The Limestones (Middle Ordovician) of Jefferson County, New York

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with a discussion of the

Analyzing and Testing of Samples

Wayne E. Brownell

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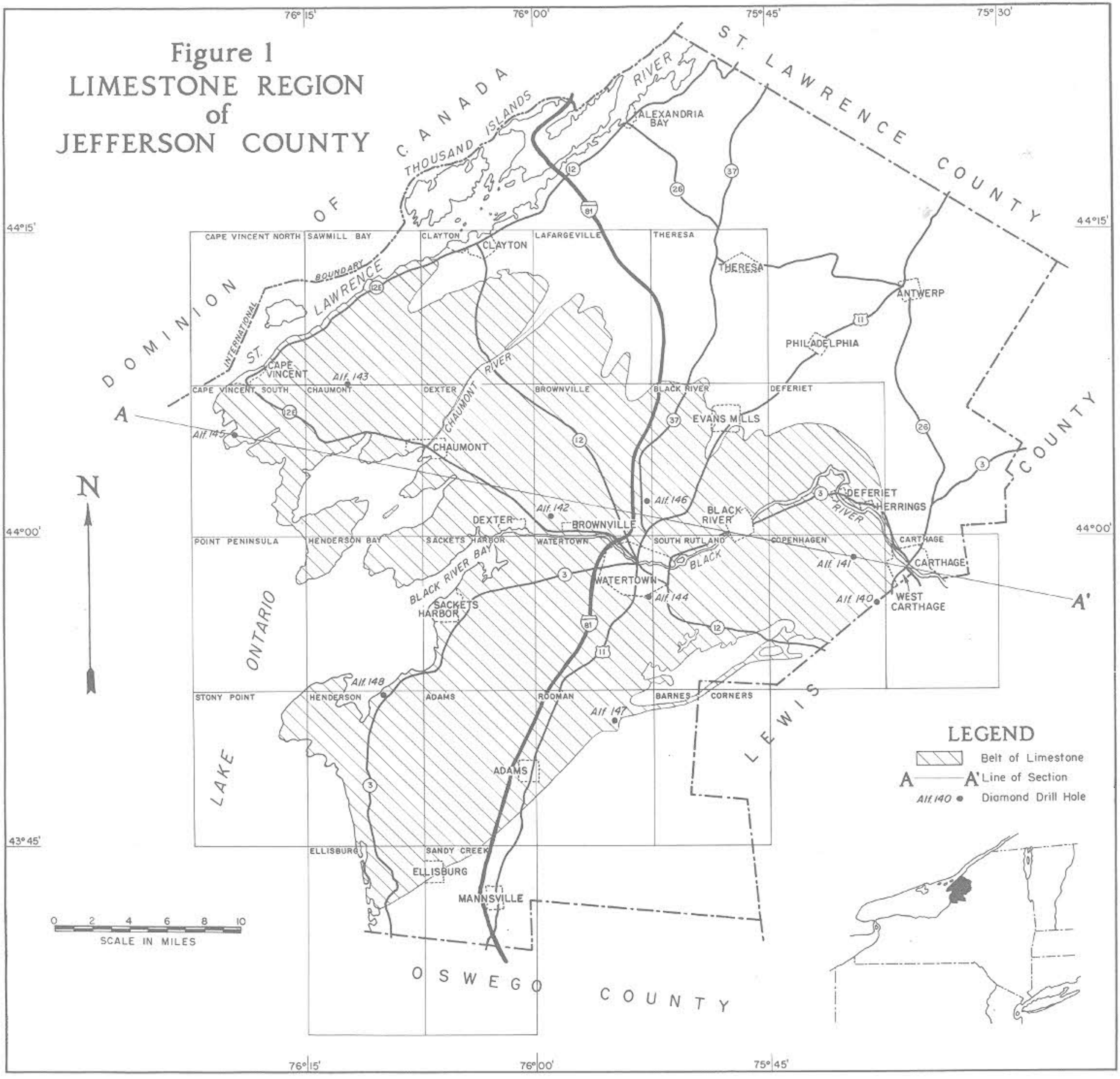
Figure 1
LIMESTONE REGION of JEFFERSON COUNTY



THE UNIVERSITY OF THE STATE OF NEW YORK

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The Limestones (Middle Ordovician) of Jefferson County, New York[1,2]

by John H. Johnsen[3]

ABSTRACT

Middle Ordovician limestones of the Black River and Trenton Groups comprise a carbonate section 725-750 feet thick underlying an area of 660 square miles adjacent to Lake Ontario in Jefferson County, New York. The carbonates dip at 1 to 2 degrees to the southwest. The Black River Group, averaging 250 feet in thickness, outcrops in the northern portion of the area and rests directly on rocks ranging from Middle Proterozoic to Early Ordovician in age. Trenton units underlie the southern portion of the mapped area and comprise a limestone sequence averaging 475 feet thick. All of the formations originally described by Kay (1937) are present in Jefferson County and their detailed distributions were mapped during this investigation.

The formational boundaries within the Black River and Trenton groups are typically gradational and contacts were established by subtle color and textural contrasts. An exception to this is the distinctive contact between the top of the Lowville Limestone and the overlying Chaumont Limestone in the upper portion of the Black River Group.

Forty-five potential quarry sites are described and indicated on the geologic map. These locations were selected on the basis of engineering tests, service history, and desirable topographic and drainage conditions. Samples for testing were obtained from drill core. Measured sections, drill core logs and engineering test results are presented.

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[1]Submitted to Geological Survey, June 2, 1968.
Revised maps and test submitted for publication November 23, 1970.

[2]With a discussion of the analyzing and testing of samples, by Wayne E. Brownell, Department of Ceramic Research, State University of New York College of Ceramics, Alfred University, Alfred, New York.

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Introduction

Purpose and Scope of Report

Limestones have always been of great interest, not only for their many commercial uses, but because the constant discovery of new processing methods and new applications of them continues to provide incentive for more accurate and more comprehensive study of the character and distribution of these sedimentary rocks.

The investigation of the carbonate rocks rimming the western edge of the Adirondack Massif is part of a continuing study of the economic potential of New York's limestone resources being made by the Geological Survey of the New York State Museum and Science Service in cooperation with the State University of New York College of Ceramics at Alfred University. This report is intended to fulfill the aims of that program in Jefferson County. It is based on careful stratigraphic and structural studies, and includes information on the extent, thickness, physical character, and chemical composition of the limestones occurring within the county. Potential quarry sites are described. The report will be helpful to anyone interested in the further development of the limestone deposits in this area.

Brief Description and Location of Area

Jefferson County includes an area of 1,293 square miles in northwestern New York State. It is bounded on the north by St. Lawrence County, on the east by Lewis County, on the south by Oswego County, and on the west by the navigable waters of Lake Ontario and the St. Lawrence River. The population of the county in 1960 was 87,835, representing an increase of 2,314 since the 1950 census. Its geographic setting, principal cities and villages, streams, and transportation facilities are shown in Figure I.

The Black River is the largest stream in Jefferson County. It enters from the east and flows generally westward across the middle of the county, falling 480 feet to Lake Ontario on the west. The river is an excellent source of local power, and it is not surprising to find the county's two largest urban centers, Watertown and Carthage-West Carthage, situated along its banks.

Watertown, the county seat, has a population of 33,306 and is located near the geographic center of the county. Within the city limits the Black River drops 110 feet over a series of falls, providing energy for several industries, primarily those engaged in the manufacture of paper and paper products and papermaking machinery. Excellent highways, including the north-south expressway Interstate 81, radiate from the municipality so that central and northern New York, and much of Ontario, Canada, are no more than a few hours travel time. By road Watertown is 70 miles north of Syracuse, 83 miles northwest of Utica, 90 miles southwest of Massena, and 26 miles south of the International Bridge to Canada which spans the Thousand Islands section of the St. Lawrence River between Clayton and Alexandria Bay.

The twin municipalities of Carthage and West Carthage have combined population 6,383 and occupy opposite banks of the Black River at the Lewis County line, 15 miles due east of Watertown. Here the "Long Falls" of the Black River descends 55 feet, furnishing power for several paper manufacturing concerns.

Camp Drum Military Reservation occupies a large tract in the northeastern corner of the county, reaching south as far as the great bend of the Black River between Carthage and Watertown.

Jefferson County is largely rural, and dairy farming is the most important single industry. The climate is temperate. The mean midwinter temperature is 20 degrees F. and the mean summer temperature is 68 to 70 degrees F. The mean annual precipitation ranges from slightly under 35 inches to slightly more than 45 inches a year. The precipitation is least on the lowland area adjoining Lake Ontario and the St. Lawrence River; it is greatest on the higher terrain in the southeastern part of the county.

Field Work

This survey of the limestones in Jefferson County was begun during the latter part of the summer of 1954, and it was essentially completed during the summer of 1956. During the 1955 field season, a portion of the work was done jointly with James R. Dunn.

The investigation included the location of natural exposures of the limestones, the determination of their identity and extent, and the plotting of this information on appropriate topographic maps. Aerial photographs were used as required. The area mapped covers approximately 660 square miles. It covers all or portions of twenty-five 7½-minute U.S. Geological Survey topographic quadrangles (Fig. 1). Each locality with a few or more scattered exposures was bounded on the maps and designated an outcrop area. All outcrop areas were not outlined precisely. Where a single bed caps a square mile or more of surface, approximation of the outcrop boundary was deemed adequate.

In addition to mapping the limestone formations, the megascopic field characteristics of these rocks were determined, stratigraphic sections were described from surface exposures and drill core, samples were obtained for laboratory study and analysis, active and abandoned quarries were examined, and priority areas for potential quarry sites were outlined.

A program of drilling the bedrock was carried on simultaneously with the geological investigation by personnel of the College of Ceramics, under the supervision of Donald A. Dickens. A total of 1,967 feet 7 inches of core was obtained from 9 localities (geologic map). Although geographic spacing, thickness of overburden, and available water were important considerations in the choice of these sites, the localities were primarily chosen to obtain as much information as possible on the total limestone section from the amount of core that could reasonably be recovered in the time that the drill was assigned to this area.

Table 1
Summary of Diamond Drilling in Jefferson County

Year	Hole No.	Section No.	Ft.	In.
1954	140	2	147	7
	141*	3	204	0
1955	142	11	260	4
	143	12	250	0
	144	8	260	3
	145	13	155	5
	146	9	230	0
1956	147	14	240	0
	148	15	220	0

*Hole No. 141 was drilled to a depth of 150 ft. 2 in. in 1954 and deepened to 204 ft. in 1956.

ACKNOWLEDGMENTS

The author sincerely appreciates the able field assistance provided by Harold Herzog in 1954, Joseph Lahoud in 1955, and Sam Stevens III in 1956. Sincere appreciation is also extended to those persons who generously allowed mapping, sampling, and exploratory drilling on their properties, which made much of the detail of this study possible. Without exception, the geological and drilling parties received courteous cooperation from the land owners and the military.

Special acknowledgment is due Donald W. Fisher, State Paleontologist, for discussing and reviewing some of the stratigraphic problems with the author in the field. Acknowledgment is also due the State University of New York College of Ceramics drill crew for occupying all of the specified borehole sites regardless of the difficulties encountered. It was a distinct pleasure to work with them.

Description of the Limestone Formations

General Statement

The rock units within Jefferson County range from the Precambrian to Ordovician in age as follows:

ORDOVICIAN SYSTEM

Cincinnatian Series
- Oswego Sandstone
- Lorraine Group
  - Pulaski Shale
  - Whetstone Gulf Shale

Mohawkian Series
- Trenton Group
  - Atwater Creek Shale
  - Deer River Shale
  - Cobourg Limestone
  - Denmark Limestone
  - Shoreham Limestone
  - Kirkfield Limestone
  - Rockland Limestone
- Black River Group
  - Chaumont Limestone
  - Lowville Limestone
  - Pamelia Dolomitic Limestone

UNCONFORMITY

Canadian Series
- Theresa Dolostone and Dolomitic Sandstone

CAMBRIAN SYSTEM

Croixian Series
- Potsdam Sandstone

UNCONFORMITY

PRECAMBRIAN

Complex of igneous and metamorphic rocks

The rocks with which this report is concerned are the Ordovician limestones of the Black River and Trenton Groups. These formations reach a combined maximum thickness of 725 to 750 feet in Jefferson County and crop out in an ever-widening belt from the Lewis County line westward across the county for 30.5 miles to Lake Ontario and the St. Lawrence River. The area immediately underlain by the limestone covers about 660 square miles and is roughly triangular in outline; Carthage-West Carthage, Clayton, and Ellisburg are situated at the eastern, northwestern, and southwestern corners of the triangle, respectively. The Black River divides the limestone area into two nearly equal parts. The formations of the Black River Group are found mostly north of the Black River. Except for an area south of N.Y. Highway 12E between Dexter and Cape Vincent, the Trenton rocks crop out south of the river.

The northern area is one of low altitude and comparatively little relief. The highest point, situated in the east-central portion of the Black River quadrangle, barely exceeds 600 feet, and the surface rolls gently downward to the west and southwest to 246 feet, the level of Lake Ontario and the St. Lawrence River. Glacial deposits may obscure the rocks locally, but there are extensive areas where the soil is very thin or bare rock is exposed. The bared limestone surfaces show considerable widening along joint cracks by solution and some small streams exhibit a tendency to go underground.

South of the Black River, the Trenton limestones crop out in a series of terraces which rise from the level of the river (514 feet at Watertown) to more than 1,180 feet above sea level in the east-central portion of the Copenhagen quadrangle.

