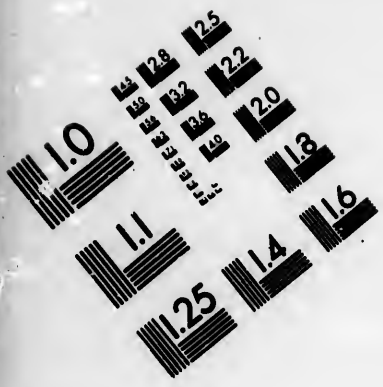

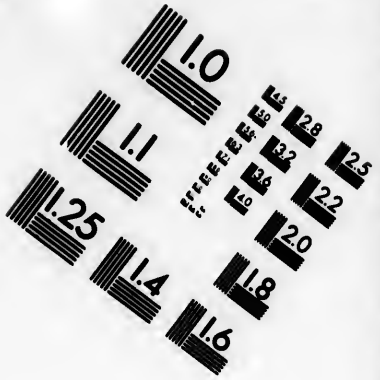

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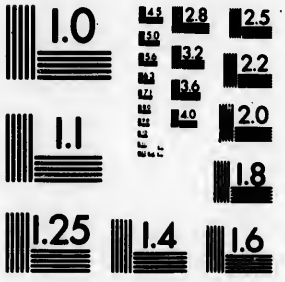

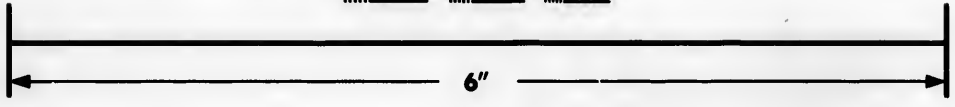

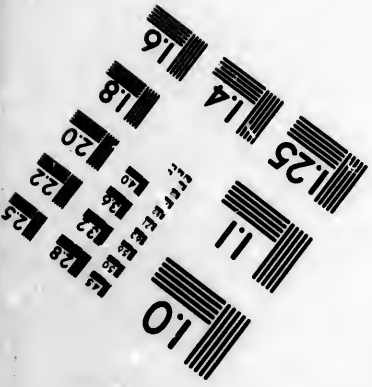

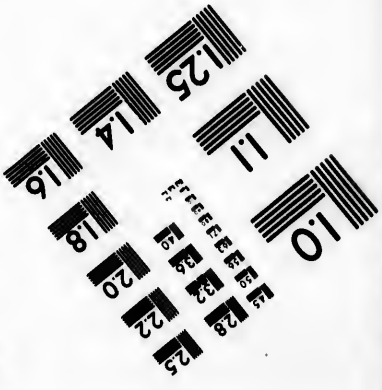

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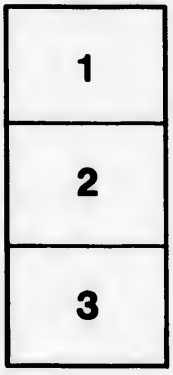

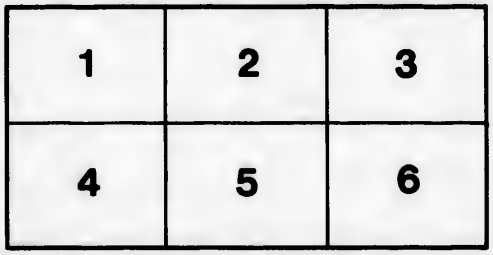

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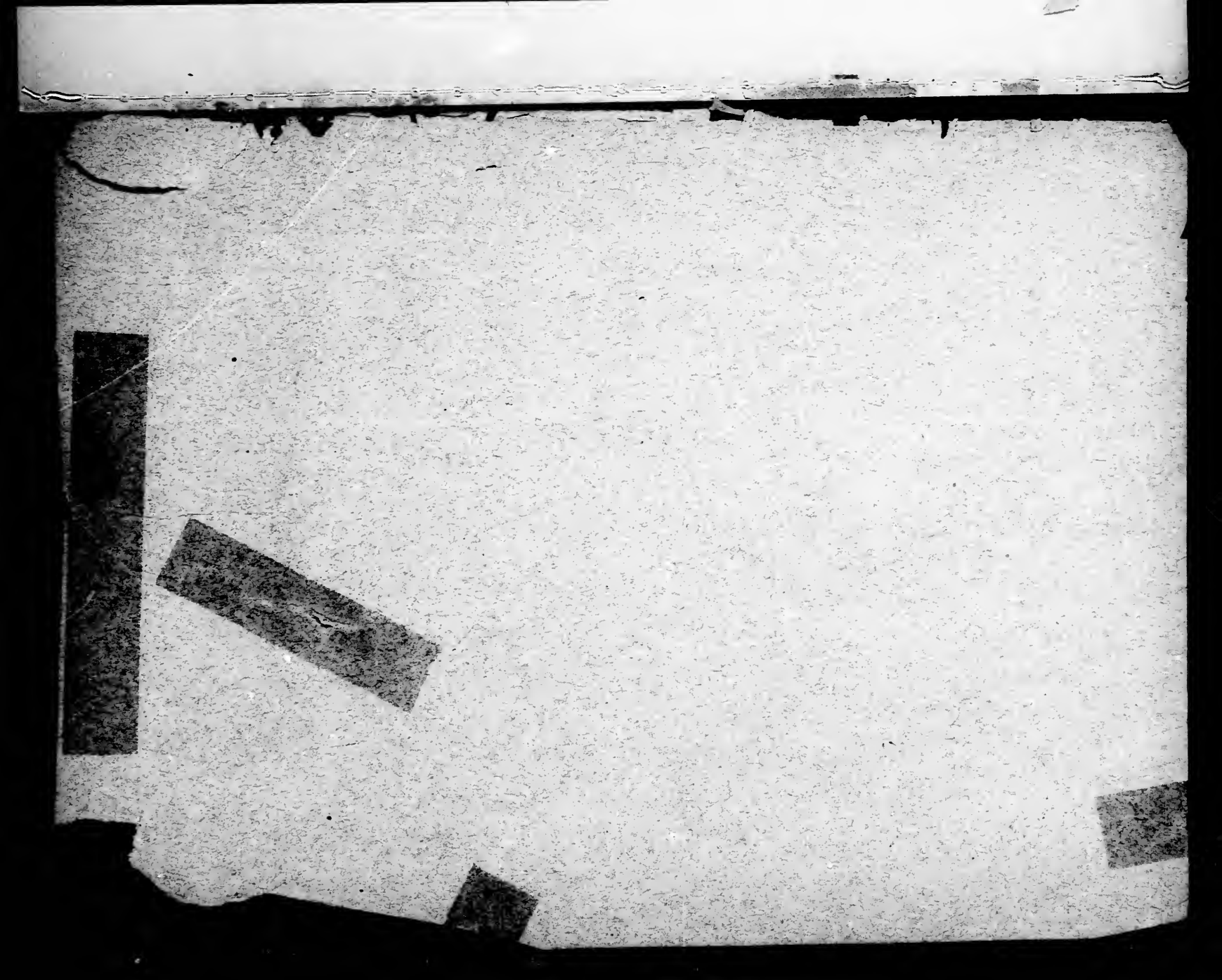

