shales........ | 400 feet |
| | | " (lower) | Millwood " ........ | 550 " |
| | Colorado | Niobrara | (Boyne shale) | |
| | | | (Morden shale).............. | 130-240 feet |
| | | | (Assiniboia shale) | |
| | | Benton shale........................ | | 180 feet |
| | | Dakota sandstone. | | |
| Devonian | Unconformity. | | | |

The detailed geological structure has not been accurately worked out, although numerous exposed sections, together with correlated elevations, indicate that, the general dip of strata of Cretaceous age is almost horizontal. Between Winnipegosis and the well drilled by the Manitoba Oil Company - 11 miles southwest of Dauphin - the dip of Upper Palaeozoic limestones is apparently about four feet to the mile, in a southwesterly direction. South of Swan river valley, Cretaceous sediments also dip at a very low angle toward the southwest. North of this point, the strata flatten out, and finally dip toward the north. The same general horizontality apparently typifies strata underlying the Pasquia Hills. Minor local folding was observed, but this in itself can scarcely be considered as of economic importance. The general physical characteristics of members of the Cretaceous system may be briefly summarized as follows:-

Pierre:-

Odanah series. Dark fissile shales, usually poor in fossils, and weathering to light grey fissile flakes. Often rusty along joint planes.

Millwood series. Soft grey shales, sometimes almost black in colour. Weathers to light grey flaky particles, which eventually disintegrate to dark plastic clay. Slopes adjacent to cut banks exhibit marked evidence of instability. Ironstone nodules are common, particularly near contact with Niobrara.

Niobrara:-

Dark grey clay shales, frequently mottled, and interbedded with heavy bands of hard calcareous shale, usually highly fossiliferous, and almost black in colour. Shale weathers to light grey colour. Comparatively weather resistant.

Benton:-

Very dark, soft, non-calcareous, somewhat carbonaceous, evenly bedded shale, poor in fossils. Weathers to small thin flakes, which rapidly disintegrate into dark plastic clay.

Dakota:-

White, light grey or greenish sandstone. Usually somewhat soft, but in places having the hardness of quartzite.

With the exception of the upper and the lower members of the Cretaceous system, the sediments exposed within the area under consideration thus consist chiefly of rather soft, greenish grey, clay shales, more or less darkened owing to the presence of hydrocarbons and iron sulphides. Moreover, many of these shales, when freshly broken, emit a marked odor of petroleum, which, on exposure, rapidly passes off. When disintegrated by the drilling tools, in the presence of water, the shale forms an emulsion of a dark green colour. This emulsion gives off a faint odor of petroleum and, after standing for a time, exhibits a thin film of petroleum on the surface. It is, therefore, not surprising that the presence of free petroleum in wells drilled through the shales has been reported from time to time.

Of Upper Cretaceous shales, the Niobrara formations is the most highly fossiliferous, hence it is within this horizon that bands of oil-shales might have been anticipated. Fossils observed in this formation comprise a large number of foraminifera, among which Globigerina cretacea is conspicuous, and an abundance of shells of a large Inoceramus, together with the following species:-[1]

1 Geol. Surv. Can., Report on North-Western Manitoba, J. B. Tyrrell, 1892.

Serpula semicoalita, (Whiteaves. N. sp.)
Ostrea congesta, (Conrad).
Anomia obliqua, (Meek & Hayden).
Inoceramus problematicus, (Schlotheim).
Belemnitella Manitobensis, (Whiteaves. N. Sp.)
Loricula Canadensis, (Whiteaves. N. sp.)
Ptychodus parvulus, (Whiteaves. N. sp.)
Lamna Manitobensis, (Whiteaves. N. sp. loose).
Enchodus Shumardi, (Leidy).
Cladocyclus occidentalis, (Leidy).

