

American Journal of Science

MARCH 1943

BLACK RIVER STRATIGRAPHY AND FAUNAS.

PART I

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ABSTRACT. The formations of the Black River group have their type localities in northwestern New York. They are, from base to top, the Pamela, Lowville, and Chaumont limestones.

Sections have been studied and faunal collections made from Newport, New York, northwestward along the Black River Valley to the Watertown area, then westward as far as Hastings County, Ontario.

The Pamela, consisting essentially of dolomitic and shaly limestones, shows a maximum thickness of 150 feet in the Watertown region. Southeastward along the Black River Valley it thins and disappears; westward in Ontario, it retains the characteristic lithology, but thins to 30 feet at Marmora, Hastings County.

The Lowville, a sublithographic argillaceous, and oolitic limestone, has a thickness of 54 feet near the type locality, and thins southeastward along Black River. In Ontario it thins westward to 47 feet at Marmora, and has beds more shaly and fossiliferous than any in New York. Characteristic Lowville fossils are found in all Ontario sections.

The massive cherty limestones of the Leray and Watertown, measuring 26 feet at Watertown, are distinguishable only near that city. The term Chaumont must be used for undifferentiated equivalent beds, which, in Ontario, are of similar thickness and locally as massive and cherty as those in New York. In the western sections, light-colored sublithographic limestones become interbedded with typical dark Chaumont limestones. The Glenburnie member is a shaly facies lying near the base of the Chaumont near Kingston, Ontario. Similar shales are found at other horizons in the formation farther west.

The faunas are listed in the form of a table, which shows their relative abundance and the important collecting localities.

INTRODUCTION.

THE Black River group, with the overlying Trenton group, constitutes the Mohawkian series of the middle Ordovician. The formations of the Black River group have their type localities in northwestern New York. They are, from base to top, the Pamela, Lowville, and Chaumont limestones.

The purpose of this study has been threefold: (1) to make collections of the faunas at the type localities and in their vicinity, in order to provide a basis for future detailed correlations; (2) to trace the formations laterally in order to establish the continuity, thickness, and nature of overlap; (3) to study the lithologies of the formations with special attention to features which have a bearing on conditions of sedimentation.

Sections have been studied and faunal collections made from Ingham Mills, Herkimer County, New York, northwestward along the Black River Valley to the Watertown area, then westward into Hastings County, Ontario.

The Pamela, consisting essentially of dolomitic and shaly limestones, shows a maximum thickness of 150 feet in the Watertown region. Southeastward along the Black River Val-

ley it thins and disappears; westward in Ontario, it retains the characteristic lithology, but thins to 50 feet at Marmora, Hastings County.

The Lowville, a sublithographic, argillaceous, and oolitic limestone, has a thickness of 55 feet near the type locality, and thins southeastward along Black River. In Ontario it thins westward to 30 feet at Marmora, and has beds more shaly and fossiliferous than any in New York. Characteristic Lowville fossils are found in all Ontario sections.

The massive cherty limestones of the Leray and Watertown, measuring 26 feet at Watertown, are distinguishable only near that city. The term Chaumont must be used for undifferentiated equivalent beds, which, in Ontario, are of similar thickness and locally as massive and cherty as those in New York. In the western sections, light-colored sublithographic limestones become interbedded with typical dark Chaumont limestones. The Glenburnie member is a shaly facies lying near the base of the Chaumont near Kingston. Similar shales are found at other horizons in the formation farther west.

Acknowledgments. The writer acknowledges his indebtedness to Prof. G. M. Kay for his guidance in the field and laboratory. Dr. T. H. Clark has aided by permitting the examination of type material, especially that of Dr. V. J. Okulitch, in the collection of McGill University. Thanks are due Dr. Barnum Brown for the opportunity of seeing type material in the American Museum of Natural History. Mr. Oliver D. Blake of Columbia University has given valuable suggestions as to the sectioning of bryozoa.

GENERAL DISTRIBUTION AND STRUCTURE OF BLACK RIVER GROUP.

In northwestern New York the Black River group, or some part of it, is present as a belt extending from north of Ingham Mills, Herkimer County, northwestward along the Black River Valley to Watertown, New York, and the Thousand Islands region. Interrupted by the St. Lawrence River, it continues westward across southern Ontario to the Lake Simcoe area. It is probable that the group is also represented on Manitoulin and St. Joseph Islands, Lake Huron. The beds are thus present nearly continuously for a distance of about 120 miles in New York, and of 150 miles in southeastern Ontario.

Along the western side of Black River in Oneida and Lewis Counties, New York, the Black River group forms one or more

conspicuous escarpments with a total elevation above Black River Valley of 100 to 150 feet. Here the belt of outcrop is narrow, usually from one-fourth to one-half mile in width. In the Watertown district, Jefferson County, the formations are much more extensive areally, forming an irregular belt about 14 miles wide. The continuation in Ontario is also a zone of considerable width (see Text Fig. 3).

In general, the structure is simple. There is a regional dip of one or two degrees towards Lake Ontario. In the Black River Valley, the formations dip gently westward and south-westward away from the Adirondack Mountains and Frontenac arch. In southern Ontario, the dip is southward. Locally the beds are horizontal or have folds producing dips as high as fifteen or twenty degrees. Jointing is ubiquitous, and there are faults of local importance. These structures have been discussed by Cushing¹ and Ruedemann² in their works on the Thousand Islands region.

Because of faulting, geologic structures are more complicated in the Mohawk Valley, and the Black River group is present discontinuously. Beds of Black River age are present, also locally, east of the Adirondacks, in the upper Hudson and Lake Champlain valleys, from Glens Falls, Saratoga County, to Isle La Motte, near the northern end of Lake Champlain. The group is extensively developed farther north. One or more of the formations have been found from Pembroke, Ontario, along the Ottawa River Valley to Montreal, and down the St. Lawrence River Valley to a point about 35 miles southwest of Quebec City. In these belts, Black River beds, with underlying lower Ordovician and overlying Trenton formations, often form outliers downfaulted into the Pre-Cambrian basement.

THE PAMELIA FORMATION.

Stratigraphy of the Pamela Formation.

The Pamela limestone has been defined by Cushing,³ from Pamela Tp., Jefferson County, New York, as that part of the

¹ Cushing, H. P., Ruedemann, R., Fairchild, H. L., and Smyth, C. H., Jr.: 1910, *Geology of the Thousand Islands region*. N. Y. State Mus., Bull. 145, pp. 103-121.

² Ruedemann, R.: 1934, Chapter on Paleozoic rocks of the Lowville quadrangle. In Buddington, A. F.: *Geology and mineral resources of the Hammond, Antwerp, and Lowville quadrangles*. N. Y. State Mus., Bull. 296, pp. 183-194.

³ Cushing, H. P.: 1908, Lower portion of the Paleozoic section in north-western New York. *Geol. Soc. Amer., Bull.*, Vol. 19, p. 158.

original Black River limestone lying below the Lowville limestone. Ebenezer Emmons⁴ had earlier applied the term "Depeauville" (now Depauville) to beds at Lafargeville, Jefferson County, now known to be part of the lower Pamela. At that time he believed that these beds overlay the Birdseye, but in his final report on the second geological district he referred them to the Calciferous,⁵ apparently realizing his error.

The Pamela formation has greatest thickness and is best exposed in northern Jefferson County, where it is divided into two parts.⁶ The lower division, with a thickness of 70 feet, always has conglomeratic and sandy basal beds, above which occurs a certain amount of sandy or calcareous shale, and dark gray to black, fossiliferous, sublithographic limestone interbedded with gray, dolomitic limestones. The upper division is 80 feet thick, and consists of light gray or whitish, earthy limestones interbedded with gray magnesian and sublithographic limestones. In both divisions, the dolomitic and earthy limestones weather to a buff or yellow-brown hue, which often makes it possible to distinguish the Pamela from the overlying Lowville. Most characteristic of the lower division are the black, fossiliferous limestones, and of the upper division, the earthy and the gray sublithographic limestones.