In general, the structure is simple. There is a regional dip of 1 to 2 degrees south and southwest toward Lake Ontario, which carries the older rocks beneath the surface in that direction. Local minor flexures however, produce dips up to 35 degrees. Jointing is ubiquitous, particularly in the Black River limestones, and there are faults of local importance.

The physical characteristics, contact relations, fossil content, and composition of each formation pertinent to this study are given in the first part of this report. Sixteen detailed stratigraphic sections, obtained from drill core and selected exposures of significant vertical extent, and a summary of the structures follow the description of the limestone formations. The latter part of the report contains discussions of the testing and analyzing of samples, test specifications, development possibilities, and descriptions of potential quarry sites. Complete chemical analyses by drill hole and by formation are tabulated at the end of the paper.

Previous Work

The last report concerning the limestones and limestone quarry industries in Jefferson County was written by Ries and Eckel (1901). In the intervening years, geological investigations in this area were largely stratigraphic, being structural and faunal studies of restricted portions of the Lower Ordovician succession. The most recent and the most comprehensive reports on the rocks of Mohawkian age in northwestern New York are those by Kay (1933, 1937), Young (1943) and Chenoweth (1952). Excellent historical background is provided by Kay and Young. A brief introduction to Mohawkian stratigraphic problems is included with the Correlation Chart of the Ordovician Rocks in New York State by Fisher (1962). Other papers are cited in the list of references.

Definition of Terms

Carbonate rocks must contain 50 percent or more of calcium carbonate or of calcium and magnesium carbonates. Few such rocks are without some magnesium carbonate, present mostly as the mineral dolomite. These are the only attributes carbonates hold in common; otherwise, they may differ widely in color, texture, structure, and origin.

Considerable variation in the nomenclature of carbonate rocks exists. The term **limestone** is normally used for those sedimentary carbonate rocks in which the carbonate fraction is composed primarily of the mineral calcite ($CaCO_3$), whereas the term **dolostone** (or **dolomite**)[4] is used for those rocks in which the carbonate fraction is primarily the mineral dolomite ($CaMg(CO_3)_2$)[5].

Carbonate rocks containing mixtures of calcite and dolomite, and therefore intermediate in composition between limestone and dolostone, have been given a variety of names. Those in which calcite exceeds dolomite are generally called **dolomitic limestones**, and those in which dolomite exceeds calcite are usually called **calcitic dolostones** (or **calcitic dolomites**)[6].

Quantitative considerations must be employed to give full meaning to the limestone-dolostone series. It is the percentage of the mineral dolomite in the rock, or its equivalent in percent of magnesia (MgO) or of magnesium carbonate ($MgCO_3$) that fixes the limits for each type, but there is considerable range in these limits depending on whether the carbonate types are defined on the basis of mineral composition or according to economic specifications. In this report carbonate terminology is the result of combining these considerations, and the rocks of the limestone-dolostone series are defined as follows:

Limestone – a carbonate rock composed chiefly of calcium carbonate, but may contain as much as 10 percent magnesium carbonate.

Dolomitic limestone – carbonate rock composed chiefly of calcium carbonate but containing 10 to 23 percent magnesium carbonate.

Calcitic dolostone – carbonate rock containing from 23 to 35 percent magnesium carbonate.

Dolostone – carbonate rock with 35 to 46 percent magnesium carbonate.

The terms **high-calcium limestone** and **high-magnesium dolostone** are used without exact definition. High-calcium limestone is considered to be more than 95 percent calcium carbonate, but many commercial high-calcium limestones are often more than 97 percent calcium carbonate. Similarly, high-magnesium dolostone is more than 95 percent calcium and magnesium carbonates, of which more than 40 percent is magnesium carbonate. The limestone-dolostone series is summarized in Table 2.

Chemical determinations show that when averaged, each of the rock units discussed in this paper has the composition of limestone with the exception of the Pamelia Formation, which is a dolomitic limestone. The Chaumont Formation has sufficient calcium carbonate to be termed a high-calcium limestone. More complete information concerning the chemistry of these rocks is given in the text which follows, and in the tables at the end of the report.

A quantitative separation of the carbonate rocks according to Table 2 is not possible in the field, but a qualitative distinction may be made by application of cold dilute hydrochloric acid (7 parts of water to 1 part of acid) to a fresh surface of the rock. Effervescence caused by the release of carbon dioxide from the reaction between the dilute acid and calcite will aid in broadly distinguishing those carbonates composed primarily of calcite from those containing appreciable quantities of dolomite.

Effervescence is energetic (acid frothy) in limestone, being especially violent and audible in high-calcium limestone, but the vigor of the reaction diminishes rapidly as the dolomite content of the rock increases. There is a steady though not vigorous froth of carbon dioxide beads

[4] The term dolomite is ambiguous, as it refers to both a mineral and a rock, but attempts to restrict the name to the mineral have met with little success. The term persists and both meanings will no doubt continue.

[5] A double carbonate of calcium and magnesium which may also be written as $CaCo_3.MgCO_3$.

[6] Also referred to as **calcdolomites.**

Table 2
A Summary of Carbonate Terminology, Showing Percent of Calcite and Dolomite in Calcitic and Dolomitic Carbonate Rocks

	Calcite	Dolomite	Approximate MgO Equivalent Percent	Approximate $MgCO_3$ Equivalent Percent
Limestone	78-100	0- 22	0- 4.8	0- 10
High-Calcium Limestone	95-100	0- 5(a)	0- 1.1	0- 2.3
Dolomitic Limestone	50- 78	22- 50	4.8-11	10- 23
Calcitic Dolostone	24- 50	50- 76	11 -16.7	23- 35
Dolostone	0- 24	76-100	16.7-22	35- 46
High-Magnesium Dolostone	0- 13	87-100(b)	19 -22	40- 46 (b)

(a) No dolomite need be present; may have up to 5 percent insoluble material, but not more than 2.5 percent silica (SiO_2).

(b) The mineral dolomite is a double carbonate of calcium and magnesium, so that a dolostone with 100 percent dolomite actually contains 54 percent calcium carbonate and 46 percent magnesium carbonate.

as the composition approaches that of dolomitic limestone, and there is little or no effervescence visible to the unaided eye as the composition reaches that of calcitic dolostone unless the surface of the rock is powdered before application of the acid. A hand lens is often necessary to detect the feeble response. There is no reaction with dolostone.

Another means by which calcitic and dolomitic carbonates are broadly separated in the field involves noting the color exhibited by the fresh and weathered surfaces of these rocks. Those carbonates containing appreciable amounts of dolomite, including dolomitic limestones, are often brownish on exposed surfaces from the oxidation of small amounts of ferrous iron which have substituted for some of the magnesium in dolomite. As the quantity of ferroan dolomite in the rock increases, its presence is also recorded by a greenish cast imparted to the normally gray color of the unweathered rock.

Carbonate rocks may also be termed according to grain size (Grabau, 1932). A **calcirudite** is a limestone in which the individual particles making up the rock correspond in size to gravel (greater than 2 mm.). The term **calcarenite** refers to a consolidated carbonate rock in which the particles are of sand size (1/16 mm. to 2 mm.); **calcisiltite** indicates that the particles are of silt size (1/256 mm. to 1/16 mm.); and a **calcilutite** has particles of mud size (less than 1/256 mm.). If a **calcilutite** is extremely fine-grained, compact, homogeneous, and breaks with a smoothly curving or conchoidal fracture, it is termed a **lithographic limestone.** None of the calcilutites in Jefferson County are sufficiently dense to be considered lithographic limestone, but they may be appropriately termed **sublithographic** limestones.

The dolomitic carbonates are treated similarly. Because quantitative considerations are impossible in the field, the prefix **dolomi** is applied to any carbonate rock with sufficient magnesium carbonate so as to give little or no reaction to cold dilute hydrochloric acid. The rocks so designated are actually dolomitic limestones and calcitic dolomites, according to chemical determinations.

Shale is used as both a textural and a compositional term for all the unctuous, thinly laminated argillaceous (clayey) rocks. The shales are mostly calcareous throughout the section.

Stratification or bedding is brought about by vertical variations in the color, texture, or composition of the rocks. The terms used to describe the thickness of beds are those recommended by Ingram (1954) and given in Table 3. All bedding surfaces are not necessarily surfaces of separation. The surfaces of separation, herein termed **layering surfaces** or **layering**, define layers which may be composed of one or more beds. They are of great significance in the quarrying process.

Formations of the Black River Group

The lithic units composing the Black River Group are, from bottom to top, the Pamelia, Lowville, and Chaumont Formations. The Pamelia and Chaumont Formations have their type localities in Jefferson County. The Lowville Formation received its name from exposures at Lowville in Lewis County, New York.

Figure 2
STRATIGRAPHIC SECTIONS of BLACK RIVER & LOWER TRENTON LIMESTONES in JEFFERSON COUNTY, NEW YORK

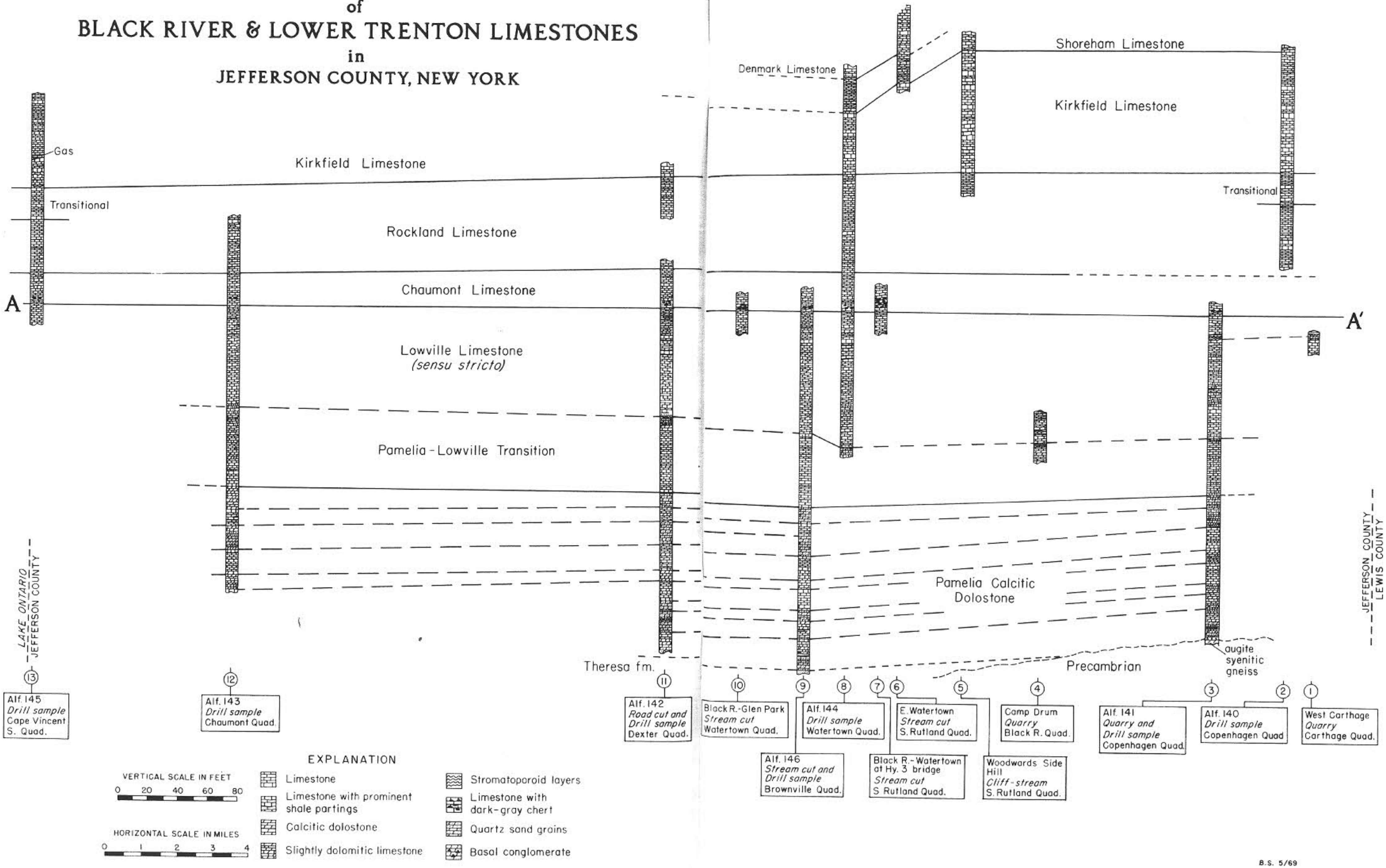

Table 3

Classification of the Thickness of Stratification

Thickness of Unit Metric System	English System	Terms for Thickness
-0.3 cm.	-1/10 in.	Thinly laminated
0.3-1.0	1/10-2/5	Thickly laminated
1-3	2/5 -1	Very thinly bedded
3-10	1-4	Thinly bedded
10-30	4-12	Mediumly bedded
30-100	1-3 ft.	Thickly bedded
100-	2/53-	Very thickly bedded

The rock colors refer to those given in the **Rock-Color Chart,** published in 1948 by the National Research Council.[7]

Underlying Rocks

The Theresa Formation, of Early Ordovician age, is recognized beneath the Black River Group everywhere in Jefferson County along the belt of Pamelia outcrop except in the extreme eastern portion. It has long been known from field studies that the Theresa Formation wedges out and disappears to the south, for the position of the Pamelia in the cliff section along the southwestern bank of the Black River at West Carthage permits little, if any, room for the Theresa between the Pamelia and the Precambrian rocks exposed in the bed of the river at this locality. Furthermore, at East Martinsburg (p. 29) in Lewis County, about 20 miles south-southeast of West Carthage, the calcitic and dolomitic arkosic carbonates at the base of the Pamelia Formation lie directly on hornblende biotite gneiss or gneissic granite of Precambrian age.

