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CONTENTS

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SUMMARY REPORT, 1919, PART G.

PALÆOZOIC ROCKS OF MATTAGAMI AND ABITIBI RIVERS.

By M. Y. Williams.

CONTENTS.

Illustrations.

INTRODUCTION.

As the need for increased production of petroleum in Canada has become more and more pressing, attention is being directed to the less known sedimentary basins as possible sources of supply. Among these, the region to the south and west of James and Hudson bays is perhaps easiest of access. For many reasons public attention has been called to this region, and as a result the Department of Mines, Canada, co-operating with the Bureau of Mines of Ontario, undertook, during the summer of 1919, the exploration of the area between the National Transcontinental railway and Moose Factory, following the valleys of the Mattagami, Abitibi, and Moose rivers. The Ontario Bureau of Mines covered the Pre-Cambrian region traversed by the upper waters of the rivers, the Department of Mines confining its attention to the sedimentary basin adjoining James bay. Mr. Keele, chief of the Ceramic Division of the Mines Branch, paid special attention to the lignite, iron ore, clay, and other surficial deposits, and the writer, representing the Geological Survey, studied more especially the Palæozoic stratigraphy and rock structure, and their significance in relation to the possible accumulation of petroleum.

Acknowledgments.

The writer wishes to acknowledge the debt he owes Mr. C. M. McCarthy, of Elk Lake, who secured guides for the trip, and accompanied the party as far as Long rapids on Mattagami river. His knowledge of the region was of great value, not only in travelling but in finding rock outcrops. The guides he selected proved faithful and efficient and added much to the success of the trip.

Acknowledgments are also due Messrs. Poole and Peters of the Forestry Department of Ontario, Mr. W. B. Way, Superintendent of the National railways at Cochrane, and other railway officials for kind co-operation and assistance.

The fossil identifications of this report have been revised by E. M. Kindle of the Geological Survey.

Route Travelled.

The party travelled by canoe downstream, via Groundhog, Mattagami, and Moose rivers, to Moose Factory, and back by Moose, Abitibi, and Frederick House

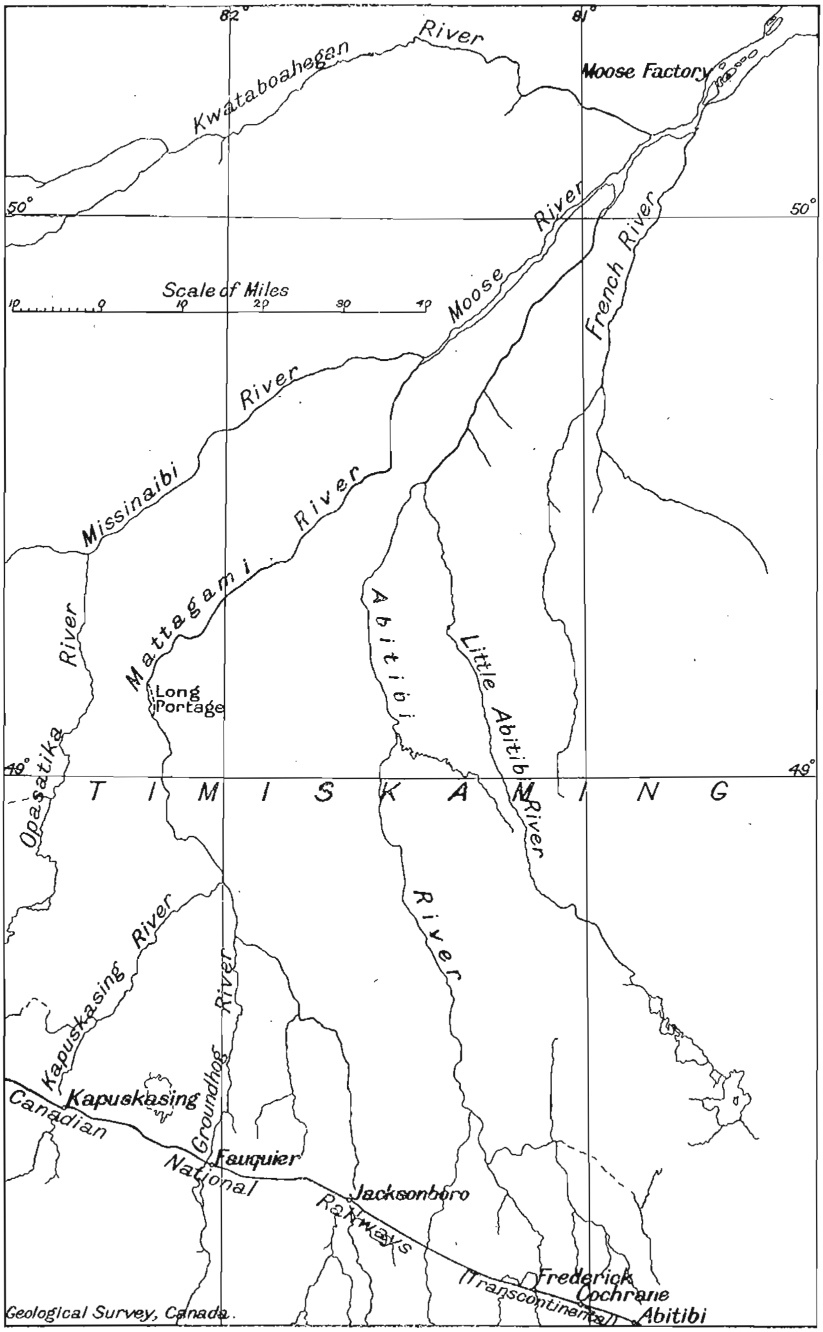

Figure 1. Index map, Moose river and lower Mattagami and Abitibi rivers, Ontario.

rivers. The start was made on August 1 from Fauquier, where the National Transcontinental crosses Groundhog river, and the trip was completed on September 5 at the landing on Frederick House river, 3 miles from Clute post-office, and 15 miles from Cochrane by wagon road. August was chosen as the best time to make the trip because of the greater facility with which the river sections may be studied at low water.

General Character of Palæozoic Basin.

At Long portage on Mattagami river, and Otter portage on Abitibi river, the Pre-Cambrian, crystalline rocks slope steeply to the north and finally disappear below the younger deposits, not to reappear along the lower waters of these rivers, where all outcrops are of sedimentary formations—sandstones, shales, limestone, and gypsum. However, to the east of the area traversed, along Little Abitibi river, a few miles above its junction with Abitibi river, Pre-Cambrian gneiss is reported to outcrop. Other Pre-Cambrian outcrops are reported from the east branch of French river, and from the country about 25 or 30 miles east of Moose Factory. Because of the ease with which the sedimentary formations weather and wear away, they outcrop only at intervals along the rivers, and in some cases as very small exposures.