There are interesting sedimentary features present in the Pamela, some of which will be taken up in greater detail later. Kindle⁷ has proposed the name "Vaughanite" for fine-textured limestone with few fossils, and breaking with more or less pronounced conchoidal fracture. This is characteristic of the upper portion of the Pamela especially, but could be applied to many beds of the Lowville as well. In this paper, such limestones are referred to as sublithographic. Stylolites are common in this type of lithology. In the earthy limestones of the upper division, nodules of crystalline calcite up to eight inches in diameter are common. Well-preserved ripple marks and mud-cracks are found at several horizons throughout the formation. The ripple marks are small, usually having an amplitude of half an inch and a crest-to-crest dimension of one to two

⁴ Emmons, E.: 1840, Fourth annual report of the survey of the second geological district. N. Y. Geol. Survey, Annual report for 1839, p. 324.

⁵ Emmons, E.: 1842, Geology of New York. Part II, comprising the survey of the second geological district, p. 381.

⁶ Cushing, H. P., Ruedemann, R., and others: *op. cit.*, pp. 68-79.

⁷ Kindle, E. M.: 1923, Nomenclature and genetic relations of certain calcareous rocks. *Pan-American Geologist*, Vol. 39, pp. 365-372.

inches. Of interest is the presence in some light gray, sublithographic beds of crystal molds of an undetermined mineral. (Pl. 1, Fig. 2). These may be analogous to those in the Silurian of Michigan.

In the type region, the Pamela forms an irregular belt with a maximum width of about five miles, and terminates northward in a bluff which rises some 60 feet above the country immediately to the north. This belt forms a fairly flat-topped terrace in some areas where it is capped by the resistant, black, sublithographic limestones of the lower division. The upper division is rather weak, since it has such a large proportion of earthy limestones, and good sections of it are usually found only where it is protected by masses of the Lowville. Southeastward through the Black River Valley, the formation expresses itself only as a narrow bench in some localities. Across southern Ontario, the Pamela forms an irregular, terrace-like belt much as it does north of Watertown, but surface exposures are rarer.

The Pamela varies much and rapidly in thickness from place to place and is far from uniform in its stratigraphic relations, lying upon various Pre-Cambrian crystallines and Cambrian sediments. These conditions are a reflection of the fact that the Pamela sea encroached upon an area of moderate relief, consisting of a hilly Pre-Cambrian surface, the depressions in which had been partially filled with lower Paleozoic sediments. The lithology of the basal Pamela is controlled by the nature of the underlying rock. Wherever the Pamela is overlain now by rocks of another formation, they are those of the Lowville.

The Pamela has its maximum thickness of 150 feet near Stone Mills, Orleans Tp., Jefferson County, and thins eastward and westward from this point. In general the upper division is more persistent than the lower, and apparently overlaps it. In going eastward the short distance of twelve miles from Stone Mills to the vicinity of Leraysville, Leray Tp., the formation has thinned to about 60 feet, and it is the lower gray magnesian limestone beds of the lower division which have disappeared, allowing the black, sublithographic, fossiliferous beds to rest on the basal sandy layers. Throughout Jefferson County, the Pamela lies disconformably upon the upper Cambrian Theresa dolomite.

Southeastward along the Black River Valley, the Pamela lies upon the Pre-Cambrian. At Lowville, Lewis County, about 32

feet are exposed, of which the lower portion is partially concealed. Neither the fossiliferous black beds nor the basal sandy layers are in evidence.

About four miles southeast of Lowville, near East Martinsburg, there is an excellent section along Roaring Brook, where it is possible to study, without any gaps in the sequence, all formations from Pre-Cambrian up into the Trenton. A description of this section appears below. This section was studied in detail by Cushing and described by Miller.⁸ Miller reports a thickness of 71 feet eight inches, but the writer would increase this to 76 feet, of which the lower 26 feet belongs to the lower division, and the remaining 50 feet to the upper. Starting at the base with nine feet of conglomerate containing syenite pebbles, sandstone, and sandy shale, the lower Pamela has, succeeding these, nine feet of sandy dolomite, and four feet three inches of black, sublithographic, fossiliferous limestone which apparently are comparable to the eight feet, four inches of similar beds so characteristic of the lower division in the area north of Watertown. A few feet of gray, dolomitic limestone complete the section of lower Pamela. The succeeding beds are alternations of the whitish earthy, gray dolomitic, and sublithographic limestones typical of the upper division. These have 62 per cent of the thickness in the type region, whereas the lower division has thinned to only 37 per cent. It is apparent that the lower division thins more rapidly than the upper away from the Watertown region, and it is significant that, in spite of this, the fossiliferous black beds of the lower division persist through the Black River Valley.

At a point about one mile north of Lyons Falls, Lewis County, and eight miles south of Roaring Brook, the Pamela has thinned to 56 feet.⁹ Above 10 feet of sandstones and sandy dolomite lying upon the Pre-Cambrian, it has four feet six inches of black limestones persisting and 41 feet like those at Roaring Brook representing the upper division.

The formation is 20 feet thick at Denley, Lewis County, thins to 10 or 12 feet¹⁰ at Mile Creek, about one and a quarter miles to the southeast, and disappears in northern Oneida County.

The Pamela is extensively exposed in the region about King-

⁸ Miller, W. J.: 1910, *Geology of the Port Leyden quadrangle*. N. Y. State Mus., Bull. 135, pp. 22-23.

⁹ *Ibid.*, p. 24.

¹⁰ *Ibid.*, p. 24.

ston, Ontario. Across Frontenac County, Ontario, it lies with apparent structural conformity on the Cambrian Potsdam sandstone. Westward it overlaps the Potsdam and lies with striking non-conformity on the Pre-Cambrian. Cushing¹¹ has expressed the belief that the formation maintains a thickness of about 80 feet as it passes across the St. Lawrence River westward. No continuous section with any such measurement has been found exposed in the Kingston area, but it seems likely that the total is close to that figure. Basal beds are at least 17 feet. Near Sunbury, and about nine miles north of Kingston, there are 36 feet of gray sublithographic and earthy limestones, all of which seem to be upper Pamela. Thus there is a total of 53 feet, and a considerable thickness of lower Pamela is not exposed.

One of the best places to see the Pamela-Pre-Cambrian contact is at Kingston Mills, where 17 feet of sandy and shaly limestone contains boulders up to three feet in diameter which have been derived from the red Algoman granite knob upon which the Pamela overlaps. This is the only exposure found in which the basal beds are highly fossiliferous. The cephalopod *Nanno kingstonensis* Whiteaves is abundant in the lower portion, practically always as fragments. This was selected by Kindle¹² as the type section for the beds which Ami¹³ had called the "Rideau sandstone" and defined as the "beds between the Black River and Pre-Cambrian west of the Frontenac axis."

Just as on the New York side, beds of upper Pamela lithology in Ontario seem to maintain their thickness better than those of the lower division. The upper gray, sublithographic beds of New York sections appear to be overlain in Ontario by platy beds of light gray, rather earthy, yellow-weathering limestone. These are well shown at the top of the section exposed in quarries at the top of the hill about one-quarter mile southwest of Rideau station.

A very interesting section may be seen at Jackson's Mill (Bur Creek) five miles northwest of Kingston, where the formation is about 47 feet thick. Equivalent to the basal Rideau beds of the Kingston Mills section are seven feet of calcareous sand-

¹¹ Cushing, H. P., Ruedemann, R., and others. op. cit., p. 69.

¹² Kindle, E. M.: 1916, The Ordovician limestones of the Kingston area. Appendix I in Ont. Bur. Mines, Ann. Rept. 25, Pt. 3, p. 40.