## Origin of Shale.

Oil shales of New Brunswick and Nova Scotia were deposited under different conditions from those of Manitoba and Saskatchewan. In the former Provinces, material from which the shale beds were derived was originally deposited in the form of fine clays on the bottom of swamps and lagoons. If the theory of Steuart[1] is accepted

1 Steuart, D.R., The Chemistry of Oil Shales. Oil Shales of the Lothians, Geol.Surv., Scotland, 1912.

there was associated with these sediments, vegetable matter converted into a pulp, as a result of maceration and microbe action in water, together with richer materials of various kinds, such as spores, and a proportion of animal matter. We may, therefore, conclude that the origin of the petroleum in the shales may be traced to fermentation and decomposition of organic matter, through microbe action. On the other hand, the shales of Manitoba and Saskatchewan were laid down in a muddy sea, and were, therefore, not subjected to the various influences that affected the shales of the Maritime provinces.

## Physical Characteristics of Shales in the Provinces of Manitoba and Saskatchewan.

It is evident that great areas of Cretaceous shales, with their notable content of organic matter, have been subjected to very slight disturbance. Had the shales been affected by folding or by compression, as a result of great earth movements, distillation of organic remains, due to heat and pressure, would doubtless have resulted in the formation of gas and petroleum.

Attempts to ignite fine splinters of the various shales examined, by means of a match, failed in nearly every instance. Niobrara shales, when partially dried, will, however, frequently ignite when placed on an open wood fire. Pierre shales examined, ignite but rarely, and then with difficulty. Benton shales showed no evidence of being combustible. Sampling was, therefore, confined largely to Niobrara shales.

In appearance and physical characteristics, as well as in the conditions under which they were deposited, these upper Cretaceous shales are thus in marked contrast to the oil shales of Nova Scotia and New Brunswick. In these Provinces, two general types of shale are recognized, viz., "plain" and "curly". A sub-variety, usually referred to as "paper shale", is apparently a weathered form of "plain" oil shale. It is thin bedded, or papyraceous, separating readily into thin, flexible sheets of considerable surface dimensions. "Plain" oil shales are usually flat surfaced, showing more or less well defined lamination. On the other hand, "curly" shale usually occurs as massive bands, somewhat curled and contorted. It is very tough, breaks with a conchoidal fracture, and is, usually, very rich in hydrocarbons.

As a rule, oil shales of Nova Scotia and New Brunswick are free from grit; and, although readily cut with a sharp knife, do not yield thin, flexible shavings as do the Scotch shales. They are strongly resistant to weathering, and fragments have remained, for many years, exposed to action of atmospheric agencies, with but little loss of their hydrocarbon content. When placed in a grate fragments may be readily ignited, giving off an intense heat, and continuing to burn with a long yellow flame for periods of from one to three hours, Small splinters of the shale may usually be ignited by means of a match.

Oil shales of New Brinswick, Nova Scotia, and Scotland, do not contain hydrocarbons which are liquid at atmospheric temperature. Numerous wells have been drilled through the shales by various companies, but, although free petroleum has been encountered in interbedded sands and sandstones, practically none has been met with in the shales themselves.

## Weathering of Shales.

Weathering of the Cretaceous shales presents an interesting study. As a rule, the hydrocarbon content of shales examined, does not prevent rapid weathering; while, on the other hand, the shales contain within themselves a variety of potent disruptive agencies. Apart from the high percentage of water present, disintegration, due to the formation of secondary minerals - as iron and calcium sulphates, hydrated iron oxides, etc., and circulating solutions containing acids and sulphates - is very marked.

## Associated Minerals.

Incidental to the examination of the Cretaceous shales, the presence of certain associated minerals was noted. None of these minerals were observed in sufficient quantity to be of present economic importance, but, pending a complete chemical analysis of the shales, their somewhat complex geochemistry may be briefly alluded to.