Additional information on the extent of the Theresa Formation was obtained during the course of this survey. Core obtained from the drill hole located in the Town of Champion Quarry (Section 3, Alf. 141), 1 mile east of Champion Huddle and 2.5 miles northwest of the Lewis County line (NE/4 Copenhagen quadrangle), showed the Pamelia Formation resting unconformably on hornblende-bearing gneiss of Precambrian age, whereas 3.5 miles north of Watertown (Section 9, Alf. 146, SE/4 Brownville quadrangle), the drill core revealed dolomitic sandstone of the Theresa Formation below the carbonate rocks at the base of the Pamelia. The Theresa Formation, therefore, wedges out and disappears in the eastern part of Jefferson County within the 12-mile interval separating these drill holes. Its subsurface limits to the west and southwest, however, are still unknown.

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[7]**The Rock-Color Chart** was reprinted in 1963 and may be obtained from the Geological Society of America, P.O. Box 1719, Colorado Bldg., Boulder, Colorado 80302.

The Pamelia Formation

General Statement

The Pamelia Formation was defined by Cushing (1908, p. 158) from scattered exposures in Pamelia Township, Jefferson County, New York, where the entire sequence is obtained by piecing together partial sections. Cushing **et al.**, (1910, pp. 72-75) indicated that the lower part of the formation is exposed best along Lowell Creek in LeRay Township, 2 miles east of Perch Lake (NW/4 Black River quadrangle), and that the upper part of the formation is viewed to best advantage 1 mile southwest of Depeauville in Clayton Township (SE/4 Clayton quadrangle) and in the railroad cut 1 mile southwest of Calcium, LeRay Township (SW/4 Black River quadrangle). Oddly enough, none of these "best" sections occur within the limits of Pamelia Township.

Distribution

The Pamelia Formation extends from about Boonville, in northern Oneida County, northwestward along the Black River Valley to the Thousand Islands region. Interrupted by the St. Lawrence River, it continues westward across Canada, at least to Hastings County in southeastern Ontario. Thus the Pamelia is continuous through Jefferson County; it is present as an irregular belt with a maximum width of about 6 miles. Glacial deposits obscure the rock in most places, but outcrop areas within the county are shown on the geologic maps.

Stratigraphic Relations

Lower Contact – Throughout most of Jefferson County (essentially that part north of the Black River) the Pamelia rests disconformably on the Theresa Formation; elsewhere along the belt of outcrop it lies nonconformably on various Precambrian crystalline rocks. Apparently the Pamelia sea encroached upon a hilly Precambrian surface in which the depressions had been partly filled by Cambrian or pre-Middle Ordovician sediments. The lithology of the basal Pamelia reflects the character of the underlying rocks.

When fresh, lowest Pamelia consists of medium dark gray (N4) to medium gray (N5) calcisiltites and occasional calcilutites, often with a slight olive tinge, interbedded with greenish gray (5GY6/1 and 5G6/1) or medium gray to medium light gray (N6) dolomisiltites which are frequently mottled grayish red (10R4/2). Weathering generally lightens the grays and greens about a shade, and the red coloration is often lost. Core samples show that zones of quartz sand grains are fairly common throughout the Pamelia succession, but the sandy nature of the formation is not so evident in field exposures except in the basal 10 to 15 feet, where concentrations of quartz sand may result in thin layers of calcareous or dolomitic sandstone. These lowest beds are seldom exposed because of their weakness.

The best localities to examine basal Pamelia lithology are in the bed of Lowell Creek on the north side of the northwest-trending secondary road, 0.75 of a mile west of N.Y. Highway 37, in the extreme northwestern corner of the Black River quadrangle (described by Cushing, 1910, pp. 72-73); and in the bank of Gillette Creek near the south margin of the Theresa quadrangle, 0.75 of a mile northeast of Cushing's locality. A partial section along Gillette Creek is as follows:

Pamelia Formation

	Ft.	In.
5. Greenish-gray (5GY6/1), pale red (10R6/2)-mottled dolomisiltite which weathers light olive gray (5Y5/2). Full thickness not exposed	3	
4. Greenish-gray (5G6/1) shale; contains scattered quartz grains of sand size	2	
3. Greenish-gray (5G6/1) to grayish-green (5G5/2), crumbly calcareous sandstone which weathers pale to moderate yellowish-brown (10YR6/2 to 10YR5/4)		6
2. As submit 4		6
1. Greenish-gray (5G6/1) calcareous sandstone which weathers pale yellowish-brown (10YR6/2), quartz sand grains well rounded	2	

Theresa Formation

Slightly more than 3 feet of highest Theresa were penetrated by a diamond drill (Alf. 146, Section 9) immediately east of U.S. Highway 11, 3.5 miles north of Watertown. Here the Theresa Formation consists of dark gray (N3) to medium dark gray (N4), saccharoidal sandstone which is mottled and sometimes banded very pale orange (10YR8/2). About 6 miles to the northwest, in the falls of Pleasant Creek on the west side of U.S. Highway 11 at Evans Mills (NE/4) Black River quadrangle, the upper portion of the Theresa Formation is composed of hard, medium light gray (N6), calcareous sandstone characterized by small "glittering" cleavages of calcite. The sandstone is almost "bluish-gray" in contrast to the olive and green coloration typical of the overlying Pamelia, and it quickly develops an olive gray (5Y4/1) to moderate yellowish-brown (10YR5/4) and grayish-orange (10YR7/4) rind on weathering which averages 1/16 inch thick.

Like the basal Pamelia, the upper beds of the Theresa Formation also vary in composition, ranging from calcareous sandstone and dolomitic sandstone to sandy dolomite. It is usually difficult to be absolutely certain of the Pamelia-Theresa contact. At many places where the contact is theoretically crossed, the rocks below the contact are not significantly different from those above. Although broad distinction of the rocks comprising these formations is not hard, any few beds of Theresa may be difficult to distinguish from any few beds of lowest Pamelia. The placing of the contact is, therefore, somewhat arbitrary. It is drawn below the greenish-gray (5G6/1 and 5GY6/1), often shaly, predominantly arenaceous dolomitic limestones typical of the basal Pamelia, and above the calcareous and dolomitic sandstones which lack the green color and are characterized by a "rusty-brown" weathering rind.

Nowhere in Jefferson County is there a natural exposure showing the Pamelia in contact with rocks of Precambrian age, but in the Roaring Brook section along N.Y. Highway 12 near East Martinsburg, Lewis County, 4 miles southeast of Lowville, it is possible to examine the Pamelia-Precambrian boundary, as well as all the formations from the Precambrian up into the Trenton without gaps in the section (see Young, 1943, p. 223). The contact relations in Jefferson County, as observed in drill core (Alf. 141) are as follows:

Pamelia Formation	Ft.	In.
5. Greenish-gray (5G6/1) dolomisiltite containing abundant quartz grains of sand size		4
4. Medium light gray (N6) calcisiltite mottled greenish-gray (5G6/1) near base; contains a few well-rounded quartz sand grains	1	0
3. Greenish-gray (5G6/1) to intermediate between greenish-gray and light greenish-gray (5G8/1) dolomisiltite; contains abundant rounded quartz grains of sand size and a few small inclusions of pale reddish-brown (10R5/4) feldspar	1	1
2. Basal conglomerate; greenish-gray (5G6/1), arenaceous dolomisiltite containing inclusions of hornblende-bearing gneissic granite up to 2 inches in diameter		4
Precambrian		
1. Hornblende biotite gneissic granite; pale-reddish-brown (10R5/4) feldspar, dusky-green (5G3/2) hornblende; quartz very rare	3	8
Bottom of Hole		

Upper Contact – The Pamelia-Lowville contact is difficult to draw; its position is also debatable. Close examination of the drill cores revealed that uppermost Pamelia, as apparently distinguished by Cushing (1908), is marked by the first appearance of quartz sand grains in pale green (5G7/2) calcisiltite which frequently contains dark greenish-gray (5G4/1) to greenish-gray (5G6/1) shale partings. This distinctive zone is present in all core sections and serves as a marker horizon. If it is considered the Pamelia-Lowville boundary, upper Pamelia is not notably dolomitic, but contains mostly calcilutites typical of the overlying Lowville (Fig. 1) Unfortunately it is not easily detected in the field. The green color is generally lost on weathering and the sand grains are not sufficiently abundant to spot readily. When exposures of light gray (N7)–weathering calcilutites only a few feet thick are encountered in the field, unless it is known that they are well up in the Lowville section, the beds must be considered either Pamelia or Lowville. In several outcrop areas, what is presumed to be the pale green zone in drill sections is marked by pale red (10R6/2) mottling, probably as a result of the reduction of ferric to ferrous iron. It was believed that the pale red mottling could be taken as the top of the Pamelia Formation, for none of the overlying beds were found to have this characteristic. The red coloration, however, can be used as a marker only locally. If the pale green (or pale red) sandy zone is designated the top of the Pamelia, the thickness of the Pamelia and Lowville Formations from east to west across the county is as follows:

	Pamelia		Lowville	
Drill Hole	Ft.	In.	Ft.	In.
Alf. 141	136	1	80	11
Alf. 144			89	10
Alf. 146	157	6	81	5
Alf. 142			72	½
Alf. 143			68	0

For surface mapping, the pale green (or pale red) sandy zone is unsatisfactory as a means of separating the Pamelia and the Lowville Formations.

The appearance of the first dolomitic bed (that which contains sufficient magnesium to give very little or no reaction when treated with dilute hydrochloric acid) downward in the section was also investigated as a means of separating the Pamelia and Lowville Formations. It, too, is generally not evident in field exposures primarily because of the lack of any vertical extent (generally only a few inches thick), and it does not appear everywhere at the same stratigraphic horizon. If the first appearance of dolomitic rock downward is taken as the Pamelia-Lowville boundary, the thicknesses of the formations are as follows:

	Pamelia		Lowville	
Drill Hole	Ft.	In.	Ft.	In.
Alf. 141	109	3	107	9
Alf. 144			89	10
Alf. 146	107	1	131	10
Alf. 142			78	1½
Alf. 143			74	7

The "upper dolomitic bed" is also unsatisfactory as a means of separating the Pamelia and Lowville Formations.

The contact may also be placed at the appearance of the first thick sequence dolomitic limestone downward, which is easily distinguished in the field because it is generally gritty in texture and weathers a conspicuous pale yellowish-brown (10YR6/2). This dolomitic limestone sequence marks the top of a mappable unit which is frequently exposed along the belt of outcrop. It gives to the formations thicknesses as follows:

	Pamelia		Lowville	
Drill Hole	Ft.	In.	Ft.	In.
Alf. 141	95	2	121	10
Alf. 146	107	1	131	10
Alf. 142	110 (estimated)		123	3.5
Alf. 143			121	2

The top of this distinctive dolomitic limestone sequence is considered the top of the Pamelia Formation for obvious reasons. It serves to delimit a series of carbonate rock that (1) is largely dolomitic, (2) contains a higher percentage of silica than the overlying rock, much of which is present as silt- and sand-sized grains of quartz, and (3) is more easily recognized and mapped particularly by persons without geological training. The Pamelia Formation **sensu-stricto** (as originally identified by Cushing, 1908) has not been redefined. The Upper Pamelia beds, which are lithologically more like the Lowville even though they contain occasional thin layers of dolomitic limestone, are mapped with the Lowville Formation but are distinguished from the Lowville **sensu-stricto** on the correlation chart (Fig. 2) by the designation Pamelia-Lowville "transition."

General Description

The Pamelia Formation, as restricted, consists of greenish-gray (5G6/1 and 5GY6/1) to dark greenish-gray (5G4/1) and intermediate between medium gray (N5) and medium light gray (N6) dolomisiltite interbedded with dark gray (N3) to medium light gray calcilutite and minor medium dark gray (N4) to medium light gray, sometimes dark greenish-gray calcisiltite. The green dolomisiltites are occasionally mottled grayish-red (10R4/2) or pale red (10R6/2); the gray dolomisiltites are occasionally mottled pale green (10G6/2). Weathering tends to lighten the colors a shade and the lighter greens may be lost. Dark gray (N3) and dark greenish-gray (5G4/1), generally calcareous, paper-thin shale partings are common. Shaly zones, 0.5 inch to 2 inches thick, are rare. The shales, and sometimes the dolomisiltites, may show mud cracks and ripple marks. Rounded quartz grains, mostly of sand size, are fairly common throughout the Pamelia succession, particularly in the dolomisiltites. The base of the formation is the sandiest, and thin beds of light olive gray (5Y6/1) sandstone may form where concentration of quartz is the heaviest. In weathered sections the bedding surfaces range from 1/16 inch to 13 inches apart, but the average separation is only 2 or 3 inches. The surfaces are usually flat and smooth. Layers are 1 to 8 inches thick.

The Pamelia contains a small fauna. The forms are typically marine, and most of them are found in the darker gray calcilutites and calcisiltites. The one distinctive form is the coral **Tetradium syringoporoides** Ulrich. Small ostracodes occur at various horizons. A list of the fossils common to the formation has been given by Young (1943, pp. 233-236).

