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PROCEEDINGS OF THE PALEONTOLOGICAL SOCIETY

**MEDINA AND CATARACT FORMATIONS OF THE SILURIC OF
NEW YORK AND ONTARIO ¹**

(Presented in abstract before the Society December 30, 1912)

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¹ Manuscript received by the Secretary of the Geological Society March 17, 1914.

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INTRODUCTION

This contribution to stratigraphy redefines the Medina formation and describes the character of its strata and fauna in the typical area in the State of New York. The new Cataract formation of Ontario is also described in detail and its fauna listed. Some of the most characteristic species of the latter formation were formerly ascribed to the Clinton, but it is here shown that the Cataract is equivalent to the Medina—the typical Medina as seen at Medina, New York. Finally, these two formations are compared with the Brassfield of Ohio, which has also been correlated with the Clinton, but is now seen to be of about the same geologic time as the Cataract and the Medina.

The following account of the Cataract, Medina, and Brassfield is divided into two parts. Part I contains a general discussion of the formations, their faunas, and their interrelations. In the second part is given a historical review of the Medina and the status of the various formation names, followed by a detailed description of sixteen sections extending from Rochester, New York, to the Manitoulin Islands, a distance of 340 miles, and taken at the places in which the Medina and Cataract formations are best exposed. Hence the detailed evidence for the nomenclature and stratigraphy discussed in Part I will be found in Part II.

PART I

THE CATARACT FORMATION

General discussion of the formation.—The writer became acquainted with this formation at Hamilton and Grimsby, Ontario, in September, 1895, under the guidance of that grand old naturalist, Col. Charles Coote Grant. The formation was then known as the Clinton formation, due

to an error made by Hall previous to 1852² and perpetuated by every geologist since working in Ontario. Even though at that time the writer collected *Dædalus archimedes* and *Arthropycus alleghaniense* at Grimsby in this so-called Clinton, he noted that these fossils had two occurrences—one in Medina, the other in the Clinton of Ontario; but it was not until the summer of 1912, while geologizing in the Georgian Bay region of Ontario with Dr. Merton Y. Williams, of the Geological Survey of Canada, that the error became apparent. Here in the northwest limestones predominate, and these had also been regarded as of Clinton age; but there is here an abundance of *Cælospira planoconvexa*, *Rhinopora verrucosa*, and *Helopora fragilis*, forms of the "Clinton" of Hamilton, with none of the guides characterizing the Clinton fauna as developed between Niagara Falls and Rochester. The former fauna rested either on the abundantly fossiliferous Richmond or on the Queenston red shales. This superposition at once raised the question, What has become of the Medina?

Later in the same season, while in the Georgian Bay-Manitoulin country, the writer was so fortunate as to meet in the field Prof. William A. Parks, and to him our difficulties were related. Together we decided to restudy the sections at Hamilton and Grimsby, and from such a study it soon became plain that the Ontario "Clinton" not only underlay a vanishing remnant of the true Clinton with *Pentamerus oblongus*, but, what surprised us more, the fossiliferous Medina was also above these beds, though greatly thinned. Professor Parks then told the writer of the well exposed section at the cataract of the Credit River, where there is not a trace of the Medina, and after two days spent here it was decided to make this the typical section for the new Cataract formation. The writer, however, then held that the Cataract underlay the Medina, and that these formations were not the equivalents of each other. These occurrences were announced before the Paleontological Society at its New Haven meeting, in December, 1912, and the results and the name *Cataract formation* were later accepted in Guide Book Number 5, prepared by Parks for the Twelfth International Geological Congress and issued by the Geological Survey of Canada in 1913.

The Cataract formation is typically developed along the forks of the Credit River, and is especially well exposed at the cataract, as has been said. Here the formation has a thickness of about 106 feet. This is the average development, though in the various sections the formation varies between 54 feet (Niagara) and 126 feet (Manitoulin). To the south-east, toward Niagara River, the formation becomes more muddy and

² Pal. N. Y., vol. II, 1852.

sandy, while toward the northwest the sands at the bottom vanish first, the middle portion becomes increasingly more limestone, and the upper shales become more and more red and unfossiliferous toward the Manitoulines. In Ontario, where the formation is typically developed, it is readily divisible on its petrologic and faunal character into three members, as follows:

Upper Cataract or Cabots Head shale member.—This was first named Kagawong by Williams;³ but as this name had been used by Foerste for an Ordovician formation, Williams now proposes to use the term Cabots Head, as given by Grabau.⁴ The member consists of a series of shales, usually greenish in color and somewhat calcareous, with occasional thin beds of magnesian limestone; toward the northwest the top of this member becomes more and more red or locally ferruginous, and finally is completely transformed into soft, red, almost unfossiliferous shales, which are in color much like Queenston, though less sandy. The thickness is variable, between 20 feet (due to erosion of the top before being covered by the Lockport) and 75 feet (where the shales are thickest the limestones below are thinnest).

These shales are locally rich in bryozoans, and particularly in the ferruginous zones near the top of the member, where there is also more or less of magnesian lime material. Here *Helopora fragilis*, *Pachydictya crassa*, *Phanopora explanata*, *P. ensiformis*, *Callopora magnopora*, and Trepostomata Bryozoa abound, especially at Limehouse and Dundas. Other fossils, except *Lingula clintoni* (*oblonga* of local collectors) and *Pterinea ? primigenia*, are very scarce. Wherever a thin limestone is present it is usually seen to be made up of one or two species of *Helopora*.

Middle Cataract or Manitoulin limestone member (Williams, 1913).⁵—Strata variable in character from heavy-bedded, somewhat magnesian limestones, with local reefs of corals and bryozoans, to thinner bedded, highly magnesian, and more or less impure limestones. Locally in the south there are even thin beds of sandstone. The thickness varies between 60 feet in the north and 9 feet (Dundas), or even nothing in the south (Niagara). In other words, the limestones are translated more and more into shale southeastward.

This division is nearly always rich in fossils and is the home of most of the Cataract forms other than the bryozoans, though many of these are also to be had here. The guide fossils are *Clathrodictyon vesiculosum*, *Acervularia (?) gracilis*, *Diphyphyllum vennori*, *Rhinopora verru-*

³ Ottawa Nat., vol. 27, 1913, p. 37.

⁴ Bull. Geol. Soc. Am., vol. 24, 1913, p. 460.

⁵ Op. cit., p. 38.

cosa, *Phylloporina angulata*, *Hebertella fausta*, *Atrypa* n. sp. (a multi-striate and large form of *A. marginalis* type), and *Caelospira planoconvexa*.

Basal Cataract or Whirlpool sandstone (Grabau).⁶—This coarse, cross-bedded, white, red, or mottled sandstone occurs at the base of the Cataract all the way from Lockport, New York, to near Collingwood, Ontario, a distance along the outcrops of about 150 miles. The thickness varies between 22 feet and 6 feet, with the maximum in the southeast. Farther northwest the limestones make the base of the Cataract formation, and therefore one of these two basal members rests with sharp distinction and disconformity on either the Queenston or Richmondian of the Ordovician.

The Whirlpool is practically barren of fossils, though at the very top a few forms may be had, chiefly worm burrows and more rarely *Modiolopsis* (?) *orthonota*.

THE CATARACT FAUNA

Hall⁷ described from or identified at Flamborough Head, near Dundas, 9 species, all erroneously determined as from the Clinton. Logan and Billings⁸ list a larger number of forms, also from the "Clinton," all of which are in the Cataract formation. Nicholson⁹ has a list of 29 species that are also said to be from the Clinton, but in reality are from the Cataract, and Parks¹⁰ lists at least 31 forms. A part of Grabau's¹¹ Medina fauna likewise belongs here.

The following list combines all previous lists, contains those additional species identified by the writer, and eliminates the forms now known not to occur in this fauna. The symbols used are as follows: * = restricted to Cataract, X = of no stratigraphic value, + = also in higher formations, ++ = affinity upward, m = also in Medina, and b = also in Brassfield.

FUCOIDS:

X *Bythotrephes gracilis intermedia* and *B. gracilis crassa* Hall. Common at various horizons in the two upper members. Identified by Nicholson.

BURROWS:

mX *Scolithus verticalis* Hall. Dundas and elsewhere in the Whirlpool. At Stony Creek, in the Medina. Originally described from the Medina of New York.

⁶ Jour. Geol., vol. 17, 1909, p. 238.

⁷ Pal. N. Y., vol. II, 1852, pp. 41-51.

⁸ Geol. Canada, 1863, pp. 313-321.

⁹ Rept. Pal. Prov. Ontario, pt. 2, 1875, pp. 40-49.

¹⁰ Guide Book No. 5, Inter. Geol. Congr., 1913, pp. 10-12.

¹¹ Loc. cit.

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× *Arenicolites sparsus* Salter. These are paired holes seen in many formations; therefore of no stratigraphic and but little biologic value. Nicholson identifies this European species at Dundas.

× *Planolites vulgaris* Nicholson. Originals from Dundas.

HYDROIDEA:

b+ *Clathrodictyon vesiculosum* Nicholson. Rare in Manitoulin member. (See Parks, Univ. Toronto Studies, Geol. Ser., 5, 1908, p. 14.)

× *Retiolites venosus* Spencer, not Hall. The writer can not make out what Spencer figures, but it is certain that he has no graptolite and certainly not the characteristic form of the Clinton.

× *Dictyonema*. At least two species occur in the Manitoulin member at Forks of Credit River.

CORALS:

+ *Zaphrentis bilateralis* (Hall). Originally described from the Clinton and higher beds. Common in Manitoulin member.

+ *Halysites microporus* (Whitfield). Always rare. In Manitoulin member at Manitowaning and elsewhere.

+ *Heliolites interstinctus* (Linnæus). Rare in southern localities, but common in Manitoulin member at Manitowaning.

b+ *Diphyphyllum cæspitosum* (Hall)? Manitoulin member, Manitowaning.

* *Diphyphyllum vennori* (Billings). Originals from the Manitoulin member at Manitowaning. A good species.

b* *Acervularia* (?) *gracilis* (Billings). Originals from Manitowaning, where it is common (*Strombodes gracilis*). Manitoulin member. In the Brassfield of Ohio is the related *A. (?) clintonensis* Nicholson.

b+ *Favosites venustus* (Hall). Common in Manitoulin member at Manitowaning.

STARFISHES:

* *Mesopaleaster granti* (Spencer). Originals from the Cabots Head member at Hamilton.

* *Mesopaleaster* (?) *cataractensis* Schuchert. Originals from the Cabots Head member at Hamilton.

TUBICOLOUS ANNELIDA:

b* *Cornulites distans* (Hall). Originally described from the "Niagara group" at Flamborough Head, but is from the Manitoulin member of the Cataract. Nicholson also notes it from Dundas.

* *Cornulites neglectus* (Nicholson and Hinde). Originals from Dundas. Probably Manitoulin member.

ERRANT ANNELIDA:

* At Dundas, Hinde got and described from the Cataract the following teeth: *Eunicites clintonensis*, *E. coronatus*, *E. chiromorphus*, *Enonites amplus*, *Æ. fragilis*, *Arabellites elegans*, *Lumbriconerites basalis*, *L. triangularis*, *L. armatus*, and *Glycerites calceolus*.

BRYOZOA:

+ *Helopora fragilis* Hall. Originally described from the Clinton of New York and the "Clinton" of Flamborough Head, Ontario. Distributed throughout the two upper members of the Cataract.

- d****Rhinopora verrucosa* Hall (syn. *R. venosa* Spencer). Originals from Flamborough Head. Widely distributed throughout the Manitoulin and lower Cabots Head member, and one of the guides.
- *Phenopora explanata** Hall. Originals from Flamborough Head, in Cabots Head member.
- +*Phenopora constellata* Hall. This Clinton species is identified by Nickles and Bassler at Hamilton.
- b****Phenopora ensiformis* Hall. Originals from Flamborough Head, in Cabots Head member.
- *Phenopora punctata** (Nicholson and Hinde). Originals from Dundas as *Ptilodictya punctata*; probably lower Cabots Head member.
- b+***Pachydictya crassa* (Hall). Originals from the Clinton of New York as *Stictopora crassa*; also identified at Flamborough Head. Cabots Head and Manitoulin members.
- Nematopora raripora* (Hall). Originals from Flamborough Head as *Stictopora raripora*; probably from lower Cabots Head member; also in Rochester of New York.
- b+***Phylloporina angulata* (Hall). Originals from the Clinton of New York as *Retepora angulata*. Not rare in Manitoulin member.
- ×***Fenestella bicornis* Spencer. Originals from Hamilton. Species not as yet recognizable.
- +*Fenestella tenuis* Hall. This Clinton form Nicholson identifies doubtfully at Dundas. Manitoulin member.
- ×***Fenestella prisca* Lonsdale. Hall has this form from Flamborough Head. What he had can not be stated, but probably not *Semicoscium tenuiceps* (Hall).
- b****Callopora magnopora* Foerste. This Brassfield species of Ohio, Bassler and Parks identify from the Cataract. Of wide distribution near top of Cabots Head member.
- b****Homotrypa (?) confluentis* (Foerste). Another Brassfield form of Ohio; also common in Cataract, in upper Cabots Head member.
- b+***Clathropora frondosa* Hall. This Rochester form is identified by Parks at Hamilton, in Cabots Head member.

BRACHIOPODA:

- *Lingula lingulata** Hall and Clarke. Original from Cabots Head member at Hamilton.
- +*Lingula clintoni* Vanuxem. This Clinton species also occurs near top of Cabots Head member.
- +*Lingula oblata* Hall. Parks identifies this Clinton species from Cabots Head member at Hamilton.
- b+***Dalmanella elegantula* (Dalman). Of wide distribution in Manitoulin and Cabots Head members.
- b+***Rhipidomella hybrida* (Sowerby). Of wide distribution in Manitoulin member.
- +*Rhipidomella circulus* (Hall). This Clinton species also occurs in Manitoulin and lower Cabots Head members and is of wide distribution.
- b+***Orthis flabellites* Foerste. This widely distributed Siluric form is also common in the Manitoulin and lower Cabots Head members. Identified by Nicholson as *O. calligramma davidsoni*.

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× *Plectorthis medinaensis* Grabau (nom. nud.).¹² Niagara River Gorge.

Is probably one of the two following species of *Hebertella*.

b* *Hebertella fausta* (Foerste). This Brassfield form also occurs in the Manitoulin member.

b* *Hebertella* cf. *daytonensis* (Foerste). This Brassfield form may also occur in the Manitoulin member.

b+ *Platystrophia biforata* (Schlotheim). Common in Manitoulin member.

b+ *Plectambonites transversalis* (Wahlenberg). At times common in Manitoulin member, as at Hamilton.

b+ *Leptaena rhomboidalis* (Wilckens). Of wide distribution throughout the two upper members of the Cataract.

b+ *Schuchertella subplana* (Conrad). This Siluric form also occurs rather rarely in the Manitoulin member.

* *Atrypa*, n. sp. This large and fine multistriate form of the *A. marginalis* group occurs in the Manitoulin member at many localities, especially at Dundas.