VIII.—*Three Deep Wells in Manitoba.*

By J. B. TYRRELL, M.A., B.Sc., F.G.S.

(Communicated by Dr. G. M. Dawson and read May 28, 1891.)

INTRODUCTION.

(Gave a short account of the pre-tertiary geology of Manitoba, of which the following is an *abstract.*)

The eastern side of Lake Winnipeg consists of Laurentian gneisses and granites, and Keewatin traps, agglomerates, quartzose sandstones, conglomerates, etc. The undulating surface of these crystalline rocks declines gently to the west beneath the palæozoic beds.

The palæozoic rocks consist of the following series :—

Chazy (*St. Peters*) formation, represented by about a hundred feet of white quartzose sandstone, with generally well-rounded grains, running down, at the bottom, into a quartzose conglomerate.

Trenton formation, consisting at the bottom of a mottled buff and grey dolomitic limestone, found at Big and Swampy Islands, etc., and probably also at East Selkirk, above which are other horizontal evenly bedded limestones and dolomites, amounting in all to a few hundred feet, and all more or less rich in fossils.

Hudson River Formation represented by less than a hundred feet of fossiliferous shales and dolomites.

Niagara formation, recently discovered by the writer on the lower part of the Saskatchewan river, and on the east side of Lakes Winnipegosis and Manitoba. As shown in the gorge of the Grand Rapids, it consists in its lower portion of about sixty feet of buff, yellow, and white limestone, brecciated at the bottom, and ripple-marked towards the top. Some bands are highly fossiliferous, *Pentamerus decussatus* being the most plentiful and characteristic species, though its vertical range is very small. The upper portion of the formation consists of a considerable thickness of a compact or porous dolomite, often containing many impressions of salt crystals. Its most typical fossils are *Isochilina grandis*, *Leperditia Hisingeri* and *Strophomena acanthoptera*. The highest beds at Stonewall may belong to this terrane.

Guelph.—Near the northeastern angle of Lake Manitoba the typical Niagara dolomites are overlain by a few feet of thick-bedded stromatoporoid magnesian limestone holding *Pycnostylus Guelphensis*, which may be of the above age.

Over these Silurian limestones there is in the lacustral region a gap in the known section, probably due to the presence of soft argillaceous shales. A few feet of soft red shales are the first beds seen above this gap, and are apparently of Devonian age.

The *Devonian*, above these shales, consists at the bottom of a hundred feet or more of harsh porous dolomites, containing *Pentamerus comis*, etc., overlain by a similar thickness of tough white dolomites containing *Stringocephelus Burtoni*. Above these dolomites are fifty to seventy feet of calcareous shales marked by many brine springs along their line of outcrop; above these is a highly fossiliferous limestone containing great beds of *Atrypa reticularis*, and these again are overlain by light grey compact brittle limestones which represent the local top of the Devonian.

As far as could be seen the Palæozoic terranes are practically conformable and almost undisturbed throughout.

On the eroded and slightly undulating surface of the Devonian the Cretaceous sandstones and shales were deposited.

Boring at Deloraine.

This well was sunk by William Ward for the town of Deloraine, which is situated at the terminus of the Pembina Mountain branch of the Canadian Pacific Railway. The town is in the southeast quarter-section of section 10, township 3, range 23, west of the principal meridian, in Manitoba. The well is about a hundred yards north of the railway station, on a level alluvial or lacustral plain stretching northward from the base of the Turtle Mountain towards the Souris river. It was begun in November, 1888, in the hope of finding a large supply of water at a moderate depth, as there is no permanent stream in the vicinity, and the water of Whitewater lake, which lies on the plain about three miles distant, is quite highly charged with sulphate of soda and other saline ingredients.

The machinery used was a percussion drill, supported by jointed rods, and worked by a small stationary engine. The well is cased to the bottom with iron tubing, and the drillings are raised with an ordinary sand pump. In many parts of the bore water had to be poured in to enable the drill to work and the drillings to be removed.

In June, 1889, the boring had reached a depth of 975 feet, and up to that time no clearly-marked specimens had been kept, and the log is given below very much as it was received from the driller.

At a depth of 1050 feet the collection of a systematic series of specimens from every five feet was begun, and was carried down to 1285 feet, between which depth and 1335 feet six specimens were obtained, numbered merely in consecutive order. This latter depth was reached in October, 1889, and then operations were suspended for a short time through lack of the necessary funds to continue the work. During this month the writer paid a short visit to Deloraine, examined as far as possible the work done up to that date, and obtained from Messrs. Stuart, Martin and Cowan the specimens collected. In company with the same gentlemen a visit was also paid to the northern boundary of the Turtle Mountain, and the beds composing it were hastily examined.