Composition

The Pamelia Formation, on the average, contains 71.79 percent carbonate, of which 59.1 percent is calcium carbonate and 12.69 percent is magnesium carbonate (6.07 percent MgO). The formation as a whole is dolomitic limestone (Table 2), although many beds throughout the Pamelia succession are limestone and several beds near the base contain sufficient quartz sand to be termed calcareous or dolomitic sandstone.

The CaO content ranges from 18.5 to 49 percent, and MgO from 2.3 to 11.3 percent. Although iron oxide is present in amounts greater than in any of the other formations in the entire carbonate sequence, it does not exceed 4.2 percent and may be as low as 0.24 percent. The greatest amount of iron occurs in the dolomitic limestones. Additional chemical data may be found in Tables 14, 16, 17, 18, 22, and 29 at the end of the report.

The Lowville Formation

General Statement

The Lowville Formation was named for Lowville, Lewis County, New York, by Clarke and Schuchert (1899). It is the "Birdseye Limestone" of earlier workers. The term "Birdseye" was given to the formation because distinctive calcite-filled circular cross sections of the presumed worm-boring **Phytopsis tubulosa** are common on the surface of the rock. No section for the type locality was described until Cushing and others (1910, p. 83) detailed the section at Lowville.

Distribution

The Lowville Limestone is the most persistent of the Black River formations, extending throughout the areas of Mohawkian outcrop in most of New York and Canada. It is continuous from the Fort Plain-Nelliston area, Montgomery County, New York, in the Mohawk Valley along the belt of Mohawkian rocks through Jefferson County and southern Ontario. In the extreme eastern portion of the county, the Lowville Formation is present in a narrow belt less than a mile wide, but westward, like the underlying Pamelia, it crops out as an irregular belt of varying width with a maximum of about 6 miles. Many excellent exposures may be studied along the Black River between Deferiet and Brownville and in the region north of Watertown. There are numerous exposures in the vicinity of Dexter, Limerick, and Chaumont, particularly in small abandoned quarries.

Stratigraphic Relations

Lower Contact — The Pamelia-Lowville contact has been discussed with the Pamelia Formation. One of the main objectives of the limestone study is to delineate mappable units which are sufficiently distinct so that quarry operators and other persons with limited or no geological background can recognize them easily. Beds regarded as Upper Pamelia by other workers (Cushing, 1908; Cushing **et al.**, 1910; Young, 1943) have therefore been mapped with the Lowville Formation but separated on the correlation chart (Fig. 2). The lower part of the Lowville as mapped is designated Pamelia-Lowville transition and the upper part is designated Lowville **sensu-stricto.** Separation of Pamelia-Lowville transition from Lowville **sensu-stricto** is made possible largely by the availability of drill core; it is not easily done in the field.

Upper Contact – The Lowville-Chaumont contact is well exposed and easily distinguished in the field. It serves as a valuable reference horizon. The features which serve best to separate the formations are as follows:

1. **Color** – The Lowville Formation ranges from dark to medium gray (N3-5), often with an olive gray (5Y4/1) to light olive gray (5Y6/1) cast, when fresh, and it weathers medium light gray (N6) to light gray (N8). In portions of the county, uppermost Lowville weathers nearly white (N9). The Chaumont Limestone is medium dark gray (N4) to medium gray and weathers a shade or two darker than the Lowville.
2. **Chert and silicification** – The Lowville Formation contains no chert or silicified fossils whereas the lower part of the Chaumont Formation is characterized by partially soluble dark gray (N3) nodules of chert generally flattened parallel to the plane of the bedding. Below the cherty portion of the Chaumont Limestone there is a persistent "transition zone" 2.5 to 3 feet thick, without chert, but with silicified fossils. The base of this zone marks the Lowville-Chaumont contact.
3. **Topographic expression** – Because of the contained silica, the lower part of the Chaumont Formation is more resistant to erosion than is the upper part of the Lowville Formation. It forms a prominent sinuous ledge, 3 to 10 feet high, above the Lowville "plateau" throughout most of the outcrop area. In some cases, a few feet of lower Chaumont cling in irregular patches to the Lowville forming small outliers in the belt of Lowville Limestone.
4. **Character of the weathered surface** – In vertical sections, the exposed edges of beds of Chaumont Limestone become rough and irregular on weathering. The Lowville is comparatively smooth on the weathered edges and more noticeably layered. The "bread crust" character of weathered Chaumont is of no value if a single bed caps a large area so that only a single bedding surface is seen.
5. **Contact springs** – In many localities, springs issue from the Lowville-Chaumont contact (p. 61) and they are an effective aid in determining the position of the boundary. Where the springs are seasonal, the hummocky character of the soil developed on the Upper Lowville surface near the contact suggests a generally more moist environment.
6. **Characteristic fossils** – Upper Lowville is typified by distinctive tubular structures **(Phytopsis)** which are filled with coarse white calcite. These structures are responsible for the name "Birdseye Limestone." **Phytopsis** is absent in the Chaumont Limestone. The Chaumont contains conspicuous large straight-shelled nautiloid cephalopods which are usually seen on any exposed bedding surface. The most distinctive form is **Gonioceras**, which resembles the skeleton of a fish. (See p. 23).

Any of these features is usually sufficient to separate the Lowville and the Chaumont Limestones.

One of the most accessible localities to view this contact is in the north bank of the Black River opposite he filtration plant at Watertown (Section 7). Similar ections may be studied along the Black River immediately south of the N.Y. Highway 3 bridge at the village of Black River (SE/4 Black River quadrangle); below the dam across the Black River at Glen Park (NW/4 Watertown quadrangle); and in the Town of Champion quarry, 1 mile east of Champion Huddle (NE/4 Copenhagen quadrangle). A detailed description of the sequence at the last-named locality is given in Section 3.

Cushing (1910, p. 85) indicated that the Chaumont Limestone lies unconformably on the Lowville Limestone. The formations appear to be conformable, but the nearly white-weathering calcilutite which marks uppermost Lowville in many areas is not everywhere present, suggesting that the relationship may be disconformable in some portions of Jefferson County or that facies changes are responsible for differing lithologies at the contact.

Thickness

The thickness of the Lowville Formation is fairly constant from east to west across the county as follows:

Drill Hole	Pamelia-Lowville transition		Lowville sensu-stricto		Total	
	Ft.	In.	Ft.	In.	Ft.	In.
Alf. 141	40	11	80	11	121	10
Alf. 144			89	10		
Alf. 146	50	5	81	5	131	10
Alf. 142	51	3	72	½	123	3½
Alf. 143	53	2	68	0	121	2

General Description

The Lowville Formation is more variable lithologically from bottom to top than are the Pamelia Formation, as restricted, and the Chaumont Formation.

Pamelia-Lowville Transition – This unit is composed of approximately equal amounts of medium dark gray (N4) to medium gray (N5) calcilutite and calcisiltite, with minor amounts of medium light gray (N6) dolomisiltite. The dolomites are sometimes vaguely mottled greenish gray (5G6/1), but the greens typical of the thick dolomitic sequences in the underlying Pamelia are absent. Weathering generally lightens the fresh colors about a shade. Dark gray (N3), occasionally greenish-gray, paper-thin shale partings, 1/16 inch to 6 inches apart, are common. They are closest together in the calcisiltites. Stylolites are found in the calcilutites. Mud cracks and ripple marks occur now and then in the shales. Zones of breccia (or limestone conglomerate) are minor. Rounded grains of quartz sand may be disseminated through the succession, but drill cores showed that in all cases the top of the Pamelia-Lowville transition is sandy and mottled greenish gray. This boundary is not easily defined in the field, but in any area where a 5- to 10-foot exposure exists the rock can be distinguished with some assurance. The difficulty is that most of the Pamelia-Lowville transition is similar to Lowville **sensu-stricto** in appearance, and enough beds must be exposed to permit determination of the unit. The differentiation suffers because identification of the Lowville **sensu-stricto** is negative, i.e., defined by the absence of certain characteristics, and it is not always easy to know how much section should be seen before a characteristic can be considered absent.

Although the Pamelia-Lowville transition is not notably dolomitic, correlation shows that it becomes more dolomitic and sandier westward.

Lowville Sensu-stricto – Lowville **sensu-stricto** is the typical "dove gray," **Phytopsis**-bearing "Birdseye Limestone" of earlier workers. On fresh surfaces it ranges from dark gray (N3) to medium gray (N5), usually with an olive gray (5Y4/1) to a light olive gray (5Y6/1) tinge. The weathered surface is medium light gray (N6) to light gray (N8) and occasionally may be nearly white (N9). Calcilutites are the most common rock type, while calcisiltites are present in lesser quantity. Thin, generally wavy, shale partings separate the limestone beds and are 1/8 inch to 7 inches apart. Prominent layering surfaces are 1 to 5 feet apart. Shaly zones are common. Minor zones of quartz sand occur throughout the Lowville **sensu-stricto**, particularly in the eastern portion of the county, but they are not easily detected. Breccias of calcilutite are present, especially in the lower half, and they are associated with undulatory or irregular lensing beds. A breccia is difficult to detect in drill core or on a fresh surface in natural exposures; it is quite evident on a weathered surface.

The upper half of the Lowville **sensu-stricto** contains a larger percentage of the medium gray **Phytopsis**-bearing limestone and tends to be more thickly bedded, whereas the lower half has a higher percentage of mud cracks and ripple marks and is more thinly bedded. Within the upper half, however, there is a 2.5- to 3-foot layer of thin-bedded, shaly limestone which weathers to a platy rubble. This layer is found about 10 feet below the Lowville-Chaumont contact and serves as a local marker horizon. It is not easily detected in drill core.

The Lowville **sensu-stricto** is more fossiliferous than any of the subjacent units. The characteristic calcite-filled worm boring **Phytopsis tubulosa** and the coral **Tetradium cellulosum** are the most common forms. Although **Tetradium** occurs in the Pamelia, as restricted, and the Pamelia-Lowville transition, the species **T. cellulosum** may be confined to the Lowville **sensu-stricto.** Cushing **et al.,** (1910, p. 80) pointed out that the upper beds contain a greater number of **T. cellulosum** and larger **Phytopsis.** In general this is true. The orthoconic cephalopod **Michelinoceras? multicameratum** Emmons is a guide to the Lowville **sensu-stricto.** It is prevalent in the upper part of the formation. Many of the forms in the upper Lowville weather a conspicuous grayish orange (10YR7/4).

Stromatoporoids occur at various horizons in the Lowville **sensu-stricto.** A prominent layer containing these forms is found 2 feet below the top of a partial section exposed in the small quarry at West Carthage (Section 1). A similar layer is present in the Town of Champion quarry (Section 3); the Town of Lyme quarry (SW/4 Dexter quadrangle) immediately south of N.Y. Highway 12E, 3 miles northwest of Limerick; and the quarry (NE/4) Chaumont quadrangle) on the east side of the Chaumont River, 0.25 mile north of Chaumont, where it is 13, 16, and 17 feet below the top of the Lowville Formation, respectively. Stromatoporoids cap an extensive area on the hill summit east of N.Y. Highway 37, one mile north of School No. 1 (SE/4 Brownville quadrangle). A more complete listing of the Lowville fauna has been given by Young (1943, pp. 233-236).

In general the Lowville **sensu-stricto** may be distinguished from the Pamelia-Lowville transition by:

1) Absence of dolomitic beds
2) Less regular bedding
3) Absence of green or pale red coloration
4) More abundant **Phytopsis**
5) Presence of **Tétradium cellulosum** and **Michelinoceras ("Orthoceras") multicamerathum**

Composition

The average carbonate content of the entire Lowville succession is 87.06 percent, with 81.38 percent of the rock composed of calcium carbonate and 5.68 percent composed of magnesium carbonate. The magnesium oxide content is 2.72 percent. Thus the Lowville Formation, as a whole, is limestone.

The Lowville Limestone contains appreciably more magnesium in the lower portion of the formation. This is due to the presence of occasional thin interbeds of dolomitic limestone which permit separation of the rock sequence that has been designated Pamelia-Lowville transition.

The Pamelia-Lowville transition beds average 84.35 percent carbonate, of which 75.72 percent is $CaCO_3$ and 8.63 percent is $MgCO_3$ (4.13 percent MgO), whereas the upper sequence termed the Lowville **sensu-stricto** averages 89.78 percent carbonate with 87.04 percent $CaCO_3$ and 2.74 percent $MgCO_3$ (1.31 percent MgO).

The Pamelia-Lowville transition generally carries more silica; in some beds the silica, mostly present as quartz sand grains, accounts for 21.1 percent of the rock by weight.

Complete chemical analyses for individual 10-foot sequences in the drill holes that penetrated a part or all of the Lowville Formation may be found in Tables 14 through 18 and the averaged analyses for each of the subdivisions and the formation as a whole appear in Table 23. Maximum and minimum values for the more important oxides are tabulated in Table 29 (p. 87).