¹³ Ami, H. M.: 1902, Ordovician succession in eastern Ontario. Geol. Soc. Amer., Bull., Vol. 13, pp. 517-518.

stone and sandy limestone lying upon white Pre-Cambrian quartzite, and containing pebbles and boulders of that rock up to 12 inches in diameter (Pl. 1, Fig. 1). Above are interbedded gray sublithographic, gray dolomitic, and whitish earthy limestones, with occasional shaly beds. The black, fossiliferous limestones characteristic of the lower division in New York, seem to be missing, as they do at points west. Kindle states that *Nanno kingstonensis* Whiteaves has been found in the basal beds. Well preserved mud-cracks appear 15 feet up in the section, and somewhat farther up is a bed of light gray, sublithographic limestone full of crystal molds. Of paleontologic interest is the finding in a two foot bed of whitish, medium textured, semi-crystalline limestone, of two specimens of a *Goniceras* which has not been distinguished from *Goniceras anceps* of the Chaumont. This same horizon has a species of *Cyrtodonta*. The Pamela here is overlain by the Lowville, which has at its base a conglomeratic limestone with one-inch pebbles, presumably of reworked Pamela.

There are many small quarries in Kingston Township which reveal portions of the Pamela. Practically all of them expose the gray, sublithographic limestones of the upper division, since these are the beds which have been sought for commercial purposes. In the quarry one mile east of Elginburg, there is a splendid display of large calcite nodules up to eight inches in diameter. Well-developed stylolites are evident also in many of these quarries.

At Marmora, Hastings County, there are 31 feet of Pamela overlying Laurentian gneiss and overlain by Lowville. This section had been listed by Logan.¹⁴ Since then, excavation in the road cut west of the town has exposed a fair section of Lowville and Chaumont as well. The basal beds apparently lack such coarse conglomerate as is present at Kingston Mills and Jackson's Mill, but consist of about 13 feet of shaly limestone, calcareous sandstone, and calcareo-arenaceous shale. Because of the absence of the black, fossiliferous limestones, and the fact that the earthy limestones of the upper division are not so conspicuous as farther east, it is difficult to determine how much of the section belongs to each of the divisions of the Pamela. However, it seems reasonable on the basis of the lithology to allot the lower 14 feet six inches to lower Pamela, and the

¹⁴ Logan, W. E.: 1863, Geology of Canada, pp. 181, 182.

overlying 16 feet nine inches to the upper division. These upper beds consist of gray and brownish sublithographic and dolomitic limestones with occasional thin shaly layers. Many of the massive beds are stylolitic, and crystal molds appear in the brownish compact beds 20 and 27 feet above the base of the section.

Marmora is the westernmost point to which the writer has traced the Pamela, but the reports of Johnston¹⁵ on the Simcoe district, 70 miles farther west, make it appear that the formation continues without much change in thickness across most of southern Ontario. In the Simcoe district there are, lying upon the Pre-Cambrian, 20 feet of red and green shales, sandstones, interbedded thin limestones, and coarse basal arkose, and above these, 10 feet of brownish weathering, gray, magnesian limestones, making a total thickness of 30 feet. Okulitch¹⁶ has applied the term "Gull River" to beds, some of which may be of Pamela age.

The Ottawa and St. Lawrence Valleys are outside of the scope of this paper, but it is necessary to consider these areas when discussing the correlation of the Pamela. Raymond¹⁷ has shown that at Ottawa there is a formation between the Chazy and the Lowville which has two easily recognizable divisions similar lithologically to those of the New York Pamela. In spite of certain faunal differences between the dark limestones of the lower division in the two regions, Raymond concluded that "the name Pamela can be adopted for the formation in the Ottawa Valley." The formation has its maximum thickness of about 70 feet near Orleans, Carleton County, where Wilson¹⁸ has described in detail 42 feet of upper, and 16 feet of lower Pamela significantly overlying Upper Chazy beds full of *Camarotoechia*. It thins eastward to 10 feet at Montreal, and has been traced by Okulitch¹⁹ to Joliette, about 40 miles north northeast of Montreal, where he reports a thickness of eight feet.

¹⁵ Johnston, W. A.: 1911, Simcoe district, Ontario. Geol. Survey Canada, Summ. report for 1910, p. 190.

¹⁶ Okulitch, V. J.: 1939, The Ordovician section at Coboconk, Ont. Royal Canadian Inst., Trans., Vol. 22, Part 2, p. 329.

¹⁷ Raymond, P. E.: 1912, Report of the paleontological division; invertebrate. Geol. Survey Canada, Summ. report for 1911, p. 353.

¹⁸ Wilson, A. E.: 1932, Notes on the Pamela member of the Black River formation of the Ottawa Valley. Amer. Jour. Sci., Vol. 24, pp. 135-146.

¹⁹ Okulitch, V. J.: 1939, The Black River group in the region between Montreal and Quebec. Amer. Jour. Sci., Vol. 237, p. 84.

Classification of the Pamela Formation.

Ideas concerning the age of the Pamela have differed greatly. Ulrich²⁰ correlated it "with the upper part of the Stones River formation, a formation of Chazy age, but laid down in a separate basin from the Chazy, so that faunally and lithologically the two are quite distinct." He thought it equivalent to upper Stones River beds near Chambersburg, Pennsylvania, where "a 200 foot thickness of limestone with an upper Chazy fauna, separates the Pamela horizon from the Lowville." This conception was expressed again by Ruedemann²¹ more recently when he stated that the New York Pamela is intermediate between the Crown Point (Middle Chazy) and Valcour (Upper Chazy) limestones of the Champlain Valley.

Grabau²² apparently considered as a part of the Lowville the beds which Cushing was later to designate as Pamela. He states that at Lowville, New York, "the Lowville limestone overlaps the preceding formations and rests, with a basal sandstone, upon the crystallines."

Sarle,²³ studying the section at Roaring Brook, East Martinsburg, New York, confused the fossiliferous lower Pamela with the Lowville, and thought the lowest beds to be Calciferous.

Most Canadian workers, with the advantage of seeing the Pamela overlying upper Chazy beds in the Ottawa Valley, have considered the Pamela to belong in the Black River group. Shortly after Ami had named the Rideau sandstone, Wilson²⁴ considered these beds to be a "shoreward extension of the early Black River rather than the Chazy." Raymond²⁵ has stated that such Pamela species "as are found are more nearly akin to the Lowville and Black River faunas than to the Chazy." Kindle,²⁶ in a tabulation of Ordovician stratigraphy in the Kingston area, lists the Pamela as a part of the Black River group.

Probably the most conclusive evidence as to the age of the

²⁰ Ulrich, E. O.: In Cushing, H. P., Ruedemann, R., and others. op. cit., p. 78.

²¹ Ruedemann, R.: op. cit., p. 188.

²² Grabau, A. W.: 1906, Types of sedimentary overlap. Geol. Soc. Amer., Bull., Vol. 17, pp. 584-585.

²³ Sarle, C. J.: 1908, Manuscript quoted by: Cushing, H. P.: Lower portion of the Paleozoic section in northwestern New York. Geol. Soc. Amer., Bull., Vol. 19, p. 168.

²⁴ Wilson, A. W. G.: 1903, The theory of the formation of sedimentary deposits. Canadian Record of Sciences, Vol. 9, p. 132.

²⁵ Raymond, P. E.: op. cit., p. 353.

²⁶ Kindle, E. M.: op. cit., p. 40.

Pamelia is that resulting from the work of Wilson²⁷ in the Ottawa Valley. There the lower Pamelia overlies the upper Chazy, which is characterized by an abundance of *Camartoechia*. Wilson states that this fossil "abruptly disappears before the lower Pamelia. The upper Pamelia contains several types of *Tetradium* which never wholly disappear except in the magnesium layers, but give place to the *Tetradium cellulolum* of the Lowville. *Bathyurus extans*, a Black River form, appears near the base of the upper Pamelia. For these reasons it is considered that the Pamelia of the Ottawa Valley is to be included in the Black River and not in the Chazy."

The writer has studied these Ottawa Valley sections and compared them with the type Pamelia of New York. Although there are some differences in the range of faunas in the beds of the two localities, *Bathyurus cf. B. extans* having been found only in the lower division in New York, the lithologies are so similar as to make their equivalency fairly certain. It seems that the weight of evidence is heavily in favor of the post-Chazyan age of the Pamelia.