During the following winter work on the well was resumed with the assistance of grants from the Canadian Government and the Canadian Geological Survey, and with very few exceptions specimens have been kept from every five feet down to a depth of 1660 feet. Below 1660 feet the rock is stated by Dr. Selwyn, who has lately visited the well, to be a similar clay shale throughout, and the specimens collected corroborate this statement.

The following is a synopsis of the log as at present determined :—

Height of Surface in Feet Above Sea Level, 1,644.					
No.	DESCRIPTION.	Thickness of layer in feet.	Depth of bottom of layer from surface.	Height in Feet above Sea.	FORMATION.
1	Black soil	3	3	1641	
2	Clay, with some small pebbles	30·5	33·5	1610·5	Pleistocene. 91 feet.
3	Hard blue clay, with pebbles	56·5	90	1554	
4	Fine black sand and gravel	4	94	1550	
5	Light blue-grey shale	56	150	1494	Pierre. (Odanah Series.) 292 feet.
6	Black sand, with water	·5	150·5	1493·5	
7	Blue shale	235·5	386	1258	
8	Soapstone, with thin layers of lime rock	401	787	857	Pierre. (Millwood Series.) 604 feet.
9	Blue clay, with round "*boulders*"	188	975	669	
10	Dark blue-grey shale	75	1050	594	
11	Grey shale	25	1075	569	Niobrara. 545 feet.
12	Mottled grey calcareous shale	200	1275	369	
13	Dark non-calcareous, or but very slightly calcareous, shale	135	1410	234	
14	Grey calcareous shale	185	1595	49	
15	Dark non-calcareous shale	205	1800	156	Benton.

Nos. 1 and 2.—These are not improbably stratified deposits laid down in the bottom of the post-glacial Lake Souris, which stretched northward from Turtle Mountain and covered the country for many miles around Deloraine. Near the foot of the mountain the land in places becomes gravelly, and occasionally a few boulders are scattered over it. A couple of miles south of Deloraine the surface rises in an easy slope for about fifty feet to a wide, even terrace that runs back to the base of the higher and rougher portion of the mountain. It clearly represents one of the shore terraces of an ancient lake, but the extent of the lake has not yet been clearly defined.

No. 3.—This is undoubtedly a hard blue-grey unstratified till with pebbles and boulders. Similar till has been thrown out of the railway tank well at the Deloraine station, which was dug to a depth of a hundred feet, passing through the Pleistocene deposits into the underlying cretaceous shales.

No. 4.—This bed would appear to be a coarser grained till, but whether it differs in age from the till overlying it is uncertain. At the bottom of this layer a moderately strong flow of water was obtained, rising to within twenty-five feet of the top of the well. It is more or less impregnated with sulphate of soda.

No. 5.—A light blueish-grey, moderately hard, non-calcareous clay shale, typical of the Odanah series. Excellent specimens of this shale were obtained from the railway tank well, a few hundred yards to the west. This series has already been described by the writer,[1] and was previously very well described by Dr. G. M. Dawson[2] as the upper portion of his Pembina Mountain Group from exposures in the valley of the Pembina river, etc. During the past summer the same formation was traced in the valley of the Assini-

[1] "The Cretaceous of Manitoba," by J. B. Tyrrell, 'Am. Jour. Sci.,' 3rd series, vol. xxxx, p. 227.
[2] "Geology and Resources of the 49th Parallel," by G. M. Dawson, Montreal, 1878, pp. 81-85.

boine river, from the mouth of Arrow river to the vicinity of Oak lake, on the Canadian Pacific Railway, and near the latter place was found to contain a few fragmentary fish remains, with the shell of an Ostrea ?, and impressions of portions of the prismatic shell of Inoceramus. Prof. Culver[1] also states that similar shale outcrops as far south as La Moure, near the south line of North Dakota, and that in it he succeeded in finding a few fossils, the best an Inoceramus, and casts of a little Baculite. These observations clearly prove an extensive areal development for this series of brittle light grey clay shales, and also that it belongs to the marine Cretaceous of the Western Plains. As was stated in the introduction, it is overlain by the coarse Laramie ? sandstones of the base of the Turtle Mountains.

No. 6.—A considerable flow of water was obtained from this thin band of sandstone. The almost utter absence of sandstone in the Pierre of this section is very noticeable, since sandstone enters so largely into the composition of the same formation farther west.

No. 7.—Apparently the same as No. 5, giving the Odanah series a thickness in this well of 290 feet.

Nos. 8 and 9.—In all probability these are both included in the Millwood series, representing the lower dark-grey shales of the Pierre formation. The "boulders" are nodules of calcareous ironstone such as are found in abundance in this formation on the banks of the Assiniboine river, in the vicinityof Mill wood. Some shells of spiral gasteropods are stated to have been found at a depth of 845 feet, but none were seen by the writer.

No. 10.—This band has been placed at the base of the Millwood series, which thus is given a thickness of 664 feet, but some or all of it may more properly belong to the top of the underlying Niobrara formation. If it were given the latter position it would represent the band of dark unctuous clay with much carbonaceous matter, etc., that is placed at the top of the Niobrara formation in Messrs. Meek and Hayden's Missouri section. A specimen from 1010 feet consists in part of a soft blueish-grey clay shale, and in part of a light grey clayey limestone. Another specimen from near the same depth contains a considerable amount of crystalline pyrite.

No. 11.—A very dark grey soft unctuous and very slightly calcareous clay shale, containing a few fragmentary remains of fishes, and at the top few foraminifera (Anomalina sp.), with the cells filled with pyrite. Mr. Hoffmann, of this Survey, states that the loss from this rock on ignition is 18 per cent, representing the amount of carbonaceous matter and water in the dried material.