The Chaumont Formation

General Statement

The Chaumont Limestone (Kay, 1929, p. 664) takes its name from the area around Chaumont Bay in Jefferson County, New York. It is the youngest of the Black River formations. In the vicinity of Watertown, especially along the Black River, there are approximately 13 feet of noncherty, dark gray (N3) to medium dark gray (N4) calcilutite and calcisiltite, to which Cushing **et al.**, (1910, pp. 84-85) gave the name Watertown Limestone. The upper portion is exceedingly pertroliferous and subsequent work by Young (1943, p. 210) showed that the highest few feet are actually basal Rockland (lowest Trenton) Limestone. Beneath the Watertown Limestone occur about 13 feet of very cherty calcilutite and calcisiltite which were called the LeRay Limestone by Cushing **et al.**, (op. cit., p. 85) and designated the top member of the Lowville Formation. Kay (op. cit., p. 664) divorced the LeRay Limestone from the Lowville Formation and considered it the lower member of the Chaumont Formation.

Except in the vicinity of Watertown, the LeRay and Watertown members are not lithologically distinguishable. Throughout the county the distribution of chert is highly inconsistent, and in Ontario, Canada, chert is equally common to the upper part of the formation. The LeRay and Watertown members were not separated in the field.

Distribution

The Chaumont Limestone is typically represented in northwestern New York and southern Ontario. Because it is more resistant than the underlying Lowville Limestone and the overlying Trenton limestones it forms a terrace 1 to 5 miles wide, which is bounded on the north by a sinuous scarp with many finger-like extensions.

Many excellent exposures are found throughout the belt of outcrop. In addition to nearly continuous exposures along the Black River, good sections may be seen in the General Crushed Stone quarry immediately north of N.Y. Highway 3 at Watertown (NW/4 South Rutland quadrangle); in the abandoned town quarry (now used as a firing range) on the east side of U.S. Highway 11, 2.25 miles north of Watertown (SE/4 Brownville quadrangle); and in the many small abandoned quarries in the vicinity of Chaumont.

Stratigraphic Relations

The lower contact is discussed with the Lowville Formation (p. 14) and the upper contact is taken up in the section on the Rockland Formation (p. 19).

Thickness

In general, the Chaumont Limestone thins regularly westward. Thicknesses obtained from drill core are as follows:

Drill Hole	Thickness Ft.	In.
Alf. 144	25	1
Alf. 142	25	5½
Alf. 143	20	0
Alf. 145	20	9

General Description

The Chaumont Limestone is predominantly medium dark gray (N4) to medium gray (N5), hackly fracturing, cherty calcilutite and fine calcisiltite which characteristically weathers to a light gray (N7) "bread crust" surface because of anastamosing argillaceous seams. The bedding surfaces are highly irregular in detail although the broad bedding units are regular strata. Individual beds are 1 to 5 inches thick. The "bread crust" character of the weathered surface is evident only on the exposed edges of the beds.

The base of the formation is marked by a persistent fossiliferous zone of medium dark gray (N4), irregularly-bedded calcisiltite, which weathers light gray to intermediate between light olive gray (5Y6/1) and yellowish gray (5Y8/1). The fossils are silicified and the unit is essentially without chert. It overlies the Lowville Formation everywhere in Jefferson County and is an invaluable aid in determining the Lowville-Chaumont contact. Immediately above the zone of silicified fossils the Chaumont contains dark gray (N3) and occasionally brownish-gray (5YR4/1) chert in the form of irregular nodular masses which are flattened parallel to the bedding surfaces and often form horizons of partly continuous chert. The chert is particularly prevalent in the lower half of the formation in the Watertown region; in the rest of the county it is mostly restricted through a few feet above the silicified fossil zone. The upper part of the formation is lithologically similar to the lower part, except that the grain size appears to decrease slightly and it lacks the chert. In the Watertown area, the upper beds are darker gray.

The Chaumont is easily distinguished in the field by its fauna. The formation is best known for its cephalopods; only a few species are represented, but they are numerous. The most abundant form is **Actinoceras tenuifilum** (Hall). Species of **Endoceras,** of which **E. subcentrale** Hall has been most commonly observed, are abundant and conspicuous because of their large size. **Gonioceras anceps** Hall is distinctive, for it resembles the skeleton of a fish when the siphuncle and septa are exposed by weathering.

Tetradium fibratum Safford is the only species of **Tetradium** in the Chaumont Formation, but this form is found in the Lowville too. Corals, stromatoporoids, brachiopods, gastropods, and trilobites are also present. In many localities along the Black River where the cherty beds are exposed, the fossils may weather to a dark yellowish orange (10YR6/6) or grayish orange (10YR7/4), as is also the tendency, to a lesser extent, of the fossils in the upper part of the Lowville Formation.

Composition

The Chaumont Formation has sufficient calcium carbonate to be considered high-calcium limestone. The average carbonate content, based on analyses from Drill Holes Alf. 142-145 is 96-96 percent; 95.5 percent is $CaCO_3$ and 1.46 percent is $MgCO_3$ (0.7 percent MgO).

The limestone contains an average of 1.65 percent SiO_2, but it may carry higher amounts of silica locally due to varying concentrations of chert. Very little nodular chert was penetrated by the drill. The iron content is extremely low; a combined average indicates 0.46 percent Fe_2O_3.

Additional data relating to the chemistry of the Chaumont Limestone is given in Tables 15, 17, 18, 19, 24, and 29.

Limestone Formations of the Trenton Group

The evolution of Trenton nomenclature is complex (Kay, 1937, 1942; Chenoweth, 1952). The limestone phase of the Trenton Group, as considered in those published accounts, comprises five formations which are from base to top, the Rockland, Kirkfield, Shoreham, Denmark, and Cobourg limestones.* That subdivision of the Trenton is adhered to so far as is possible in this paper. There is, however, difficulty in delineating these units in Jefferson County. Lithologic similarity of much Trenton limestone frequently necessitates the use of faunal evidence as a basis of recognition; that is, where lithic characteristics are not distinguishable the geographic names of the individual divisions apply to biostratigraphic units, a practice which is most undesirable. Although certain gross features may broadly separate the formations in the field, precise determination of the boundaries cannot always be made. Consequently the validity of the Trenton limestone divisions is questioned, and over large portions of the area under discussion the limestones are not mappable units. In drill cores, where fossils are rarely recovered and distinction relies on physical characters, even broad separation is nearly impossible, so that the placing of the "formational" boundaries must be somewhat arbitary.

Not only are the formational contacts between the limestones within the Trenton Group difficult to detect, but there is a lack of significant sections at the Black River-Trenton boundary, which precludes precise location of the base of the Trenton succession. The contact between the Cobourg Limestone and the overlying shales is sharp, but hidden beneath glacial deposits over a large part of the area. The Trenton limestones are, therefore, best designated as a single map unit; i.e., indicated by a single color, but each of the "formational" boundaries, excepting that between the Denmark and Cobourg (p. 26) is drawn as accurately as is possible.

Topographic expression is often useful in distinguishing the limestones of the Trenton Group. The formations may crop out in a series of conspicuous terraces. In general, the break in slope from one terrace upward to the next marks the approximate position of the contact between adjoining limestone units.

*There is some doubt whether the true Kirkfield of Kirkfield, Ontario occurs in New York. B.A. Liberty of the Geological Survey of Canada believes that it does not.

Clay seams composed of "altered volcanic materials and related clays" have been found at several horizons in the Black River-Trenton succession by Kay (1930, 1931, 1935, and 1937), who called them "metabentonites," even though the term carries an erroneous connotation (1935, p. 226). Save for a single occurrence, all of Kay's metabentonite localities are outside of Jefferson County. The one exception is reported by him (1937, p. 252) to occur in the face of a small abandoned quarry not more than a few feet deep, one mile (actually 2 miles) east of Dexter, which is the site of Drill Hole Alf. 142 (see Section 11). This clay seam was designated the Hounsfield Metabentonite by Kay (1931, p. 253), and is described as not more than ½ inch thick, 3 feet above the base of the Rockland Limestone (1937, p. 253). This writer was unable to find this thin clay layer. It may have weathered out over the years or it may have been completely obscured by vegetation. Drill Hole Alf. 142, situated a few yards north of the quarry, began 3 feet 7 inches above the base of the Rockland. The first few feet of core were thoroughly examined for the metabentonite seam but it was not found. In fact, careful inspection of all of the Jefferson County core (nearly 2,000 feet) revealed no trace of metabentonites. Either none were penetrated or the clays were washed out in the drilling process. There was no concentrated effort to search for seams of altered volcanic ash, since ashfalls mark lines of contemporaneity which have no bearing on the delineation of rock-stratigraphic units that are known to be time-transgressive, nor do they serve as a measure of the economic potential of the limestone, the main goal of this study.

The limestone formations of the Trenton Group have a combined maximum thickness of about 475 feet in Jefferson County.

The Rockland Formation

General Statement

The type section of the Rockland Limestone is exposed in the valley of the Ottawa River near Rockland in Russell County, Ontario, about 25 miles east of Ottawa. Kay (1937, pp. 252-256) distinguished two separable subdivisions in southeastern Ontario and northwestern New York. The Selby Member, named for exposures along Selby Creek in Lennox and Addington County, Ontario, was defined to include those beds at the base of the Rockland Limestone characterized by the brachiopod **Doleroides ottawanus** Wilson, whereas the Napanee Member (type section 1 mile north of Napanee, Lennox and Addington County, Ontario) was defined to include the beds overlying the Selby and underlying the Kirkfield Limestone. In southeastern Ontario and northwestern New York, the top of the Napanee (and thus the Rockland) is considered to be the highest bed in which the distinctive brachiopod **Triplesia cuspidata** (Hall), which because of its prominent incurving beaks and general appearance is thought by some to resemble a bicuspid tooth, occurs. In Jefferson County, Kay (ibid, p. 253) reported the Selby 7 feet 10 inches thick and the Napanee 56 feet thick (see Section 11).

Only the upper 4 feet of the Selby are exposed in the type section thereby concealing its contact with the subjacent Black River limestones, but the basal beds of the overlying Napanee are readily distinguished in having prominent shaly partings and an abundance of the brachipods **Paucicrura-Dalmanella rogata** (Sardeson) and **Sowerbyella curdsvillensis** (Foerste), species that are uncommon in the Selby. The members are not separated in this study, primarily because of the lack of exposures and because they are not distinguishable in drill core. Wherever the drill penetrated the Rockland-Chaumont boundary, the core showed limestone of Chaumont lithology that gradually became shalier upward until typical Napanee lithology prevailed. Insofar as economic considerations are concerned, the lowest portion of the Rockland Limestone is more closely allied to the Chaumont on the basis of its chemistry and physical characteristics.

Distribution

The Rockland Formation is present along the belt of Trenton outcrop from the Boonville area in northern Oneida County northwestward along the Black River Valley through Lewis and Jefferson counties. It continues westward into southeastern Ontario.

There are not many sections in which to view the Rockland Formation within the county, and they are of limited vertical extent. One of the better sections is exposed in the cut on the northeast side of the old Brownville-Limerick road (Section 11), and another occurs in the bed of Shaver Creek (NW/4 Chaumont quadrangle), 0.75 mile west of the village of Three Mile Bay. The formation is mostly covered and much of the data has been obtained from drill core.

Stratigraphic Relations

Lower Contact – Because of the similarity between highest Chaumont and lowest Rockland and because of the lack of adequate exposures, the boundary between the Black River and Trenton Groups is difficult to draw. There are no natural exposures spanning this boundary in Jefferson County. The contact, in fact, is visible only in the small and shallow, abandoned quarry 2 miles east of Dexter (Section 11) where Kay (1937, p. 253) described the lowest 2 feet of Rockland (Selby) Limestone as medium-grained "rather heavy-ledged but laminated limestone, similar in appearance to that below (Chaumont) but blacker, and with shaly partings containing **Doleroides ottawanus** Wilson."

Wherever the basal portion of the Rockland Formation is exposed in the area of study, the outcrop is restricted to a single bed, or at the most a few layers. In stream courses, differential solution imparts a very rough and choppy appearance to the bedding surface. The more resistant "knobs" are quite angular and sharp. Good stream exposures showing this characteristic are found immediately south of N.Y. Highway 12E along the road to Doanes Hill, 1 mile southwest of Limerick (SE/4 Dexter quadrangle), but they may be examined only during periods of low water. The Rockland Limestone may easily be mistaken for Chaumont in this area. Its identity, however, can be established paleontologically but diagnostic fossils are rare.

In the Chaumont, Sawmill Bay, Cape Vincent North, and Cape Vincent South quadrangles, much of what had been mapped as Chaumont Limestone by Cushing **et al.**, (1910) is Selby Limestone. Here, too, the evidence is largely paleontological. Because any single layer of Upper Chaumont or Lower Selby may cap a broad area, extreme care must be exercised to differentiate the strata.

The following characteristics are helpful in distinguishing the Selby Member of the Rockland Limestone from the Chaumont:

1. The Selby Limestone is usually a shade darker gray on a fresh surface.
2. The Selby commonly has a fetid or petroliferous odor on a freshly broken surface or when struck a glancing blow.
3. The Selby contains the distinctive brachiopods **Doleroides ottawanus** (rare) and **Paucicrura rogata.** The latter is fairly abundant and a long-ranging Trenton form. The Chaumont carries its characteristic cephalopods (p. 17).

The Selby contains no chert in Jefferson County, but the absence of chert nodules is not a reliable criterion for distinguishing the Selby because the chert in the

Chaumont is normally found in the lower part of that formation.

Since the Selby is not ordinarily exposed in most areas, the first Trenton limestone beds usually encountered above the Chaumont belong to the Napanee Member and they are readily identified (p. 19).