++ *Atrypa rugosa* Hall? A form similar to this species occurs at many localities in the Manitoulin member.

* *Cælospira planoconvexa* (Hall). Originals from Flamborough Head as *Atrypa planoconvexa*. Restricted to Manitoulin member and the best guide to the Cataract.

Whitfieldella, 2 sp. A small form that is common in the Manitoulin member. Another larger form is less often seen and has been identified as *W. naviformis*, a Clinton species of New York.

m* *Whitfieldella* cf. *oblata* (Hall). This may be the Upper Medina *W. oblata*. It occurs rarely in the Manitoulin and Cabots Head members at Cataract and Stony Creek.

× *Hyattidina congesta* (Conrad). Hall (1852) identifies this form as *Atrypa congesta*, from Flamborough Head. As no one has since seen this fossil in the Cataract, it seems probable that an error was made here. In the lower Manitoulin at Hamilton occurs a *Whitfieldella* that may have been identified as that form. As *Hyatella* is preoccupied, Schuchert in 1913 changed it to *Hyattidina*.

m+ *Camarotæchia neglecta* (Hall). This widely distributed form is common throughout the two upper members of the Cataract.

* *Camarotæchia janea* (Billings). In Manitoulin member, Manitowaning.

+ *Uncinulus stricklandi* (Sowerby).¹³ Niagara River Gorge. In all probability not the higher Siluric *U. stricklandi*.

PELECYPODA:

m* *Modiolopsis* (?) *orthonota* (Conrad). This Medina form also occurs at the top of the Whirlpool member and in the Manitoulin.

m* *Pterinea* (?) *primigenia* (Conrad). This Medina species is also in the upper part of the Cabots Head member.

GASTROPODA:

+ *Cyclonema cancellatum* (Hall). This Clinton form also occurs in the Manitoulin member of the Cataract.

¹² Loc. cit.

¹³ Grabau: Loc. cit.

bm+*Bucanopsis trilobata* (Conrad). In the Manitoulin and Cabots Head members at Hamilton; also in Medina and Clinton.

+*Platystoma cf. niagarense* Hall. Small specimens rare in Manitoulin member at Cataract and elsewhere.

OSTRACODA:

m**Isochilina cylindrica* (Hall). This Medina form or a very similar one also occurs rarely in the Manitoulin member.

TRILOBITA:

×*Calymene niagarensis* Hall? Fragments are common in the Manitoulin member. May turn out to be *C. vogdesi*.

×*Dalmanites*, sp. undet.¹⁴ Niagara Gorge.

b+*Encrinurus cf. punctatus* Wahlenberg. Fragments of two species of *Encrinurus* occur in the Manitoulin member.

×*Acidaspis* sp. Manitoulin member at Hamilton.

×*Lichas* sp. Manitoulin member near Collingwood.

THE MEDINA FORMATION

In the second part of this paper the history of the Medina formation is given, and it is there shown that although Vanuxem was the first to use the name in print, the credit rightly belongs to Hall and dates from 1840. The name then embraced a great thickness of red sandy shales and some sandstones, constituting the lower and the greater part of the formation, which is terminated by variegated sandstones and shales. This definition of the Medina was retained everywhere until 1905, when Grabau split the formation into two series, referring the lower red shales to the Ordovician as the shore phase of the Richmondian. Subsequently, in 1908, he named these shales the Queenston (synonym Lewiston, Chadwick, 1908), retaining the name Medina for the upper sandstones and shales, the only part that had been characterized by fossils. This procedure was altogether correct, for we now know that the Queenston is the easterly and shore phase of the Richmondian, a fact that can be seen by any one who will take the time to study these deposits from Niagara Falls northwestward to the Manitoulin Islands, at the north end of Lake Huron. In the east not a single fossil is to be had in the entire formation other than the burrows *Palaeophycus tortuosum*, but gradually more and more appear from the base upward as we proceed to the northwest, until finally the entire red beds have changed through lateral transition into bluish calcareous shales and thin limestone replete with Richmondian fossils. Under these circumstances the Queenston must be separated from the higher sandstones, leaving the latter as the typical expression of the Medina, for at Medina along Oak Orchard Creek one practically sees only these red and white sandstones characterized by the well known

¹⁴ Grabau: Loc. cit.

fauna first developed by Conrad and later supplemented by Hall. We can no longer use the term Medina in the old sense to include the Richmondian and Medina *sensu stricto*, since by general consent through a half century of geologic endeavor the line distinguishing the Ordovician from the Siluric has been drawn in America and Europe at the top of the Richmondian and its equivalents, and beneath the fossiliferous Medina (or at least so by inference) or lower formations having the faunal impress of Siluric time. The two series of deposits are marked by dissimilar faunas and are separated by a time break, to which hiatus no formations are as yet referable as having faunas that will bridge the life of the Richmondian (Ordovician or Cincinnati) and the Medina. For these contacts see plate 13, figures 1 and 2, and plate 14, figure 2. Even if such transition faunas were at hand, it would then not necessarily follow that the Richmondian is better placed in the Siluric system. It remains for those departing from the old and accepted classification to show the desirability for this striking change.

Grabau is also correct in restricting the term Medina to the upper or sandy Medina of Hall, and there was therefore no need for Clarke to propose Albion to take its place, as he has recently done; the term is, however, adopted in the lately published Niagara folio.¹⁵ Even if it were necessary to use another name than Medina, Oneida of Vanuxem could well have been made to serve this purpose. On the other hand, the writer well understands why Albion was proposed, this being due to the view that Queenston and Richmondian are better referred to the Siluric than to the Ordovician. This opinion is, however, at variance with all previous classifications and the writer has heretofore protested against it. He is prepared to show that the opinions of the older stratigraphers in America and Europe are correct in their general premises, and, further, that on the principle of diastrophic movement and faunal dissimilarity the Siluric invasion did not begin with the Richmondian, but rather, as so long held and without dissenting opinion, at the base of the fossiliferous Medina or other older formations that are clearly younger than Richmondian—for example, Lyckholm and Borkholm of Estland, Etage 5 of Norway, Trinucleus beds of Sweden, or Keisley of Britain.

If we are to be purists in nomenclature and strict adherents to the rule of priority, then Conrad's term Niagara sandstone of 1836 (see Part II for detail) clearly has right of way over Medina *sensu stricto*. Hall should have adopted this term, as he gives evidence that he knew of its existence; but, as is well known, he was a great and forceful leader, never

¹⁵ Kindle and Taylor: Geol. Folio No. 190, U. S. Geological Survey, 1913, p. 6.
Why Kindle did this is explained in Science, vol. 39, 1914, p. 915.

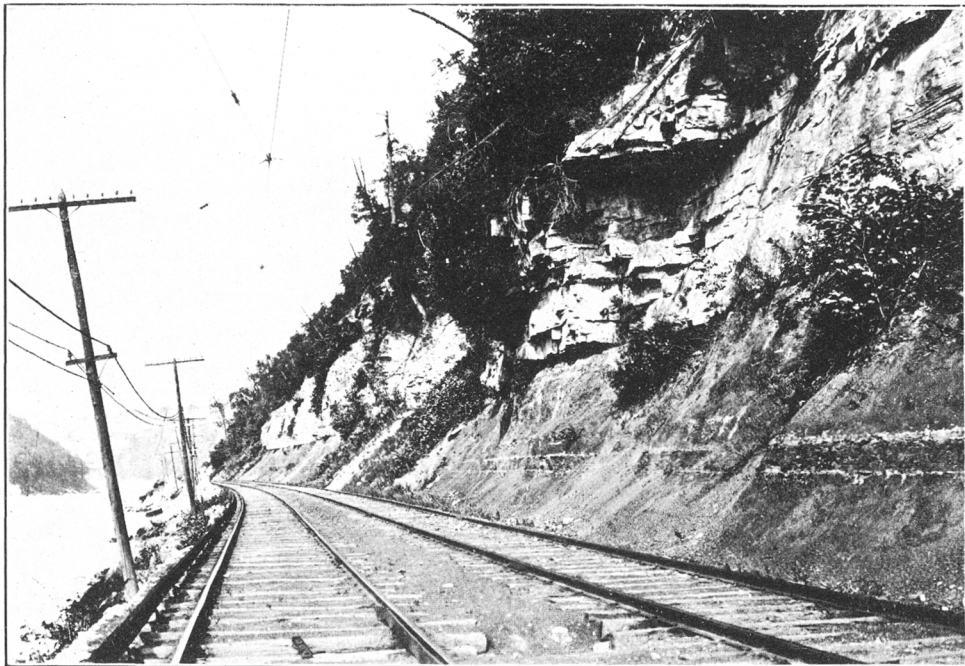


FIGURE 1.—CONTACT OF THE CATARACT (WHIRLPOOL) SANDSTONE ON THE BRICK RED QUEENSTON SHALES

Exposure along the Grand Gorge Railway, Niagara Falls, New York

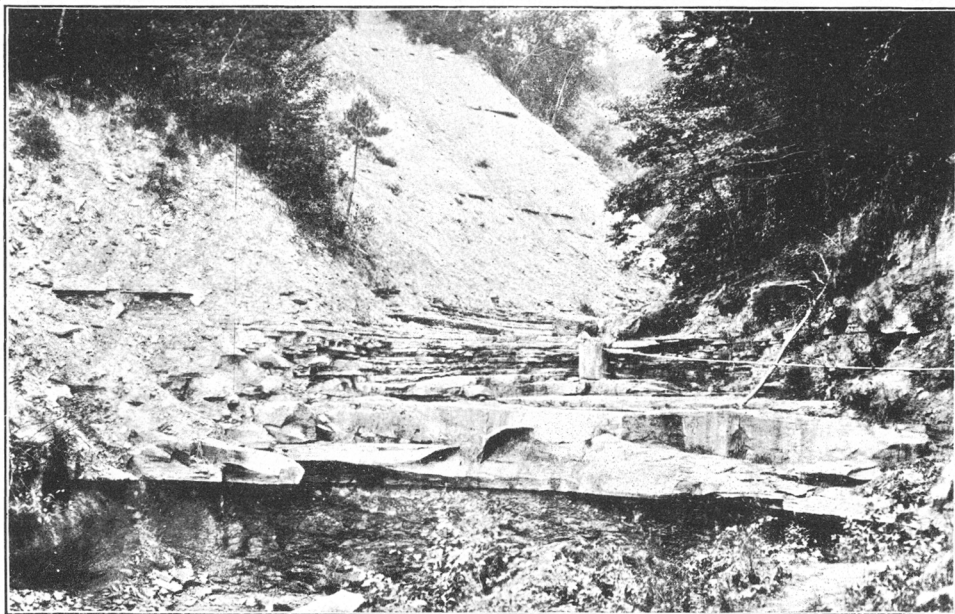


FIGURE 2.—CONTACT OF THE CATARACT (WHIRLPOOL) SANDSTONE ON QUEENSTON SHALE

Stony Creek, Ontario, Canada

CONTACTS BETWEEN SILURIC AND ORDOVICIC (CINCINNATIC) SYSTEMS

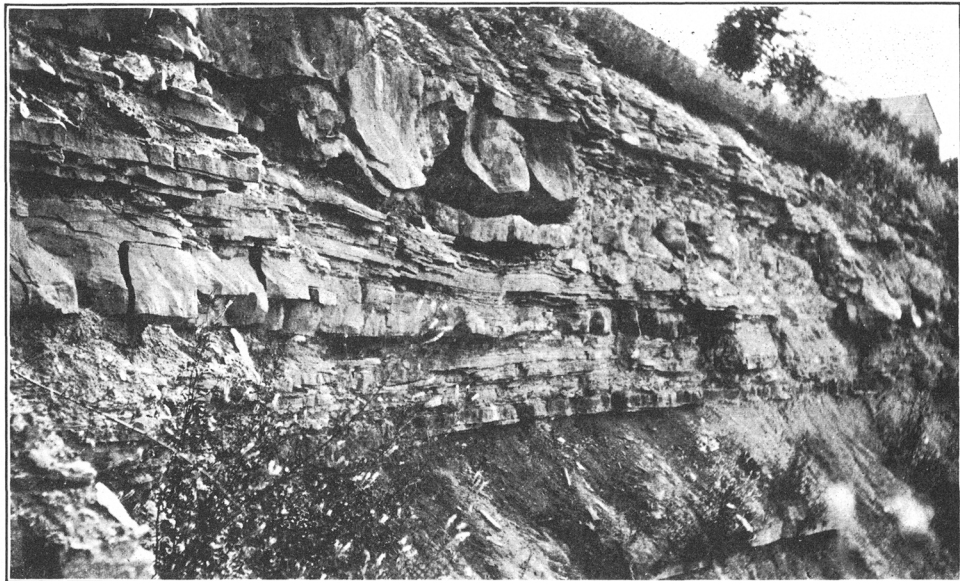


FIGURE 1.—MEDINA SANDSTONE AND CATARACT (CABOTS HEAD) SHALE CONTACT AT HAMILTON, ONTARIO, CANADA

Note the wave-rolled layer in the Medina. Photographed by Merton Y. Williams

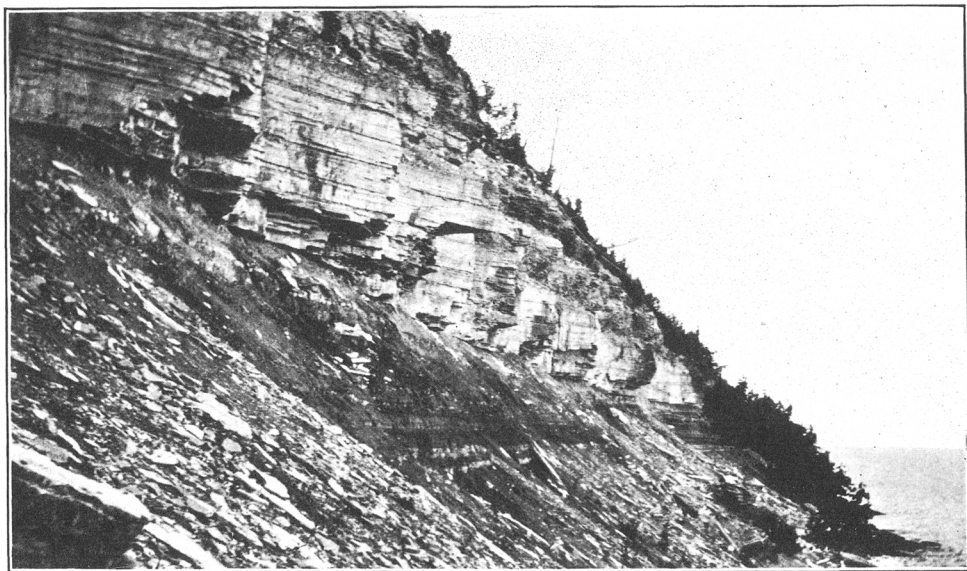


FIGURE 2.—CATARACT (MANITOULIN) DOLOMITE RESTING ON RED QUEENSTON SHALES, 2 MILES WEST OF CABOTS HEAD, GEORGIAN BAY, ONTARIO, CANADA

Photographed by Merton Y. Williams

CONTACTS OF THE CATARACT IN ONTARIO, CANADA

a follower. Then, too, he was the first American to lay down in writing the rule as to how formation names should be proposed (see quotation in Part II), and as he then said nothing about priority, and as this second rule was not formulated even by the biologists until 1844, we may overlook his neglect in accepting Conrad's term. To do otherwise now would bring on more confusion than clarity, because in 1842 and 1843 Vanuxem and Hall both used the same name, Niagara, for a group term of wide acceptance at present to embrace the Rochester shale and Lockport limestone.