Facies of the Pamelia Formation.

Basal Clastics. The basal beds of the Pamelia form an excellent illustration of the way in which equivalent beds may vary, depending upon the local conditions under which they have been deposited. About the only similarity between some of the lowest Pamelia beds in different localities is their stratigraphic position. In the Black River Valley the basal beds are red and green arkosic conglomerates and sandstones containing small and medium-sized pebbles of the underlying Pre-Cambrian granite or syenite. In the region north of Watertown, New York, the sandy basal layers are finer textured, thinner, more shaly, and a less prominent feature, because the Pamelia sea advanced here over the Tribes Hill sandy dolomite, which was not so capable as the igneous rocks of supplying coarse clastic material. In the Kingston, Ontario, district the very striking coarse conglomerates found lying against Pre-Cambrian knobs at Kingston Mills and at Jackson's Mill, would indicate that the sea advanced over an area of somewhat stronger relief in southeastern Ontario than in northwestern New York. Strangely, these coarsest clastics are the only basal

²⁷ Wilson, A. E.: op. cit., p. 145.

beds in which fossils have been found. At Marmora, Ontario, the lowest strata are shaly limestones, with some sandy beds. These differences between the lower clastics of the Pamela are partly due to the fact that the observed outcrops do not all have the same relation to the original Pamela shore-line of any one time.

Dolomitic Limestones. The dull gray, fine-textured, dolomitic limestones, which tend to be earthy at some horizons where they contain more sand, are believed to have been deposited in shallow water. They are rather high in silica and magnesium carbonate, as is shown in the following analysis²⁸ of typical yellow-weathering, platy beds in a Kingston quarry. SiO_2 7.32; Fe_2O_3 .74; Al_2O_3 1.87; Calcium phosphate .07; CaCO_3 74.73; MgCO_3 15.56. These more platy types commonly have mud-cracks, and the thin, intercalated shaly beds sometimes show ripple marks. The only fossils found are ostracodes. It is possible that these beds became dolomitized by metasomatic replacement before the consolidation of the sediments, and that a rather high salinity brought about an environment unfavorable to normal marine life. McKee²⁹ has discussed similar lithologies in the Permian sediments of Arizona.

Sublithographic Limestones. The gray sublithographic limestones, called "dove" by many authors, make up about half the thickness of the upper Pamela division in most sections. The following analysis³⁰ is the average for 12 feet of beds in the same quarry as that from which the rock of the preceding analysis was taken. This is probably a little dolomitic limestone interbedded here. SiO_2 4.76; Fe_2O_3 .47; Al_2O_3 1.90; Calcium phosphate .07; CaCO_3 85.52; MgCO_3 6.68. Like the dolomitic limestones, the "dove" beds often have shaly intercalations which show mud-cracks. In Ontario, notably at Jackson's Mill and Marmora, some layers have abundant molds of an undetermined mineral (see Pl. I, Fig. 2). These are distributed through layers several inches thick, and not confined to bedding planes, so probably do not represent evaporites. At present some of the molds are partially filled with calcite,

²⁸ Goudge, M. F.: 1933, Canadian limestones for building purposes. Canada, Dept. of Mines, Mines Branch, No. 733, p. 87.

²⁹ McKee, E. D.: 1938, The environment and history of the Toroweap and Kaibab formations of northern Arizona and southern Utah. Carnegie Institution of Washington, publication No. 492.

³⁰ Goudge, M. F.: op. cit., p. 87.

which appears to be secondary. Sherzer³¹ found similar cavities in upper Silurian dolomites of Michigan, and aptly called these rocks "gashed dolomites." It was his belief that the cavities had been occupied by calcite. A concentration of celestite in cavities in this region suggests the possibility that the molds in the Monroe series had once been occupied by that mineral. The fauna in this facies of the Pamela is limited to ostracodes and probable worm-borings. These limestones are somewhat like the well-known Solnhofen lithographic limestone of Germany, except in color and purity. Walther³² has shown that the cementing material of this fine calcilutite is due to chemical precipitation. Grabau³³ points out that mud-cracks in the Solnhofen limestone show that the deposits were exposed before solidification. It is the opinion of the writer that the nearly unfossiliferous, sublithographic limestones of the Pamela were deposited largely by chemical precipitation in very shallow water, and under conditions possibly similar to those studied by Field³⁴ and others on the Bahama Bank northwest of Andros Island. Here a sea-bottom of fine, soft, lime mud forms ecological conditions unsuitable for life other than worms and algae.

Black Fossiliferous Limestones. Most of the Pamela fauna is found in the dark-gray to black, fine-textured limestones of the lower division. They are sublithographic, or slightly coarser and semi-crystalline, and in places rather argillaceous. Their dark color shows that they have a larger content of organic material than any other Pamela facies. In them, the coral *Tetradium* most commonly appears, and they have yielded *Bathyrurus*, cephalopods and gastropods. Brachiopods are very rare. This is the only facies which represents fairly normal marine conditions during Pamela time.

History of the Pamela Formation.

Pamelia deposition took place in an arm of the interior sea which seems to have advanced from the southwest and overlapped northeastward. The axis of this arm probably passed

³¹ Sherzer, W. H.: 1900, Geological report on Monroe County, Michigan. Mich. Geol. Survey, Vol. 7, Pt. I, p. 85.

³² Walther, J.: 1904, Die solnhofen Plattenkalke Bionomisch betrachtet, p. 212.

³³ Grabau, A. W.: 1924, Principles of stratigraphy. New York, A. G. Seiler, p. 336.

³⁴ Field, R. M.: 1931, Geology of the Bahamas. Geol. Soc. Amer., Bull. Vol. 42, pp. 759-784.

Black, Maurice: 1933, The precipitation of calcium carbonate on the Great Bahama Bank. Geol. Mag., Vol. 70, pp. 455-466.

through northwestern New York, where the formation is thickest. The waters advanced over an area of Pre-Cambrian crystallines and lower Paleozoic sediments. This area was probably gently sloping regionally, but had moderate relief in places, as is shown by the presence of the Pre-Cambrian knobs, upon which the Pamela sediments overlap, and are overlapped. Most of the sedimentation took place in very shallow water, and much of it within the intertidal zone, as is indicated by the presence of mud-cracks and ripple marks, and by marine fossils.

Shortly after the beginning of Pamela time, unrestricted marine waters had access to the eastern portion of the embayment. The black fossiliferous beds are characteristic of the New York area but have not been recognized in central Ontario. The magnesian limestones that overlie them seem to represent conditions of chemical precipitation in shallower waters, in which, of shell-bearing organisms, only ostracodes could thrive. The fossiliferous limestones appear again near the top of the lower division in New York sections.

Apparently all the latter part of Pamela time was characterized by intermittent deposition under shallow water conditions. In addition to the ripple marks and mud-cracks already mentioned, the occasional conglomeratic and sandy layers interbedded in the upper division, show such a history.

THE LOWVILLE FORMATION.

Stratigraphy of the Lowville Formation.

The Lowville³⁵ limestone, named for Lowville, Lewis County, New York, is the "Birdseye limestone" of earlier workers. The term "Birdseye" had been given to the formation because of its appearance on a surface showing cross-sections of the common *Phytopsis tubulosa*, which probably represents a worm-boring. Raymond³⁶ has brought out evidence that this is the burrow of a tubicolous worm excavated while the surface of the Lowville was an exposed, partially hardened mud-flat. No section for the type locality was described until Cushing and Ruedemann³⁷ detailed the section at Lowville. Unfortunately, the formation is neither as thick nor as well-exposed continu-

³⁵ Clarke, J. M., and Schuchert, C.: 1899, Nomenclature of the New York series of geologic formations. *Science*, n. s., Vol. 10, pp. 874-878.