Upper Contact – The Rockland Formation is transitional to the overlying Kirkfield Formation through its upper 20 to 35.5 feet (Sections 2, 8, and 13). The transition is so gradual in some areas that there is no basis for a formational boundary. The Rockland Limestone is primarily composed of smooth-breaking calcilutites, 0.5 to 6 inches thick, with minor fine-grained to medium-grained calcarenite beds of similar thickness which become more abundant upward. The Kirkfield Limestone consists predominantly of heavy-ledged, coarse-grained, occasionally cross-bedded and ripple-marked, coquinal calcarenites which measure 0.5 to 15 inches thick but averaging 4 to 10 inches in thickness. The Rockland is similar to the Kirkfield so far as lithologic types are concerned, but it contains them in different proportions. Lithologically the position of the boundary is arbitrary, but a break may be established faunally if an adequate section containing the critical fossils is exposed. The distinctive brachiopod **Triplesia cuspidata** (Hall) is restricted to the Rockland (Napanee member) Formation. This form, however, has been noted at only two localities in the county: 1) in the small section exposed in the drainage ditch on the west side of the north-south road at Champion Huddle (NW/4 Copenhagen quadrangle) and 2) in the cut along the old Brownville-Limerick road (Section 11). Any bed containing **T. cuspidata** is considered Rockland. The brachiopod **Parastrophina hemiplicata** (Hall), a long-ranging Trenton form, normally is common in the lower part of the Kirkfield and rare in the top of the Rockland; its presence aids in distinguishing the formations. The distinctive trilobite **Encrinurus cybeliformis** Raymond is present in lowest Kirkfield but absent in the Rockland Formation.

Thickness

The full thickness of the Rockland Formation is obtained from natural exposures at only one locality in Jefferson County. The piecing together of partial sections exposed in the small abandoned quarry and the cut on the northeast side of the old Brownville-Limerick road (Section 11) gives a thickness of 63 feet 1 inch. This figure is in accord with most of the thickness figures obtained from drill sections.

The entire Rockland was not penetrated by Drill Hole Alf. 140 (Section 2) in the eastern part of the county, but correlation suggests a thickness of about 69 feet. At Watertown (Alf. 144) the Rockland; and Kirkfield Formations have a combined thickness of 107 feet 2 inches. Here they are gradational through 35.5 feet (see Section 8). Although precise location of the Rockland-Kirkfield boundary is impossible, the Rockland has a suggested maximum thickness of about 63 feet at this locality. In the western part of the county the Rockland measures 57 feet 2 inches (Section 13).

Kay (1937, p. 251) reported the Rockland Formation as 58 feet thick at the type locality. The formation seemingly maintains fairly constant thickness, with slight thinning westward into southeastern Ontario.

General Description

The Rockland Formation is primarily composed of dark gray (N3) to medium dark gray (N4), smooth-breaking calcilutites and medium dark gray to medium gray (N5) fine calcisiltites interbedded with minor (generally 5 to 10 percent) medium gray to intermediate between olive gray (5Y4/1) and light olive gray (5Y6/1), fine- to medium-grained calcarenites which increase in importance in the lower and upper portions of the formation. The grays lighten a shade on weathering. Grayish black (N2) to dark gray, mostly smooth and flat, paper-thin limy shale partings separate the limestone beds and zones of limy shale, up to 2.5 inches thick, are locally common. The shale may account for as much as 20 percent of the rock, but it generally constitutes a much smaller percentage of the formation. The individual limestone beds measure 0.5 inch to 8 inches thick and average 2.5 to 3 inches thick; the calcilutites are usually the thicker beds. Layering coincides with bedding.

The Rockland Formation carries the ubiquitous Trenton Limestone fauna, although the forms are not as prevalent as in the overlying carbonate divisions. In addition to the diagnostic forms that serve to distinguish the formation, there are present **Columnaria halli** Nicholson, **Prasopora orientalis** Ulrich, **Phragmolites compressus** Conrad, **Rafinesquina alternata** (Conrad) and **Flexicalymene senaria** (Conrad). A faunal list has been given by Kay (1937, pp. 251-256). The calcarenites are the most fossiliferous of the rock types in the Rockland Formation, but they do not show the coquinal character typical of the calcarenites in the Kirkfield Limestone.

Composition

The composition of the Rockland Limestone does not differ significantly from the composition of the other carbonate formations in the Trenton Group. Each of the Trenton carbonate subdivisions contains sufficient $CaCO_3$ to be defined as a limestone, but the Rockland and Kirkfield Formations are slightly purer limestone, as a whole, than are the Shoreham, Denmark, and Cobourg Formations.

The Rockland Formation was penetrated in its entirety by drill at only one locality, along the shore of Lake Ontario in Wilson's Bay (Alf. 145, Section 13) near the western outcrop limit of this limestone in Jefferson County. Here the formation is composed of 87.48 percent carbonate, of which 83.66 percent is $CaCO_3$ and 3.82 percent is $MgCO_3$. Magnesium oxide content is 1.83 percent. Drill Hole Alf. 143 (Section 12), located 0.75 mile southeast of Rosiere and about 6.5 miles northeast of Alf. 145, penetrated the lowest 39 feet of Rockland Limestone and chemical analysis of this sequence indicated a carbonate content of 87.27 percent, with 83.30 percent $CaCO_3$ and 3.97 percent $MgCO_3$ (1.9 percent MgO).

In the extreme eastern portion of the area under study, at the Jefferson-Lewis County line, Drill Hole Alf. 140 (Section 2) penetrated nearly the entire Rockland succession; only a few feet at the base of the formation were not cored. At this locality the carbonate content of the Rockland is 82.53 percent, of which 78.85 percent is $CaCO_3$ and 3.68 percent is $MgCO_3$ (1.76 percent MgO). It appears that the Rockland Formation becomes somewhat limier westward.

Additional data relating to the composition of the Rockland Limestone are given in Tables 13, 15, 18, 19, 25, and 29.

The Kirkfield Formation

General Statement

The Kirkfield Limestone, named for Kirkfield, Victoria County, Ontario, includes all the strata above the **Triplesia**-bearing Rockland Formation and below the thinner-bedded, shaly Shoreham Formation. More resistant than the succeeding Shoreham, it commonly forms steep cliffs and waterfalls.

Distribution

In New York, the Kirkfield is continuous along the belt of Trenton outcrop from the Central Mohawk Valley to Lake Ontario; the formation persists westward through southern Ontario to Michigan. It enters Jefferson County 1.5 miles southwest of Carthage (NE/4 Copenhagen quadrangle) in a narrow belt less than 0.5 mile wide and, like the underlying Rockland, widens gradually to a maximum of about 6 miles in the western part of the county. The Kirkfield is completely exposed at only a few localities in the Black River Valley. Two localities afford this opportunity in Jefferson County. These are: 1) in the falls of Lake Creek immediately west of the Lewis County line, 0.75 mile northeast of School 11 (site of Alf. 140, Section 2) and 2) on the steep north-facing slope immediately south of the Black River, which is known locally as Woodwards Side Hill (Section 5). Good partial sections are exposed in many small quarries throughout the county. Particularly good are those sections in the quarries at the northwest corner of Thompson's Park in Watertown, and on the northeast side of Cemetery Road, 0.25 mile southeast of Watertown Center (NE/4 Watertown quadrangle).

Stratigraphic Relations

Upper Contact – Chenoweth (1952, p. 523) placed the upper limit of the coarse-grained, predominantly medium-bedded, coquinal Kirkfield Limestone at the first appearance upward of the thinner-bedded **Cryptolithus** (trilobite) bearing calcarenites carrying abundant **Prasopora orientalis** Ulrich, a distinctive colonial bryozoan with a shape resembling that of a chocolate drop.

The Kirkfield and Shoreham Limestones differ in the following respects:

1. Shoreham contains the distinctive trilobite **Cryptolithus tesselatus** Green; it apparently lacks the Kirkfield trilobite **Encrinurus cybeliformis** Raymond. **Prasopora orientalis** Ulrich appears to be fairly common in lowest Shoreham, particularly the larger forms, 3 to 4 inches in diameter.
2. Coarse, occasionally cross-bedded and ripple-marked, coquinal calcarenites predominate in the Kirkfield. Fine calcarenites and coarse calcisiltites are the dominant rock types in the Shoreham; coarse calcarenites are present but not important.
3. Kirkfield beds are thicker, measuring 0.5 to 15 inches thick with most beds ranging from 4 to 10 inches thick, whereas Shoreham beds average 1 inch and rarely exceed 4 inches in thickness.

Although these differences seem obvious, in Jefferson County the formations are very similar in appearance, and they are not always easy to distinguish. The transition from Kirkfield to Shoreham lithology is so gradual in some areas that precise location of the boundary is difficult. The differences are largely statistical, and where not enough beds are present to obtain reliable statistics they may not be distinguished. This is complicated by the fact that beds of Shoreham-like lithology locally occur in the Upper Kirkfield, and distinction must be based on faunal evidence. **Cryptolithus** is too rare to be of any great value, except locally, having been found either by accident or by much time-consuming search. **Prasopora** occurs throughout the Trenton limestones and is an aid in distinguishing Shoreham only if one knows the approximate stratigraphic position and uses the form in combination with other criteria. The difficulty of separating these formations can be appreciated by examining the sections in the Thompson Municipal Park quarry in Watertown and the Cemetery Road quarry (½-mile southeast of Watertown Center). In both places the contact is exposed near the top of the quarry wall. The contact, on the other hand, is very sharp in the cut at the hill summit on the east side of U.S. Highway 11, immediately south of the Watertown city limits (NE/4 Watertown quadrangle).

Calcirudites (conglomeratic limestone) and subsolifluction folds mark the base of the Shoreham Limestone at several localities in Lewis County to the southeast, but no such lithology or structure was seen in Jefferson County.

Thickness

Kay (1937, p. 261) reported the Hull Limestone (earlier name for the Kirkfield) 85 to 100 feet thick in northwestern New York, but no reference to a specific locality was made. The thickness in Jefferson County is actually much less and, according to Chenoweth (1952, p. 524), the Kirkfield thins southeastward in Lewis and Oneida counties. Field studies by the author in those areas substantiate Chenoweth's findings.

The full thickness of the Kirkfield may be obtained from natural sections only in the eastern part of Jefferson County. Elsewhere in the county, approximations of the thickness may be made by piecing together partial sections. The Kirkfield's thickness in the central and western portions is best determined by drill.

The formation is 80 feet 2½ inches thick in the falls of Lake Creek[8], and 80 feet 5 inches thick at Woodwards Side Hill (Section 5). In the western part of the county, Drill Hole Alf. 145 (Section 13) began in the upper part of the Kirkfield Limestone and penetrated 62 feet 11 inches of the formation, suggesting that the full thickness here may be comparable to that in the eastern portion of the county.

The Kirkfield thickness is atypical in the central part of the county. In Drill Hole Alf. 144 (Section 8) the combined Rockland-Kirkfield succession measures 107 feet 2 inches. The Kirkfield Formation has a minimum thickness of 42 feet 1 inch. The drill core showed no evidence of a fault. Because the position of the boundary is somewhat arbitrary here (p. 41), it is possible to increase the thickness of the Kirkfield by about 20 feet provided the thickness of the Rockland Formation is reduced correspondingly.

General Description

In contrast to the underlying Rockland Formation, the Kirkfield Limestone consists mainly of medium gray (N5) to medium light gray (N6) and pale yellowish brown (10YR6/2), very thin- to thick-bedded, frequently cross-bedded and ripple-marked, uneven, coarse coquinal calcarenites (40 to 80 percent of the formation) which are interbedded with lesser amounts (10 to 25 percent) of medium dark gray (N4) calcisiltite and dark gray (N3) calcilutite. The finer limestones are more abundant in the lower and upper portions of the formation, which accounts for some of the difficulty in placing the formational boundaries. The colors generally lighten shade on weathering. Olive black (5Y2/1) to dark gray, plane and wavy, paper-thin limy shale partings and thinly laminated plane zones of limy shale, up to 3 inches thick, separate the limestone beds.

The calcarenites are 0.5 inch to 15 inches thick; most of the calcarenites are between 4 and 10 inches thick. The thicker beds of calcarenite are in the minority, but because they resist erosion and give rise to the prominent ledges and waterfalls in which the Kirkfield is commonly observed in the field, they are readily seen and serve as a guide to the formation. The calcisiltites and calcilutites are not over 6 inches thick, generally averaging 2 to 3 inches thick. Layering coincides with bedding. The calcarenites appear to increase in quantity westward across the county at the expense of the other rock types.

The Kirkfield has a large and abundant fauna. Among the distinctive forms are the trilobites **Bathyurus ingalli** Raymond, **Encrinurus cybeliformis** Raymond, **Hemiarges paulianus** (Clarke), **Flexicalymene senaria** (Conrad) and **Isotelus gigas** DeKay. All but the two latter forms are not present in the Trenton limestones above the Kirkfield. The long-ranging Trenton brachiopods **Parastrophina, Rafinesquina, Paucicrura,** and **Sowerbyella** are common. **Hesperorthis tricenaria** (Conrad) is occasionally found; it has not been observed in any of the other formations. Bryozoa are moderately abundant. Specimens of **Prasopora** and **Subretipora,** both of which are more characteristic of the overlying Shoreham Formation, become fairly common in the upper part of the Kirkfield.

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[8] Verified by drilling; see Section 2, Alf. 140.

Pelmatozoan stem fragments are present throughout the sequence. Some beds may yield planospiral and high-spired gastropods (snails). A more complete listing of the Kirkfield fauna has been given by Kay (1937) and Chenoweth (1952).