Further, the term Cayuga sandstone (Vanuxem, 1839) is older than the accepted Oneida conglomerate (Vanuxem, 1840) and even than the Medina of Hall, and Oswego sandstone (Vanuxem, 1839) could well have been made to serve the place now taken by Queenston (Grabau, 1908). Most of these terms are, however, still of use to express local facies differences, but for time terms we should now disregard the rules and use here the younger names, Queenston and Medina. The "gray band" of Eaton, at the top of the Medina, is now known as the Thorold member,¹⁶ while the basal white sandstone along the Niagara River is well named Whirlpool sandstone.¹⁷ It will be shown that the latter is a member, not of the Medina, but of the Cataract formation, a series of calcareous sediments that in passing southeastward through Ontario gradually merges into a part of the sandy and fossiliferous Medina.

The Medina is typically developed along Oak Orchard Creek, which runs through the town of Medina. Here the formation is about 60 feet thick; it is described in detail in the second part of this paper. This thickness and the physical characters are about the same all the way from Rochester, which is 40 miles east of Medina, to Niagara Falls, an additional distance of 35 miles. At the last named place, however, the Cataract formation, 54 feet in thickness, is wedged underneath the upper Medina, consisting of the basal Whirlpool sandstone 22 feet thick, followed above by 32 feet of green shales, with a little of impure magnesian limestone. In all the sections from Niagara Falls eastward to Rochester there is a basal white, more or less coarse sandstone; but as it is clearly tangential in space and time, it is wrong to call it at all these places the Whirlpool sandstone. Certainly east of Lockport none of the basal sandstones hold the time of that along the Niagara River. From Niagara Falls northwestward the Whirlpool sandstone is far less or almost not at all tangential in time, and the name can be applied, without doing violence to correlation, to the basal sandstones in all of these sections.

¹⁶ Kindle and Taylor: *Op. cit.*

Grabau: *Bull. Geol. Soc. Am.*, vol. 24, 1913, p. 460. Here Thorold quartzite.

¹⁷ Grabau: *Jour. Geol.*, vol. 17, 1909, p. 238.

The Medina formation as here restricted may be described as follows:

Thorold member or gray band, 2 to 8 feet thick. This is nearly always a white, cleanly washed, more or less resistant, thick-bedded sandstone. No fossils are known from it other than the sand fillings in sun-cracks, which are more or less water-rilled, such as are seen at Medina and were described by Conrad in 1838 as *Dictuolites beckii*.

The *Upper Medina* is composed of red, cross-bedded sandstone, more or less impure intraformational shale pebble conglomerates, and some red shales, with a thickness of from 8 to 15 feet. These beds are marked by the burrows *Dædalus archimedes* and *Arthropycus alleghaniense*.

The *Middle Medina* consists of thin-bedded sandstones and shales, more or less red in color, with some white sandstones. The amount of coarse sand is variable in the sections, most abundant east of Lockport, and with more shale at this place and at Niagara. The thickness in eastern sections is about 20 to 25 feet and about 40 feet at Niagara, where there is, however, no basal sandstone. The Medina brachiopod and molluscan fauna listed elsewhere is from this zone, and especially from Medina. *A. alleghaniense* may occur in the upper half of this zone.

The *Lower Medina* is made up of basal, thick-bedded, coarse, cross-bedded, more or less red and dirty sandstones, though in places white and fairly clean. Thickness, about 20 feet. This rests with a very even base on the Queenston. Fossils are very scarce and of no significance.

THE MEDINA FAUNA

Because of the sandy, shifting nature of the Medina formation the fauna, of a very shallow sea, is not a large one. *Lingula cuneata* is often found in pure white sandstones and always as single valves washed about by the waves. Very little else is found associated in such deposits, though a bivalve may also be present and as well *Isochilina cylindrica*. In less clean sands the vertical spiral or lamellar burrows of *Dædalus archimedes* occur in great quantity; but as a rule this form and *Arthropycus alleghaniense* prefer dirty sands, while the latter and the so-called fucoids are most often seen in the dirtiest of sandy beds in thin shale partings. The bivalves and ostracods also preferred the dirty sands, but all have been washed about by the waves, while the calcareous shelled brachiopods, gastropods, and cephalopods occur in very thin zones that are more or less limy, though dirty and sometimes even decidedly ferruginous.

The fauna was originally described by Conrad¹⁸ and by Hall,¹⁹ and is, with subsequent additions, listed below. Some of the species listed by

¹⁸ Second and Third Repts., N. Y. State Geol., 1838 and 1839.

¹⁹ Geol. N. Y., Fourth Dist., 1843, pp. 36-57.

Pal. N. Y., vol. II, 1852, pp. 4-14.

Grabau²⁰ are now referred to the Cataract formation. The localities given are the type localities for the species, and the symbols are as follows: * = restricted to Medina formation, X = of no stratigraphic value, + = also in higher formations, ++ = affinity upward, and c = also in Cataract.

PROBABLE BURROWS:

X *Fucoides heterophyllus* Hall, 1843, 1852. Rochester.

X *Fucoides auriformis* Hall, 1843, 1852. Rochester and Medina.

BURROWS:

cX *Scolithus verticalis* Hall, 1852. Monroe County.

X *Palæophycus tortuosum* Hall, 1852. Rochester. These forms occur only in the upper portion of the Queenston and are burrows that are badly distorted by consolidation of the muds.

* *Dædalus archimedes* (Ringueberg). Lockport. As *Spirophyton archimedes* (see Sarle, Proc. Rochester Acad. Sci., 4, 1906:203). Described by Hall as *Arthropycus* sp. (Pal. N. Y., II, 1852:6, pl. 2, fig. 2).

* *Arthropycus alleghaniense* (Harlan). Tuscarora sandstone, 10 miles east of Lewiston, Mifflin County, Pennsylvania. The following is the synonymy:

Fucoides alleghaniensis Harlan, Jour. Acad. Nat. Sci. Phila., 6, 1831:289, pl. 15, figs. 1-3.

Fucoides alleghaniensis Harlan, Med. and Phys. Researches, 1835:393, fig. 1.

Fucoides Brongniartii Harlan, ibid.:398, fig. 2.

Encrinus giganteus Eaton, Geol. Text-book, sec. ed., 1832:37, pl. 1, fig. 8.

Fucoides harlani Conrad, Second Ann. Rept., N. Y. State Geol. Surv., 1838:113 (not defined, but *F. brongniartii* cited as syn.).

Fucoides harlani Hall, Geol. N. Y., Fourth Dist., 1843:46, figs. 1, 2.

Arthropycus harlani Hall, Pal. N. Y., II, 1852:5, pl. 1, fig. 1; pl. 2, figs. 1a-c.

Arthropycus alleghaniensis Sarle, Proc. Rochester Acad. Sci., 4, 1906:203.

BRYOZOA:

X *Pachydictya*, sp. undet. A fine large foliar form with pointed monticules. Lockport. Original in American Museum of Natural History.

X *Trepostomata* Bryozoa. Medina. One or more species in American Museum of Natural History.

BRACHIOPODA:

* *Lingula cuneata* Conrad, 1839 (Third Ann. Rep.:64). Medina.

++ *Schuchertella*, sp. undet. This species is identified by Whitfield as *Strophonella* (?) *orthididea* of the Clinton. The originals are in the American Museum.

++ *Camarotachia* (?) *plicata* (Hall), 1852. Lockport. May be related to *Rhynchotreta cuneata* of the higher formations.

²⁰ Loc. cit.

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c+*Camarotoechia neglecta* (Hall)? Specimen in American Museum. Occurs also in Cataract and Niagaran.

c**Whitfieldella oblata* (Hall), 1852. Lockport. Closely related to Clinton forms.

PELECYPODA:

c**Pterinea* (?) *primigenia* (Conrad), 1839. Medina. Syn. *Oypricardia alata* Hall, 1852: 11.

**Pterinea*, n. sp. Related to last species. Lockport and Medina.

c**Modiolopsis* (?) *orthonota* (Conrad), 1839. Medina.

GASTROPODA:

**Pleurotomaria* (?) *pervetusta* (Conrad), 1839. Medina.

**Liospira* (?) *litorea* (Hall), 1852. Lockport.

**Liospira*, n. sp. Much higher spire. Medina. American Museum.

**Holopea* (?) *conoidea* (Hall), 1852. Lockport.

c+*Bucanopsis trilobata* (Conrad), 1839. Medina. Also in Cataract and Clinton.

CEPHALOPODA:

×*Orthoceras multiseptum* Hall, 1852. Lockport.

×*Oncoceras gibbosum* Hall, 1852. Lockport.

OSTRACODA:

c**Ischilina cylindrica* (Hall). Medina.

RELATIONS OF THE CATARACT TO OTHER SILURIC FAUNAS

Species of the Cataract fauna.—The Cataract fauna so far as determined has about 76 species, but when all of the material so far collected is worked up the number will certainly exceed 100 forms. Enough is now known, however, to indicate clearly the relationships of this early Siluric fauna.

Relation to the Medina.—In common with the Medina, the Cataract has 7 species, and when one notes that the latter is essentially a limestone fauna and the former one of sands, the stratigraphic significance of these figures is apparent. However, it will be better to reverse the statement, and say that of the 22 forms constituting the Medina biota, 7 are also found in the Cataract. These are (1) *Scolithus verticalis*, (2) *Whitfieldella oblata* (not yet established), (3) *Camarotoechia neglecta*, (4) *Modiolopsis* (?) *orthonota*, (5) *Pterinea* (?) *primigenia*, (6) *Bucanopsis trilobata*, and (7) *Ischilina cylindrica*. These fossils show that the two formations are probably nearly of one time, although species 1, 3, and 6 have little stratigraphic value. The guide fossils restricted to the Medina are (1) *Dædalus archimedes*, (2) *Arthropycus alleghaniense*, (3) *Lingula cuneata*, (4) *Pleurotomaria* (?) *pervetusta*, and (5) *Holopea conoidea*. We may state the evidence in another way by saying that the Medina biota has 22 forms, and of these 6 have no stratigraphic significance. This leaves 16 species, of which 7 are also in the Cataract, 7

are restricted to the Medina, and 2 either pass into the Clinton or have close relations with forms of this fauna; the total number, however, that persists into the Clinton is 4. These statements indicate that the Medina is more closely related to the Cataract than to the Clinton.

It should also be stated that the Medina is of the Appalachian province, while the Cataract is either of the St. Lawrence or of the Arctic realm. These waters came in over the continent from different oceanic areas and accordingly have different organic associations. Hence the similarity of the biotas can not be close, and this, with the marked difference in sedimentation, gives additional reason why considerable weight is laid on the forms held in common, as showing that both formations are the deposits of about one time.

Relation to the Brassfield.—The Cataract may also be compared with the Brassfield formation of Ohio and Indiana, as the two are clearly related, and also as both are of a limestone facies. The former has 76 species and the latter 140.²¹ Between the two there are 24 forms in common, and of these the following have the most significance in correlation: *Clathrodictyon vesiculosum*, *Acervularia* (?) *gracilis* (in Ohio, *A. clintonensis*), *Rhinopora verrucosa*, *Phænopora ensiformis*, *Callopora magnopora*, *Homotrypa* (?) *confluens*, and *Hebertella fausta*. When the two biotas are finally carefully compared with each other, there will undoubtedly be added more significant forms, strengthening the view that the Cataract and Brassfield are fairly close correlates in time. However, as these two faunas are not of the same epicontinental basin, one can not expect a large percentage of the forms to be common to both; the Brassfield element came in from the Gulf of Mexico region, while the Cataract migrated into Ontario through the Gulf of St. Lawrence embayment across the Province of Quebec or came in from the Arctic. The Brassfield is marked by the guide fossils *Triplecia ortonii* and *Stricklandinia triplesiana*, forms never seen in the Cataract, while the latter has as its markers *Helopora fragilis*, *Rhinopora verrucosa*, *Rhipidomella circulus*, *Atrypa* n. sp., and *Cælospira planoconvexa*. On the other hand, both are closely related to the Clinton, for of the Cataract fauna fully 30 species pass upward and about the same percentage (40 per cent) from the Brassfield.

That the Cataract is a close correlate with the Medina has been shown, and that it is equally so with the Brassfield can be brought out in still another way. The Cataract fauna has 76 forms, and of these 22 have no stratigraphic significance (those marked X and the Errant Annelida).

²¹ Foerste: Geol. Surv. Ohio, vol. vii, 1893, pp. 516-601, pls. 25-37a.

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Of these 54 species, 24 also occur in the Brassfield, 7 in the Medina, 10 are restricted, while 30 pass upward into the Clinton or higher formations.

Relation to the Siluric of Anticosti.—The Cataract does not readily correlate with the Anticosti section²² because of the marked differences and generalized character of the faunas there, and more especially because of the long range of most of the species. With the Becsie River, the only guide fossil in common is *Cælospira planoconvexa* (appearing about 70 feet above the base of the Becsie River); but the Anticosti individuals are only half grown compared with those of the Cataract, a condition seemingly in harmony with the conclusion that the latter are of a younger time. Then the absence in the Cataract of the Becsie River guide, *Clorinda barrandei*, also seems to indicate that the former formation is of younger age. At the top of the Becsie River, however, the fauna is more like that of the Cataract, and this similarity continues in the succeeding 300 feet of the Gun River formation.

On the other hand, the Brassfield of Ohio correlates more readily with the Anticosti section and apparently best with zone D₈ of the Gun River, which is from 240 to 305 feet above the Becsie River. It is here that *Triplecia insularis* (compares with *T. ortonii* of Ohio) and *Stricklandinia lens* (compares with *S. triplesiana* of Ohio) appear for the first time. That the correlation can not be made with the next higher zone, D₉, is attested by the presence here of *Atrypa reticularis*, *Pentamerus oblongus*, and *Cælospira hemispherica*, species that in New York and Ontario are not seen below the Clinton. For these reasons, then, it may be said that the Brassfield, Cataract, and Medina seem to hold the horizon of the lower part of the Gun River formation, or more exactly from D₆ to D₈, a thickness of 178 feet. From these statements it will be seen that this correlation is different from that by Schuchert and Twenhofel in 1910, where the "Ohio Clinton," now the Brassfield, was correlated with the zones D₉ and E₁₋₃. Further, the Medina was then doubtfully placed beneath the Brassfield and correlated with most of the Gun River, whereas now, by regarding the Medina and Brassfield as equivalents of each other and of the Cataract, and with a better knowledge of all three formations, it appears better to regard them as equivalents of zones D₆ to D₈ of the Gun River formation.