This band has been placed at the top of the Niobrara formation in the section, as it is the highest bed from which foraminifera have been definitely recognized.

No. 12.—A mottled grey calcareous shale or marlite, containing, in varying numbers, foraminifera, prisms of the shells of Inoceramus, fragments of fish remains, crystalline masses of pyrite, occasional fragments of the pearly shells of Ostrea, and crystals of selenite. The following list gives the results of the examination of the specimens from every five (or ten) feet :—

1075. Slightly calcareous shale, with fish remains, a few foraminifera, Inoceramus prisms, and crystals of selenite.

1080. Soft moderately calcareous dark-grey mottled clay shale, with small crystals and crystalline masses of pyrite.

[1] A report on the preliminary investigation to determine the proper location of artesian wells, etc. U. S. Senate Document, No. 222, Washington, 1890, p. 59.

1085. Similar shale, with several species of foraminifera, some fish remains, and a large amount of pyrite.

1090. Similar shale, with foraminifera and fish remains.

1100–1105. More calcareous shale, with a large amount of pyrite.

1110. Highly calcareous mottled shale, with fish remains, Inoceramus prisms and many foraminifera.

1115. Dark and light clay shale, both highly calcareous, containing pyrite, prisms of Inoceramus, fish remains, and many species of foraminifera, of which Mr. C. Davies Sherborn has kindly determined the following, viz. :—*Globigerin acretacea*, d'Orb., *G. bulloides*, d'Orb., *Cristellaria rotulata*, Lam., *Planorbulina ammonoides*, Reuss, *Anomalina rotula*, d'Orb., *Bulimina variabilis*, d'Orb., *Textularia globulosa*, Ehr., *Verneuilina triquetra*, d'Orb., *Marginulina variabilis*, Neug.

1120. Very similar shale.

1125. Slightly calcareous clay shale, with fish remains, Inoceramus prisms, a few foraminifera and crystals of selenite.

1130. Soft light-grey clay shale, with many fragments of shells of Inoceramus and Ostrea, and many foraminifera, crystals of pyrite and selenite.

1134–1140. Similar shale, with crystals of pyrite, and a few badly preserved foraminifera and prisms of Inoceramus.

1145–1180. Similar shale or marl, with pyrite, fish remains, Inoceramus prisms and many foraminifera, *Globigerina cretacea* being especially abundant.

1185–1195. Slightly calcareous shale, a few fish remains, crystals of selenite and a few foraminifera.

1205. Slightly calcareous shale, a few fish remains, and irregular fragments of calcite and selenite.

1210–1245. Similar shale, with pyrite, a few fish remains, foraminifera, and prisms of Inoceramus.

1250–1275. Similar shale, with fish remains, prisms of Inoceramus, pieces of shells of Ostrea, a few foraminifera and crystals of pyrite.

No. 13.—The material brought up by the drill in this part of the boring is generally a very dark-grey soft unctuous, and but slightly calcareous clay, from which were separated by washing some fine graphite-like flakes of clay shale. These have much the appearance of the Benton shales elsewhere in Manitoba, and was previously regarded as such by the writer, but as this band comes between two highly calcareous zones, it has been thought advisable to group it in with the Niobrara formation. The following list gives the particulars of some of the beds:—

1280. Dark grey non-calcareous clay shale, with a few fish remains and many crystals of selenite.

1285–1295 ?. Dark slightly calcareous shale, with a few prisms of Inoceramus and fragments of fish remains.

1300 ?. Similar shale, with a few specimens of *Globigerina cretacea.*

1305–1345. Dark unctuous non-calcareous clay shale.

1350. Similar shale, with fragments of a nodule of calcareous ironstone.

1355–1380. Similar shale breaking into minute flakes.

1385. Slightly more compact shale.

1390–1395. Similar shale, with a few crystals of selenite.
1400–1405. Similar shale, without selenite.

No. 14.—This series is a downward continuation of the last, the shale gradually becoming more calcareous, till it appears to terminate in a band of coarse fragmental limestone, called sandstone by the driller. From this limestone band there was a considerable flow of water which rose rapidly in the pipe to within eight feet of the top. The water had a flattish taste from the presence of salts of soda. This limestone band is regarded as the base of the Niobrara formation. The following is a serial description of the beds:—

1410. Dark grey non-calcareous clay shale, with a few rotaline foraminifera, and some moderately large fragments of the shell of Inoceramus.
1415–1425. Similar shale, with a few fragments of fish remains, but no foraminifera.
1430–1445. Similar shale, with a few prisms of Inoceramus.
1450. Lighter grey calcareous clay shale, with large and small prisms of the shells of Inoceramus, pieces of shells of Ostrea, and a few fragmentary fish remains.
1455. Similar shale, with a large number of foraminifera, *Globigerina cretacea* being especially abundant.
1460–1485.—Similar shale, with a few Inoceramus prisms, and a greater or less number of small foraminifera belonging to such genera as Textularia, Anomalina, etc.
1490–1510. A light-grey calcareous shale, with numerous specks of pyrite, many small species of foraminifera, prisms of Inoceramus, and pieces of the pearly shell of Ostrea, and fish remains.
1515–1555. A harder grey calcareous shale, holding similar organic remains, in varying quantities.
1565. Dark grey slightly calcareous thin-bedded shale, holding a few foraminifera, and fragments of fish remains.
1570. Dark grey non-calcareous thin-bedded shale, without organic remains.
1575. Dark grey clay shale, with many fragments of the shells of Inoceramus. With these are a few species of foraminifera of such genera as Textularia, Anomalina, etc., with fragmentary fish remains, and moderately large masses of pyrite. This gritty or fragmental layer formed the sandstone of the driller, and from it quite a large supply of water rose in the tube.
1580–1590. Dark grey clay shale, with a few corroded prisms of Inoceramus, small foraminifera, and fragments of fish remains. When the drillings are washed almost all is carried away in the water as a fine mud. The latter specimen, when drying, became covered with a white efflorescence of sulphate of soda?
1595. Similar shale, breaking down into thin flakes, and containing small cubical crystals of pyrite, prisms of Inoceramus, fragments of fish remains, and pieces of the shell of Ostrea, but no recognizable foraminifera.