³⁶ Raymond, P. E.: 1931, The nature of *Phytopsis tubulosum* Hall. *Harvard Coll., Mus. Comp. Zool., Bull.*, Vol. 53, No. 6, pp. 194-198.

³⁷ Cushing, H. P., Ruedemann, R., and others. *op. cit.*, p. 83.

ously at Lowville as it is four miles to the southeast at Roaring Brook, East Martinsburg, being 34 feet in thickness at the former, and 54 feet at the latter locality.

In the type area, and throughout the upper Black River Valley, the Lowville formation is present in a narrow belt because of its outcrop along the steep slope on the eastern side of the Black River terrace. Usually it is capped by the more resistant Chaumont formation, and not a conspicuous topographic feature, but in places it caps a narrow terrace.

In the area north of Watertown, the Lowville, like the underlying Pamela, outcrops as a belt of varying width, but with a maximum of about five miles. In this region, the Lowville does not usually rise above the Pamela plain with as conspicuous an escarpment as that formed by the latter formation where it overlies the Theresa, but in places, notably near Evans Mills, Jefferson County, the Lowville is bounded by an escarpment 40 feet high. The formation has somewhat similar topographic expression across southern Ontario.

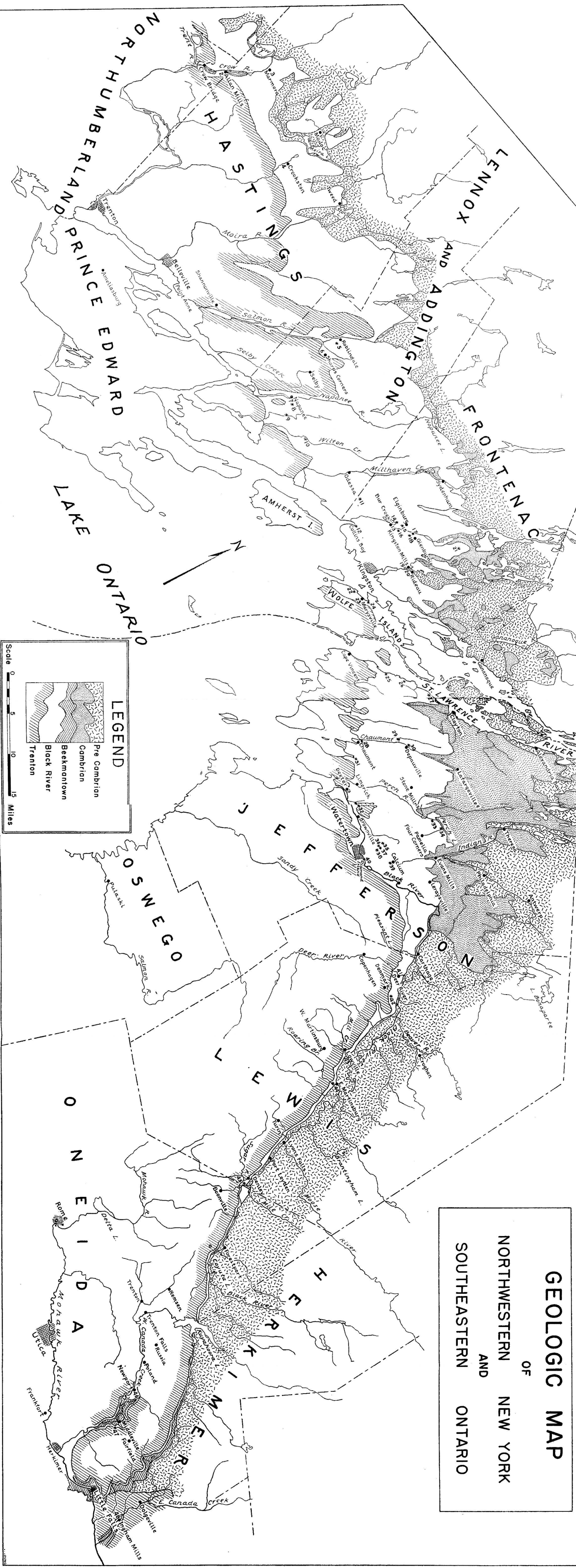
In New York sections it is possible to distinguish two divisions of the Lowville with approximately equal thickness. To a certain extent, this is also true in Ontario. The upper division tends to be thicker-bedded and to contain a large percentage of massive "dove" limestones, a lithology which is most characteristic of the Lowville in this area. The term "dove" has been applied to light and medium purplish-gray, sublithographic limestones, most of which weather white or light gray (see Pl. 2, Fig. 1). There are all gradations from these into black, sublithographic limestones in both the upper and lower divisions. The upper division also contains beds of dark gray, semi-crystalline limestone, thinner-bedded argillaceous limestone, and occasional oolitic layers. On the whole, the lower division is thinner-bedded than the upper, and consists of thin-bedded argillaceous limestones, thin shaly beds, oolitic limestones, occasional sandy beds, and usually several conglomeratic limestone layers at various horizons. Fairly thick beds of sublithographic and slightly coarser semi-crystalline limestones also occur. Kay³⁸ has observed a three inch metabentonitic clay 19 feet below the top of the formation near Middleville, N. Y.

Cushing³⁹ has pointed out that there is a certain faunal distinction between the divisions, in that the upper contains more

³⁸ Kay, G. M.: 1942, Letter to author.

³⁹ Cushing, H. P., Ruedemann, R., and others. op. cit., p. 80.

GEOLOGIC MAP
 OF
 NORTHWESTERN NEW YORK
 AND
 SOUTHEASTERN ONTARIO



LEGEND

	Pre Cambrian
	Cambrian
	Beekmantown
	Black River
	Trenton

Scale 0 5 10 15 Miles

abundant *Tetradium cellulosum* and a larger *Phytopsis*, whereas the lower has smaller forms of *Tetradium* and *Phytopsis*. In general, this has been found to be true.

The Lowville varies more lithologically from base to summit than do the Pamela and Chaumont. A brief discussion of the section along Roaring Brook, East Martinsburg, will serve to bring this out. (See the detailed section.) Here, as elsewhere, the formation has at its base semi-crystalline limestones full of small and medium sized pebbles of Pamela limestone. This conglomerate is only two feet thick, but at Lowville equivalent beds comprise five feet of very irregularly-bedded, lensing, limestone conglomerate. Above a few inches of shale over the basal beds, are 18 inches of massive semi-crystalline and sublithographic limestones, and then 14 inches of shaly argillaceous, showing ripples and mud-cracks. Then follow some 40 inches of massive, sublithographic limestone with stylolites and several horizons of intraformational limestone conglomerate. Above are four feet of thin-bedded, argillaceous limestone with mud-cracks, followed by 12 feet of alternating sublithographic, argillaceous, shaly, and oolitic limestones. At this point a significant 30 inches of irregularly-bedded limestone conglomerate appears, overlain by one foot of shale, and a pebbly oolitic stratum. The remainder of the section consists of some 25 feet of rather thick-bedded, sublithographic, semi-crystalline, and argillaceous limestones interrupted by shaly partings, some of which have mud-cracks.

In addition to the variety of facies exhibited by the Roaring Brook section, the very significant things which will aid in the interpretation of Lowville history are well shown. Limestone conglomerates appear not only at the base, but at two other horizons, in beds between five and eight feet, and between 25 and 29 feet above the base of the section. Oolitic beds, locally pebbly, are present at 20, 29 and 51 feet. Well-developed mud-cracks are seen at five, 12 and 38 feet, and ripples at five, 17, and 25 feet in the section. Some of the partings between beds are marked by a very lumpy surface. This is most common where there is a conspicuous change in lithology, and probably indicates some interruption of sedimentation. Ripple marks and mud-cracks are more common in the lower half of the formation.