CONTACTS BETWEEN THE MEDINA, CATARACT, AND CLINTON

At Rochester, where the Clinton appears to be fully represented, there seems to be no break in deposition, or at least a very slight one, between the Medina sandstone and the lowest member of the Clinton—the Sodus

²² Schuchert and Twenhofel: *Bull. Geol. Soc. Am.*, vol. 21, 1910, pp. 704-710.

shale. The contact here is sharp and without transition from the sandstone into the shale. Farther east the transition in the character of the sediments is said to be more gentle and complete, and this condition probably obtains throughout Pennsylvania and Maryland. In the latter state, at Cumberland, a complete and gradual transition can be seen, and it is clear that *Cælospira hemispherica* gradually appears and finally dominates the Clinton there.

At Rochester the Clinton consists of four members. From below these are the Sodus shale (24 feet), Wolcott limestone (14), Williamson shale (24), and Irondequoit limestone (18). At Medina, which is 40 miles west of Rochester, the Sodus has thinned to 3 feet, and although there is a basal Clinton shale, sometimes called Sodus, farther west, there is no proof that it holds the time of this member as developed at Rochester. In the Niagara gorge the Clinton, of continuous deposition, is 30 feet thick and represents the time from the Irondequoit to the Wolcott, as no intermediate shale representing the Williamson is developed here or to the westward. Going farther west and then north along the Niagara escarpment, the Clinton limestone gradually pinches out and none is present north of Glenwilliam. In this region the higher Rochester shale pinches out in the same way and none is seen north of Limehouse. For these reasons the Lockport dolomite in these northern sections comes to rest directly on the Cataract, and there is here, therefore, an easily discerned disconformity, indicating a time break of considerable length. [Grabau as censor of this paper thinks there is no break here, only a lateral sedimentary change from the Rochester shale to the limestones of the Lockport type. In the same way he explains the broken contacts between the Medina and Clinton. To these views the writer does not assent.] To the southeast the break becomes less and less long and from Thorold and the Niagara gorge east to Rochester, while the contacts are uneven, with the basal Lockport sediments disturbed and wave-rolled, still there appears to be no break in sedimentation between the Rochester and Lockport.

On the other hand, the Medina at Rochester is about 60 feet thick, and this depth is maintained to Lockport; but in the Niagara Gorge the thickness is usually given as about 120 feet. A reexamination of this famous Siluric section shows that about 54 feet are referable, on the basis of fossils, to the Cataract, so that the Medina as here restricted has the regulation thickness of about 60 to 65 feet. The contact between them is easily determined, as the Medina is always a sandstone resting on the Cataract shales (see plate 14, figure 1). In tracing the Medina to the northwest, it is seen to pinch out as do the Clinton and Rochester, and is observed for the last time at Dundas, with about 8 feet thickness. The

contacts in this area are always easily made out—a sandstone on a shale. As the Medina thins out to the northwest, so the Cataract thickens in the opposite direction, being 54 feet in the Niagara Gorge, 80 feet at Grimsby, 90 feet at Stony Creek, Hamilton, and Dundas, and 105 feet or more to the northwest.

At first the writer interpreted these sharp contacts as disconformities; but he now sees, on the basis of the faunal evidence, that this interpretation is not the correct one. Further, the Stony Creek section shows practically a complete and sandy transition from the Cataract into the Medina. In other words, the top of the Medina—that is, the typical Medina, about 60 feet thick—gradually loses its sandy character from Thorold northwestward and is transformed first into sandy shales and then into argillaceous shales, the Cabots Head or topmost member of the Cataract. On the other hand, the two lower members of the Cataract—the Whirlpool sandstone and the Manitoulin limestone—maintain their Ontario petrologic characters into the Niagara Gorge (see plate 13 and plate 14, figure 2). Finally, the latter member is either absent or modified at Lockport, while farther east both are absent. As the Medina and Cataract have at least 7 species in common, the easily discerned contacts between these formations as seen from Niagara Gorge to Dundas can not be interpreted as disconformities. In other words, the typical Medina formation shades through lateral alteration into the typical Cataract.

Even though the Medina, Cataract, and Brassfield are correlates of one another, it does not follow that each one is wholly the equivalent of any other. Each formation invades eastern North America from a different direction and each one has its own peculiar faunal assemblage (see figure 1). They therefore represent three physical provinces and marine basins. The Medina is of the northern Appalachian province, is a sandstone formation, and finally invades to a slight extent the area of the Cataract. The Brassfield province lies in the main west of the Cincinnati axis, is of southern origin, with limestone-making seas, spreads also up the southern portion of the Appalachian province, and finally invades slightly the area of the Cataract sea. On the other hand, the Cataract province spreads westward through the Saint Lawrence embayment, and finally in eastern Ontario and northeastern Ohio (known from the Clinton oil wells) unites with the other two provinces; but as the Medina waters form a shoal sandy area in northeastern Ohio between the other two provinces, very few of the species of either area intermigrate. Probably it would be more correct to state that the normal marine junction of the Cataract and Brassfield seas is prevented by the Medina delta. For these reasons Medina, Cataract, and Brassfield are to be retained as names for independent marine faunas and formations.

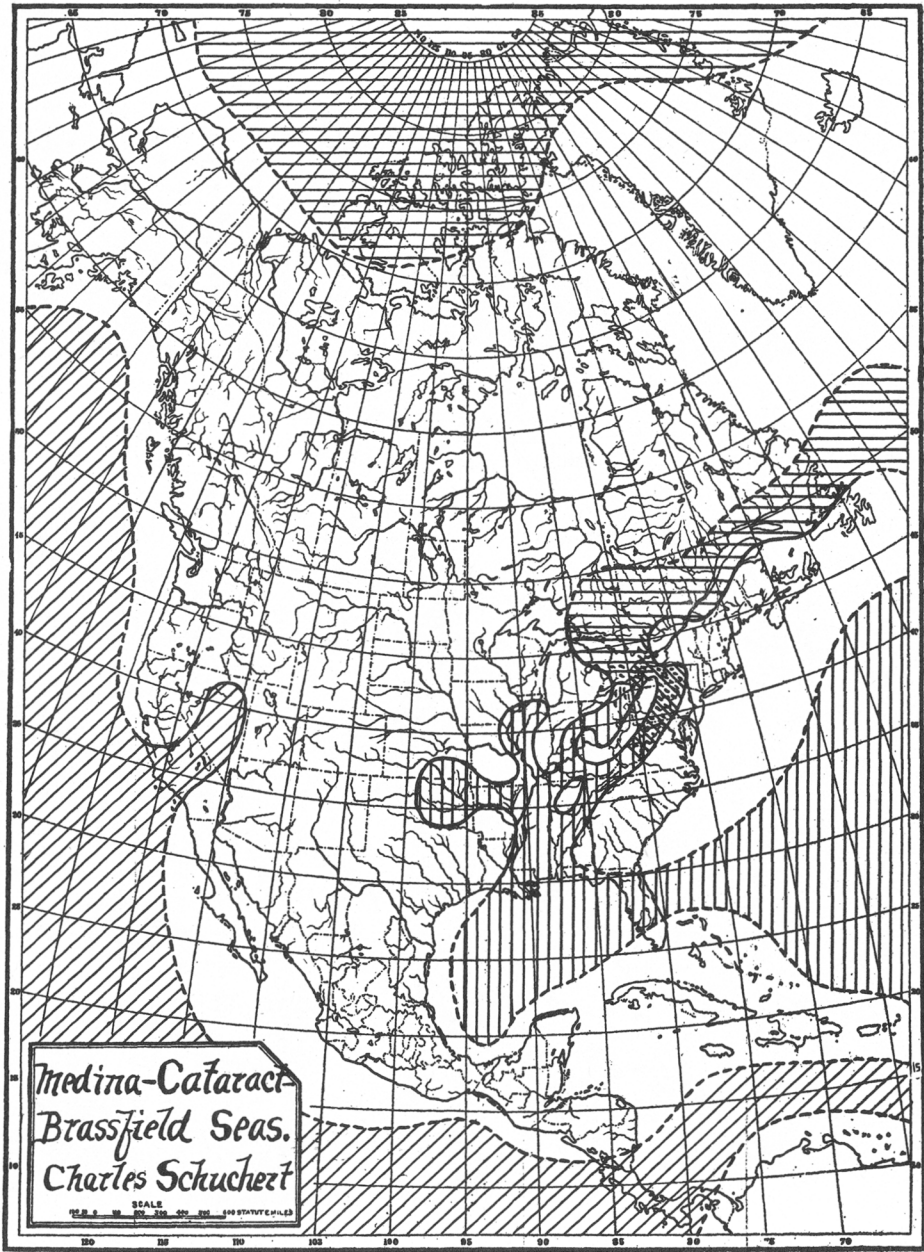


FIGURE 1.—Paleogeography of Medina (diagonal lines), Cataract (horizontal lines), and Brassfield (vertical lines) Seas

SUMMARY OF SECTIONS 340 MILES APART

0 = not present, X = present but thickness not determined, double lines = section broken

	Lockport		Rochester	Clinton				Medina	Cataract			Queenston	Richmond
	Lockport	De Cew		Irondequoit	Williamson	Wolcott	Sodus		Cabots Head	Manitoulin	Whirlpool		
Rochester, New York	125	2-5	85	18	24	14	24	60				900	
Medina, " (40 miles west)				10-15			3	65				X	
Lockport, " (15 " ")	150	5	60	10-15	0	12-21	0	53	0	0	17	X	
Niagara gorge, " (20 " ")	150	6-9	60	10-15	0	12-21	0	65		32	22	1085	
Thorold, Ontario (10 miles west)	X	X	71	10	0	16	0	X					
Grimsby, " (20 " ")	X	8	39	4	0	10	0	25	74		6		
Stony Creek, " (10 " ")	X	?	25	4	0	9	0	18	70	8	12	X	
Hamilton, " (6 " ")	X	?	15	4	0	10	0	12	50	30	10	X	
Dundas, " (5 " northwest)	170	0	6	5	0	9	0	8	76	9	8	535	
Limehouse, " (25 " north)	X					6.5			X			X	
Glenwilliam, " (5 " ")										X	12	X	
Cataract, " (8 " ")	X								65	25	16	X	
Collingwood, " (48 " northwest)	160								20	12	0	45	430
Owen Sound, " (38 " west)	X								75	30	0	50	X
Cabots Head, " (53 " northwest)	165								45	15	0	45	X
Manitowaning, " (45 " ")	240								27-66	50-60	0	0	435

PART II

HISTORY OF THE MEDINA FORMATION

Amos Eaton.—This pioneer geologist of New York, who was the first to write of the rocks now under discussion, states in 1824²³ that he was the first “who attempted a particular classification of American rocks,” and justifies his ability to do this with the statement that he had then taught over two thousand pupils in geology, and “had travelled more than three thousand miles on foot, and two thousand by water and carriage conveyance, in search of geological facts,” before he came under the patronage of Hon. Stephen van Rensselaer. “I have added more than five thousand miles of land and canal travelling, in pursuit of the same object, during the last four years,” he states as further proof of his ability.

In this old book we see applied to the Medina formation for the first time the names “Saliferous Rock,” “Grey Band (or Grey Feke),” and “Millstone Grit.” The term “Grey Band” is still in use, though recently Grabau (in Kindle) has proposed to replace it by Thorold sandstone. The Saliferous Rock, Eaton states, “is an aggregate of minute rounded grains of quartzose sand, or of minute argillaceous and quartzose grains, formed into red or greenish sandstone, or soft red or greenish brittle clay slate.” The gray band “is a hard fine-grained grey rock, which is so compact that it may be considered as homogeneous. It is a thin but continuous stratum, everywhere overlaying the red saliferous rock; and might be called *grey saliferous rock*.” Among the localities cited are Genesee Falls, Oak Orchard Creek, 4 miles west of Rochester to Lockport, and Lewiston; a number of other places are given where red rocks are exposed, but these clearly belong in the Salina formation, and from the occurrence of salt in these localities came the term Saliferous, a name somewhat though not entirely misapplied to the Medina. At Oak Orchard Creek are noted an abundance of stylarites, “with very distinct transverse or torulose ridges.”²⁴ These are now known as *Arthropycus alleghaniense*.

The same formations and names appear in Eaton’s *Geological Text-Book*,²⁵ where they are classified as of the “Lower Secondary, or Third Series.” In the second edition of this text-book²⁶ Eaton is in doubt as to the proper disposition of the Saliferous in the geological column (he had included in it Queenston, Medina, and Salina, hence his trouble),

²³ Geol. and Agric. Surv. Erie Canal, N. Y., 1824, p. 9.

²⁴ Op. cit., pp. 12, 35-36, 102-116.

²⁵ 1830, pp. 39-40.

²⁶ 1832, pp. 65, 82-83, 94, 96, 120.

and he now refers it to a "Subordinate Series, embraced in the third Regular series (Lower Secondary)." Here again the gray band is placed as before, and he cites the same localities, with the addition of the Niagara River. The most interesting addition here, however, is that Eaton mentions *Lingula mytiloides* (= *L. acuminata*) and *Encrinus giganteus* (described as new) as the fossils characterizing the "Saliferous." The latter turns out to be nothing other than the widely known *Arthropycus harlani* Conrad, though no one would readily come to this conclusion from Eaton's figure 8 on plate 1. It is defined thus: "*E. giganteus* (red coralline) branching, red or grey: often compressed, whirls uniform and generally obscure: branches of great length; mostly lying in the direction of the layers, or nearly so. Found in saliferous rocks at Oak Orchard, Mineral Hill in Blenheim, and a mile south of Mt. House [Catskills]" (page 37). The two last named localities must refer to something else and are not typical, for on page 83 he states: "I find the encrinus giganteus in all of them; though the whorls are often indistinct or not manifest. They are most perfect at Oak Orchard Creek." This conclusion is confirmed on page 120. Eaton is, of course, in error in regarding these burrows as casts of the stems of crinoids.

T. A. Conrad.—We now pass over an interval of five years before another mention is made of the Medina formation. In 1836 the Geological Survey of the State of New York was authorized and organized, and in the following year was printed the first report. T. A. Conrad, who was appointed State Geologist of the Third District, reported on the Medina as follows:

"*Red or Variegated Sandstone of Niagara River.* We have chosen this name because it is descriptive of the only sandstone developed in the course of the Niagara River. . . . This widely distributed series of red and gray sandstones and shales has been termed 'saliferous rock' by Eaton, but it is by no means proved that it contains salt. . . . This formation is very interesting, in consequence of the peculiar and uniform nature of its organic remains." Those that he notes, however, are from Oak Orchard Creek at Medina. "The most striking feature in these sandstones and shales, is the vast abundance of fucoid, or marine plants, particularly that species termed *Fucoides Brongniartii* by Dr. Harlan. These penetrate every portion of the shale which constitutes the upper portion of the mass. . . . Testaceous remains are seldom found where fucoids are numerous, but immediately beneath the strata containing them, fresh water [an error which he recognizes and corrects in the Fifth Report, 1841, page 41] and marine shells abound in a limited space." They occur in "three narrow approximate veins filled with *Cyclostoma*,

Planorbis and *Unios* [also *Orthoceras*], and with marine depositions above and beneath them. . . . They occur below the fall in the banks of Oak Orchard Creek at Medina. Mingled with these, we find a few specimens of *Lingula* [*cuneata*], which just below are profusely disseminated through the rock. . . . All the larger layers are variegated with stripes of different hue, oblique to the plane of stratification, dipping at various angles and in different strata to opposite points of the compass. . . . Other fine sections of variegated sandstone are furnished by the Genesee River, north of Rochester, in the vicinity of the two lower falls" (pages 166-168).