No. 15.—Consists throughout, as far as could be determined from the specimens, of a dark-grey, non-calcareous clay shale. In its upper portion it is apparently very bituminous, and breaks into minute flakes, while below it is somewhat lighter in colour, does not break into thin flakes, and contains minute angular grains of clear quartz sand.

The following is a somewhat more detailed categorical description of the beds passed through:—

1600. Dark grey and rather hard fissile clay shale, brought up in fragments, some of which are more than an inch and a half in greatest diameter. It is quite free from calcareous matter, and under the microscope shows no traces of organic remains, but a few globules of pyrite may be seen.

1605–1620. Soft dark-grey unctuous non-calcareous clay shale, breaking into thin, scaly flakes. No trace of organic remains.

1620–1645. Similar shale, with minute fragments of fish remains.

1655. Similar shale with traces of pyrite, mixed with a few particles of fine white soft sandstone, possibly adventitious. The specimen as returned was composed almost entirely of a soft, impalpable clay, and the fragments of shale, etc., were procured by washing a considerable quantity.

1660. Soft dark-grey fissile non-calcareous shale, with a few minute fragments of fish remains, and pieces of concretionary nodules of limestone, and crystalline masses of pyrite.

1665–1715. No specimens received, but stated to be a similar dark-grey shale.

1720. A large proportion of the specimen received is a soft clay that is readily washed away by the water. What remains is a grey non-calcareous clay shale, much lighter in colour than the last, is rather compact, and does not break into thin flakes. It contains a few fragments of fish remains, and some fine irregular angular grains of clear quartz sand.

1730. Similar shale, through which the fine sand is seen to run in thin streaks.

1735. Shale similar to the last with some crystalline aggregates of pyrite, and a considerable number of fragments of a hard, very slightly calcareous fine grained sandstone.

1745. A similar dark grey clay shale, with a few fragments of soft granular sandstone, but without any of the hard sandy fragments seen in the last specimen.

1800. A light grey rather hard fissile non-calcareous clay shale with a few small crystals or crystalline masses of pyrite. Some of the fragments procured were an inch or more in diameter, and in one of them was a small imperfect shell of a Lingula. The well has not yet reached the bottom of the Benton shales.

Boring at Morden.

This boring was drilled by Edward Moore for the town of Morden in the winter and spring of 1889-1890. The town is situated on the Pembina Mountain branch of the Canadian Pacific railway, and the boring is in the middle of the town on the north side of the railway track, and about 150 yards northwest from the railway station, the surface at the well being on a level with the track. It is about a mile from the foot of the Pembina mountain and near the western edge of the level alluvial plain stretching westward from the Red river. The object of the bore was to obtain a large supply of fresh artesian water for the use of the town.

The machinery used was an ordinary percussion drill, and the well was cased first with eight inch tubing, and then with six inch tubing, to below the bottom of the cretaceous rocks.

The writer paid a short visit to Morden in July, 1890, at the time when the work on the boring was discontinued, and obtained specimens of the drillings taken at very irregular intervals. As no systematic and consecutive collection of drillings was kept,

the log is given very much as it was received from Mr. McMillan, the man in charge of the drill, modified by the result of my examination of the specimens. A further statement of the character of these specimens is given after the following table:—

Height of Surface at Boring above Sea Level, 978 Feet.

No.	Description of Material passed through.	Thickness of layer in feet.	Depth of bottom of layer from surface.	Height above sea.	FORMATION.
1	Light sandy soil	8	8	970	Alluvium, 15 feet.
2	Quicksand	3	11	967	
3	Quicksand, red	1	12	966	
4	Fine gravel, red	3	15	963	
5	Lead coloured clay, with pebbles	10	25	953	Till, 16 feet.
6	Limestone boulder with fine scratches	2·5	27·5	950·5	
7	Small boulders and shale	3·5	31	947	
8	Dark grey shale	24	55	923	Pierre, 24 feet. (Millwood Series.)
9	Hard streak	·5	55·5	922·5	Niobrara, 160 feet.
10	Dark grey shale	4·5	60	918	
11	Hard streak	3	62	916	
12	Dark grey shale	6	68	910	
13	Hard streak	1	69	909	
14	Dark grey shale	11	80	898	
15	Hard streak, a mixture of stones and shale	1	81	897	
16	Dark grey shale	4	85	893	
17	Black shale, very gritty	1	86	892	
18	Dark grey shale	7	93	885	
19	Black shale, hard and gritty	1	94	884	
20	Grey calcareous clay shale	121	215	763	
21	Dark grey shale	35	250	728	Benton, 105 feet.
22	Soapstone	3	253	725	
23	Dark grey shale	67	320	658	
24	White sand with water	4	324	654	Dakota, 92 feet.
25	White sand with particles of coal	54	378	600	
26	White shale	2	380	598	
27	White sand				
28	Soft grey shale	10	390	588	
29	Black shale	10	400	578	
30	Grey shale with sandstone	12	412	566	
31	Red and grey shale	88	500	478	Devonian, 188 feet.
32	Porous limestone at		500		
33	Red and grey shale	100	600	378	

Nos. 1–4.—These represent the coarse alluvial material deposited near the western shore of Lake Winnipeg, when its waters washed the foot of the Pembina escarpment during the period described by Mr. Warren Upham as that of the McCauleyville beaches. From No. 3 a considerable supply of good water was obtained.