The river banks rise, on an average, to an elevation of about 50 feet, where a terrace is commonly found, covered with a fine growth of white spruce, white and black poplar, and white birch. White cedar, tamarack, and jackpine do not extend much farther north than the edge of the Pre-Cambrian rocks. Back of the river terrace, there is commonly a slope of 30 or 40 feet up to the general level of the country, which appears to be nearly flat and is covered with typical northern muskeg—a floor of sphagnum moss, labrador tea, and laurel, studded with distantly spaced, stunted black spruce. The outcrops of rock seen are along the water's edge, and they rarely rise as high as 50 feet. The overlying deposits are of glacial and fluviatile, unconsolidated materials, more specifically described by Mr. Keele. Along lower Moose river the topography changes, in that ice has shoved up the banks of the river from 4 to 8 feet above the general elevation of the country, which gradually decreases towards James bay.

Summary and Conclusions. The Palæozoic formations exposed are indicated in the accompanying table.

Palæozoic Section.

	Formations.	Mattagami river.	Abitibi river.
Devonian	Portage	Green and black shale	Green and black shale; age (?)
	Genessee? Ohio shales	Black shale	Black shale.
	Tully		Thin green limestone in green and black shale.
	Hamilton		Green and brown shale; age (?)
	Onondaga	Buff dolomite	Buff dolomite.
Silurian	Salina	Gypsum Red shale Grey shale	
		Laminated limestones	
	Formation not determined		Grey argillaceous limestone; age(?)
Ordovician	Queenston (?)	(Not seen)	Red shale.
	Basal clastics		White sandstone.

Igneous Intrusives. Dykes of green trap cut the Onondaga limestone and lower formations.

Secondary Deposits. Concretionary ironstone occurs in caverns in Onondaga limestone and includes lignite fragments.

The Palæozoic sections on Mattagami and Abitibi rivers contain rocks representing the Ordovician (Queenston ?), Silurian (doubtful beds and Salina), and Devonian (Onondaga, Hamilton, Tully, Genessee and Portage) systems.

Economic possibilities within the Palæozoic formations appear to be confined to the gypsum deposits of Moose river, the oil-bearing shales of Mattagami and Abitibi rivers, and the chances of oil occurrence through this large basin of sedimentary rocks. Under present conditions of transportation the chance of oil occurrence is the only inducement for prospecting.

DETAILED GEOLOGY.

Oldest Formations and Sextant Portage Section.

The oldest recognized Palæozoic strata are seen in the fine section in the east bank of Abitibi river about one-quarter mile below Sextant portage. Trap rock occurs near the foot of the portage, but it is doubtful, as described below, whether this is a part of the basal Pre-Cambrian floor or a later intrusive. The lowest observed deposits consist of about 5 feet of coarse, friable, white sandstone, mixed with sandy shale and conglomerate. Judging from their conformable relationships with the overlying beds, they are probably of Ordovician age. The succeeding 10 feet consists of loose, arkosic conglomerate and sand, made up of fragments of Pre-Cambrian rocks. Above this is 10 feet of soft, red shale, identical in field characters with the Queenston shale of Ontario and New York. This shale is exposed in the west bank, up the river for about one-half the distance between Sextant and Otter portages. Mr. Keele has made test bricks of this material and finds that for brick making it compares closely with the Queenston shale of Milton, Ontario. The red shale is succeeded upward by about 5 feet of red sandstone and shale and 2 feet of thin, green beds, suggesting glauconite. Above these again is about 5 feet of limestone alternating with red shale. As no fossils were found in the red shale formation, its age determination depends upon its position in the section and its physical characters. On these grounds it is classed as Queenston (?).

About 18 to 20 feet of green, grey, argillaceous limestone succeeds the red shale formation. A few fucoidal markings were all the indications of fossils seen in these beds, which appear to overlie the red shales conformably. It is probable, however, that what appears to be glauconite represents a disconformity, in which case the limestones with red shale partings would belong to the shaly limestones above. From their position in the section it seems probable that these impure limestones represent an inshore phase of some of the Silurian deposits, but their exact age cannot be determined from the evidence at hand. The shallow water conditions and the proximity to the Pre-Cambrian old land, with the consequent large supply of clastic material derived from it, offer a satisfactory explanation of the characters of the deposits in this section.

Buff magnesian limestone of Onondaga age rests on the impure limestones. No unconformity is evident, but the abrupt change in sediments with an equally abrupt appearance of typical Onondaga fossils may be interpreted as indicating a time lapse between the Silurian and the Devonian periods, or an Epi-Silurian emergence followed by erosion and submergence. A sea favouring coral and crinoid life characterized Onondaga time here as elsewhere in the interior of North America.

A fine, sedimentary-igneous contact occurs on the west side of the river, opposite Coral portage, where a trap rock of Pre-Cambrian age about 50 feet across, rises about 30 feet above the level of the water. Its surface is irregular, jointed, and deeply eroded, its upper 15 feet being so weathered as to be friable, residual green clay covering part of the surface. The Onondaga limestone resting against the south side of this rock has suffered local faulting, evidently due to a solution channel which has formed along the contact with the trap. On the north side of the trap mass, horizontal arkose