Conrad's usage here of Niagara as a formation name is original, and that he intended the name to stand is proven by the Third Annual Report (1839, page 63), where in a table it is placed as "Niagara sandstone (red)," and more especially by the Fourth Report (1840, page 201). Under these circumstances, and according to the rules of formation nomenclature, it should have been adopted. In this case, it would have applied through characterization rather to the Medina sandstone than to the "red marl," now the Queenston, which was also included in his discussion of the section along the Genesee. In the Fifth Report (1841, page 31), however, Conrad seems to have forgotten his term Niagara sandstone, for here he writes "Red sandstone." In any case, to revive at this date the term Niagara for the Medina would displace the series term Niagara or Niagaran introduced by Vanuxem in 1842, and as this would cause more confusion than otherwise the writer does not care to make the substitution.

James Hall.—Conrad, after his first year as field geologist of the New York State Survey, became the State Paleontologist, and James Hall, a pupil of Eaton, was assigned Conrad's area in the western part of New York. In the Second Report (1838, pages 294-297, 357) Hall writes of the Medina, and the following extracts are taken from his report:

"*Red Marl and Sandstone.*" As may be seen above, Conrad had the year before called this formation the "Red or Variegated Sandstone of the Niagara River;" Hall now objects to the characterization "variegated" as "being already appropriated, as designating a member of the new red sandstone series. . . . Besides this, there are only a few of the upper strata which are variegated."

"The rock below the grayband is variegated to the depth of 20 or 30 feet, with gray or greenish gray spots and seams. Although this formation has been called sandstone, much the largest proportion of it is an indurated marl, containing too little siliceous matter to entitle it to the name of sandstone. On the Niagara River, where there are more than

five hundred feet in thickness developed, we find no more than forty feet of a siliceous character. . . . The marl in the lower part of the formation is striped, vertically and horizontally, with seams of green shale." It is therefore seen that Hall here follows the example of Eaton and Conrad in including the marl (= Queenston) and the higher sandstones (= Medina) all in one formation, a correlation that was continued until 1905.

"At Medina, about forty feet from the top of this rock, we find a stratum, two feet thick, of siliceous sandstone of a greenish gray colour, containing *Lingula*, *Cyclostoma*, *Planorbis*, *Unio* and *Cytherina*. . . . The points at which this formation can be most advantageously examined, are along the Genesee River, below Rochester, at Medina, Orleans County, and along the Niagara River, near Lewiston."

We now come to Hall's Third Annual Report (1839), important because it is here for the first time that the principle is defined as to how formations shall be named. The use of a geographic name of the locality where the formation is typically developed was not new with Hall; but to him we must give the credit in that he was the first American to see clearly what must be done in this matter and to act accordingly, so that stratigraphers thereafter might become more certain of what they described.

Hall relates that he traveled with his colleague, Vanuxem, for "several weeks in examination along the boundary line between the Third and Fourth Districts." Vanuxem, learned and conservative, a graduate of the School of Mines in Paris, had great influence over Hall, as the latter related to the writer in 1889. Undoubtedly the principle of a type locality was formulated by Hall during this association in the summer of 1838, and in his report of 1839 many of our formation names now in use take their origin. He says:

"Hereafter we shall be enabled to avoid collision and discrepancy in our descriptions, and to designate groups without confounding them with each other. We have also found the solution of many difficulties, in part arising from previous partial examinations, and also from the fact that the character of several rocks below the Onondaga limestone entirely or materially change in their eastern prolongation; and more especially after passing the longitude of Cayuga Lake. . . .

"Every one who has studied rocks even partially, is aware of the insufficiency of mineral or lithological characters for giving nomenclature, and the many errors into which he may be led, whether in his own researches or by the mistakes of others. So likewise in the present state of our knowledge, we are unable in all cases to give names from fossil

characters; for though without doubt every group embraces its peculiar fossils, yet in all localities these may not be so marked as to excite attention, and in some may possibly be absent. It thus becomes a desideratum to distinguish rocks by names which cannot be traduced, and which, when the attendant circumstances are fully understood, will never prove fallacious. The basis of this nomenclature is derived from localities; and the rock or group will receive its name from the place where it is best developed. For example, the rock denominated in the section [of the last report] calcareous shale, simply to distinguish it from the green argillaceous shales below, will be called Rochester shale. In lithological characters it is extremely like one far higher in the series, but the fossil contents are entirely different. This contains the *Asaphus caudatus*, *Trimerus delphinocephalus*, *Platynotus Boltoni*, besides species of *Orthis* and *Delthyris*, all peculiar to this rock, and the characters if studied and well understood at Rochester, will guide the observer in all subsequent examinations. The limestone at Lockport excavated for the passage of the canal, we propose to call Lockport limestone. At this place the rock possesses in an eminent degree the geodiferous character, which has hitherto given it its name; but this is quite inapplicable to the same rock where seen in Wayne County" (1839, pages 288-289).

In the Fourth Annual Report (1840, pages 374, 453-455) we meet for the first time with the term Medina in Vanuxem's report. Evidently he did not intend to stand sponsor for the name, as Medina is not in his geological district (Third), but is in Hall's Fourth District. Vanuxem writes: "*Medina sandstone*. Called in former reports the red sandstone of Oswego. Predominant colour red, more rarely whitish and greenish. This rock is confined to Oswego County, to the high grounds of Oneida at Florence village, and other parts of the town of Florence, and to the extreme north parts of the counties of Onondaga and Cayuga" (page 374).

Hall in the same report writes as follows: "Medina sandstone, red marl and shale. This rock is the lowest in the 4th District, it being found bordering the shore of Lake Ontario, from Niagara River to the eastern limits of Wayne County." He intimates that it rests on the Salmon River group, which is now known to be of Lorraine or Maysville age. The fossils mentioned are the regulation Medina species.

In the final report,²⁷ in 1843, Hall gives a general summary of the Medina, and here he notes as synonyms all the names given above and as well Niagara sandstone, but as to this latter name states nothing further. He says: "At Medina, on the Oak-orchard Creek, we have the best exposure of the mass which exists in the State, and hence its name.

²⁷ Geol. N. Y., Fourth Dist., 1843, pp. 24, 34-57.

The thickness here exposed is not greater than on the Genesee River, nor so great as on the Niagara at Lewiston, but it exhibits all its fossil types in the greatest perfection" (page 43). He then gives a generalized section of the Medina, separating it into four divisions as follows:

- (1) Grey-band of Eaton. "The grey or greenish grey terminal portion. . . . It always appears more or less as a part of the Medina sandstone, possessing the same lithological features." Thickness, 2 to 10 feet. = Thorold member of Grabau.
- (2) The main red sandstone mass. Red marls and sandstones "gradually passing into a more sandy form in the western portion of the district."
- (3) "Grey quartzose sandstone entirely distinct" from the grey-band. At Niagara Falls the basal sandstone, 25 feet thick, has been named the Whirlpool sandstone member. These three members were later called the Upper Medina and redefined as the true Medina by Grabau.
- (4) "Red marl, and marly or shaly sandstone." Later on this member was called the Lower Medina and the Queenston by Grabau, who referred it to the Ordovician as the equivalent of the Richmond and Lorraine of the Cincinnati series.

C. A. Hartnagel.—In 1907²⁸ Hartnagel gave a good account of the Medina (as defined by Hall) as exposed about Rochester. Here he divides it into the "Lower Medina shale" and the "Upper Medina sandstone and shale." The former, he states, extends east to Rome, and is underlain by the Oswego sandstone, while the latter goes 40 miles farther to Cherry Valley. East of Oneida County the Upper Medina is known as the Oneida conglomerate and has the characteristic fossil *Arthropycus alleghaniense*. The year before,²⁹ Hartnagel had clearly shown that the Oneida is equivalent to the Upper Medina, as the above mentioned fossil had been found near Utica, in the type section of the formation, near Verona, in Oneida County, and at the falls of the Oswego. "The presence of this fossil and the stratigraphic relations of the Oneida conglomerate as shown in the Mohawk Valley can leave no doubt of the upper Medina age of the Oneida conglomerate."

A. W. Grabau.—In his well known *Guide to the Geology and Paleontology of Niagara Falls and Vicinity*,³⁰ Grabau gives a good detailed description of the four members of the Medina and includes all in the Silurian system. In 1905³¹ he returns to this formation, separating the lowest or fourth member from the Medina proper and placing it in the Ordovician. He states that the Oneida and Medina "were not deposited in the open sea, but rather under peculiar conditions, *i. e.*, estuarine, if not

²⁸ Bull. 114, N. Y. State Mus., 1907, pp. 10-12.

²⁹ Bull. 107, N. Y. State Mus., 1906, pp. 34-35.

³⁰ Bull. 45, N. Y. State Mus., 1901, pp. 87-95.

³¹ Science, vol. 22, 1905, pp. 528-529, 532-533.

continental. . . . Moreover, it is now pretty well ascertained that the typical Oneida conglomerate of Oneida County is the time equivalent of the Upper Medina of the Niagara section, and that both probably should be united to the Clinton, while the lower 1,100 feet of the Medina of western New York may possibly represent the continental or estuarine phase of deposits, representing elsewhere the later Richmond period."

In 1908³² Grabau names the Lower Medina the Queenston, writing as follows: "The dividing line between Ordovician and Silurian is drawn at the base of the Upper Medina or the Medina proper [about 125 feet thick at Niagara River]. For the red Medina shales now recognized as of Ordovician age the name Queenston beds is proposed, from the town of that name on the Niagara River opposite Lewiston, where these beds are partly exposed." Later in the same year Chadwick³³ also names the Lower Medina, calling it Lewiston after Lewiston, Ontario, and regarding it as the equivalent of the Richmondian. With the Clinton the Upper Medina "might be merged without violence. In any case the (restricted) Medina falls within the Niagaran." Finally, in 1909,³⁴ Grabau ranges the Medina and Oneida of New York and the Tuscarora of Pennsylvania with the Clinton in the Silurian, while the Oswego of New York and the Tyrone (later renamed Bald Eagle because of preoccupation) are referred to the Lorraine; the Queenston and the Juniata are, in the main, regarded as of Richmond time, while "the lower part must be considered as Lorraine."

Lardner Vanuxem.—If we are to remain strictly by the law of priority in naming formations, we can not accept either Queenston or Lewiston, but must go back to Vanuxem, 1839,³⁵ and his term Oswego. To make this matter clear let us study Vanuxem in the original. He says: "*Red Sandstone of Oswego.* The red sandstone of Oswego is the lowest rock" of the counties "Madison, Onondaga and Cayuga. . . . From the eastern part of Oswego County, to the Niagara River, numerous brine springs are found in this red sandstone." The rocks which "appear from under the 'millstone grit' [= Oneida = Upper Medina], and from above the green shale of Herkimer . . . are the shales and green sandstone of Salmon River, and the red sandstone of Oswego." The latter appears "immediately under the 'grit.'"

Nor can we accept Oneida, for Vanuxem has named an equivalent in 1839:³⁶ "*Gray Sandstone of Cayuga.* To the south of the red sand-

³² Science, vol. 27, 1908, p. 622.

³³ Ibid., vol. 28, 1908, p. 347.

³⁴ Ibid., vol. 29, 1909, pp. 354-356; also Jour. Geol., vol. 17, 1909, pp. 234-238.

³⁵ Third Ann. Rept. N. Y. State Geol. Surv., 1839, pp. 244-246.

³⁶ Op. cit., pp. 242, 246.

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stone, and reposing upon it, is a gray sandstone, the lower part often variegated with the red oxide of iron, and the upper variegated with green shale. . . . This mass for position corresponds with the 'mill stone grit' to the east and the 'gray band' to the west." "The 'millstone grit,' which is thirty and more feet in thickness in Herkimer and Oneida, gradually attenuates in going westward, being from four to five feet at Rochester. The materials of which this rock is formed, gravel and sand, prove that their source was eastwardly." It is in the following report (1840, page 374) that he proposes "*Oneida conglomerate*. The 'millstone grit' of Prof. Eaton, which has been changed, to do away with all ambiguity." Here it is, too, that Vanuxem lays aside his term Oswego for "*Medina sandstone*. Called in former reports the red sandstone of Oswego."

THE SILURIC SECTIONS IN DETAIL FROM ROCHESTER, NEW YORK, TO THE
HEAD OF LAKE HURON

Rochester, New York, section.—Examined by the writer in August, 1913. Use has also been made of Hartnagel, Bulletin of the New York State Museum, page 114, 1907, and Hall, Geology of New York, Fourth District, 1843, pages 58-117.

Lockport dolomite. Thickness present, 107-125 feet. The lowest beds are studied to best advantage in the large quarry on North Goodman street, where the Rochester is also worked for building stone (foundations). Here the lower 5 feet of the regulation Lockport consists at the top of fine-grained, dense, crystalline dolomite. Downward in this 5 feet appears more and more of sand, and finally the lowest foot or more is a regularly bedded, laminated, fine-grained, brittle sandstone. Beneath is a dark, bituminous, thin-bedded sandy shale, filling the hummocky depressions in the beds below. The same irregular contact may be seen at the Upper Falls of the Genesee.

De Cew member (Williams MS., 1914). The top of the Rochester is hummocky to the extent of at least 4 feet. Between these depressions and over the top of the ridges is deposited from 2 to 5 feet or slightly more of irregularly bedded (sea-churned) impure limy cement beds, not unlike the Rochester below.

Irregular wavy contact? Time break, if any, short.

Rochester shale. Thickness about 85 feet. At Rochester the formation has more lime and the strata are much harder and more resistant to weathering than at Niagara Falls, where there is less lime and the beds are more laminated into thin-bedded shales.

Clinton formation. Thickness about 80 feet.

Irondequoit limestone member, 18 feet thick. Thin-bedded limestones with shale partings. Locally between Rochester and Niagara Falls small Bryozoa reefs are developed near the top of this member, and some of these project several feet into the Rochester shale. Other-

wise the transition between the Clinton and Rochester is quick, but no break in sedimentation is apparent. Then, too, many of the species are common to both formations. Below there is a gradual transition into the

Williamson shale member, 24 feet thick. Thins rapidly to the west and is absent at Lockport. A green shale series at the top (8 feet), below which are more green shales (4 feet) with very thin pearly limestones replete with *Cælospira hemispherica*, and finally purplish and black shales (12 feet), the latter with *Monograptus clintonensis* and *Retiolites venosus* in abundance.