These associated minerals fall into two classes, viz., those which, being deep seated, have not been subjected to oxidizing influences; and others, which have been deposited at, or near the surface, in the presence of circulating waters, and under the influence of other oxidizing agencies. In addition to bentonite, the principal deep seated minerals comprise pyrite, siderite, and glauconite. Owing to the length of time during which they have been forming, these minerals occur in considerable quantity and exhibit comparative purity. Surface deposits comprise marcasite, iron sulphate, limonite, gypsum (in the forms of selenite and satinspar), native sulphur, and small amounts of iron oxide. Pyrite - in the form of small cubes - sometimes occurs in narrow lenses, but is more often disseminated and invisible to the naked eye. Siderite is most abundant in the Pierre Series, at times forming beds a few inches thick. Bentonite occurs as uniform, sharply defined beds, having a maximum observed thickness of 24 inches. Pyrite and marcasite, in the presence of oxidation agents give rise to the formation of small quantities of sulphurous and sulphuric acids. It may be possible that these acids, circulating through the shales, form soluble sulphates which are subsequently leached out, leaving bentonite as a residual product. To the oxidation of iron sulphides may also be attributed the nauseating sulphurous odor which, at times, emanates from shale banks, and has frequently been construed as indicating the presence of natural gas.

Absorption of oxygen, assisted by oxidation of iron sulphides, is responsible for slow spontaneous combustion in progress in many of the banks of shale. At one locality a column of thin blue smoke was observed rising from a smouldering bank, the talus at the foot of the bank being cemented together by various sulphates. Moreover, traces of free petroleum, released as a result of recognized chemical reactions, as well as small amounts of colloidal iron hydroxide, frequently accumulate to form a scum which, at times, has been mistaken for a true petroleum seepage.

## Sampling and Analyses.

In securing samples, overburden was removed and trenches cut from top to bottom of exposed sections. The depth at which samples were taken varied from four to eight feet from the face; but it is considered that in each instance unaltered shale was produced. A number of samples were tested in the field, and satisfactory results were obtained by the use of a retorting apparatus[1] somewhat similar to that recommended by the U.S. Bureau of Mines. Only the petroleum content was determined. In the case of certain other samples, subsequently tested in the laboratory, the yield of ammonium

1 Reports of Investigations, U. S. Bureau of Mines, Serial No.2229.

sulphate was also determined. Twenty-two representative samples were procured on the northern branch of the Pas river, Man river, Cracking river, Papikwan river, Jordan river, and Carrot river, in the province of Saskatchewan; and nineteen samples from Steeprock river, Birch river, Favel river (east and west branches), Sinclair river, North Duck river, Sclater river, North Pine river, Vermilion river, and Ochre river, in the province of Manitoba.

Certain of these samples showed merely a trace of hydrocarbons, hence reference to them is omitted in the following summary[2]:-