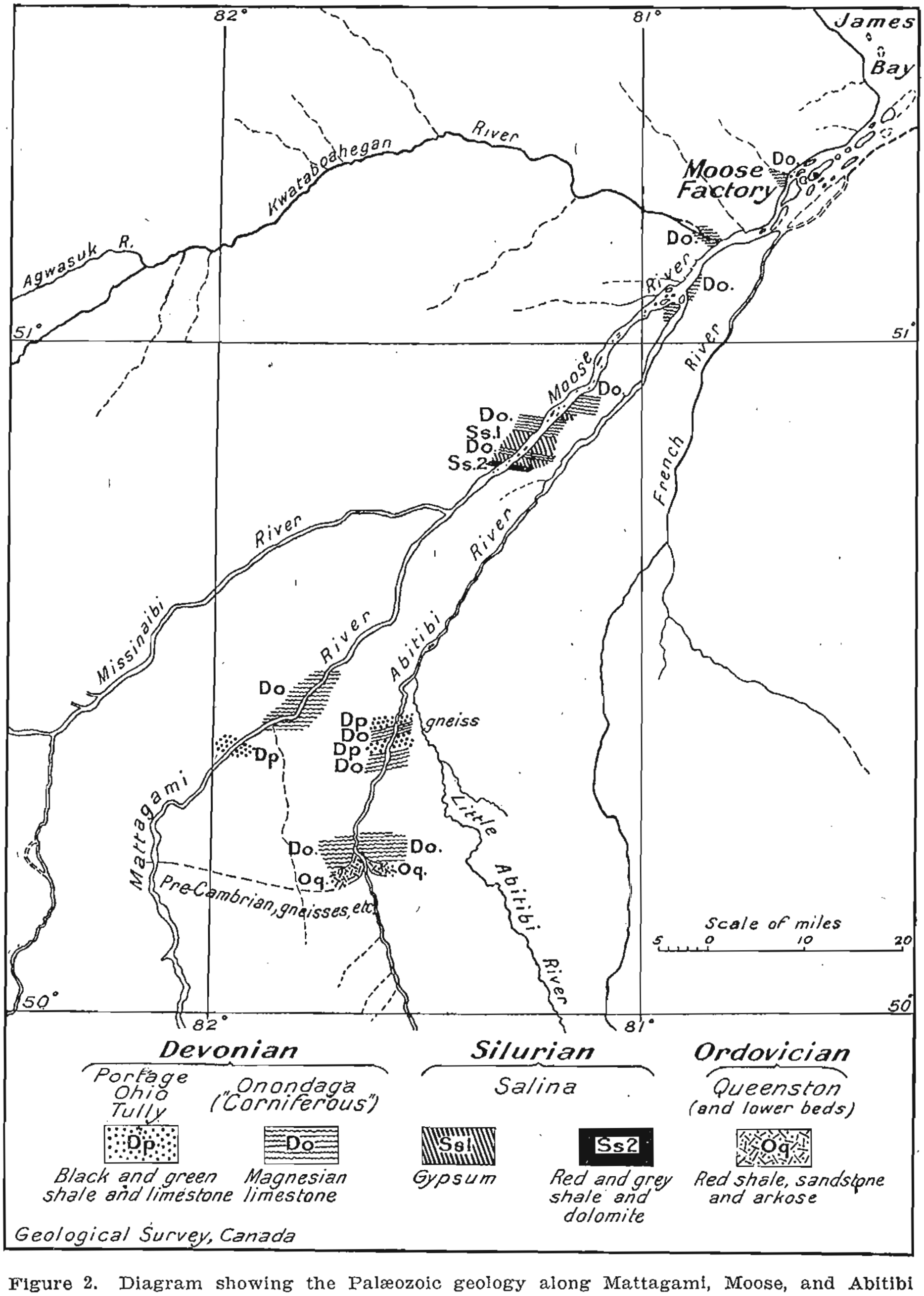

Figure 2. Diagram showing the Palæozoic geology along Mattagami, Moose, and Abitibi rivers, Ontario.

(at base) and coarse-grained sandstone beds rest on the eroded surface of the trap, rising in a 15-foot section. The Onondaga limestone beds of Coral portage dip to the east as though underlain by an extension of the trap mass. Thin sheets of intrusive trap penetrate the fractures of the limestone in the faulted zone mentioned. Other intrusives in this vicinity are described below.

The horizontal, undisturbed condition of the sandstone, and the basal arkose, suggest a much younger age than that of any of the other rocks. The material appears to be derived from the sandstone seen at Sextant portage, and may correspond in age with the lignite beds. The deeply weathered condition of the Palæozoic floor is very suggestive of the emergent conditions prevailing before the Palæozoic seas encroached on this part of the ancestral Canadian shield.

Silurian Formations.

Strata of Niagara age occur on Albany and other rivers to the northwest, but are not known on Moose river and its tributaries. The impure limestones of Sextant Portage section are doubtfully considered as Silurian, their closer affinities being unknown. Strata believed to be of upper Silurian age, however, outcrop on Moose river, below the mouth of Missinaibi river. There, shales and thin limestones outcrop at the head of the third island from the foot of the Grey Goose Island group. The strike of the beds is 81 degrees, the dip northerly 13 to 19 degrees. The section is as follows in ascending order: thin, grey, laminated dolomite, with dark partings, 8 feet; covered interval, 15 feet; soft, thin-bedded, cream-coloured dolomite, 15 feet; dolomite in 1-foot beds, 15 feet, to horizon of poorly preserved gastropods; soft, yellow dolomite, 20 feet; hard, pink and grey dolomite, 2 feet; covered interval, 20 feet; soft, green sandstone, 7 feet; soft, red, plastic shale, 29 feet; green shales, mostly removed by erosion.

Red and green shales outcrop near the centre of the west side of the island, in an exposure 20 feet high. If the dip of the formation is northerly for this distance, which is probable, these beds occupy a higher position in the section than those above described.

Buff limestone containing fossils of Onondaga age, outcrops at the head of the large island next to the lowest of the Grey Goose group. This outcrop is in the form of an anticline, the direction of the axis being about north 80 degrees east. The cross section is exposed for about 500 feet; the dip on the north limb is 16 degrees, and on the south 25 degrees, the top being flat.

Just north of the exposure described, the strike of the beds is south 49 degrees east, and the dip southwest at an angle of 9 degrees. Other small folds succeed to the north.

Gypsum and selenite beds occur in the west bank of the river opposite the lower third of the island with the limestone exposures. These dip southerly beneath brecciated limestone which is elsewhere seen at the base of the Onondaga limestone. Gypsum also occurs on the east bank opposite the foot of the island. The structure is somewhat confusing, but it is clear that the gypsum overlies the shale series and the Onondaga limestone overlies the gypsum. Although no fossils were found below the Onondaga, it is safe to infer from their position in the geological column and their close resemblance to the Salina of Ontario and New York that the red and green shales are Salina in age, as is also the overlying gypsum. Bluffs of gypsum, rising as much as 20 feet in height, continue downstream for about 4 miles. At a number of different localities the gypsum is overlain by Onondaga limestone, which rests in irregular, eroded channels in the top of the gypsum. A good exposure of the contact may be seen east of the lower end of the lowest of the Grey Goose Island group. Gypsum is also exposed for about 200 yards along the east bank of the river opposite the third island of the group below the Grey Goose group. The surface dips to the north and is overlain by Onondaga limestone. The total thickness of the gypsum deposits cannot be directly measured, but may be estimated to be at least 40 feet. No gypsum deposits are known on Abitibi river, but about 1 mile above its mouth, a 10-foot section of dolomite containing some gypsum occurs in the west bank of the river. The beds of Onondaga limestone at the mouth of the Abitibi appear to correspond with those usually overlying the gypsum deposits. The gypsum may lie a short distance below.

Onondaga Magnesian Limestone.

The lowest beds of the Onondaga ("Corniferous") limestone rest, as described above, in eroded channels in the underlying gypsum. A decided unconformity is here present between the rocks of Silurian and Devonian age, and formations represented elsewhere are absent. In many places, the lowest Onondaga beds are nodular, or brecciated, gypsiferous, and unfossiliferous. Examples of such beds occur above the gypsum beds of Moose river and at the base of the iron ore deposits at Long rapids of Mattagami river, where domes 25 yards across with a 5-foot rise at the centre are a common feature. There, a considerable amount of pyrite occurs in the limestone, although most of it has altered to limonite. At the head of Long rapids the beds of limestone exposed near the low water-level are saccharoidal, finely granular, pea-green in colour, weathering grey or more rarely rusty red or brown. These beds are probably near the base of the Onondaga formation. The 12-foot cliff of limestone at the angle between Moose and Abitibi rivers in thin-bedded, hummocky, and unfossiliferous and resembles closely the basal limestone described above. Hummocky limestone along Abitibi river about one mile below the head of Long rapids is similar in character but probably represents a higher horizon. The basal beds of the Onondaga, where seen opposite Coral portage resting upon a green trap rock, are green and probably glauconitic. The basal Onondaga beds at Sextant portage are fossiliferous and not different from higher beds.