Wolcott limestone member, 14 feet thick. Thin-bedded greenish limestones that come in rather sharply over the Sodus shale, but shade into the Williamson. Three feet above the base occurs the *Furnaceville iron-ore*, here about 1 foot thick. It is decidedly cross-bedded, made up of fragmented and worn fossils, some sand, and less oolite; the fossils are crinoidal fragments, Bryozoa, and Tentaculites, all altered or coated with iron. The beds below the ore and the ore itself show wave action. *Pentamerus oblongus* (Clinton form) and *Hyattidina congesta* are guide fossils.

Sodus shale member, 24 feet thick. A green, fine-grained shale almost devoid of fossils, other than "fucoids" and trailings. It rests abruptly and without the least transition upon the Medina. The Sodus thins rapidly to the west and is only 3 feet thick at Medina.

Contact very sharp between adjacent beds. Probably no time break.

Medina formation. Thickness about 60 feet.

Thorold member, or "gray band." A massive white sandstone, 5 feet thick.

Heavy-bedded, channeled, red and mottled, dirty sandstones, with but little shale and many zones of intraformational shale pebble conglomerates, 15 feet thick, with *Dædalus archimedes* throughout and *Arthropycus alleghaniense* in upper 6 feet.

Regularly thin-bedded, lighter red sandstones, with more prominent shale partings, about 20 feet thick. *A. alleghaniense* and *Lingula cuneata* in upper 5 feet and much sun-cracking in upper 2 feet.

Basal thick-bedded, very coarse red sandstones, as follows: At the top 10 feet of irregularly bedded sandstones, followed by one bed 4 feet thick, also much cross-bedded, and then the basal zone of 6 feet, regularly bedded below, and cross-bedded and often deeply channeled above. Here again the sandstone fills into the sun-cracked surface of the Queenston below.

Disconformity. Base of Siluric.

Queenston formation. Top of Ordovician (Richmondian). There has been much uncertainty here as to the lower limit of the Medina, but the heavy, and much cross-bedded gray sandstones easily mark the base. The uncertainty is due to the fact that the Queenston is here much more sandy than farther west and that there are horizons of local sandstones. Still farther east these sandstones pass into the Oswego. Here the Queenston in the upper 40 feet consists of red, micaceous, sandy shales, with thin zones of gray localized sandstone. There are many

worm burrows, now distorted, squeezed, and slickensided, but none are of *Arthropycus*. These are *Paleophycus tortuosum*. Then a shaly red sandstone, 10 feet thick, followed below by more red sandy shales.

Total thickness of Queenston, exposed and underground, is said to be about 900 feet.

Medina, New York, section (40 miles west of Rochester).—Hall, Geology of New York, Fourth District, 1843, pages 34-57.

Clinton.

Medina formation. At least 54 feet, but probably nearer 65 feet. The upper part is to be seen in the many quarries along the Erie canal and along Oak Orchard creek, while the lower beds are exposed below Medina Falls, to the west and northwest.

"Gray band." Hall says this is 4 feet thick. The zone from which came the originals of *Dictuolites beekii*, which are sand fillings in sun-cracks filled by water.

A zone estimated to be 8 feet thick, not seen by the writer.

Thin-bedded dark red sandstones and a considerable amount of red sandy shales, 8 feet thick. Intraformational conglomerates of shale pebbles are common. Seen along the tow path of the canal. Two feet down occurs a zone 18 to 34 inches thick, made up of the spirals of *Dædalus archimedes* (in the creek above the falls this zone is 30 inches thick and made up of vertical plates only). *Arthropycus alleghaniense* occurs throughout the 8 feet. The lowest part of these beds is again seen at the top of the quarries.

Upper quarry level of thin-bedded red and pinkish sandstones with thin red shale partings. 15 feet thick. *A. alleghaniense* occurs here also in the upper half. In the lowest beds are found *L. cuneata* in abundance and *Modiolopsis* rarely.

Lower quarry level near the falls, of thin-bedded red sandstones with red shale partings, 10 feet thick. *Lingula cuneata* throughout these beds. In the top of this zone occurs the bulk of the described fauna, as *Pterinea* (?) *primigenia*, *Modiolopsis* (?) *orthonota*, *Pleurotomaria* (?) *pervetusta*, *Bucanopsis trilobata*, and *Isochilina cylindrica*.

White sandstones, sometimes slightly tinged with red blotches or faintly pinkish, about 21 feet thick. The upper 3 feet are thinner bedded, with shale partings, with the sandstones often replete with *L. cuneata*. Here also occur *Isochilina cylindrica*, *Modiolopsis* (?) *orthonota*, *Pterinea* (?) *primigenia*, *Pleurotomaria* (?) *pervetusta*, and *Bucanopsis trilobata*, all of which were originally derived from this locality and horizon. The greater central mass (12 feet) is more heavily bedded, with almost no shale (formerly quarried at the falls), while the lower 6 feet of thick beds (in places up to 10 feet) are much cross-bedded, of much coarser sand, with many black or greenish black streaks. All of the lower beds appear to be barren of fossils.

Disconformity. Base of Siluric.

Queenston brick-red shale. Top of Ordovician (Richmondian). At water-level some distance below the falls.

Lockport, New York, section (15 miles west of Medina).—The sequence here is difficult to make out because of the disconnected local sections. A visit in August, 1913, revealed the following:

Lockport dolomite. Thickness about 150 feet.

Gasport limestone member (Kindle, 1913), about as at Niagara gorge.

De Cew member (Williams MS., 1914). At the head of the "Gulf" near the brick-paved north-south road may be seen the basal beds. They are essentially like those in the Niagara gorge, with the upper contact line much more irregular than the lower one, which is fairly even with the Rochester shale. Thickness about 5 feet.

Irregular wavy contact. Time break, if any, short.

Rochester shale. About 60 feet thick. About as at Niagara gorge.

Clinton formation. About 30 feet thick, and as at Niagara gorge.

Disconformity. Sodus shale absent. [Grabau as censor questions the break here. He says it is another case of lateral change.]

Medina formation. Thickness about 53 feet without the basal sandstone, with it 70 feet. This formation was studied back of the United Indurated Pipe Co., along the stream, on the opposite bank, and finally in Whitmore quarries. The Medina is here essentially a very shallow water deposit with occasional preservation of the strand-line, or nearly so.

"Gray band," a white fine-grained sandstone, 2 feet thick.

Dark red thin-bedded sandstones and red sandy shales, 10 feet thick.

Arthropycus alleghaniense occurs at the very top and probably also throughout the entire zone.

Local zones of *Dædalus archimedes* (the type locality for this fossil).

Here in two beds with a combined thickness of 2.5 feet. In one horizontal direction these burrows were seen to vanish within 500 feet.

Red sandy shales, thin ferruginous mud bands, and red and white sandstones, with an estimated thickness of 30 feet. It is in the upper 20 feet that the Whitmore quarries are located, from which, in the red and ferruginous layers near the top of the quarry, the bulk of the Medina fauna of Lockport has been derived. From this zone and place Hall described *Rhynchotreta* (?) *plicata*, *Whitfieldella oblata*, *Pleurotomaria* (?) *litorea*, *Murchisonia* (?) *conoidea*, *Oncoceras gibbosum*, and *Orthoceras multiseptum*. The red sandstones are often replete with intraformational red shale pebble conglomerates in layers up to 4 inches thick. Some of the white sandstones abound in *Lingula cuneata*, and some of the layers have smooth beach-washed surfaces with stranded *Lingulas*, proving the shore conditions of deposition. The sandstones are a series of shallow lenses laid down in red muds.

Light greenish sandy shales alternating with thin sandstones, with an estimated thickness of 10 feet. No fossils were seen.

Basal white sandstone, 17 feet thick. The upper 11 feet are thin-bedded, while the lower 6 feet are massive. The under surface fills in the sun-cracked furrows of the Queenston below. May be equivalent to the Whirlpool sandstone.

Disconformity. Base of Siluric.

Queenston. Top of Ordovician (Richmondian). Four feet of this formation may be seen above the canal leading to the turbine of the Pipe Co.

Niagara Gorge, New York-Ontario, section (20 miles west of Lockport).—Along line of New York Central Railroad and Grand Gorge Trolley. See Grabau, Bulletin 45, New York State Museum, 1901, pages 87-95, and Kindle and Taylor, Geologic Folio 190, U. S. Geological Survey, 1913.

Lockport dolomite. Thickness about 150 feet.

The main upper mass of about 120 feet is a dark bluish gray to brownish colored, thin-and thick-bedded, more or less coarsely crystalline dolomite that is somewhat petroliferous and with geode cavities containing gypsum, selenite, dog-toothed spar, etc. In the highest beds are the precursors of the Guelph fauna, here always rare in species (see Clarke and Ruedemann, Mem. 5, N. Y. State Mus., 1903). The fossils include *Cœlidium macrospira*, *Pterinea subplana*, *Phragmoceras parvum*, etc. Otherwise the fauna is largely a modified Rochester assemblage.

Gasport member (Kindle, 1913). "Crinoidal limestone" or marble. Usually a non-magnesian limestone, but may also be transformed into a dolomite; replete with crinoidal fragments and local diagenetically changed Bryozoa reefs. From 7 to 20 feet thick. Fauna essentially that of the Rochester, with *Callicrinus*, *Ichthyocrinus conoideus*, *Eucalyptocrinus tuberculatus*, etc.

DeCew member. Drab to bluish gray, fine-grained, impure limestone or cement rock, that in the upper 3.5 feet is more or less strongly wave-worked, 6 to 9.5 feet thick. This horizon is in many places marked by irregular contacts, both above and below, and by the lithic differences between the adjacent formations. The upper contact is very regular, but the lower one is here decidedly irregular. No fossils. In some ways this member seems to be a transition zone under disturbed conditions from a shallow muddy sea to deeper limestone-making waters.

Irregular wavy (? eroded) contact. Time break, if any, short. [Grabau as censor questions the broken contact here. It becomes, according to the writer, more and more prominent to the northwest. The former states that it is another case of lateral change in the sedimentation.]

Rochester shale. About 60 feet thick.

The upper part of this formation has many thin layers of limestone replete with many species of Bryozoa described by Bassler (Bull. 292, U. S. Geol. Surv., 1906). The fauna gradually vanishes upward and in the uppermost beds there are almost no fossils.

The lower portion is all shale and is rich in fossils, especially toward the base. It has been described by Hall (Pal. N. Y., II, 1852) and is in the main derived from about Lockport. Much of this fauna appears in the Clinton below (Irondequoit). The more characteristic common fossils are *Caryocrinus ornatus*, *Stephanocrinus angulatus*, *Eucalyptocrinus cœlatus*, *Thysanocrinus liliiformis*, *Lyriocrinus dactylus*, *Ichthyocrinus lævis*, *Dictyonella corallifera*, *Anastrophia interplicata*, *Rhynchotreta americana*, *Spirifer niagarensis*, *Trematospira camura*,

Dalmanites umulurus, *Homalonotus delphinocephalus*, *Lichas boltoni*, etc.

Clinton formation. Thickness about 30 feet.

Irondequoit limestone member, 10 to 15 feet thick. Very heavy-bedded, crystalline, crinoidal, pinkish gray limestone, with occasional Bryozoa reefs within and at the top of the limestone. In the latter case the reefs project several feet into the Rochester. Also has zones of stylolites. Transition into Rochester quick, almost abrupt. Fauna essentially that of the Rochester shale.

Wolcott limestone member, 12 to 21 feet thick. Thin-bedded magnesian limestones with a sparse fauna. *Pentamerus oblongus*, *Ocelospira plicatula*, *Hyattidina congesta*.

Basal shale, 2.5 to 6 feet thick. Green to grayish shales, with *Ocelospira hemispherica* and *C. plicatula*. Rests abruptly on the Medina. This zone is often correlated with the Sodus member at Rochester, but there is nothing of value to support this reference.

Disconformity. Contacts sharp between adjacent formations. Sodus shale absent.

Medina formation. Thickness about 65 feet.

Thorold member. Massive, greenish white, cross-bedded sandstone, 8 feet thick. The "gray band" of Eaton.

Red and greenish gray, much cross-bedded and channeled sandstone, with very little shale, about 15 feet thick. *Arthropycus alleghaniense* and *Lingula cuneata* occur 2 feet beneath the top.

Thin-bedded red sandstones, with considerable red shales, and two or more zones of localized storm-rolled mud balls (concretions of authors), 35 to 40 feet thick.

Gray sandstone with green shale partings, 5 feet thick. Poor Medina fossils here, noted by Hall in 1838.

Cataract formation. Thickness about 54 feet. Seen best on each side of the small tunnel and in Evan's gully, on N. Y. C. R. R.

Upper dark green shales, 5 feet.

Thin-bedded green sandstone at top, followed by yellowish magnesian and argillaceous limestone, with small black shale pebbles, 5 feet, abounding in *Helopora fragilis*, fragments of *Lingula*, *Camarotoechia neglecta*, *Isochilina cylindrica*, and small gastropods.

Middle green shales, 10 feet.

Dark green shales, with very thin-bedded argillaceous magnesian limestones, 5 feet. *Helopora fragilis* common, *Lingula* in fragments, *Camarotoechia neglecta*, and *Whitfieldella*.

Lower dark green fissile shales, 7 feet.

Whirlpool sandstone member (Grabau, 1909), 22 feet thick. Heavy-bedded, clean, white, somewhat coarse, cross-bedded sandstone. Thin-bedded in upper 5 feet. No fossils seen in the gorge exposures. See plate 13, figure 1.

Disconformity. Base of Siluric. The slightly undulatory contact with the Queenston is well shown along the Grand Gorge trolley line.

Queenston (Grabau). Top of Ordovician (Richmondian). Exposed for 115 feet. Thickness in deep wells 1,085 feet. Brick-red sandy shales with oxidized green streaks. No fossils.

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Thorold, Ontario, section (10 miles west of Niagara Gorge).—Reconstructed from Logan, *Geology of Canada*, 1863, pages 313, 322-323.

Lockport dolomite. Present about 33 feet.

Eroded unconformity as at Niagara Gorge.

Rochester shale. Thickness about 71 feet.

Dark bluish bituminous limestone, often rich in Rochester fossils. Thickness 8 feet. Many corals, *Stephanocrinus angulatus*, *Eucalyptocrinus decorus*, *Caryocrinus ornatus*, etc.

Bluish gray cement rock. Thickness 8 feet.

Bluish black shales, with thin bands of impure limestone having *Dalmanites limulurus*. Thickness 55 feet.

Clinton formation. Thickness 26 feet.

Irondequoit limestone member. Gray, coarse-grained, subcrystalline limestone, with iron and copper pyrites. Thickness 10 feet. *Rhynchotretra cuneata*, *Whitfieldella cylindrica*.