2 Determinations by Chemical Laboratories, Mines Branch, Department of Mines.

## Analyses.

| Locality. | Imperial gals. crude petroleum per ton.[1] | Sp. gr. of crude petroleum at 60°F. | Imperial gals. water per ton. | Pounds ammonium sulphate per ton. |
|---|---|---|---|---|
| Tee river, Sask., (2 samples), Tp.53, R.1, W.of 2nd. | 3.1-5.3 | .972-.984 | 12.5-16.0 | - - |
| Man river, Sask., (8 samples), Tp.50, R.5, W.of 2nd. | 5.[illegible]-9.4 | .942-.964 | - - | 3.1-8.7 |
| Cracking river, Sask., (6 samples) Tp.49, R.7, W.of 2nd. | 7.0-12.8 | .949-.970 | 11.6-28.0 | 2.6-4.5 |
| Jordon river, Sask., (float), Sec.6, Tp.48, R.10, W.of 2nd. | 10.9 | .964 | - - | 3.0 |
| Carrot river, Sask., (2 samples), Sec.25, Tp.48, R.11, W.of 2nd. | 4.9-6.[illegible] | .958-.959 | - - | 1.7-2.8 |
| Birch river, Man., Sec.3[illegible], Tp.39, R.26, W.of 1st. | 0 | - - | 42.7 | - - |
| Favel river, Man., Sec.30, Tp.35, R.25, W.of 1st. | 6.2 | .972 | 12.1 | - - |
| Sec.26, Tp.35, R.26, W.of 1st. | 6.8 | .984 | 7.0 | - - |
| " " " " " " " " " | 5.9 | .965 | 15.2 | - - |
| Solater river, Man., (2 samples), Sec.15, Tp.34, R.23, W.of 1st. | 4.8-7.5 | .966-.968 | 9.2-18.7 | - - |
| Pine river, Man., Sec.6, Tp.33, R.22, W.of 1st. | 3.5 | .969 | 4.5 | - - |
| Vermilion river, Man. (2 samples) Sec.12, Tp.24, R.20, W.of 1st. | 1.1-5.1 | .952 | 8.1-22.0 | - - |
| Ochre river, Man., (2 samples), Sec.29, Tp.22, R.17, W.of 1st. | 4.0-5.3 | .955 | 14.6-15.2 | - - |

1 Calculations based on ton of 2000 pounds.

The sulphur content of the crude petroleum recovered from six representative samples of shale, varied from 5.3% - 7.7%, with an average for the six samples of 6.5%. A sample of crude petroleum distilled from shale secured on Ochre river, Man., (Sec. 29, Tp. 22, R. 17, W. of 1st) was fractionated with the following result:-

Distillation Range. Barom. 766.0 mm.

| | |
|---|---|
| 1st drop | 79°C |
| 10% | 149°C |
| 20% | 170°C |
| 30% | 221°C |
| 40% | 254°C |
| 50% | 281°C |
| 60% | 301°C |
| 70% | 336°C |
| 80% | 350°C |
| 90% | 361°C |

92% Dry point, (Cracking occurred)

The gas yield from 13 representative samples of shale was also determined, and varied from 410 - 1130 cubic feet per ton, with an average yield of 695 cubic feet. Analyses of two samples of gas recovered from shale secured on Man river, Sask., (Tp. 50, R.5, W. of 2nd) are as follows:-

| | Sample No. 1825 | Sample No. 1831 |
|---|---|---|
| Carbon dioxide % | 32.6 | 23.3 |
| Oxygen % | 2.1 | 3.1 |
| Ethylene % | 3.7 | 3.8 |
| Carbon Monoxide % | 2.4 | 1.9 |
| Methane % | 28.7 | 30.6 |
| Hydrogen % | 9.1 | 7.5 |
| Nitrogen % | 21.4 | 29.8 |
| Inflammable Gas % | 43.9 | 43.8 |
| Calorific Value, gross, | 383 | 297 B.T.U.per cu.ft. |
| Calorific Value, net, | 346 | 359 B.T.U.per cu.ft. |

## Conclusion.

It is, therefore, obvious that shales examined during the past season in the provinces of Manitoba and Saskatchewan are of little present economic importance as a possible source of petroleum or of ammonium sulphate. Should conditions at any time warrant commercial development, open-cut mining could be undertaken in many areas under favourable conditions. Over very considerable areas, the shales examined are covered by a comparatively light overburden, consisting chiefly of boulder clays and gravel, which could be readily removed by hydraulicing methods.