Nos. 5–7.—Evidently till, consisting of harder clay with pebbles and striated boulders.

No. 8.—Was described to me as being precisely the same as the shale outcropping on the sides of the deep valley of Horse Creek, about a mile west of the town. This valley cuts down through the face of the Pembina escarpment and exposes a number of sections of the dark grey clay shales, with many crystals of selenite, typical of the Millwood subdivision of the Pierre shales. No fossils were collected from these exposures, but in the continuation of the same escarpment south of the international boundary line Mr. Warren Upham[1] collected *Baculites compressus* and other typical Pierre fossils.

Nos. 9–19.—In the absence of specimens it is impossible to correlate these beds precisely, either with the base of the Pierre, in which the "hard streaks" would represent layers of ironstone, or with the top of the Niobrara, where they would be bands of fragmental limestone similar to that seen outcropping on the Assiniboine river, below the mouth of Cypress Creek. It is not improbable that the line between the Pierre and Niobrara should be drawn somewhere through this series, as the lower "gritty" portions almost certainly belong to the latter formation. No great error, however, can be committed in grouping these as above.

No. 20.—Evidently to a large extent the mottled calcareous shale of the Niobrara formation. A specimen collected from 125 feet is a light grey, rather hard, mottled, calcareous clay, not splitting very readily along lines of bedding, but breaking into small polygonal masses of moderate size. Many rather large fragments of fish remains are scattered through it. Under the microscope it is seen to contain many small prisms of Inoceramus and a considerable number of foraminifera.

From 135 feet was collected a soft, very light-bluish-grey, non-calcareous clay containing fine acicular crystals of marcasite. From 180 feet the drillings consist of light-grey, non-calcareous clay like the last, mixed with some moderately dark-grey, mottled, calcareous clay, the latter containing a few fragments of fish remains, with many small foraminifera. From 215 feet was obtained a light grey, calcareous, mottled clay shale, breaking evenly, though not very readily, along the lines of bedding. It contains several both large and small species of foraminifera.

Nos. 21–23.—Would appear to represent the soft, unctuous, dark grey fissile, non-calcareous clay shale of the Benton formation. No specimens obtained.

Nos. 24–27.—This is in the main a beautiful white quartz sand, through which are mingled particles of clear white mica. The grains of sand are very irregular, some of them being moderately sharply angular, while others are more or less rounded.

In this sandstone are veins about 15 inches thick of incoherent running sand, one of them being struck at a depth of 360 feet and another at a depth of 377 feet.

At a depth of 324 feet water, strongly charged with chloride of sodium, was struck in a bed of fine white sand, and rose 250 feet in the well within a few minutes, after which it rose more slowly to within six feet of the surface. At one time, when the casing

[1] Upper Beaches and Deltas of the Glacial Lake Agassiz by Warren Upham. Bull. U. S., Geol. Survey No. 39. Washington 1887, p. 79.

was driven below the base of the sandstone and the water pumped out of it, the water from the sides worked under the bottom of the pipes, and, washing in, carried sand along with it, filling the well to a height of 70 feet.

In the sandstone some little particles of coal were said to have been struck.

Nos. 28, 29 and 30.—No specimens were obtained, but No 28 was described as a rotten grey shale, very soft and sticky when cut up by the drill; No. 29 as gritty, strong, black shale, and No. 30 grey shale, similar to No. 28. All through this shale were little bands of sandstone from three to six inches in thickness, and some of the shale was very similar to that overlying the sandstone. The beds evidently represent the base of the Dakota formation, which, in its typical area on the Missouri River, consists of alternating beds of shale and sandstone.

No. 31.—Six specimens of the drillings were kept to represent this 88 feet of rock, numbered in order from above downwards, but whether they represent the whole or only a part of the series is quite uncertain. The record as received gives a red shale similar throughout, from 412 to 440 feet; at 455 feet thin beds of grey shale begin to make their appearance, and lower down this is also stated to be intercalated with thin beds of limestone. The specimens were stated to be characteristic of the whole thickness of beds, and are as follows: No. 1 is a light bluish-grey, soft, argillaceous limestone, with a few grains of well-rounded, clear quartz sand. No. 2, the same, mixed with some red shale. No. 3, a brick-red calcareous clay in a finely divided condition. No. 4, a mixture of light-blue argillaceous limestone and red clay, pieces of soft white sandstone, and aggregations of small cubical crystals of pyrite. Among the washed material are some fragments of a hard, grey, even-grained limestone, large and small rounded grains of clear quartz, a fragment of whitish limestone very like the harder portion of the limestone at Grand Rapids near the mouth of the Saskatchewan river. No. 5, very similar to No. 3, but lighter in colour and not calcareous. No. 6, a mixture of red and blue clay, through which are scattered many little fragments of a hard, compact, light bluish-grey dolomitic limestone, a yellowish-white limestone containing a great number of grains of clear quartz sand, aggregations of grains of sand and crystals of pyrite, large but well-rounded grains of clear quartz, and a fine white and buff, well-rounded quartz sand.

No. 32.—A specimen labelled between 500 and 550 feet probably comes from this band. It is a soft, white, porous and apparently massive limestone, in which are a great number of small, flattened, sharply cut rectangular cavities, that have evidently been occupied by crystals of chloride of sodium. This rock contains no traces of organic remains, but small, clear crystals of quartz are quite plentiful.

No. 33.—This band is simply a downward continuation of the others, and several specimens were collected from it having the following characters:

505 feet.—A mixture of red and grey, very slightly calcareous clay, with some small fragments of light brown sandstone.

509 feet.—Similar clay, with fragments of limestone like No. 31. Also a whitish limestone, in which are fragments of cylindrical fossils like Colcolus, a fragment of a small shell like Pterinea, with other indistinguishable fragments of shells.