Composition

The entire Kirkfield Limestone was cored and the formational boundaries distinguished only in the extreme eastern portion of the study area, 0.1 of a mile from the Lewis County line (Alf. 140, Section 2). Analysis of the core from this locality showed that the formation is here composed of 87.29 percent carbonate, 83.84 percent is $CaCO_3$, and 3.45 percent is $MgCO_3$ (1.65 percent MgO).

At Wilson's Bay (Alf. 145, Section 13), in the western part of Jefferson County, only the lowest 62 feet 11 inches of the Kirkfield Limestone were penetrated. This much of the formation analyzed 80.81 percent $CaCO_3$ and 3.89 percent $MgCO_3$ (1.86 percent MgO), suggesting that in contrast to the Rockland Limestone below, the Kirkfield may well become somewhat less pure westward.

Drill Hole Alf. 144 (Section 8) passed through the entire Kirkfield and Rockland Limestones, but the boundary between these formations could not be recognized in the core. As discussed earlier (p. 20), the combined thickness of these limestones is considerably less here than in the eastern and western portions of the county. The composition of the Rockland-Kirkfield succession, when averaged, shows 82.62 percent carbonate, of which 78.98 percent is $CaCO_3$ and 3.64 percent is $MgCO_3$ (1.74 percent MgO). As might be expected in this area, roughly halfway between holes Alf. 140 and 145, these figures compare favorably with the composition of the Rockland in the eastern section and the Kirkfield in the western section.

The complete chemistry of the Kirkfield Limestone may be determined by consulting Tables 13, 15, 19, 26, and 29.

The Shoreham Formation

General Statement

The Shoreham Limestone takes its name from Shoreham Township in Addison County, Vermont. Kay (1937, p. 264) originally defined the Shoreham as the thin-bedded (**Cryptolithus**-bearing) limestone as the base of the Sherman Fall Formation, but he subsequently (1942a, p. 1611) elevated it to formational rank. It corresponds to the **Prasopora orientalis**-bearing beds of Johnston, Raymond, and others (Kay, 1929, p. 664). In 1952, Chenoweth (p. 525) extended the Shoreham to include the Rathbun Member (basal Denmark in the valley of West Canada Creek, Herkimer and Oneida Counties), which he reported lithologically and faunally equivalent to topmost Shoreham in western Jefferson County.

Distribution

The Shoreham Formation is the most persistent of the Trenton Limestones. It is found east of the Adirondack Arch in the southern Lake Champlain, upper Hudson, and lower Mohawk region. West of the Arch it is present from the upper part of the valley of West Canada Creek into Canada. The Shoreham is covered through most of Oneida County, but reappears near Boonville (Oneida-Lewis County line) and forms a belt on the west side of the Black River Valley northwest to Watertown, where it swings westward to meet Lake Ontario at Sackets Harbor. The formation is again exposed on Pillar Point and Point Peninsula (Henderson Bay and Chaumont quadrangles). It continues into southeastern Ontario.

In eastern Jefferson County, the Shoreham crops out in a narrow belt generally less than a thousand feet wide but, in the extreme western part of the county, it forms an irregular belt with a maximum width of a little more than a mile. Except for a small area along N.Y. Highway 3 and Mill Creek (NW/4 Sackets Harbor quadrangle), the Shoreham Formation is largely obscured by glacial drift in the region between Watertown and Sackets Harbor.

Exposures of the Shoreham Formation are plentiful, but they are usually of limited vertical extent. Many partial sections may be studied in Rutland Hollow and along the north-facing Trenton scarp between the Lewis County line and Watertown (Copenhagen, South Rutland, and Watertown quadrangles). An exceptionally good locality for collecting **Cryptolithus** is found on a small promontory near the top of the scarp immediately north of the point at which Ridge Road begins to descend the cliff, 7,000 feet south-southeast of Felts Mills (SE/4 Black River quadrangle). A complete section of the Shoreham is found in the bed of the small unnamed stream near East Watertown (Section 6).

Stratigraphic Relations

Upper Contact – As is true of most formational boundaries within the Trenton Group, the Shoreham-Denmark contact is difficult to draw with certainty.

Chenoweth (1952, p. 525) placed the upper limit of the Shoreham Formation throughout its area of outcrop in northwestern New York at the top of a "persistent thick **Cryptolithus**-bearing calcarenite," which is succeeded by the argillaceous calcilutites and shales of the Denmark Formation that carry the planospiral cephalopod **Trocholites** and the bellerophontid gastropod **Sinuites.** These formations may be distinguished on a faunal basis in one part of Jefferson County, but in other parts of the county separation is made on a lithic basis, and sometimes the transition is so gradual that there appears to be no basis for a formational boundary at all. This is complicated by the lack of natural exposures that span the contact. There are only four sections within the county that include the Shoreham-Denmark boundary. From east to west these are: 1) Ridge Road locality at the 800 foot contour; 2) in a small intermittent stream gully which crosses the northeast-trending secondary road 400 feet northeast of the intersection with Rutland Hollow Road, 1.6 miles east-northeast of School No. 9 (NE/4 South Rutland quadrangle); 3) site of Section 6 at East Watertown; and 4) in the bed of Mill Creek, 1,500 feet east of N.Y. Highway 3 (NW/4 Sackets Harbor quadrangle). The Ridge Road locality has small gaps in the section.

The following characteristics aid in distinguishing the Shoreham and the Denmark Formations:

1. Typical Shoreham is composed almost entirely of irregular lensing beds of fine fossiliferous calcarenite and coarse calcisiltite which are 0.5 inch to 5 inches thick and average 1 to 2 inches thick, whereas Denmark is typified by an abundance of thicker (5 to 10 inches common), generally planar coarse calcarenites and occasional calcirudites.
2. The Shoreham rarely has the ripple-marked and cross-bedded calcarenites characteristic of the Denmark (and Kirkfield) Formation.
3. The basal beds of the Denmark may not always be typical of the formation. In some areas (notably in Rutland Hollow) lowest Denmark is largely composed of calcisiltite and calcilutite with a preponderance of limy shale interbeds. Some of the less pure calcilutites weather to a knobby surface and break down into conspicuous cobbles.
4. Shoreham contains species of the distinctive trilobite **Cryptolithus.** C. **tesselatus** appears restricted to the Shoreham, but **C. quadrillineus** is present in the Denmark, too. These forms are generally difficult to find. **Sinuites** is present in both formations, but **Trocholites** (very rare) in combination with **Sinuites** is restricted to Denmark. The small smooth-surfaced pelecypod **Ctenodonta** is abundant in the Lower Denmark. **Prasopora** is common to both formations, but the larger forms, up to 3 or 4 inches in diameter, suggest Shoreham.

Thickness

Three thicknesses have been obtained for the Shoreham Formation. They are: 1) 20 feet 6 inches (Section 6), 2) 24 feet 1 inch (Section 8) and 3) about 25 feet (by hand level) in Thompson Park, Watertown.

General Description

The Shoreham Formation consists almost wholly of very thin- to medium-bedded limestone ranging from medium dark gray (N4) and medium gray (N5) coarse calcisiltite to medium light gray (N6), occasionally pale yellowish brown (10YR6/2), coarse calcarenite. Fine calcarenite and calcisiltite predominate. The pale yellowish brown color is characteristic only of the coarsest calcarenites; it is apparently restricted to the larger grains of calcite. The gray colors are a shade lighter on weathered surfaces.

The limestone beds range in thickness from 0.5 inch to 7.5 inches; they rarely measure over 5 inches thick, however, and average 1 to 3 inches thick. The calcarenites tend to have wavy surfaces which give the beds an irregular lensing appearance, but they are rarely ripple-marked and cross-bedded. Dark gray (N3), plane and wavy, 0.5 to 1 inch limy shale partings separate the limestone beds and compose 20 to 25 percent of the formation.

Subsolifluction folds and associated intraformational flow conglomerates (Kay, 1937, p. 266 and Chenoweth, 1952, p. 553) have been observed by the writer in Lewis County, but these phenomena have not been observed in Jefferson County. Structures of this type are known not to exist in the underlying Kirkfield but they are sometimes found in the Denmark above.

The Shoreham Formation contains the well-known Trenton fauna; it is largely restricted to the calcarenites. In addition to the forms which aid in distinguishing the formation there are present the common brachiopods **Rafinesquina, Paucicrura,** and **Sowerbyella,** and the trilobites **Flexicalymene** and **Isotelus.** Pelmatozoan stem fragments and bryozoans are abundant. The frondescent bryozoan **Subretipora** is characteristic of the lower half of the formation. Several specimens of the graptolite **Diplograptus?** were noted on the surfaces of the limy shales (Ridge Road). A few conspicuous partial remains of large **"Orthoceras"** were recovered from the lower part of the formation, particularly in the Watertown (Thompson Park) and East Watertown (Section 6) areas. Some of these incomplete forms were as much as 2 feet long and 4 to 5 inches in diameter at the widest end. A complete list of the fossils in the Shoreham Formation has been given by Chenoweth (1952, p. 528).

Composition

The Shoreham Limestone is seemingly slightly less pure than the Trenton limestones above and below. The formation averages 83.51 percent carbonate, of which 80.06 percent is $CaCO_3$ and 3.45 percent is $MgCO_3$ (1.65 percent MgO).

In the Watertown area (Drill Hole Alf. 144, Section 8), the Shoreham Limestone contains 77.16 percent $CaCO_3$ and 3.66 percent $MgCO_3$ (1.75 percent MgO), whereas near Henderson Harbor (Drill Hole Alf. 148, Section 15), 17 miles southwest of Watertown, the Shoreham contains 82.95 percent $CaCO_3$ and 3.24 percent $MgCO_3$ (1.55 percent MgO). The entire Shoreham may not have been cored at the last-named locality since the purpose of drilling at that site was to penetrate the Denmark Formation. In so doing, 22 feet 1 inch of Shoreham were penetrated, a figure which compares favorably with thicknesses reported for the Shoreham elsewhere in the county. The composition, as determined by analysis of this core, is assumed to reflect the chemistry of the formation in this area.

Not only does the Shoreham contain somewhat more carbonate in the western part of the county, but the SiO_2 content also increases, being 11.2 percent at Henderson Harbor and 6.9 percent at Watertown. The other oxides reported in the analyses are present in essentially equal amounts in both areas.

Additional information concerning the composition of the Shoreham Limestone is given in Tables 15, 21, 27, and 29.

The Denmark and Cobourg Formations

Lithically the upper Denmark and Lower Cobourg limestones are typically inseparable in Jefferson County. It is recognized that distinct divisions may occur within the formations, but these are not in those portions that span the Denmark-Cobourg boundary. It is further recognized that along the belt of outcrop in parts of northwestern New York and southeastern Ontario, facies changes may create lithic differences sufficiently distinct to effect separation of these rock units, but such is not the case in the area of this study. It has been said by Kay (1937, p. 251) that where differences are obscure, faunal evidence may of necessity be the useful basis of recognition. Even fossils are of questionable value in Jefferson County. That outcrop width of the Denmark Formation has been determined by using local dip (1 to 2 degrees) and an assumed thickness of approximately 170 feet as based upon the section of Drill Hole Alf. 148 (see Section 14).

Each formation is therefore discussed separately to preserve the formational names and to avoid confusion with the many published accounts.

The Denmark Formation

General Statement

The Denmark Limestone was defined by Kay (1937, p. 267) from exposures in Denmark Township, Lewis County, New York. Kay originally considered the Denmark an upper member of the Sherman Fall Formation (Shoreham plus Denmark), but he has since (1942a, p. 1611) raised the member to formational rank and subdivided it into three members which are: the Rathbun (lowest), the Poland, and the Russia (highest). The two higher members are not recognized north of Trenton Falls (Herkimer-Oneida County line). Chenoweth (1952, p. 257) subsequently removed the Rathbun member from the Denmark and considered it an upper member of the Shoreham Formation. In the region north of Trenton Falls, Chenoweth subdivided the lower part of the Denmark Formation into the Camp and Glendale members. He described (op. cit., p. 528-529) the Camp as 11 feet of nodular argillaceous calcilutite and shales at the base of the Denmark which persists to Sackets Harbor in Jefferson County and correlates with the **Trocholites** subzone of the Poland in sections along West Canada Creek. The Glendale is described as a tongue of the Poland, and it is not known north of Lowville, Lewis County.

Distribution

The Denmark Formation persists from Trenton Falls northwestward through New York into southeastern Ontario. Southeast of Trenton Falls the Denmark Limestone becomes thinner and grades laterally into the black shales of the Canajoharie Formation (Dolgeville Facies). The Denmark follows the belt of Trenton outcrop across Jefferson County but, owing to its greater thickness, the area of exposure is broader than that of any of the underlying Trenton formations. It enters Jefferson County east of Pleasant Lake (Copenhagen quadrangle) and continues westward across the county in an irregular belt with an approximate maximum width of about 6 miles. Limestone considered Upper Denmark because of its stratigraphic position disappears beneath Lake Ontario at Henderson Bay. Much of the area where Denmarkian limestone should form the surface rock in the Sackets Harbor quadrangle is covered by glacial drift.

Stratigraphic Relations

Upper Contact – The Denmark-Cobourg contact is the most deceptive of all the interformational boundaries within the Trenton Group. Upper Denmark and lower Cobourg are lithically nearly identical and differentiation of the formations is very difficult and uncertain. Neither formation has distinctive guide fossils, at least in Jefferson County, and in many sections beds at or near the "contact" are concealed.