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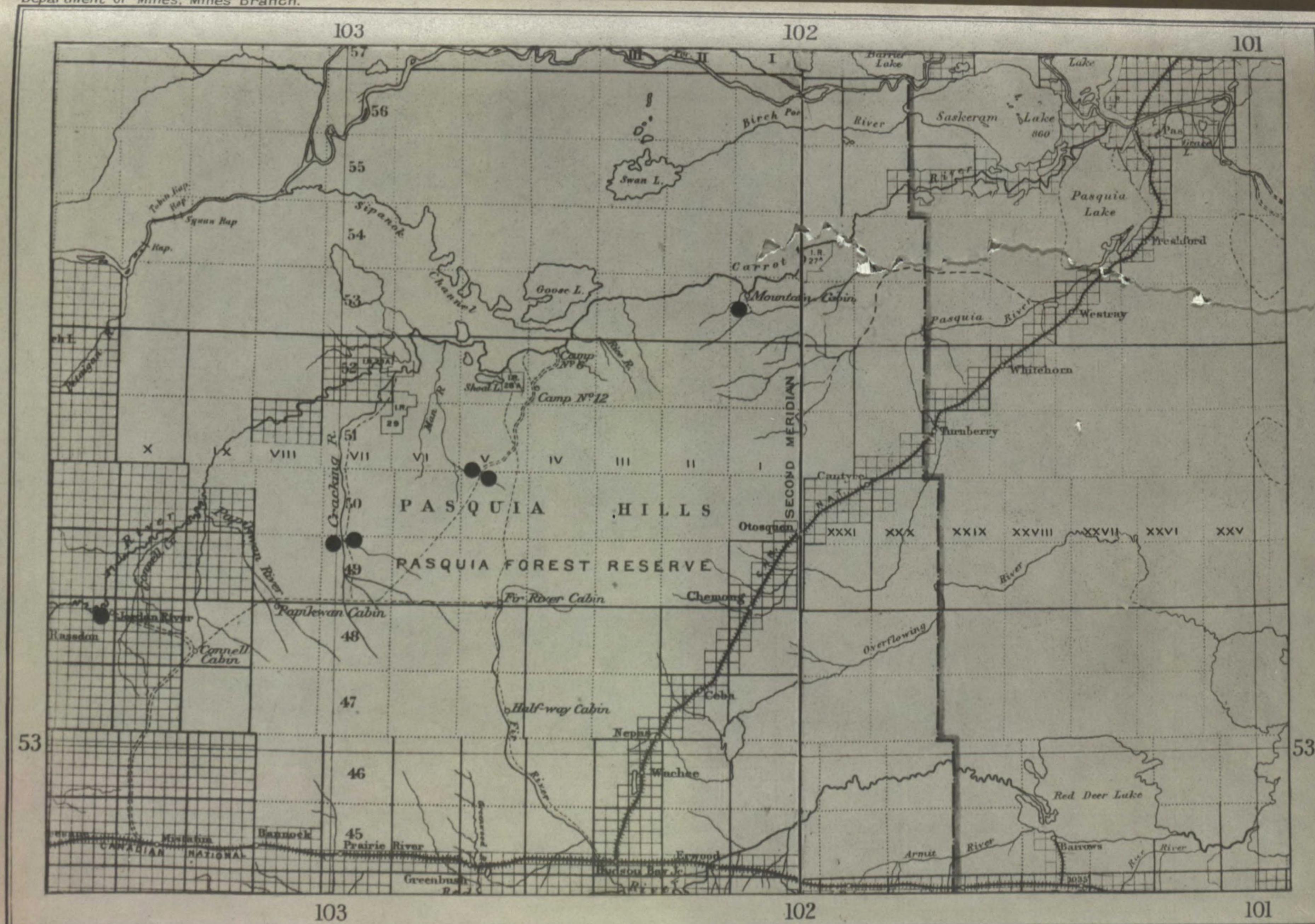
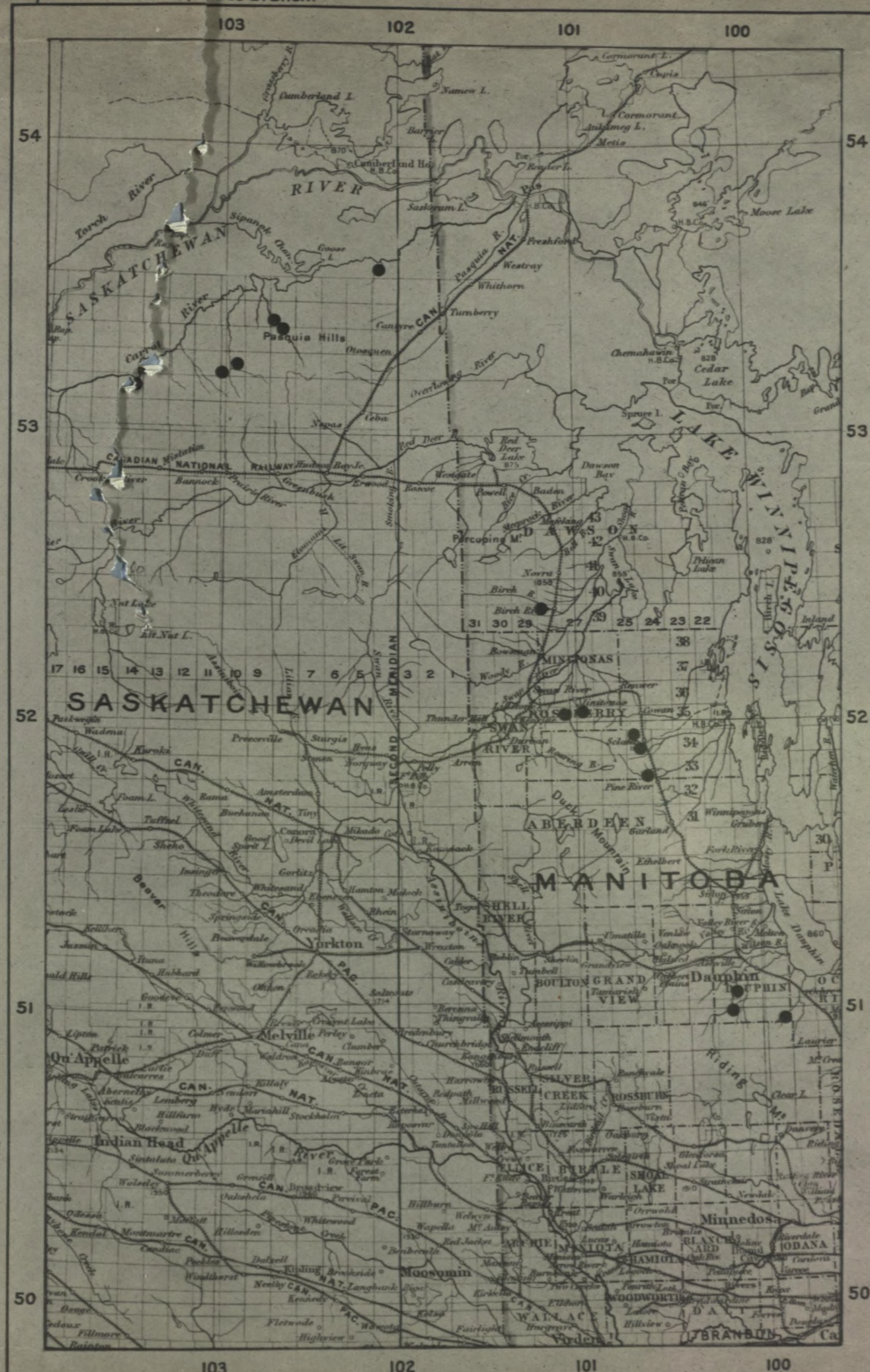



*Map showing position of Outcrops of Cretaceous Shales sampled during year 1921, in Pasquia Forest Reserve, Saskatchewan.*
*Scale:- 12½ miles to 1 inch*

Department of Mines, Mines Branch.




S.C.Ells, C.E.1921

*Map showing position of Outcrops of Cretaceous Shales sampled during year 1921, in Manitoba and Saskatchewan.*
*Scale:- 12½ miles to 1 inch*