The thickest section of Onondaga limestone seen is that along Long rapids of Mattagami river. On the east side of the river and about 300 yards from the head of the rapids, a cliff of limestone rises 50 feet above low water-level. Beds exposed along the river, upstream and down, appear to belong to lower horizons, so that the thickness exposed is probably not less than 60 feet. The vertical cliff section is as follows: 8 feet of thin beds at bottom, containing crinoid columns; 6 feet of massive rock, containing cup and compound corals and stromatoporoids; upper 36 feet in beds 2 to 3 feet thick, more or less cross-bedded halfway up, and containing a rich fauna. The following species collected in the vicinity are mostly from this division: *Streptelasma prolifica* Billings, *Cystiphyllum varians* Hall, *Cyathophyllum robustum* Hall, *Favosites americana* Hall?, *Michelinia convexa* (d'Orbigny), *Rhipidomella livia* (Billings), *Gypidula comis* (Owen), *Atrypa reticularis* (Linnæus), *Delthyris consobrina* (d'Orbigny), *Meristella nasuta* (Conrad), *M. doris* (Hall), *Conocardium cuneus* (Conrad), *Orthoceras bebryx* Hall?, *O. troas* Hall, *Proetus macrocephalus* Hall. The upper beds are brown in colour weathering creamy, and the lower beds are cream-coloured. The rock is deeply weathered and saccharoidal and proves on examination to be a somewhat argillaceous, magnesian limestone.

The higher beds of the Onondaga limestone are represented by much loose rock at the mouth of Kwataboahegan river; by rock nearly in place just above tide-level, about 1½ miles (estimated) up Maidman creek, and in Fishingtent rapids on the east side of Moose river below the mouth of Abitibi river. The highest beds of Onondaga limestone are seen along Long rapids of Abitibi river where they are overlain by shales as described below. The upper 20 feet of limestone consists of beds which are heavy and uneven at the top, but are thinner lower down. The colour is buff or grey. Small worm castings or fucoids were the only fossils seen.

The limestone of Coral portage represents about 40 feet of a section, being probably the middle Onondaga beds. Corals and stromatoporoids are the common fossils. On the west side of the rapids, opposite the portage, the limestone overlies a green, Pre-Cambrian trap rock as already described.

At the section on the east side of the river below Sextant portage, the Onondaga is represented by about 15 feet of basal beds as already described.

Fossils. Many species of fossils have been collected from the Onondaga limestone south of James bay, by previous workers in the region. Those collected by the author were taken merely for stratigraphic purposes, and consist of the following, besides those mentioned above:

East side Moose river opposite Grey Goose island:

Cystiphyllum vesiculosum Goldfuss, *Martinia subumbona* (Hall).

Head of second island from foot of Grey Goose group, Moose river:

Gypidula comis (Owen), *Atrypa reticularis* (Linnæus), *Atrypa spinosa* (Hall), *Reticularia fimbriata* (Conrad), *Martinia subumbona* (Hall), *Pleurotomaria doris* Hall?

East bank of Moose river opposite north island of Grey Goose group:

Atrypa reticularis (Linnæus), *Delthyris* cf *sculptilis* (Hall).

Corals are abundant in the vicinity of Coral and Sextant portages, including *Streptelasma prolifica* Billings, *Cystiphyllum vesiculosum* Goldfuss, and *Heliophyllum prolificum* Hall?

An analysis of the fossils listed supports the conclusion that these limestones are of Onondaga age, as *Meristella doris, Rhipidomella livia,* and *Conocardium cuneus* are confined to the Onondaga limestone in southwestern Ontario. Of these, *C. cuneus* is the best guide to the Onondaga in the region south of James bay. The presence in the same formation of *Martinia subumbona* suggests the Delaware formation of southwestern Ontario and *Gypidula comis, Delthyris consobrina,* and *Proetus macrocephalus* suggest the Hamilton formation. As these formations are conformable in southern Ontario and New York state, the fossils are very distinct and it is quite possible that the limestones of the James Bay region may represent in part all three formations as known farther south.

Upper Devonian Formations.

Long rapids of Abitibi river are caused by the water flowing over transverse folds, involving the top of the Onondaga limestone and the overlying grey and black shales and interbedded limestones.

As a result of structural conditions, the section continues on and off for about 4 miles. The outcrops from which the following description was taken, occur along the west side of the river opposite the large limestone island near the foot of the rapids. As reconstructed in ascending order, it is about as follows: 20 feet of heavy, unevenly bedded limestone, of Onondaga age; probably 6 or 7 feet of green clay shale; about 8 to 10 feet of brown to black shale; a 2-foot bed of green limestone with shale partings, and carrying considerable amounts of pyrite. This limestone bed contains *Hypothyris cuboides* (Sowerby) and Leiorhynchus (?) sp., the former being characteristic of the Tully limestone of New York state.

It would thus seem probable that the 13 or 18 feet of shale overlying the Onondaga limestone contains any Hamilton shale present, the limestone above being Tully in age. The presence of Hamilton beds here is not established.

Above the Tully limestone several sections of brown and black shales from 15 to 30 feet thick are exposed along the river and thin beds of soft green shale occur at different horizons. On the east side of the river fine shale sections are exposed, the probable thickness represented being 50 feet. All told, it is probable that about 100 feet of brown and black shales occur along the river. Numerous small spores occur in shale beds which represent approximately the middle portion of the section. These are somewhat smaller than the spores seen in the Huron shale of Kettle point, but there appears no good reason for considering them other than *Protosalvinia huronensis* (Dawson). On the evidence of these spores, the only fossils seen, the shales above the limestone referred to the Tully are probably to be correlated with the Huron shales of Kettle point, Ontario, and of Ohio, these shales forming the lower division of the Ohio shales. It has not been determined whether or not the higher beds represent the Cleveland or upper division of the Ohio shale.

Portage Shales.

On Mattagami river, about 4 miles above Pike creek, a very small outcrop of bluish shale containing nodular limestone, about 1 foot thick, occurs near low water-level. Calcareous concretions of spheroidal shape and one foot or less in diameter occur in the limestone along with pyrite concretions. The only fossil recognized is *Pugnax pugnus* (Martin). About 1 foot of pea-green shale overlies the limestone, this in turn being overlain by a few inches of black shale, which is covered by glacial till. *Pugnax pugnus* is characteristic of the Portage phase of the Ithaca fauna of New York state, and it consequently appears that this outcrop is of Portage age, and that the Huron shale may be expected below it. Mr. C. M. McCarthy has found brown shale on the west side of Mattagami river a little higher up. No fossils were found in the specimen submitted but it is probable that the beds represented are lower than the limestone outcrop and are of Ohio shale age.

Post Middle Devonian Trap Intrusives.

In the vicinity of Coral and Sextant portages, thin dykes and sheets of trap cut the sedimentary rocks from the base of the section as high up as the Onondaga limestone. The author found sheets of trap, a few inches thick, cutting Onondaga limestone on the west side of Abitibi river opposite Coral portage; and just above Sextant portage, a dyke dipping to the north at a steep angle, cuts up through the red Queenston shale. The author did not examine this close at hand, but W. R. Maher, locating engineer of the Timiskaming and Northern Ontario Railway Commission, obtained samples of it and reports that the dyke varies in thickness from 2 feet to 6 inches. The lowest 5 feet exposed, dips vertically and becomes much contorted.

Mr. Maher also found thin trap sheets lying upon limestone beds west of Abitibi river between Otter and Sextant portages. Some of the igneous rock at the foot of Sextant portage may be of the same age.