When traced along its belt of outcrop, the Lowville proves

to be more consistent in thickness than are the Pamela and Chaumont. As already stated, it is 54 feet thick at East Martinsburg. At a point one and a half miles northwest of Lyons Falls, Lewis County, which is eight miles southeast of the Roaring Brook section, the formation is 54 feet in thickness. At Denley, Lewis County, seven miles farther south, it measures 57 feet and thins to 40 feet in Oneida County. Throughout Jefferson and Lewis Counties, the Lowville lies disconformably upon the Pamela (see Pl. 2, Fig. 2) but since the latter formation thins out and disappears in northern Oneida County, from that point southeastward the Lowville overlaps the Pamela and lies upon Beekmantownian Tribes Hill dolomite. A thickness of 31 feet of Lowville has been measured at Newport, Herkimer County, and 15 feet are visible in the interesting quarry about half a mile south of the Middleville town line, just east of Highway 169, where the formation is overlain by the Hull formation of the Trenton. Cushing⁴⁰ states that the thickness in this area is 21 feet as a maximum, but the writer thinks it is greater, because of the fact that at Ingham Mills, Herkimer County, about 12 miles southeast of Middleville, 27 feet are exposed, and the base of the formation is not visible. The Lowville disappears in the vicinity of Canajoharie, but reappears in the lower Mohawk Valley, with a thickness of six feet at Amsterdam, and a maximum thickness of 10 feet farther eastward. In the Champlain lowland, about six feet of Lowville are present from Glens Falls northward to Isle La Motte.

In the type region, in and about Lowville, many partial sections of the formation may be seen, as well as the fairly complete, but not well-exposed section along Mill Creek. Notable are the two quarries in the town of Lowville, one just north of Mill Creek (see Pl. 2, Fig. 1) where the railroad trestle crosses it, and the other about a fourth of a mile eastward on the south side of the creek. A newer quarry one mile north of town, due west of Dadville, exposes the Lowville-Pamelia contact.

Many small quarries have been opened in the bluff west of Black River north of Lowville, but they are shallow. One east of Denmark exhibits 19 feet of Lowville beneath its resistant capping of Chaumont. A similar thickness, somewhat better-exposed, can be seen in the quarries and along Deer River at

⁴⁰ Cushing, H. P.: 1905, *Geology of the vicinity of Little Falls, Herkimer County, N. Y. State Mus., Bull. 77, p. 30.*

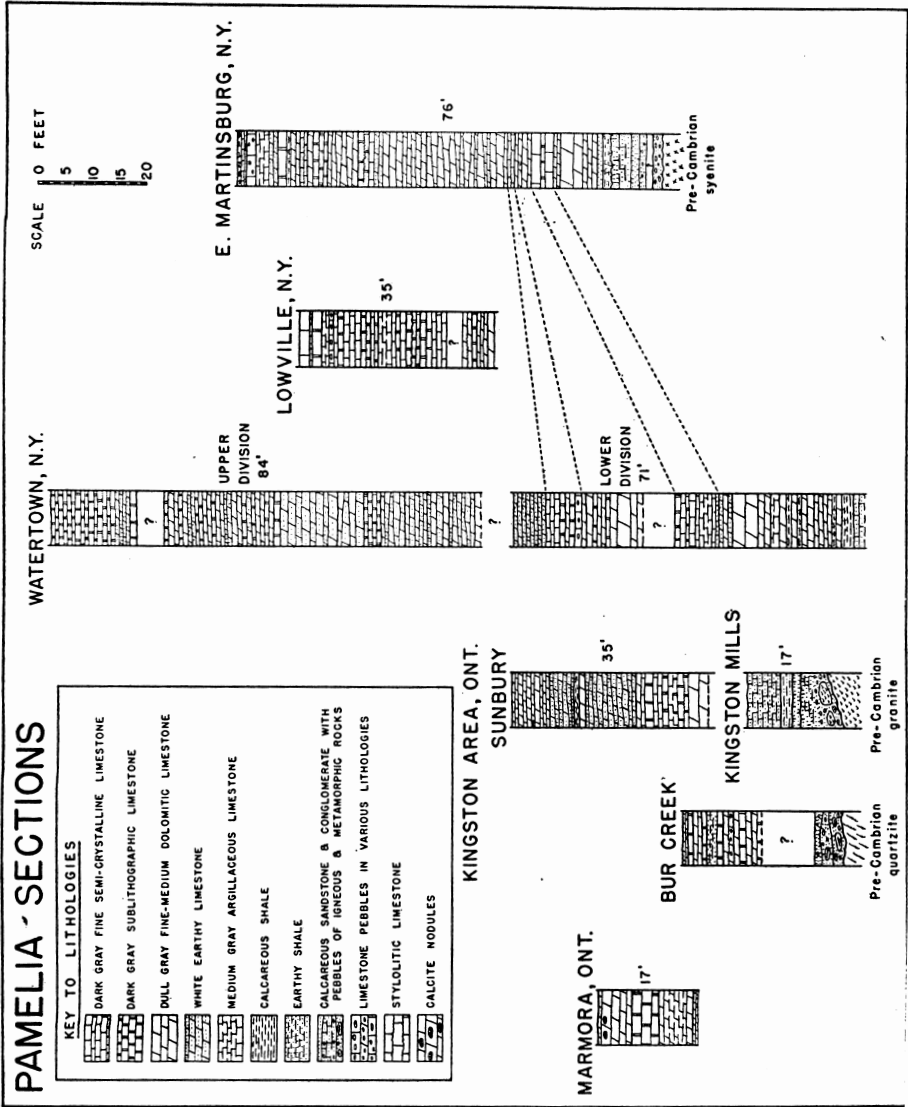
Deer River Village, Lewis County. One of the most striking characteristics of the Lowville is the persistence over considerable distances of distinctive lithologies at approximately the same horizon. At Denmark and Deer River, three miles apart, a very petroliferous stratum appears 14 feet below the top of the formation.

Throughout Jefferson County, the Lowville maintains the thickness of the type area. Many excellent exposures may be studied along Black River at Watertown, and in the region north of that city. In the present town quarry on U. S. highway 11, about one and eight-tenths miles north of the Black River, 24 feet are exposed, and a shallow quarry about one mile to the north and west of the same road, has supplied some of the best fossil-collecting in northern New York.

To the westward, there are numerous exposures in the vicinity of Dexter, Limerick, and Chaumont. In quarries at Limerick and Chaumont, respective sections of 18 and 24 feet are of special interest because of the presence of a conspicuous horizon of *Stromatocerium* at about the same stratigraphic position below the top of the Lowville, 16 feet below at the former, and 17 feet at the latter. This suggests the persistence of similar ecological conditions over considerable distances, two and a half miles in this case.

The Lowville shows similar lithologic and faunal characteristics when followed westward into Ontario. Exposures on the western side of Wolfe Island, in the vicinity of Marysville, show abundant *Tetradium cellulosum* in the upper ten feet of the formation, just as it appears at Lowville, Roaring Brook, Deer River, Watertown and Chaumont. In the Kingston district, the formation is 40 feet thick, and well exposed. At the Glenburnie type locality there are some 30 feet of Lowville intermittently exposed, part in the Glenburnie quarry, and lower beds in the hillside to the eastward. Oolitic beds full of the pelecypod *Cyrtodonta huronensis* appear exactly like those in the same general part of the section in the Black River Valley. Reef-like layers of *Stromatocerium* occur somewhat higher in the formation than they do in northwestern New York. In a shallow quarry one mile south of Elginburg, Kingston Township, there are large hemispherical heads up to three feet in diameter.

Certain lithologic changes become apparent in studying the Lowville from the Kingston area westward. Instead of being



light gray, the sublithographic facies tends to be brownish gray in color. This is probably due to a higher content of organic material. Argillaceous limestones and shaly beds are more abundant in Ontario than in New York, and in these facies there occur genera which have not been seen in New York sections. Several quarries near Highway 2 between Kingston and Napanee, and in the vicinity of the latter town, have satisfactory exposures of these beds.