514 feet.—A mixture of light grey and red sandy clay, effervescing freely in H.Cl. Otherwise much like the last.

515 feet.—Similar clay, with fragments of light grey sandstone and aggregations of small crystals of pyrite.

518 feet.—Very similar to the last.

523 feet.—A mixture of red and light greenish-grey calcareous clay. When washed this leaves a residue of light red, fine-grained sandstone, with a few fragments of a white sandstone, whitish, sandy limestone and crystals of pyrite. Also a number of well preserved fragments of shells, among which Mr. Whiteaves recognizes a species of Chonetes, with which are associated numbers of fragments of Coleolus? and beautifully preserved segments of the arms of Crinoids. One of these latter is somewhat similar to the axillary radial of Bathycrinus shown on Plate VII a, fig. 17, Report on Crinoidæ, by P. H. Carpenter, Challenger Report, vol. xi.

525 feet.—A mixture of reddish and light grey shale, and a soft, light greenish-grey, fine-grained sandstone, with a light brown calcareous sandstone, and a vesicular, light grey, dolomitic limestone.

527 feet.—Composed almost entirely of a soft, red, calcareous clay. The washed material consisted of one moderate sized fragment of light grey dolomitic limestone and a few grains of quartz sand.

One specimen of similar clay, etc., from between 500 and 600 feet, but the exact depth of which is not stated, contains a well-preserved fragment of the shell of Chonetes, showing three of the cardinal spines. A specimen marked 590-600 feet is a mixture of red and greenish-grey shale and a light brownish compound of clay and sand. When washed a large portion of the bulk of the specimen is decanted off as fine clay, etc., held readily in suspension by the water, while the coarse residue is composed of some white sandstone, occasionally coloured to a dark grey, a light grey, visicular, sandy limestone, a soft, reddish-brown, calcareous argillite, and a few coarse grains of clear quartz. Also segments of small circular or pentagonal stems of crinoids, pieces of the shell of Coleolus? and a large number of fragments of other shells, some probably Chonetes, while other and larger specimens, with a finely striated sculpture, would appear to belong to the genus Pterinea.

The boring was discontinued at a depth of 600 feet, there being no prospect of obtaining a supply of fresh water at a greater depth.

The exact taxonomic position of the last 188 feet of shales, limestones and sandstones is rather difficult to determine; first, on account of the imperfections of the well record; secondly, on account of the paucity of the organic remains obtained, and, thirdly, on account of our as yet incomplete knowledge of the Palæozoic section in Manitoba.

The Niagara formation, where known just beyond the northern limit of the province of Manitoba, consists of detrital limestones comparatively poor in fossils, overlain by dolomites, both open-grained and compact, in which fossils are only occasionally and locally found, and all are in the form of casts, the true shell not being preserved. Over these is a gap of more or less uncertain thickness, possibly a hundred feet or more, which would seem to consist of shales or other soft rocks, the top bed being known to be a red shale. These shales, etc., doubtless form the base of the Devonian. They are overlain by the Middle Devonian dolomites, and these again by the shales and limestones of the Upper Devonian.

Turning now to the consideration of the fossils found in the drillings, the fragments of crinoids and the Pterinea? are of but little service in the determination of the horizon of the beds. The Coleolus? is very like a form that is common in the Stringocephalus zone at various exposures on the shores of Lakes Manitoba and Winnipegosis, and would thus indicate to some extent a Devonian horizon. The fragments of Chonetes are too imperfect to allow of the specific identification of the species, but as in several specimens the hinge-line is preserved they leave no doubt as to the genus. This genus in America ranges from the Clinton, or base of the Niagara, to the Carboniferous, but is most common in the Devonian. In Manitoba two species are locally abundant in the shales and argillaceous limestones of this latter system, while none have been found in the Silurian. This also points strongly to the Devonian age of the red and grey shales at Morden, and makes it quite certain that they are not older than the Niagara. As far as is known, however, the Niagara formation consists entirely of light grey limestones and dolomites, without any sign of red or grey shales, and unless the character of the rock changes very greatly as it is followed from north to south, the shales penetrated in the Morden well would not belong to this formation.

It remains therefore to consider the Devonian affinities of the beds in question. From the well at Rosenfeld, twenty-four miles east of Morden, Dr Dawson has recorded a thickness of 352 feet of red and grey shales, etc, at the top of the Palæozoic section, but from these drillings no determinable fossils were obtained. Below these shales no dolomites were met with, and no rocks that could be supposed to represent the Middle Devonian dolomites. The shales from the Morden well appear to represent a portion of this Rosenfeld series, and the absence of the Stringocephalus zone seems to indicate that these beds represent a lower horizon. The inference is therefore very strong that they lie below the Stringocephalus zone, and represent the basal shales of the Devonian, which have been eroded away and have left no salient exposures in the lacustral area to the north. It has been seen, too, that in the lacustral area the strike of the contact of the Devonian and Silurian runs in a fairly straight line N. 25° W., and this line being extended from the southeast angle of Lake Manitoba, would cross the international boundary line a few miles west of the Red river. A south-westerly dip from this line at a hypothetical elevation of 810 feet, the elevation of Lake Manitoba, at the rate of 10 feet to the mile, probably about the true dip of the beds here, will bring the top of the Silurian 300 feet above the sea at Morden, or 75 feet below the present bottom of the well.

Boring on Vermilion River.

This boring was sunk by the Manitoba Oil Company on the west bank of the Vermilion River, a short distance below the crossing of the Strathclair and Lake Dauphin trail, in township 23, range 20, west of the principal meridian.

In the spring of 1887 a percussion drill was hauled north from Strathclair station, on the Manitoba and Northwestern Railway, and the well was drilled to a depth of 292 feet, when an accident happened to the machinery which delayed the work for a time.