The dyke was mentioned by W. J. Wilson,[1] who, however, did not examine it. He also found "seemingly bedded eruptive rocks" on the west side of the river opposite Sextant portage. Mr. LeRoy reports on these as follows:

"The hand specimens represent a very dark almost black augite lamprophyre of a type closely allied to the monchiquites. The section consists of aggregates of calcite and serpentine as pseudomorphs after olivine and pale brown and pink idiomorphic augites in a groundmass of augite, shreds of biotite, calcite, chlorite, magnetite and a fibrous zeolite." Specimens of the dyke opposite Sextant portage were collected by Mr. Maher. Dr. N. L. Bowen, who examined them, reports that the material is deeply weathered, and that he can add nothing to Mr. LeRoy's description except that the fibrous mineral proves to be a new species related to the zeolites, which he has named "echellite."[2]

Although previously noted, the importance of these intrusives appears to have been overlooked. Their age is clearly post middle Devonian, and they compare in general characters with the dykes of similar age at Ithaca, New York state. The intrusives in the vicinity of Montreal may be of the same age, but elsewhere, no intrusives younger than Pre-Cambrian are known in central Canada. It is possible that some of the trap dykes cutting Pre-Cambrian rocks in northern Ontario and Quebec may belong to the same period of intrusion.

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1 Geol. Surv., Can., Sum. Rept., 1902, p. 237A.
2 Am. Min., vol. V, No. 1, Jan., 1920, pp. 1-3.

ECONOMIC DEPOSITS.

Iron Ore.

The iron ore deposits are described by J. Keele,[1] but their relationship to the Onondaga limestone may be mentioned here. At Long rapids of Mattagami river, the Onondaga limestone shows numerous sections of solution cavities, some 30 feet deep, and 50 feet or more across, the bottoms being near the present low water-level of the river. The limestone at these localities is deeply weathered. Some beds of the formation contain considerable quantities of iron pyrite, as may be seen at exposures about 4 miles below Long rapids, and streams issuing from the limestone are commonly coloured with hydroxide of iron which collects under suitable conditions. The iron ore as already described by Mr. Baker consists of ironstone or bog ore, which includes limestone fragments and in part replaces the limestone. Unconsolidated sand and fragments of lignite were also found to be included in the ore. This may not mean that the whole iron formation is post-lignite in age, for some bog ore is forming at the present time, and some may have formed at a much earlier period. Of whatever age the deposits, the iron pyrite of the adjoining Onondaga limestone formation is probably the source of the iron. It is noticeable that no iron deposits of this character occur along Mattagami river except in the cavities of the limestone.

Gypsum.

As already described the gypsum beds underlie the Onondaga limestone and were deeply eroded before Onondaga time. It seems very probable in these circumstances that the gypsum is of Salina age, or approximately of the same age as the gypsum beds of southern Ontario. The shale beds underlying the gypsum are very similar to the Salina shales.

The gypsum has already been well described by previous writers.[2] Although cut by cracks and solution channels which have allowed soil and clay to penetrate the beds, much gypsum is still little contaminated, and large masses of selenite and marbled gypsum occur. The total thickness of the beds is not known, but as much as 20 feet of gypsum occurs in some of the cliffs. These deposits may be looked upon as a reserve to be drawn upon when transportation and market conditions make their exploitation possible.

Possibilities of Oil Accumulations.

Extensive basins of sedimentary rocks of Palæozoic or later age are commonly found to contain oil accumulations, which may or may not be indicated by oil seepages or springs. The extensive Palæozoic area to the south and west of James and Hudson bays, is known to contain formations of the same age as oil-bearing formations elsewhere, but to date no oil seepages are known to occur. Owing, however, to the long period of weathering along the rivers, which may have dissipated any oil formerly present, and to the heavy burden of clay, silt, and muskeg moss which covers the interstream areas, the lack of observed oil seepages is not to be wondered at.

The Trenton formation outcrops on Nelson and Churchill rivers, the Niagara on Nelson, Albany, and the intervening rivers, and the Salina and the Onondaga ("Corniferous") on lower Albany river and Moose river with its tributaries. From analogy with other occurrences, these formations may be expected to contain oil. Economic accumulations, however, may only be looked for where there is an impervious cover to retain oil in the formation, and where the structure of the formations is favourable for oil accumulation.

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[1] See also Baker, M. B., 20th Ann. Rept., Ont. Bureau of Mines, 1911.

[2] Bell, Robert, Geol. Surv., Can., Rept. of Prog., 1875-76, pp. 321-322.
Bell, J. M., Ont. Bureau of Mines, 1904, pt. I, p. 156.

In this region drained by Moose river and its tributaries, the Onondaga limestone and the Salina shales are known to occur, but the Niagara and Trenton have not been observed, although they may be present beneath the outcropping formations. The Salina is not generally oil-bearing, but some of the lower dolomitic beds of this formation contain large quantities of oil in parts of southwestern Ontario, notably in Tilbury township, Kent county. As the Salina consists of alternating shales and limestones, it is probable that suitable cover is present for any oil-bearing horizons which may be present. The Salina formation as a whole is generally well covered by younger formations.

The Onondaga limestone, which has been the most uniformly productive formation of southwestern Ontario, outcrops at the surface over wide areas, as already described, and for that reason an impervious cover is generally lacking. In the vicinity of Long rapids of Abitibi river, and about 4 miles above Long rapids of Mattagami river the Onondaga is covered in part by impervious shales. The areas known to be covered, however, are comparatively small and unless larger areas occur beneath the interstream regions in the vicinity, it is scarcely likely that extensive accumulations of oil are present in the Onondaga. The shale areas, however, probably indicate the deepest part of the basin (that is the greatest accumulation of sediments) and consequently a suitable location for testing the lower formations.

The structure in the Long Rapids region of Abitibi river consists of a well-marked series of low folds, the major anticlines being represented respectively by the limestone areas near the head and the foot of Long rapids. The axes appear to extend north about 65 degrees east, and the dips of the limbs probably average 6 degrees, although one was noted measuring 13 degrees. Smaller subsidiary folds are superimposed on the larger folds, the whole structure being clearly expressed in the exposures on the islands and in the banks of the river. The proximity of the Pre-Cambrian gneiss reported about 4 miles to the northeast on Little Abitibi river suggests that the folding is due to the uneven surface of the underlying crystalline rocks.

On Mattagami river the formations lie nearly flat.

Among the islands in Moose river below Grey Goose island, a series of folds occur with axes running nearly east and west and with dips as high as 25 degrees. The large island, next to the lowest of the group, lies in a syncline, but has at its head, a sharp local anticline with dips to the north of 15 degrees and to the south of 25 degrees. The gypsum deposits appear to indicate a broad, low anticline, and the Salina red and grey shale and limestone series of the third lowest island of the Grey Goose group evidently forms the northern limb of another anticline. The alignment of the gypsum outcrops of Moose river, Gypsum "mountain," and of the French River valley suggests the location of one of the best marked anticlines in the region.