One of the most interesting sections may be seen at Napanee, Lennox and Addington County. This is described in detail below. In the road cut just east of town, 52 feet of Lowville are capped by Chaumont. Below the base of these exposures, there are some 42 feet of beds concealed before Napanee River is reached. Along the river are 25 feet of beds which seem to be Lowville. They have Lowville lithology, with such characteristic fossils as *Tetradium cellulosum* and *Bathyrurus extans* among others. If this were a normal, undisturbed section, the Lowville would have a thickness of at least 119 feet, which is very improbable. It is thought that the great apparent thickness may be due to repetition of beds caused by faulting or folding. It is rather significant that the course of the lower Napanee River parallels the Picton monocline, which Kay⁴¹ has described as passing through the Prince Edward Peninsula, to the south of Napanee. However, no surface evidence of such structure has been found in these outcrops. The beds exposed in upper and lower sections are approximately horizontal.

In accordance with the lithologic changes which have been mentioned above, the Lowville at Napanee has very little light gray, sublithographic stone, the finer-textured facies being dark gray or brownish gray. There is a large proportion of thin shaly beds. In the Napanee road-cut section there are several significant features, some of which may be advantageously compared with those in New York exposures. Limestone conglomerates are present at the base of the exposures, a stratigraphic position which just about coincides with that of the basal conglomerates at East Martinsburg, New York. Other pebbly layers, most of them also oolitic, appear at nine to 10 feet, 14, 22, and 30 feet above the base of the section. Oolitic beds occur at two feet, 15 feet, 29 feet six inches, and 38 feet. Those

⁴¹ Kay, G. M.: 1937, Stratigraphy of the Trenton group. Geol. Soc. Amer., Bull. Vol. 48, p. 279.

at 29 and 38 feet correspond very closely in position to two oolitic strata at Chaumont, New York. Most important is the presence of crystal molds or impressions, like those in the Pamela, at five, nine, 22 and 27 feet above the base. These usually occur in dark, fine-textured, semi-crystalline limestones.

In the Point Anne quarries, three miles east of Belleville, there are only six feet of Lowville exposed, and overlapped by the Chaumont. A well in the quarry has shown that there are 100 feet additional of limestones before reaching basal sandy beds, indicating that the formation is probably at least as thick here as at Napanee, with an allowance for a considerable thickness of Pamela, also.

In the belt of country extending for about 20 miles northward, there are many Lowville exposures. At Larkins, Hastings County, crystal impressions occur, as at Napanee.

Continuing westward, Marmora, Hastings County, affords one of the best sections in this area, because both the Pamela and Chaumont contacts with the Lowville can be determined, the former less accurately than the latter. The Lowville has a thickness of 47 feet, exhibits the more massive character of the upper division, the shaly nature of the lower portion, and has intraformational limestone conglomerates at 12 and 21 feet above the base of the section.

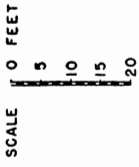
At Allan Mills and Crow Bridge, on Crow River in Northumberland County, fair exposures may be seen. The Lowville at Crow Bridge is exposed for 20 feet of its thickness, and consists of typical gray, sublithographic limestones with *Phytopsis*, and interbedded gray, platy and shaly limestones with *Bathyrus* and pelecypods.

The Lowville is well-represented in the Ottawa and St. Lawrence Valleys. The maximum thickness of 50 feet occurs in the upper Ottawa Valley. Like the Pamela, it thins eastward to a thickness of 30 feet at Ottawa City, to 16 feet at Montreal,⁴² and to nine feet at the Ouareau River,⁴³ 40 miles northeast of Montreal. Here again the persistence of Lowville lithologies is well illustrated. Near Rockland, about 20 miles east of Ottawa, a large part of the section exposed consists of the typical gray, sublithographic beds, with *Tetradium cellulosum* very abundant in the upper portion. Below these are

⁴² Okulitch, V. J.: op. cit., pp. 84-85.

⁴³ Ibid.

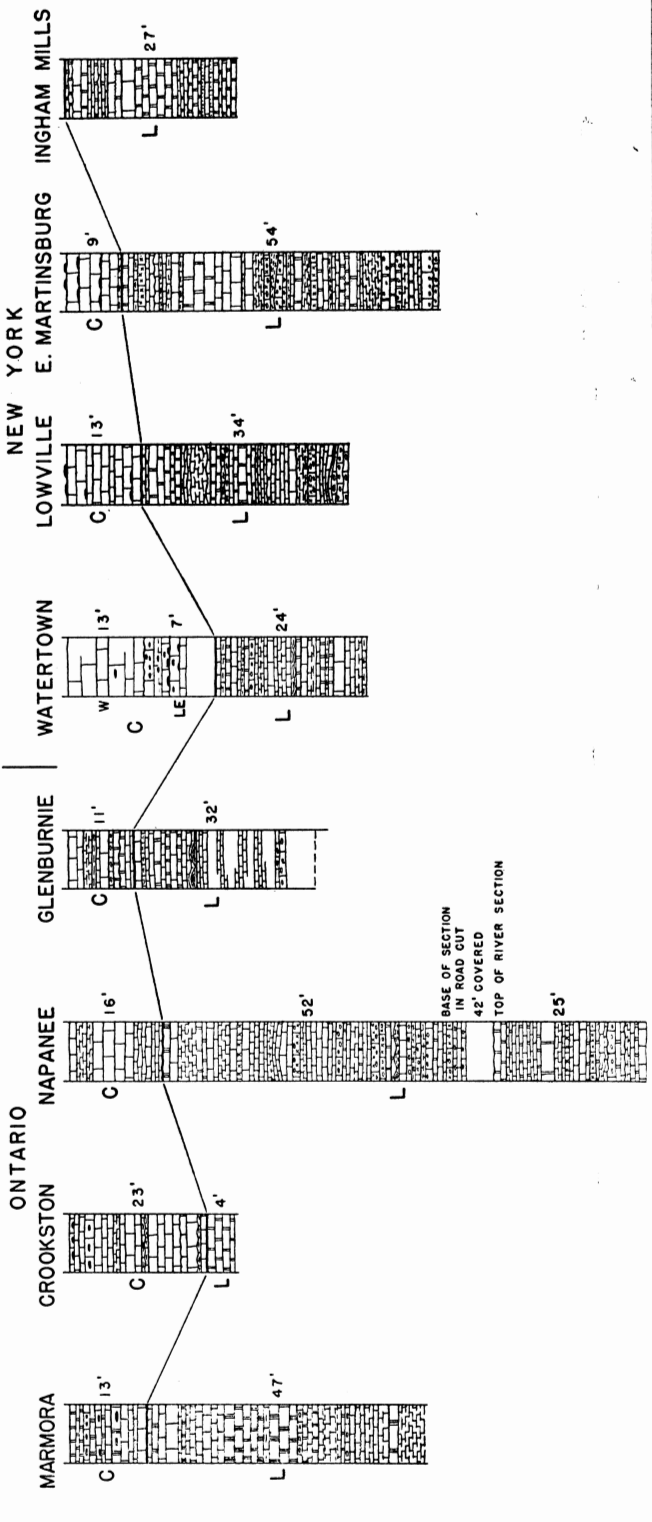
CHAUMONT AND LOWVILLE SECTIONS



C= CHAUMONT
W= WATERTOWN
LE= LERAY
L= LOWVILLE

KEY TO LITHOLOGIES

	DARK GRAY-BLACK, FINE & MODERATELY FINE SEMI-CRYSTALLINE LIMESTONE		LIMESTONE CONGLOMERATE
	BLACK CHERT IN THE CHAUMONT LIMESTONES		OOLITIC LIMESTONE
	BROWNISH SUBLITHOGRAPHIC LIMESTONE		STYLOLITIC LIMESTONE
	SOMEWHAT MORE ARGILLACEOUS LIMESTONE		



5. Lowville and Chaumont columnar sections.

semi-crystalline, oolitic, and shaly beds with other characteristic Lowville fossils. These same lithologies persist for 40 miles and more down the St. Lawrence Valley.

Facies of the Lowville Formation.

Sublithographic Limestones. The sublithographic limestones of the Lowville may be roughly subdivided into two groups, the lighter gray "dove" white-weathering type, and those which are dark gray to black.