Wolcott limestone member. Bluish gray magnesian limestones with shale partings. Thickness 10 feet. Common near base, *Pentamerus oblongus* and *Stricklandinia canadensis*. According to Logan these two members thicken to the west.

Bluish drab argillaceous limestone, a cement rock. Thickness 3 feet.

Bluish gray limestone with much iron pyrite. Thickness nearly 3 feet.

Disconformity.

Medina formation. Thickness exposed 14 feet.

Bluish green argillaceous shale, with *Arthropycus alleghaniense*. Thickness 4 feet.

Thorold member or "gray band." A white fine-grained sandstone. Thickness 10 feet.

Grimsby, Ontario, section (20 miles west of Thorold).—In cuesta along both sides of Forty Mile Creek, back of the "Village Inn" (see Parks, *Guide Book No. 4*, Twelfth International Geological Congress, 1913, pages 130-136).

Lockport dolomite. Present 12 to 25 feet.

Gasport limestone member. A thick-bedded crinoidal limestone with a fauna that is essentially Rochester in character (*Atrypa nodostrata*, *Rhynchotretra americana*, *Spirifer crispus*, *S. radiatus*, *Whitfieldella nitida*, many Bryozoa, etc.), but it also has *Spirifer eudora* and *Eucalyptocrinus tuberculatus*.

DeCew member. The basal thin-bedded, impure, undulatory limestone (cement rock) has a thickness of 8 feet. At the head of the falls and in the cliffs above, the contacts with the Rochester and the Lockport are well shown. The upper contact is seen to have decided undulations with the pyritiferous layer at the base of the Gasport limestone. The higher beds are harder than those of the DeCew, and therefore make projecting cliffs.

Disconformity. Contact between adjacent beds easily found, but the lithic difference not marked. Time break short, with about 20 feet of the Rochester lost through erosion.

Rochester shale. Thickness about 39 feet.

Dark blue shale beds that become more and more fossiliferous and softer downward. The greatest abundance of fossils is in the lower 15 feet, in which may be noted *Caryocrinus ornatus*, *Stephanocrinus angulatus*, *Ichthyocrinus lavis*, *Eucalyptocrinus celatus*, *Orthis flabel-lites*, *Spirifer niagarensis*, *Dalmanites limulurus*, *Lichas boltoni*, many Bryozoa, etc. (See Parks, pages 131-133, for more complete fauna.)

Clinton limestone. Thickness 14 feet.

Irondequoit limestone in one bed 4 feet thick. Hard, crystalline, pinkish, crinoidal limestone, with zones of stylolites. There is no break between this bed and the Rochester, as the fauna continues largely from one to the other.

Wolcott limestone member. Thin-bedded magnesian limestones, with green shale partings, 10 feet thick. At 18 inches above the base *Pentamerus oblongus* is common and more rarely *Stricklandinia canadensis* and *Dinobolus conradi*.

The base of the Clinton is somewhat irregular in form and pyritiferous. One inch of shale separates it from the Medina.

Disconformity. Contact sharp between adjacent beds.

Medina formation. Thickness about 25 feet.

Dædalus archimedes bed at the top 18 inches thick. Locally the entire bed is made up of these lamellar and spiral burrows. On the under side of this bed occurs *Arthropycus alleghaniense*. In other places are seen regularly bedded gray sandstones ("gray band") with thin green shale partings through a thickness of 6 feet. This is the chief horizon of *A. alleghaniense*. Then a red sandy shale zone, barren of fossils, for 3 to 4 feet, below which are about 15 feet of thick-bedded, somewhat cross-bedded, gray and red mottled sandstones.

Cataract formation. Thickness about 80 feet. Not well exposed. For fauna see Parks, pages 135-136.

The **Whirlpool** heavy-bedded basal sandstone is here 6 feet thick. The basal 4 inches has much pyrite and green shale pebbles derived from the Queenston. The sandstone also fills sun-cracks in the red shales below.

Disconformity. Base of Siluric.

Queenston brick-red shales, exposed for over 100 feet. Top of Ordovician (Richmondian).

Stony Creek, Ontario, section (10 miles west of Grimsby).—On cuesta in gulch directly back of village. The Canadian Pacific Railway crosses over the mouth of the gulch. This is the finest single exposure along the entire cuesta in Ontario, but above the Cataract is difficult of access.

Lockport dolomite. Present about 32 feet.

At the top are seen thin-bedded, chert-bearing, gray dolomites with a thickness of about 12 feet. Below this are about 20 feet more of gray dolomites with far fewer chert nodules. The base of the Lockport is decidedly sandy and pyritiferous and the weathering away of this zone easily distinguishes the contact with the Rochester.

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Disconformity. Contact sharp between adjacent beds. About 40 feet of Rochester is absent.

Rochester shale. Thickness about 25 feet.

Hard dark blue shales alternating with thin limestone bands, many of which are replete with bryozoans and some brachiopods. The contact with the Clinton is also sharp, but no break in sedimentation is recorded.

Clinton limestone. Thickness about 14 feet.

Irondequoit limestone member, in a single bed 4.5 feet thick.

Wolcott limestone member. The thin-bedded Clinton in sharp contact with the Medina below. Thickness about 9 feet. The basal 2 to 8 inches of the Clinton is a clean-washed sandstone with occasional small pebbles of a greenish sandstone, both derived from the Medina. As usual, 18 inches above the base *Pentamerus oblongus* (Clinton form) is common.

Disconformity. The evenly bedded Clinton limestone on the decidedly cross-bedded sandstones of the Medina makes a sharp and broken contact.

Medina sandstone. Thickness about 18 feet.

Light green, thin-bedded, decidedly cross-bedded, clean-washed sandstones, with a thickness of about 7 feet.

Variegated, green and red, thin-bedded sandstones, with a thickness of about 10 feet. Near the middle of this zone occur mud-ball formations (sea-churning) like those seen in the Medina of the Niagara Falls Gorge.

Light green sandstone and shale in thin alternating beds with a total thickness of about 1 foot (basal sandstone 1.5, shale 2, sandstone 2, and shale and thin sandstones 4 inches). Marked by an abundance of *Scolithus verticalis* burrows. On the under side of the lowest sandstone occur rarely *Helopora* and undescribed bivalves, forms that also occur below in the Cataract.

Cataract formation. Thickness about 90 feet. Exposure complete.

Cabots Head shale member. Upper red and green sandy shales with bands of impure magnesian limestones having a thickness of about 22 feet. Toward the top the formation becomes more and more sandy and in the uppermost 5 feet has intraformational conglomerates, the pebbles of which are small. At 3 to 5 feet below the Medina occur abundantly *Helopora fragilis*, *Lingula clintoni* and undescribed bivalves. These occurrences prove that there is no break here between the Cataract and the Medina.

Lower olive green shales (decidedly so in upper half) with many thin layers of magnesian limestone that become more abundant downward and are replete with fossils. Total thickness 48 feet. *Rhinopora verrucosa* and *Celospira planoconvexa* appear 10 feet above the Whirlpool sandstone. Twenty-five feet higher occurs an abundance of large *Whitfieldella* near *oblata*.

Manitoulin limestone member. Basal magnesian limestones, 8 feet thick.

Whirlpool sandstone member, 12 feet thick. The upper 3 feet or more are thin-bedded, greenish, shaly sandstones, more or less cross-bedded. Below, the sandstone is regularly and heavy bedded, greenish white in color, and may or may not be blotched with red. The basal 1 or 2

inches has green weathered shale pebbles of the lower red Queenston, and there is here also much iron pyrite. The under side of the Whirlpool fills into the sun-cracked (the cracks are sometimes 2.5 inches deep), but otherwise almost even surface of the Queenston.

Disconformity. Base of Siluric. See contact in plate 13, figure 2.

Queenston brick-red shales barren of organisms. Top of Ordovician (Richmondian).

Hamilton, Ontario, section (6 miles west of Stony Creek).—On cuesta back of the city between the two inclined planes. See Logan, *Geology of Canada*, 1863, pages 310-334; Spencer, *Canadian Naturalist*, vol. 10, 1883, page 8; and Parks, *Guide Book No. 4*, Twelfth International Geological Congress, 1913, pages 136-139.

Lockport dolomite. Present about 37 feet. The base of the formation is best studied at the head of John street beside the road up the "mountain." At the very base here occurs an iron-pyrite fine-grained sandstone up to 3 inches thick. This is followed by a dolomite 2 to 4 inches thick, slightly sandy, pyritiferous, and with shale pebbles up to 1 inch in diameter, derived from the Rochester below. Higher there usually occurs a thin irregular shale (in layers or pockets up to 4 inches thick) of reworked Rochester, indicating that this formation had not yet been covered everywhere. Over these overlapping basal deposits follows the regular thin-bedded, cavernous, dark Lockport dolomite, but here devoid of chert nodules through a thickness of 5 feet. In the next higher 18 inches there are some of these diagenetic nodules, followed by light gray, thin-bedded, fine-grained dolomite that becomes more and more replete with nodules (many containing *Astyplospongia præmorsa* and *Aulocopina granti*) and chert stringers. (For a more complete faunal list see Parks, 1913: 137.) The great majority of the graptolites (Dictyonemoid) described by Bassler are from these chert beds.

Disconformity. Contact sharp between adjacent beds. The break in sedimentation is here clearly made out, as the greater part of the Rochester is absent.

Rochester formation. Thickness about 15 feet.

The greater part of the upper Rochester is absent.

A series of dark green, somewhat calcareous, limy shales, interbedded with thin bands of fine-grained magnesian limestones (the "blue building stone"). Fossils are practically absent in the upper 6 feet, followed by a zone a few inches thick replete with Trepostomata Bryozoa, more rarely *Fenestella*, *Dictyonema*, *Meristina*, and *Rhynchotrete americana*. The most abundant fossils throughout this zone are crinoidal ossicles, and none of the Rochester guide fossils are present.

The contact with the Clinton is sharp, but the fauna indicates no time break. At the very base of the Rochester there is a shale zone 1 inch thick, followed by a Clinton-like limestone 2 inches thick, with *Atrypa reticularis*. Another shale zone, several inches thick, follows, and is succeeded by a thin bed of magnesian limestone more like

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those higher in the formation. Both of these limestones have small shale pebbles, and as these latter do not come from the Clinton, they are regarded as of intraformational origin.

Clinton limestone. Contact sharp with Rochester. Thickness about 15 feet. Seen best at head of Wentworth Street incline.

Irondequoit limestone member. One bed of hard, cavernous, crystalline, slightly pinkish, crinoidal limestone. Thickness 4 feet 5 inches.

Wolcott limestone member. Seven beds of gray magnesian limestones with shale partings. Thickness (16, 18, 16, 18, 18, 10, 8 inches) 8 feet 8 inches.

Basal thin-bedded, gray, magnesian limestone, 18 inches thick. At the base it is sandy, glauconitic, and pyritiferous for about 2 inches, then the sand is less abundant, but the glauconite and pyrite continue into the limestone; near the top is an abundance of *Pentamerus oblongus* (Clinton form).

The sharp contact with the Medina, the very different sediments, and the marked faunal difference indicate that the Clinton-Medina contact is here broken.

Disconformity. Contact sharp between adjacent beds.

Medina sandstone. Thickness about 12 feet. Seen to best advantage at the head of John street beneath the large road-metal quarry between two stone crushers and back of the covered reservoir building.

At the top about 4 feet of thin-bedded light green sandstones, interbedded with sandy shale. Below, a horizon 4 to 6 feet thick of heavy-bedded sandstones, with localized zones of large (2 feet deep) mud-ball (sea-churning) formation. Next lower occur 4 to 6 feet of thin-bedded sandstones, alternating with shales, the basal bed of 1 foot thickness having in abundance *Lingula clintoni*, a form also found in the Cataract below. The contact between the Cataract and the Medina is, however, a sharp one, as may be seen in plate 14, figure 1.

Cataract formation. Thickness about 90 feet. Seen to best advantage beneath and to the south of the Wentworth Street incline and along the Jolly Cut road. Contact with Medina above is sharp, Cataract green shale below and gray sandstones above. There appears, however, to be no break in sedimentation here.

Cabots Head shale member. Green shales at the top variable in thickness from 6 to 18 inches. These then change below into red shales, and at about 5 feet beneath the top abound in *Phænopora* and other Bryozoa.

Red argillaceous and sandy beds, 6 feet thick, abounding in *Helopora*.

Red shales with an occasional sandy magnesian limestone, 10 feet seen.

All of the above beds especially rich in bryozoans.

Covered area. Thickness about 30 feet.

The rest of the Cataract occurs in the Mills and Webb quarry.

Manitoulin member. Thin-bedded, green and reddish, magnesian limestone, with much interbedded shale, 20 feet thick. Abounds in *Helopora* and other fossils.

Sandstone layer, 4 inches thick.

Thin-bedded magnesian limestones, without shale partings, 8 feet thick. Fossils are common, among them *Helopora*, *Favosites*, and *Plectambonites transversalis*.

A dolomite bed 12 to 16 inches thick.

Sandy shale zone 2 to 10 inches thick.

Whirlpool sandstone member. Basal greenish gray sandstone in one bed 10 feet thick.

Disconformity. Base of Siluric.

Queenston. Brick-red sandy shales. Exposed for about 250 feet. No fossils.

Top of Ordovician (Richmondian).

Dundas, Ontario, section (5 miles northwest of Hamilton).—On cuesta and gulch back of the town about one mile in and around the large quarries. See Logan, *Geology of Canada*, 1863, pages 313-314 and 325-326; and Spencer, *Canadian Naturalist*, vol. 10, 1883, pages 6-7.

Lockport dolomite. Present 37 to 169 feet. The contact with the Rochester is not easy to make out here. The basal few inches of the Lockport, however, have a conglomerate of shale pebbles, but there is far less of sand and pyrite than at Hamilton. The Lockport at this place begins with the Gasport crinoidal magnesian limestone.

Disconformity. Nearly all of the Rochester is absent.

Rochester formation. Thickness about 6 to 7 feet. Seen to best advantage at the waterfall in the steep gulch. Here these dark calcareo-arenaceous shales are hard to distinguish from the overlying Lockport, but elsewhere under the influence of weathering they break up into shaly material, as the Lockport never does. Fossils scarce. Billings reports *Rhynchonella* (?) *robusta*, *Spirifer radiatus*, *Meristina naviformis*, *Atrypa reticularis*, etc.

Clinton limestone. Contact sharp with Rochester. Thickness about 14 feet. This formation has here about the same characters as at Hamilton. The Irondequoit member has a thickness of 5.5 feet and the Wolcott member of about 8.5 feet. The basal layer of the Clinton is replete with glauconite and there is also much sand in the dolomite. Eighteen inches above the base occurs an abundance of *Pentamerus oblongus* (Clinton form), and 6 inches higher occur *Favosites niagarensis* and *F. favosus*.

Disconformity. Contact sharp between adjacent beds. Section broken here.

Medina sandstone. Thickness apparently not over 8 feet. At the top are evenly bedded thin sandstones for about 5 feet, then green shales with some sandstones, and at the base 2 feet of sandstones. No mud-ball formation seen here. Contact with the Cataract below also sharp.