As Pre-Cambrian crystalline rocks outcrop at various places throughout the region east of Abitibi river, it is scarcely probable that the Palæozoic basin is very deep anywhere in their vicinity. It is more likely that the basin is deeper to the west, the centre possibly being near the centre of the Onondaga outcrops in the interstream region between Moose and Albany rivers. It is doubtful whether a depth of Palæozoic strata greater than 600 or 700 feet is to be expected even there.

Oil shales.

The Ohio shales, as already described, outcrop on Mattagami river, just north of Speight's 1911 base line, and on Abitibi river, in Long rapids. The outcrops along the Mattagami are of limited extent, but there is evidence that the outcropping beds are of Portage age; and if they are the whole Ohio shale section may be present. Prospecting may show that still larger areas of shale are present than is indicated by the discoveries made so far. The shales along Abitibi river near the upper end of Long rapids, occur in a syncline about 1½ miles wide, and as north dipping beds about one-half mile across near the lower end of the rapids. These beds probably also lie in a syncline. The section extends upward from the top of the Onondaga limestone and may be as much as 100 feet thick. Exposed sections in the west bank of Abitibi river are 30 feet high, and sections seen in the east bank are probably higher. The black shales are interbedded with soft, green shales of varying amount, and even within the black shales, the oil content varies considerably. The following analyses of the shales of the lower part of Long rapids of Abitibi river were made by the Mines Branch of the Department of Mines, the report being as follows:

"No. 1575. Oil-shale (surface exposure from Long rapids, Abitibi river, Ont., sent in by M. Y. Williams, Geological Survey).

	Per cent.
Moisture	1·7
Ash	86·6
Volatile matter	10·2
Nitrogen	0·41
Oil yield (crude)	3·9
	Cals. per gram.
Calorific value	599

"Nos. 1572 and 1573. Sample of oil-shale sent in by J. Keele from Long rapids, Abitibi river; No. 1572 being a weathered sample (bituminous limestone), No. 1573 being an unweathered sample (black shale).

	1572. Per cent.	1573. Per cent.
Moisture	0·4	1·4
Volatile matter	26·8	13·1
Ash	31 4	84·8
Nitrogen	0·20	0·37
Oil yield (crude)	1·6	5·5
	Cals. per gram.	
Calorific value	230	639"

As these shales were taken from the bank of the river, and must have suffered much from weathering, it is probable that deeper buried portions would have a somewhat higher oil content.

MESOZOIC CLAYS IN NORTHERN ONTARIO.

By J. Keele (Mines Branch).

CONTENTS.

INTRODUCTION.

A wide belt of lowland plain, underlain chiefly by Palæozoic rocks, encircles the southern and western portion of Hudson bay in northern Ontario. A great area of Pre-Cambrian rock, standing at a somewhat higher elevation, lies south of the Palæozoic plain. The rocks of both the plain and the upland are mostly concealed by a thick sheet of glacial drift, principally boulder clay.

A considerable portion of the drainage of the Pre-Cambrian upland flows northward and the streams which carry it have cut down through the glacial drift, reaching in some places the underlying bedrock.

The Palæozoic rocks exposed along the streams are Silurian and Devonian, mostly limestone beds, but shales and sandstones are also included in both series. The Pre-Cambrian rocks which underlie the Palæozoic rocks and rise above them to the south are mostly gneisses and schists, cut by numerous dykes.

A full description of the Palæozoic rocks of the region is given by Dr. Williams elsewhere in this report.

It has hitherto been assumed that no pre-Glacial rocks later than Devonian were ever laid down on the coastal plain, or that if any were laid down they were subsequently entirely removed by erosion and denudation, and that there are no rocks there at present above the Devonian except the products of Pleistocene glaciation.

The existence of certain high grade clays which occur underlying the glacial drift in this region was made known by explorers several years ago, but their presence was attributed to the agency of moving ice sheets.

A laboratory examination of samples of these clays convinced the writer that the deposits were pre-Glacial, but fossil evidence was not available until the summer of 1919 when a personal scrutiny of the beds revealed a layer of sandstone interbedded with the clays, which contained fossil leaves and tree remains. These fossils although fragmentary were sufficient to indicate that they belonged to Mesozoic times.

As a result of this discovery the present ideas concerning the geological history of the Hudson Bay basin will have to be readjusted and some of the former conceptions of the mechanics of glaciation modified.

The clays on Missinaibi river were not seen by the writer, so a brief account of the findings of the earlier explorers on that stream is given here.

CLAYS ON MISSINAIBI RIVER.

In his report on the basin of Moose river, 1890, Mr. E. B. Borron gives an account of borings he made on the banks of Coal brook when examining the lignite beds of the Missinaibi.

Coal brook is a small stream entering the Missinaibi about 5½ miles below the foot of Long portage where the farthest north, Pre-Cambrian rocks outcrop on the river.

The borings revealed a thickness of 45 feet of lignite seams and clay beds, 35 feet of which lay below water level. All the clays were described as smooth and plastic, the colours being black, grey, white, reddish, and variegated, and the deepest hole bored ending in a bed of white sand. All the clays associted with the lignite were free from lime and appeared to be good fire-clays. They were recognized as quite different in colour and texture from the ordinary glacial clays of the region.

In the same report Mr. Borron describes a deposit of beautiful, white sand, associated with what he called kaolin in white and mottled pink and brown colours, which occurs on the east bank of the Missinaibi about 5 miles below the mouth of Coal brook. This deposit extends for about a mile along the river and rises to a height of not less than 100 feet.

Mr. J. M. Bell reported similar materials on the Wabiskagami[1] river, a tributary of the Missinaibi, at a point about 2 miles west of the deposit described by Mr. Borron.

The white clay and sand deposits on Missinaibi and Wabiskagami rivers were staked in 1911 by Messrs. Curran and Caulkins of Montreal. A description of these deposits sent to the Department of Mines by Mr. Caulkins states that the white clays are visible in the bed of the river and that they attain a height of 74 feet above water level. The boring operations were not successful in penetrating through the clay, so that the material that underlies it is unknown. It was suggested that the outcrops on the Wabiskagami were continuous with those on the Missinaibi, but the cover of glacial drift makes it difficult to prove the continuity of the beds.

Samples of the white clay from the above property were examined by the writer, who found them to be very plastic. They burned to a good white colour and were refractory enough to be classed as fire-clays as they did not soften below pyrometric cone 28 (1690 degrees C.).

The pink and yellowish portions of the deposit burned to pink and reddish colours and were not so refractory as the white, owing to their larger content of iron oxide, which rendered them slightly more fusible at high temperatures.

The following chemical analysis of the white clay from Missinaibi river was made by Mr. M. F. Connor of the Mines Branch.

	Per cent.
Silica	58·90
Alumina	26·63
Ferric oxide	1·40
Titanic oxide	1·25
Lime	0·56
Magnesia	0·16
Manganese	0·01
Potash	0·31
Soda	0·42
Water	10·30
	99·94

In an endeavour to account for the presence of these extraordinary clays the earlier writers invoked the aid of glaciation.

Mr. Borron in his report states the opinion that the white sand and clay were gathered up at some point not less than 100 miles to the north and transported to their present position by the southward-moving continental ice sheet. Mr. J. M. Bell likewise attributed the occurrence to transportation and deposition by ice action.