(a) *"Dove" sublithographic limestones:* These occur most commonly in thick beds, and are sparingly fossiliferous. The worm-boring *Phytopsis* is abundant in this facies. *Tetradium* appears here, but is much more abundant in the darker sublithographic and argillaceous limestones. Some gastropods are found where the lithology is a bit darker. This facies gives the impression of being a very pure limestone. The analysis⁴⁴ of a sample from near Port Leyden, Lewis County, New York, shows this Lowville "dove" to be higher in calcium and lower in magnesium than somewhat similar beds of the Pamela. The silica content is surprisingly high. SiO_2 6.5; Fe_2O_3 .76; Al_2O_3 1.67; CaCO_3 88.44; MgCO_3 2.68. Shaly partings between beds of this facies have mud-cracks, showing that they must have been exposed at times. It is believed that the limestone beds were largely chemical precipitates formed in shallow water, where there was very little marine life.

(b) *Darker sublithographic limestones:* All the Lowville facies intergrade, and it is difficult to separate the dark, sublithographic beds from the dark limestones which are slightly coarser in texture. In any one thick stratum, one is likely to find several intergrading facies present. The dark gray or black, sublithographic beds are more fossiliferous than the "dove" facies, and their darker color is undoubtedly due to a higher content of organic material. *Tetradium*, cephalopods, brachiopods, gastropods, and trilobites are common. This limestone is often stylolitic, and, when interbedded with coarser, semi-crystalline beds, locally contains limestone pebbles. The indication is that all the sublithographic facies was deposited in shallow water.

Dark Semi-Crystalline and Argillaceous Limestones. These

⁴⁴ Ries, H., and Eckel, E. C.: 1901, Lime and cement industries of New York. N. Y. State Mus., Bull. 44, pp. 790-791.



FIG. 1

Pamelia lying on, and containing boulders of, white Pre-Cambrian quartzite. Hammer head at the contact. Bur Creek, Lot 14, Conc. V, Kingston Tp., Frontenac Co., Ont.



FIG. 2

Mineral molds in Lowville limestone. x 1.

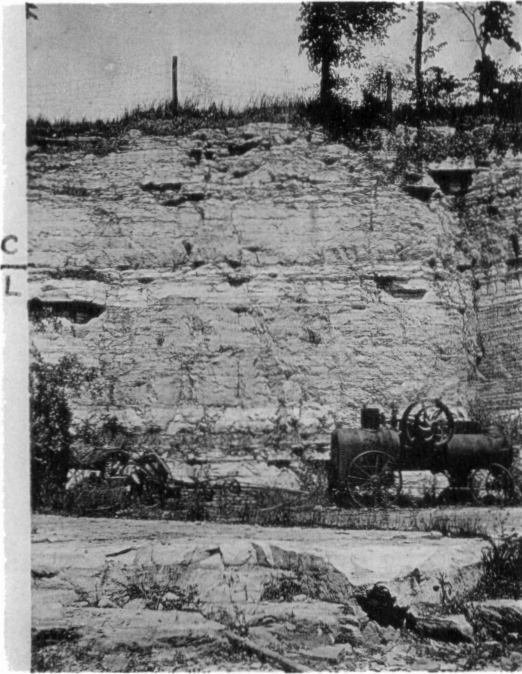


FIG. 1
Quarry at Lowville, N. Y., showing about 18 feet of Lowville, including the white-weathering beds, and some 10 feet of overlying Chaumont.

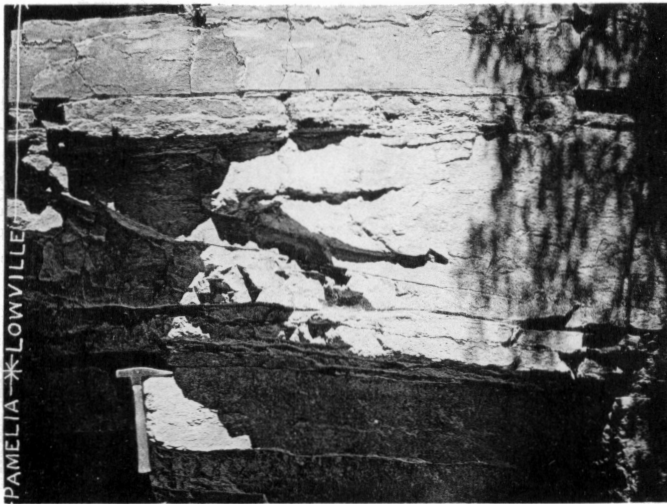


FIG. 2
The Lowville-Pamelia contact (at hammer head) exposed in the north bank of Mill Creek, Lowville, N. Y., just east of the railroad bridge. Shows the lensing character of the conglomeratic basal Lowville.

limestones are usually interbedded with sublithographic beds, and form a large part of the upper division of the Lowville, as well as much of the lower division, in New York and Ontario. They are very fossiliferous and one of the facies most likely to contain limestone pebbles. The crystal impressions occur in dark gray, fine, semi-crystalline beds, and have been found in the Lowville only in Ontario sections. It has been noted that these features in the Pamela are also confined to Ontario. Where the crystal markings are found, the beds are unfossiliferous. It appears that all these limestones, partially chemical and partially clastic in origin, were formed in rather shallow water.

Granular and Oolitic Limestones. Medium-textured, granular limestones, associated with semi-crystalline and oolitic limestones, make up only a small part of the Lowville, but are of interest because they are often highly fossiliferous. Certain beds consist almost entirely of pelecypod and gastropod shells which have been replaced by white calcite.

The oolites of the Lowville have sharp boundaries, form oolite sands, and thus appear to have been reworked. The oolitic beds are usually fossiliferous and often contain limestone pebbles. It is common to find thin oolitic layers interbedded with the semi-crystalline limestones.

Shales. The argillaceous limestones mentioned under the heading "Dark Semi-Crystalline and Argillaceous Limestones" commonly grade into shaly beds which are most characteristic of the lower portion of the formation in New York sections. It has been mentioned that shaly facies become more common in Ontario. In them there are not only genera foreign to New York sections, but fossil-preservation seems to have been better in some of these beds, thus making their collection easier. These shales are important for interpretation because they have the ripple marks and mud-cracks, which show them to have been deposited in very shallow water. Such sedimentary structures are more common in the lower half of the Lowville.

History of the Lowville Formation.

The Lowville formation is apparently disconformable upon the Pamela, and upon older formations where it overlaps the Pamela. The base of the Lowville is always conglomeratic, but not coarsely so, and there is little indication of much erosion

having taken place upon the surface of the Pamela. The Lowville seas continued the transgression of Pamela time, and were more extensive. Even after Pamela deposition, the region now represented by southern Ontario seems to have been one of stronger relief than the area in New York over which the Lowville sea advanced. This is illustrated by the overlapping relations of successively higher formations about the flanks of many Pre-Cambrian knobs in southern Ontario. The relief of the Pre-Cambrian surface in the vicinity of Belleville, Hastings County, seems to have been at least 320 feet. The Ameliasburg inlier, near Shannonville, Hastings County, consists of a granite knob rising some 75 feet above the surrounding country. Beds of late Trenton age lie against it, overlapping even the Chaumont and earlier Trenton beds. There is no indication of any such topographic relief having existed in Black River time in the New York area.

Mud-cracks, ripple marks, and limestone conglomerates are, as a rule, confined to the lower division of the Lowville, indicating that marine waters were very shallow, although extensive, in earlier Lowville time. Most of the beds of the upper division, more uniform and massive in character, were probably deposited somewhat farther from shore, and indicate that the Lowville sea was a constantly advancing sea, foreshadowing the more normal marine conditions of Chaumont time.

The more plentiful shaly beds in western areas may be an expression of the fact that the shoreline in Ontario was probably more irregular, due to overlap on a region of some relief. It is likely that fine clastics were deposited in embayments along this irregular shore, or about islands.

To be continued.