Cataract formation. Thickness about 94 feet (Logan).

Cabots Head shale member. Green shales with interbedded thin magnesian limestones, 6 feet.

[The rest of the section is taken from Logan.]

Red ferruginous shale and shaly limestones, 7 feet.

Red, ferruginous, impure, thin-bedded limestones, abounding in fossils, 7 feet thick. *Helopora fragilis*, *Rhinopora verrucosa*, *Phænopora explanata*, *Leptæna rhomboidalis*, *Camarotoechia neglecta*, *Pterinea* (?) *primigenia*.

Red marly shale (4 feet), green shale (2), and red, calcareous, thin-bedded sandstones (1). Thickness 7 feet.

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Green and gray, impure, calcareous shale, with the same fossils as above. Thickness about 11 feet.

Bluish gray calcareo-arenaceous shale, 11 feet.

Concealed area, 7 feet.

Buff shales, with thin beds of fossiliferous magnesian limestone, 12 feet. *Helopora fragilis*, *Rhinopora verrucosa*, *Platystrophia biforata*, *Leptæna rhomboidalis*, *Cælospira planoconvexa*.

Bluish gray and green shales, with thin bed of magnesian fossiliferous limestone, 8 feet. Fossils same as those below.

Manitoulin member. Dark bluish gray magnesian limestones and shale weathering a pale red, 7 feet. The most fossiliferous horizon and the type locality for *Cælospira planoconvexa*. Also here *Helopora fragilis*, *Pachydictya crassa*, *Phænopora ensiformis*, *Rhinopora verrucosa*, *Rhipidomella circulus*, *Orthis flabellites*, *Hebertella fausta*, *Leptæna rhomboidalis*, *Platystrophia biforata*, *Atrypa rugosa*, *Whitfieldella naviformis* (this identification very doubtful), *Cornulites distans*, *Modiolopsis* (?) *orthonota*, *Encrinurus* cf. *punctatus*, etc.

Gray, compact, calcareous sandstone in two beds, 21 inches thick. *Zaphrentis*, *Helopora fragilis*, *Pachydictya crassa*, *Phænopora ensiformis*, *Leptæna rhomboidalis*, *Dalmanella elegantula*, *Camarotoechia neglecta*, *Cælospira planoconvexa*, and *Cornulites distans*.

Gray, thin-bedded, shaly sandstones with greenish shale partings, *Cælospira planoconvexa*, *Modiolopsis* (?) *orthonota*.

Whirlpool sandstone member. Basal gray, heavy-bedded sandstones, 8.5 feet thick.

Disconformity. Base of Siluric.

Queenston. Top of Ordovician (Richmondian). According to the Dundas artesian well the thickness is estimated at 535 feet.

Limehouse, Ontario, section (25 miles north of Dundas).—On cuesta cut by Grand Trunk Railway, 3 miles west of Georgetown, Ontario.

Lockport bluish gray, heavy-bedded, cavernous dolomite, with much fragmental organic material. Quarried for lime burning. Thickness present 20 feet. The lowest 2 to 4 inches consists of a basal conglomerate made up of small and weathered (yellow) Clinton limestone pebbles in a muddy dolomite. The regular Lockport dolomite appears at about 6 inches above the Clinton. In the basal beds occur many heads and tails of a large *Ilænus* (near *I. ioxus*) piled upon one another like saucers. Also *Halysites* with large corallites in loose chains.

Disconformity. No Rochester here. Contact sharp between adjacent beds. [Grabau as censor holds that all of the Rochester here and elsewhere is changed in character to that of the Lockport, and therefore that there is no break. Likewise for the next disconformity, where all of the Medina is said to be changed into the Cataract facies. The writer does not subscribe to these conclusions.]

Clinton thin-bedded, gray to greenish (weathering yellowish to white), and more or less impure limestone (sometimes called a water-lime, but not used for lime). Thickness 6.5 feet.

Disconformity. No Medina sandstone here. Contact sharp between adjacent beds.

Cataract formation. Thickness exposed 18 feet.

Cabots Head shale member. Upper green shales with very thin bands of magnesian limestone abounding in *Helopora* to within 18 inches of top; 7 feet thick.

Red shales dominated by ferruginous (almost an iron-ore), more or less magnesian limestones, 6 feet thick. Replete with many species of bifoliate and Trepostomata Bryozoa typical of upper Cataract. Also here *Leptæna rhomboidalis*, *Camarotoechia neglecta*, and small hemispheric masses of *Favosites*.

Red shales, with some thin bands of green shales down to railway; 5 feet seen. *Helopora* are also common, but the bryozoans of the higher beds are practically absent.

The remainder of the Cataract is not exposed here. At Kelso, 13 miles southwest, the formation has a thickness, according to Williams, of 92 feet.

Glenwilliam, Ontario, section (5 miles north of Limehouse).—On the lower part of cuesta.

Cataract formation. Lowest part only exposed.

Manitoulin member. Magnesian thin-bedded limestones, more sandy and shaly than usual. Fossils are also less abundant. *Clathrodictyon vesiculosum*, *Favosites venustus*, *Heliolites interstinctus*, *Halysites microporus*, *Zaphrentis bilateralis*, *Rhinopora verrucosa*, *Rhipidomella circulus*, *Leptæna rhomboidalis*, *Atrypa rugosa*, *Calymene*, *Encrinurus*.

Whirlpool member. Basal gray sandstone, 12 feet thick. The lowest 2 to 4 inches abound in pyrite, and the sands fit into the sun-crackings of the Queenston below. The lower 9 feet regularly bedded and making a good building stone much used in Toronto. In color it is usually gray, but in places is blotched with red or passes entirely into a light red color. The upper 3 feet are much cross-bedded and contain many *Modiolopsis* (?) *orthonota* and an abundance of "fucoid" markings and vertical "worm burrows" (the shape of cup corals).

Disconformity. Base of Siluric.

Queenston brick-red shales, much used here for pottery, drain pipes, and brick. Top of Ordovician (Richmondian).

Cataract, Ontario, section (13 miles north of Limehouse and 48 miles northwest of Toronto).—Cuesta along Forks of Credit. Type section of Cataract formation along the valley of the Credit and about the cataract. See Parks, Guide Book No. 5, Twelfth International Geological Congress, 1913, pages 8-13.

Lockport dolomite. Heavy-bedded, cavernous, light gray dolomite seen on the railway to Elora at the spring near Cataract Junction. Thickness present 30 feet.

Disconformity. No Rochester or Clinton here.

Cataract formation. About 106 feet thick.

Cabots Head member. Upper green shales with very thin magnesian limestones, about 20 feet thick. *Helopora fragilis* is common in the limestones. At Limehouse this zone is only 6 feet thick.

Red, decidedly ferruginous, shaly limestone, with thin shale zones, 5 feet. *Helopora fragilis* very common here. Other Bryozoa also occur, but not so abundantly as at Limehouse or Dundas.

Middle green shales, with occasional thin magnesian limestones, that become more abundant downward; about 40 feet thick. In the shales fossils are scarce, but in the limestones *Helopora* (two or more species) are exceedingly common. Also here *Orthis flabellites* and other forms of the Manitoulin member.

Manitoulin member. Greenish magnesian limestones in beds up to 12 inches thick, with irregular zones of chert, separated by thin bands of green shale, about 25 feet. The transition zone to the Whirlpool consists of not over 3 inches of shale. The main horizon for Cataract fossils. At 8 feet above the base, a thin shale abounds in many small fossils, *Whitfieldella* n. sp., *W. cf. oblata*, *Atrypa rugosa*, *A. n. sp.* *Calospira planoconvexa* is common between 8 and 15 feet above the base.

Whirlpool member. Basal heavy-bedded, rippled and decidedly cross-bedded, white, or mottled with red spots, or pinkish, fine-grained sandstones, 16.5 feet thick. Much quarried for building stone all along the Credit. At the top occurs *Modiolopsis (?) orthonota*.

Disconformity. Base of Siluric.

Queenston. Top of Ordovician (Richmondian). Brick-red sandy shales. Exposed about 250 feet.

Collingwood, Ontario, section (48 miles northwest of Cataract).—Five miles to the south of Collingwood rises the high cuesta, "Blue Mountain," the top of which is fully 800 feet above Georgian Bay. The section is toward the top of the mountain.

Lockport dolomite making vertical cliffs at the top of the mountain. Thickness present 160 feet (Logan).

Disconformity. All Rochester and Clinton absent.

Cataract formation. Thickness about 32 feet.

Cabots Head shale member covered and replete with springs. Thickness estimated at 20 feet. Loose magnesian limestones along the roadside abound in bryozoans. The top is in all probability eroded away.

Manitoulin member. Thin-bedded, light blue, finely granular, magnesian limestones, without shale partings. At crest of mountain road. Thickness 12 feet, but near Meaford (20 miles to the northwest) attains 29 feet (S. E. Whittaker). Fossils scarce except *Leptæna rhomboidalis*.

Whirlpool member not present here. Last seen at Glen Huron, 12 miles south of Collingwood (Williams).

Disconformity. Base of Siluric.

Queenston. Top of Ordovician. Brick-red sandy shales devoid of fossils, about 45 feet thick.

Richmondian. Green sandy shales with thin zones of magnesian limestones having minute Bryozoa, Ostracoda, *Zygospira recurvirostris* and *Leperditia* cf. *cacigena*. Thickness about 90 feet.

A thick series of light blue, somewhat calcareous shales. At the top thin zones of limestone occur rarely, but increase in quantity more and more downward, and in the same way occurs a greater abundance of characteristic Richmondian fossils. From the dominantly calcareous strata in the lower part of the section, with many fossils, one rises higher into more and more shaly and then sandy strata, the corals and brachiopods drop out, the bryozoans continue, but the Trepostomata finally also drop out, leaving only the minute forms to attain the top of the green shales. Thickness up to Queenston not clearly made out, but apparently not less than 340 feet. Some of the Richmondian fossils are *Tetradium fibratum* (rare), *Streptelasma rusticum* (rare), *Hebertella insculpta* (common), *Ambonychia radiata*, *Modiolopsis concentrica*, and *Whiteavesia pholadiformis*.

Owen Sound, Ontario, section (38 miles west of Collingwood).

Lockport limestone well exposed in West Owen Sound. Heavy-bedded, fine-grained, light gray, fossiliferous dolomite, at least 70 feet thick. "White rock" of quarrymen.

Disconformity. Actual contact not seen.

Cataract formation. About 130 feet (thickness determined by Williams).

Cabots Head member. Covered zone of shale, with red zones and ferruginous bands. Thickness estimated at 50 feet.

Blue-green shales with thin-bedded, nodular, and even-bedded limestones replete with Cataract fossils. Thickness 25 feet. Seen at Wright's flour mill in West Owen Sound.

Manitoulin limestone member, 30 feet thick. Thin-bedded, light blue ("blue rock" of quarrymen) to gray, finely granular, magnesian limestones, with thin zones of chert. Quarried for lime to the east of Owen Sound. In the upper 10 feet the chert zones abound in fine fossils, among them *Rhinopora verrucosa*, *Platystrophia biforata*, *Orthis flabellites*, *Dalmanella elegantula*, *Schuchertella subplana*, *Leptæna rhomboidalis*, and *Cælospira planoconvexa* (exceedingly common here).

Disconformity. Base of Siluric.

Queenston formation. Top of Ordovician (Richmondian). Brick-red, soft, sandy shales, with very thin sandstones in the upper 8 feet; about 50 feet. No fossils. In places near the top occur zones of sun-cracking with the prisms small. Thirty feet beneath the top occur lumps of secondary impure gypsum. Forty feet from the Cataract in a thin green shale occur *Hebertella sinuata*, Richmondian Bryozoa, *Leperditia* cf. *cacigena*, and other Ostracoda.

Cabots Head, Bruce Peninsula, Ontario, section (53 miles northwest of Owen Sound).—Information from Dr. M. Y. Williams. Also see Logan, *Geology of Canada*, 1863, pages 319-320.

Lockport dolomite. Massive cliff-making. Present 165 feet (Logan).

Disconformity.

Cataract formation. Thickness 60 feet.

Cabots Head member. Top probably eroded away. Soft gray shale locally tinged with red, 4 feet.

Thin-bedded limestones with branching *Favosites* and *Helopora fragilis*, 5 feet.

Hard green argillaceous shale, 36 feet.

Manitoulin member. Massive dolomite, 15 feet.

Disconformity. Base of Siluric. This contact is illustrated in plate 14, figure 2.

Queenston. Top of Ordovician (Richmondian). Hard and soft red shales, about 45 feet, down to level of Lake Huron. The last place to the north that these red shales are seen, for on the Manitoulin all of the strata beneath the Cataract are calcareous normal marine deposits and have an abundance of Richmondian fossils.

Manitowaning, Manitoulin Island, Ontario, section (45 miles north-west of Cabots Head).—Seen by the writer in 1912 under the guidance of M. Y. Williams. See Williams, Guide Book No. 5, Twelfth International Geological Congress, 1913, pages 89-97.

Lockport dolomite. Actual thickness as measured by Williams 240 feet (Bell's 450 feet was calculated from the dip).

Disconformity.

Cataract formation. (Clinton of Bell.) Thickness averaging 100 feet.

Cabots Head member. Usually a covered zone of friable red clay (red marl of Bell), almost barren of fossils, from 27 to 66 feet thick. At the top the shales are nearly always oxidized into green shale by percolating waters.

Manitoulin member, 50 to 60 feet thick. Thin-bedded, gray to yellowish, fine-grained, magnesian limestones to massive dolomites, without shale partings. In the upper 20 feet there are many small reefs of Bryozoa, Stromatopora, and corals. Fossils as pseudomorphs. *Clathrodictyon vesiculosum*, *Halysites microporus*, *Heliolites*, *Favosites venustus*, *Diphyphyllum vennori*, *Acervularia* (?) *gracilis*, *Pachydictya crassa*, *Platystrophia biforata*, *Orthis flabellites*, *Hebertella* cf. *daytonensis*, *Dalmanella elegantula*, *Rhipidomella hybrida*, *Schuchertella subplana*, *Camarotoechia neglecta*, *Atrypa* n. sp., *Cælospira planoconvexa*, *Whitfieldella*, *Cyclonema cancellatum*, etc.

Disconformity. Queenston red shales absent and transformed into the

Richmondian formation. The best exposures are at Clay cliff on the eastern end of the island, where good fossils are plentiful in a Richmondian section at least 160 feet thick. Beneath are about 100 feet of Lorraine, and 130 feet of Eden. Deep wells give the thickness of the entire Cincinnati deposits as not less than 435 feet.

East of Manitowaning 1.5 miles may be seen along the roadside a good exposure of the uppermost Richmondian in contact with the Cataract sandy limestone. Below these Siluric beds are 12 feet of greenish clays without fossils, followed by a series of thin-bedded, sandy and shaly, magnesian limestones, 15 feet thick, with many Bryozoa throughout, other fossils being almost absent.

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Medina and cataract formations of the Siluric of New York and Ontario

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