These views are erroneous, because large deposits of this character cannot be moved by ice action without becoming hopelessly intermingled with glacial debris, and their identity lost. Neither can they be attributed to interglacial deposition, because sediments of this kind cannot be laid down from the drainage basin of a

[1] Ont. Bureau of Mines, 1904, vol. LXIII, p. 160.

region that has been subjected to glaciation. In order that such high-grade, selected sediments can be accumulated it is necessary that all the debris resulting from former glaciation be removed and another cycle of rock weathering and decay, transportation, and deposition completed. It is probable that the entire period assigned to Pleistocene glaciation would not be long enough to accomplish this change and hence we must look for a pre-glacial origin for these clays.

CLAYS ON MATTAGAMI RIVER.

The occurrences of white clay on Mattagami river was first reported by Mr. E. B. Borron[1] as follows: "The yellow ochre crops out on the eastern bank of the Mattagami river about a quarter of a mile below the north end of the Long portage, and at the same place may be seen a fine white clay strongly resembling the china clay already referred to as having been found by me two years ago on the Missinaibi branch of the Moose river."

The last Pre-Cambrian rocks seen on the river going north are at the foot of Long portage, which is a distance of about 50 miles in a straight line north of the Transcontinental Railway line.

The white and coloured clays mentioned by Mr. Borron were not noticed again until 1916 when the attention of Mr. C. M. McCarthy was directed to them by some Indians during a journey up the Mattagami from James bay. Mr. McCarthy re-visited and staked claims on the deposit in the following year. He also collected samples of all the beds he could find and submitted them to the writer for testing. The results of the tests on these clays were published in the Summary Report of the Mines Branch for 1918, in which it was stated that one of the beds proved to be the most refractory fire-clay so far found in Canada.

The occurrence of this high grade clay was verified by the writer during a visit to the locality in August, 1919.

The fire-clays outcrop at intervals from beneath the river wash along the strip of sloping bank between low and high water levels, the greatest vertical height to which they rise being about 8 feet.

Above this level rise high banks of glacial clay. The fire-clays are mostly brightly coloured—pink, yellow, and greyish white—in strong contrast to the monotonously drab, glacial clays that are everywhere over the region.

A number of holes were bored at intervals along the strip of clay outcrops in order to ascertain the thickness of the clays and the variation in the beds. None of the holes put down went very deep, owing to the fact that in every case a bed of white or pale yellowish sand was encountered, which invariably let water into the bore-hole sooner or later and stopped the operation. The following three examples summarize the results of the borings.

	Feet.	Inches.
(1) Bright red and grey mottled clay	2	0
Yellow and grew mottled clay	2	0
Black clay	3	0
White clay	1	0
Sand	1	0
Water	1	0
(2) Dark grey, highly plastic clay	3	0
White clay	3	0
White sand with clay bond	10	0
Water	..	..
(3) White clay	3	0
Mottled pink and yellow clay	2	0
Reddish pink clay	2	0
Silty grey clay	3	6
White sand	1	0
Water	..	..

An effort was made to find the clay at higher levels by boring through the glacial drift in the high banks. Five holes were started on terraces, at different levels on the

[1] "Part of the basin of Hudson bay," Toronto, 1883.

boulder clay, but none of them succeeded in getting down very far, owing to the stones scattered through the clay. There are no surface indications of the fire-clays on the slopes of the higher part of the bank, but the constant slumping of the glacial clay and the thick forest and plant growth are sufficient to conceal any outcrops. The bottom of a small creek which enters the river not far from the fire-clay outcrop was followed up, but although the little stream had cut deeply into the glacial clays it did not reveal any fire-clays beneath them.

The details regarding the laboratory tests of these clays are published in the Summary Report of the Mines Branch, 1918, page 167.

The clays fall into two groups—those that have a comparatively high iron content and those that contain little or no iron. The iron has an effect on the colour, both in the raw and burned state, and lowers the refractoriness; nevertheless, the coloured clays are refractory enough to be classed as fire-clays. The white, black, and grey clays are highly refractory, as they do not deform under heat treatment below temperatures from 1,750 to 1,800 degrees C.

The following chemical analysis of a sample from one of the lighter coloured beds, collected by Mr. McCarthy, was made by Mr. W. K. McNeill of the Ontario Bureau of Mines.

Silica	53·10
Alumina	31·92
Ferric oxide	1·52
Lime	0·51
Magnesia	trace.
Potash	0·28
Soda	0·54
Water	12·35
	100·22

Owing to their plasticity, smoothness, good working and drying qualities, and their refractoriness, these clays would be extremely important from an industrial point of view, if they were within reach of transportation.

One of the black beds is highly plastic, but contains lignite fragments and quartz sand which can be easily removed by washing. The clay burns to a white colour and has properties resembling ball clay, a variety which is used to a great extent in the pottery industry. No occurrence of ball clay has hitherto been reported in Canada.

The white sands which underlie the clay beds are composed almost entirely of sub-angular and rounded quartz grains coated with white clay. There is also enough clay intermingled with the sand to make it coherent when wet. The sand when washed and freed from clay is pure enough to be suitable for the manufacture of glass and the clay washed from the sand burns white and is highly refractory.

About 6 miles below the foot of Long portage, at the big bend on the Mattagami, another outcrop of fire-clays occurs in the lower part of the bank of the river. The following beds were seen between the overburden of glacial clay and the river level.

	Feet.
Stiff, plastic, bluish clay	4
Well indurated, yellowish sandstone with abundant fossil plant remains	2
Light, blue-grey clay	2
Laminated, bluish-grey, silty clay	2
Massive bed of dark grey, micaceous, plastic clay	3

A little farther down stream, a bed of hard, black lignite with a woody structure, accompanied by white and black plastic clays, outcrops at intervals near the river level for a distance of 100 yards.

Only about 2 or 3 feet of these beds are exposed below the glacial drift and from the upturned attitude of the lignite seam they seem to have slumped from a higher level. It is possible that the lignite and the white and black clays really overlie the section given above.

The 3-foot, massive bed of micaceous clay at the bottom of the section (page 16) was the only one sampled for testing, as it looked the least promising from a refractory point of view; it proved to be a fire-clay. It was assumed that all the upper beds were fire-clays, as well as the beds accompanying the lignite, which are similar to those occurring just below Long portage.

Borings made in this locality in 1910 by Prof. M. B. Baker show that the fire-clays reach a depth of 16 feet below the river, but no lignite appears to have been encountered below the seam which outcrops on the river bank.[1] The bottom of the clays was not reached in the borings, so that the material underlying them is unknown.

AGE OF THE FIRE-CLAYS.

As these clays occur in such a remote region, isolated from all other known deposits of a similar kind, it is of interest to compare them with clays of a similar character which are used in the clay-working industry at accessible localities.

The fire-clays of northern Ontario, as far as known, are all situated on the low, rather flat area of Palæozoic rocks, which lies between the great area of Pre-Cambrian rocks and Hudson bay. The bottom of the fire-clay beds was not seen at any point where they were examined, as they extend below water level and borings failed to get through them.