In the following year the drill was moved a short distance farther down the valley, work was resumed, and a final depth of 743 feet was reached.

From a comparison of the sections, the second well is found to have been begun nine feet lower, geologically, than the first, and therefore the levels of all the specimens

obtained from it have been corrected by the uniform subtraction of nine feet, in order to give them their proper position in the total section.

For the log of this well, with illustrative specimens, I am indebted to the kindness of W. R. Baker, Esq., Superintendent of the Manitoba and Northwestern Railway, who was one of those most deeply interested in the success of the well.

The record as given below is compiled from the log kept by the driller and the results of my examination of the specimens.

Height of Surface at Boring above Sea, 1300 Feet.					
No.	Description of Material passed through.	Thickness of layer in feet.	Depth of bottom of layer from surface.	Height above sea.	FORMATION.
1	Soft, dark gray clay shale.....	95	95	1205	Pierre (Millwood Series).
2	Fragmental limestone.....	4	99	1201	Niobrara.
3	Grey calcareous shale	124	223	1077	
4	Dark grey fissile shale.....	178	401	899	Benton.
5	Coarse sandstone, with pyrites....	19	420	880	Dakota.
6	Compact white limestone.....	120	540	760	Devonian.
7	Blue-grey clay shale.....	10	550	750	
8	White gypsum.....	15	565	735	
9	Red shale.....	110	675	625	
10	Shale and limestone.....	68	743	557	
11	Red shale	At	bottom.		

No. 1.—Specimens from 30, 48 and 91 feet show this to be a soft, dark grey, non-calcareous clay shale belonging to the Millwood series of the Pierre shales, similar to that seen in the naked and almost vertical cliffs washed by the river a few hundred yards above the trail crossing.

No. 2.—This is a hard band that was spoken of as "sandstone" by the driller. It consists almost entirely of fragments of the prisms of the shells of a large Inoceramus, mixed with fragments of *Ostrea congesta?* This evidently represents the band of sandstone-like limestone that outcrops on the Assiniboine river below the mouth of Cypress Creek, and is also seen at several places along the eastern face of the Riding Mountain. It lies at the top of the Niobrara formation.

No. 3.—Specimens collected from 146 and 164 feet shew this to be a mottled, blue-grey, calcareous clay shale or marl. Under the microscope it is found to be mixed with prisms of the shells of Inoceramus, fragments of the shells of *Ostrea congesta?*, minute portions of fish skeletons and quite a large number of foraminifera. These comprise such forms as *Globigerina cretacea* and several species of Textularia, and with them are associated many Coccoliths and Rhabdoliths. These evidently represent the characteristic shales and marls of the Niobrara formation.

No. 4.—Specimens obtained from 213–247 feet consist of a dark blue-grey, fine-grained, unctuous, non-calcareous clay shale, breaking down into thin flakes. These represent the typical Benton shales.

No. 5 —A specimen from 411 feet consists of grains, varying greatly in size, of clear, white quartz. Some of these grains are quite angular in shape, and many are stained on the outside with iron. With the sand grains are mixed small cubical crystals of pyrite. In a paper published in 'The American Journal of Science' for September, 1890, the writer gave the Dakota formation in this well a thickness of 55 feet, but he has since found reason to believe that a specimen of sandstone labelled 369 feet is not to be depended on, and the record has therefore been altered as above to agree with the log kept by the driller, thus reducing the thickness of the Dakota to 19 feet.

No. 6.—A specimen from 509 feet is a moderately hard, fine and even-grained, light grey limestone, through which are scattered small subangular grains of colourless quartz and grains of pyrite. A specimen marked 510-540 feet consists of similar limestone, with fragments of light and dark grey clay shale.

No. 7.—A specimen from the lower part of the band consists of a mixture of light blue-grey clay shale, particles of limestone, some few crystals of colourless quartz, and particles of opaque white gypsum from the top of the band below.

No. 8.—A specimen marked 550–565 feet is made up largely of fragments of opaque white gypsum, mixed with a few fragments of limestone, crystals and fragments of colourless quartz, and small nodular masses of pyrite.

No. 9.—A specimen marked 565–645 feet consists of a soft, light brownish-red, fine-grained shale, mixed with fragments of light grey shale and particles of limestone. In the clayey mass are also many minute and very perfect crystals, as well as irregular particles of clear transparent quartz.

No. 10.—A specimen from 718 feet consists of a light pink, hard, compact, fine-grained limestone that effervesces strongly in H.Cl., leaving a similarly coloured fine clayey precipitate. With the limestones are many fragments of a fine-grained, white sandstone, and a very few white, opaque particles of gypsum. A specimen from 740 feet is a mixture of fragments of cream-coloured limestone and reddish shale. It effervesces strongly in H.Cl., leaving a residue of dark grey and buff-coloured shale, fine grains of quartz and small particles of pyrite.

No fossils have been obtained from the palæozoic rocks drilled through in this well, and in the absence of direct stratigraphical correlation their exact age cannot at present be determined. However, their geographical position clearly shews that they are of post-silurian age, and the absence of dolomites excludes them from the middle or Winnipegosan formation of the Devonian. It is also altogether unlikely that fossils would have been so uniformly absent from the drillings if some of the lower highly fossiliferous beds of the Manitoban formation or Upper Devonian had been passed through. Many of the limestone fragments from near the bottom of the bore correspond closely with the limestone outcropping near the mouth of Mossy River, at Point Wilkins, etc., belonging to the higher portions of the Manitoban formation exposed in natural sections, and the known southwesterly dip of a few feet to the mile would account for the difference in elevation of the beds.

It is therefore probable that the palæozoic beds passed through in the Vermilion River boring represent an upward continuation of the Point Wilkins limestones, and therefore in the main overlie the highest Devonian beds seen on the shores of Swan Lake or Lake Winnipegosis.