The Palæozoic rocks found nearest to the clays were those of the upper Devonian and it is very likely that the fire-clay beds rest directly on the upper Devonian.

The fire-clays are all transported, fine-grained sediments and, as the name implies, they are fairly pure materials, free from an excess of fluxing impurities such as iron, lime, magnesia, and alkalis. Thin seams of well indurated, woody lignite accompany the clays, but so far as seen none of these is thick enough to be of economic value. A bed of pure, coarse-grained quartz sand, with which is intermingled a small amount of white clay, accompanies the fire-clays in one locality.

These materials are undoubtedly of pre-Glacial age, but of more recent origin than upper Devonian. They are approximately fixed in age by certain fossil plant remains in a bed of sandstone included in the clay beds at a point about 6 miles below the foot of Long rapid on Mattagami river.

Through the courtesy of Mr. David White a collection of these fossils was examined by the palæobotanists of the United States Geological Survey, who stated that "the material you transmitted is so fragmentary that with the few specimens in hand it is impossible to determine even the genera with certainty. However, most of the large fragments belong to a leaf of Taeniopteroid aspect. The nervation suggests some of the later types, such as are found in the older Mesozoic.

It is almost certain that the beds are not younger than Kootenay and they are surely not older than Permian."

As previously stated, no lignite beds were seen in the section containing the fossils, but there is very little doubt that the lignite and its associated clays, which occur about 200 feet farther down stream, belong to the same deposit.

As far as is known at present clays of this type are extremely rare in eastern Canada. In fact the only occurrence is in the Musquodoboit valley in Nova Scotia, where clays of this character are covered by glacial drift and overlie Lower Carboniferous rocks, but no fossils have yet been found in them. They are very similar to the Lower Cretaceous clays which occur so extensively on the Atlantic coastal plain in the state of New Jersey. Certain portions of the clay deposit on the Mattagami correspond in all their physical properties to some of the Musquodoboit clays.

The nearest point in western Canada where such materials occur is at Swan River,[2] Manitoba. At this locality lead grey clays containing a thin layer of lignite are overlain by soft white sandstone. These beds are of Cretaceous age and are generally referred to as Dakota.

[1] Ont. Bureau of Mines, vol. XX, pt. 1, p. 236.

[2] Geol. Surv., Can., Sum. Rept., 1917, pt. D, p. 37D.

Cretaceous sediments of Dakota age occur in a narrow belt along the southern margin of the Pre-Cambrian rocks in the province of Saskatchewan and are evidently the western extension of the Manitoba beds. The Dakota beds in Saskatchewan as observed by McInnes[1] are made up principally of soft, white sandstone and thin lignite seams, and the clay content appears to be very small.

The most extensive clay beds of Lower Cretaceous age occur in northern Alberta on Athabaska river and its tributaries north of Fort McMurray.[2]

The Athabaska clays were deposited on the western margin of the Pre-Cambrian area, where they overlie Devonian limestone and are associated with incoherent white sands which have become impregnated with bitumen and hence are often referred to as tar sands. Although many of the clay beds in this region are useful materials of fairly high grade none of them was found to equal the best of the Mattagami clays.

The exact position of these sediments in the Cretaceous is only approximately known at present, but it appears that the Manitoba and Saskatchewan beds are more recent than the Athabaska and northern Ontario series, the latter being probably the oldest of all.

ORIGIN OF CLAYS.

The Cretaceous clays and sands found at intervals near the margin of the great Pre-Cambrian area in Canada are derived from the weathering and decay of the older crystalline rocks. The clays had their principal source in the superficial kaolinization through weathering of the feldspar in these rocks, and the residual quartz particles formed the sands. A climate favourable to weathering and leaching, a long period of stability of the region with regard to sea-level, abundant plant growth, and leisurely drainage are the conditions which influence the origin, transportation, and accumulation of high grade clays and sands.

Superficial kaolinization was probably general in Cretaceous and Jurassic times over many parts of the area of Pre-Cambrian rocks, but the effects of kaolinization do not appear to have extended to any great depth. There was a dearth of residual clay on the Pre-Cambrian upland during the period immediately preceding the Pleistocene glaciation, as shown by the almost complete lack of clay in the composition of glacial drift derived solely from Pre-Cambrian rock surfaces.

Mr. J. G. Cross made an examination in 1919, for the Ontario Bureau of Mines, of the Pre-Cambrian rocks on Mattagami and Abitibi rivers. He reported the occurrence of kaolinized garnet gneiss on Mattagami river in the vicinity of Long portage. The kaolinized zone is about 400 feet wide and is of a whitish colour. The feldspars are entirely altered into kaolin, but the garnet and biotite mica content of the rock is intact. A pegmatite dyke which cuts the gneiss at this point is also semi-kaolinized.

The sample of material submitted for examination is rather too hard to be called a residual clay, but it probably represents the zone of gradation between the unaltered rock below and the residual clay above, which has been removed. It is precisely the kind of material which when worked over by water would produce the high-grade plastic clays found a few miles farther down the river.

This is the only remnant of kaolin resulting from weathering known to the writer in the Pre-Cambrian area of Canada, but it is not unlikely that there are others in the northern portion of Ontario and other provinces, concealed beneath glacial drift.

It is not known whether the basin in which the clays settled contained salt water or fresh. A lowering of the land by 300 feet would cause the sea from Hudson bay to cover the Palæozoic coastal plane and change the shore-line to the northern margin of the Pre-Cambrian rocks, a distance of 70 miles south of the present limit of tidal water. This limit corresponds approximately with the encroachment of the sea in late Pleistocene times. Folding of the Palæozoic rocks with uplift might block the

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[1] Geol. Surv., Can., Mem. 30, p. 65.

[2] Mines Branch, Ottawa, Bull. No. 10, "Notes on clay deposits near McMurray, Alberta."

northward flowing drainage from the Pre-Cambrian upland and cause temporary freshwater lakes to exist in depressions between the upland and the folded zones.

The Silurian rocks on Moose river have been gently folded, whereas the Devonian rocks which lie between them and the Pre-Cambrian escarpment are quite flat and apparently undisturbed and it it is on this area that the Mesozoic clays have been found. It is easier, however, to account for the presence of the sediments as the result of marine submergence in Mesozoic time.

INTERGLACIAL LIGNITES AND CLAYS.

Certain lignite seams associated with clays exposed along some of the streams flowing over the Palæozoic coastal plain in northern Ontario have been referred to as interglacial by more than one observer in this region. These deposits are stated to be underlain and overlain by glacial till carrying striated pebbles, and are best exposed on Missinaibi river and its branches.[1]

Deposits of this kind were not seen by the writer during his examination of Mattagami river and the interglacial section on the Missinaibi was not visited by him.

In view of the fact, however, that the pre-Glacial clays and lignites on Coal brook and the white clay on Missinaibi and Wabiskagami rivers were classed as interglacial, although the bottoms of these deposits were never seen, a closer scrutiny of the other occurrences in the field would be desirable.

[1] Bell, J. M., Ont. Bureau of Mines, pt. I, 1904, p. 143.

INDEX.

A.

I.

K.

L.

M.

N.

O.

P.

R.

S.

T.

W.