The upper limit of the Denmark Formation has been arbitrarily placed by Kay (1937, p. 263) at the base of a bed having "locally" abundant **Cyclocrinites (= Pasceolus) globosus** (Billings), a form which is not unlike a golf ball in appearance, whereas Chenoweth (1952, p. 529) arbitrarily placed the boundary at the first appearance upward of persistent thick calcarenites having common **Hormotoma trentonensis** and occasional **Fusispira** sp., both high-spired snails. Chenoweth's contact essentially corresponds to that of Kay. Not one specimen of **Cyclocrinites** was found during the course of this study.

Rafinesquina deltoidea is typical of, but not restricted to, the lower Cobourg Formation and is of limited use in defining the base of the Cobourg. Because of the lack of critical exposures and because quasi-differentiation of the formations is primarily faunal, the Denmark and the Cobourg (at least the lower member) should remain undifferentiated within Jefferson County except for a trigonometric extrapolation such as that shown on the map.

Thickness

Only one thickness figure for the Denmark Formation was obtained. A little more than 0.5 mile northeast of the village of Henderson Harbor, Drill Hole Alf. 148 presumably began in the lower part of the Cobourg Formation and bottomed in the Shoreham Formation (Section 15). Although the position of the Denmark-Cobourg contact is arbitrary, it was placed at the first appearance of persistent thicker calcarenites upward (Chenoweth's basis), which gives the Denmark a thickness of 169 feet 8 inches at this locality. Drill Hole Alf. 147 (Section 14), which began in Upper Cobourg, must have penetrated most of the Denmark Formation, but the Denmark-Cobourg boundary could not be distinguished in the core.

Kay (1943, p. 601) reported a thickness of 130 feet for the Denmark Formation at Trenton Falls on West Canada Creek (Herkimer-Oneida County line) where the boundaries are perhaps more clearly defined.

General Description

Within Jefferson County, the Denmark (and overlying basal Cobourg) is lithologically more like the Kirkfield than anywhere else along the belt of outcrop. Differentiation of the formations often depends on recognition of the Shoreham. The Denmark primarily contains (60 to 80 percent) medium gray (N5) to medium light gray (N6), occasionally pale yellowish brown (10YR6/2) flecked, very thin- to medium-bedded, coarse fossiliferous calcarenites which are sometimes cross bedded and ripple-marked. The very coarsely crystalline varieties often have a pale red (5R6/2) to moderate red (5R5/4) cast. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray calcilutites or medium dark gray calcisiltites are found every few feet, and dark gray limy shale partings separate most of the limestone beds. The amount of shale is variable; it ranges from less than 5 percent of the rock in some portions of the formation to a maximum of 20 or 25 percent in other portions. The shales seem to be more abundant than in the Kirkfield, but statistically this is not so. Calcirudites (limestone conglomerates) are present but have been noted only in weathered sections.

The calcarenite beds are 0.5 inch to 12 inches thick. Most of them measure less than 5 inches, but the thicker beds (5 to 10 inches) are readily observed in the field and give the impression of dominating the sequence. This is especially true of weathered sections. The calcilutites are 1 to 10 inches thick, the calcisiltites are 0.25 inch to 4 inches thick, and the limy shales measure 0.125 inch to 4 inches in thickness. Bedding surfaces are both plane and wavy but, in general, they are more even than those of the Kirkfield.

Beds of Camp lithology have been noted at the base of the Denmark, but they apparently do not persist everywhere within the county and the member was not separated in the field. The Camp Member is seemingly present at Ridge Road and in Rutland Hollow sections. At the latter locality it measures 10.5 feet. The member consists of medium dark gray (N4) to medium gray (N5), somewhat agrillaceous knobby-weathering calcilutites, calcisiltites, and minor fine calcarenites, with intercalated dark gray (N3) limy shale. Coarse calcarenites are absent. On a freshly broken surface the more fossiliferous rocks often have a light bluish gray (5B7/1) to bluish white (5B9/1) coating. The member contains abundant specimens of the small smooth-surfaces clam **Ctenodonta.** The snail **Sinuites cancellatus** is uncommon. The Camp Member is well exposed along the banks of Mill Creek between N.Y. Highway 3 and the New York Central Railroad bridge, 1 to 2 miles east of Sackets Harbor (NW/4) Sackets Harbor quadrangle), where it measures 12 feet 7 inches thick. **Ctenodonta** and **Sinuites** are both common to the nodular calcilutites. This is Chenoweth's (1952, p. 533) type section. At the base of the Denmark Formation in Drill Hole Alf. 148 (Section 15) there are 13 feet 1 inch of rock with Camp-like lithology. Basal Denmark in the Watertown area (Sections 6 and 8) is typical of the formation as a whole; Camp lithology is lacking.

The significant tossils ot the Denmark Formation have been discussed. Becasue the Denmark is best exposed at Trenton Falls it is "typical Trenton," and its most common fossils are the brachiopods **Dinorthis, Rafinesquina, Paucicrura** and **Sowerbyella** and the trilobites **Flexicalymene** and **Isotelus. Prasopora** persists from the underlying Shoreham but is less abundant upward. The brachiopods **Platystrophia** and **Trematis** (also found in the Shoreham) are present. The high-spired gastropod **Hormotoma trentonensis,** which has always been stated as being a guide to the Cobourg, occurs in the upper portions of the Denmark Formation which further adds to the difficulty of placing the Denmark-Cobourg boundary. Fucoidal markings have been noted on the bedding surfaces of some calcilutites. Graptolites are rare.

Composition

Because it is difficult to separate Denmark from Cobourg, it is equally difficult to obtain a true chemical analysis of that rock which is called Denmark Limestone. The limestone occupying an interval in the Trenton succession that may be designated Denmark was penetrated at only two localities in Jefferson County. These are 1) in the bed of Gulf Creek near Rodman (Drill Hole Alf. 147, Section 14 – partial penetration) in the central part of the outcrop belt and 2) just south of the Harbor Road 0.6 mile northeast of the village of Henderson Harbor (Drill Hole Alf. 148, Section 15 – total penetration) in the western part of the limestone belt.

At the Rodman locality, it was impossible to distinguish the Denmark from the Cobourg even though drilling began in the Cobourg Formation 12 feet below its contact with the overlying Deer River Shale (Holland Patent equivalent) and penetrated 240 feet of limestone, sufficient to have obtained core from well within the limestone occupying the stratigraphic interval assigned to the Denmark Formation.

At Henderson Harbor, however, there was some basis for making a separation. Analysis of the highest 146.5 feet of core thought to represent Denmark Limestone (exclusive of the Camp Member) showed 86.95 percent carbonate, of which 83.46 percent is $CaCO_3$ and 3.49 percent is $MgCO_3$ (1.67 percent MgO). Within this interval the $CaCO_3$ content ranges from a minimum of 79.57 percent to a maximum of 88.82 percent, and $MgCO_3$ ranges from a minimum of 2.71 percent to a maximum of 3.97 percent. It is interesting to note (see Table 21) that there are definite chemical boundaries for the Denmark sequence here. The underlying Shoreham contains 82.95 percent $CaCO_3$ and the 28 feet of Cobourg above contains 75.82 percent $CaCO_3$.

Since this is the only rock occupying the Denmark interval that was obtained for chemical analysis, its composition may not be truly representative of the formation as a whole. This single analysis, however, suggests that the Denmark is one of the purer Trenton limestones. A glance at the CaO content of the rock penetrated in the lower part of Drill Hole Alf. 147, which is assumed to be Denmark, shows considerably less calcium carbonate than at Henderson Harbor, also suggesting that the Denmark is less pure eastward.

A complete analysis showing the averages of all oxides is given in Table 28.

The Cobourg Formation

General Statement

The Cobourg Limestone (Cobourg, Northumberland County, Ontario) was named by Raymond (1921, p. 1). It replaced the earlier name Picton Limestone (found to be preoccupied) which had been applied by Raymond (1914, pp. 345-349) for the sequence of "heavy-bedded limestone with the gastropod fauna, and the underlying thinner-bedded limestone with **Rafinesquina deltoidea**" exposed at Picton, Prince Edward County, Ontario. Kay (1937, p. 278) designated the lower subdivision the Hallowell Member and the upper subdivision the Hillier Member.

Distribution

The Cobourg Limestone is continuous in northwestern New York and southern Ontario from Trenton Falls on the Herkimer-Oneida county line to the Georgian Bay area on Lake Huron. It is absent in the Mohawk Valley and east of the Adirondacks; in these regions equivalent beds are the black shales of the Utica Formation and its correlatives. The Hallowell Member persists throughout the area of Cobourg outcrop. The Hillier Member is present in Canada and in Jefferson County, New York, but it disappears southeastward somewhere in Lewis County. The top of the Cobourg Formation marks the southern limit of the limestone succession in Jefferson County.

Complete natural sections of the Cobourg are unknown in this area. Excellent partial sections are exposed at Talcott Falls (Section 16), in the bluffs facing Lake Ontario at Henderson Harbor (NW/4 Henderson quadrangle), in the bed of the North Branch of Sandy Creek at Adams (SW/4 Adams quadrangle) and at Burrs Mills (SW/4 South Rutland quadrangle). Other areas of outcrop are indicated on the geologic maps.

Stratigraphic Relations

Upper Contact – Everywhere in Jefferson County the dark gray (N3) to black (N1) graptolite (**Climacograptus**)-bearing shales of the Deer River Formation (Upper Utica or Holland Patent equivalent) rest disconformably on the Upper Cobourg Limestone; Lower Utica shales are absent. When not obscured by glacial drift, the contact is easily determined. It is exposed in a number of places along the North Branch of Sandy Creek and its tributary Gulf Creek (Rodman, Barnes Corners, and South Rutland quadrangles). Along Sandy Creek the position of the contact fluctuates slightly, producing a map pattern that suggests gentle folding.

The highest few feet of Cobourg consist of medium dark gray (N4), knobby or nodular, fine- to medium-bedded calcisiltite with intercalated, undulating thin seams of dark gray (N3) shale which become abundant upward. The top of the Cobourg is sometimes marked by a conspicuous bed of calcirudite or limestone conglomerate (1 mile east of Tylerville, South Rutland quadrangle, and 0.5 mile east of East Rodman, Barnes Corners quadrangle).

The base of the Deer River Formation consists of dark gray (N3) to medium dark gray (N4), fissile, argillaceous shale which breaks into small thin chips on weathering. The distinctive trilobite **Triarthrus eatoni** (Hall) is common to the formation. A thin layer of pyrite or marcasite crystals and concretions marks the contact between the Cobourg Limestone and the Deer River Shale.

By far the best place in the county to view this boundary is along Gulf Creek, 0.5 mile east of Rodman (NE/4 Rodman quadrangle). The contact relations at this locality are described in Section 14.

Thickness

Nowhere in the county is there an exposed section of Cobourg Limestone sufficiently complete to determine the full thickness of the formation. It was hoped that Drill Hole Alf. 147 (Gulf Creek, Rodman quadrangle), which began about 12 feet below the Cobourg-Deer River contact and penetrated 240 feet of topmost Trenton Limestone (Cobourg and Upper Denmark), would provide the thickness, but the position of the Denmark-Cobourg boundary was impossible to place. The piecing together of partial sections gives a combined total thickness of about 310 to 315 feet for the Denmark and Cobourg formations, suggesting that the Cobourg is 140 to 155 feet thick, if the thickness given to the Denmark (p. 28) is correct. Kay (1937, p. 280) reported a thickness of about 100 feet for the Hallowell Member, and 60 to 70 feet for the Hillier Member in "northwestern New York," which gives a total thickness of about 160 to 170 feet to the formation.

General Description

Hallowell Member – The Hallowell Member (Hallowell Township, Prince Edward County, Ontario) corresponds to Lower Cobourg Limestone; it is the **Rafinesquina deltoidea** zone of Raymond (1914). The base of the member marks the Denmark-Cobourg contact. The lithology of the Hallowell does not differ distinctly from that of most of the Denmark. It is composed primarily of medium gray (N5) to medium light gray (N6), very thin- to medium-bedded, fossiliferous calcarenites interbedded with 0.125- to 2-inch dark gray (N3) limy shales. Medium dark gray (N4) to medium gray calcisiltites and calcilutites are minor. Bedding surfaces are 0.5 to 9 inches apart and mostly plane. The weathered edges of some beds exhibit a pock-marked appearance. The Hallowell is increasingly resistant to erosion upward as the percentage of intercalated shale decreases sharply; the contrast with the more agrillaceous strata of the overlying Hillier is responsible for the formation of a prominent terrace at the top of the Hallowell wherever it is exposed.

The Hallowell fauna is composed largely of the omnipresent Trenton forms that are so typically represented in the Denmark. Specimens of **Cyclocrinites globosus**, reported locally abundant at the base by Kay (1937, p. 263), were not found. **Rafinesquina deltoidea** is present throughout the member but is abundant and most characteristic of the upper part. **Hormotoma trentonensis** and **Fusispira fusiformis** frequently appear in the calcarenites, particularly in the upper part of the

Hallowell, but they are more common in the overlying Hillier Member. Locally many fossil forms are limonitic and weather moderate yellowish brown (10YR5/4).

Hillier Member – The Hillier Member (Hillier Township, Prince Edward County, Ontario) corresponds to the Upper Cobourg Limestone; the top of the member marks the top of the limestone succession in Jefferson County. It consists mainly of medium dark gray (N4), coarse calcisiltites (80 percent) with interbedded dark gray (N3) 0.5- to 2-inch limy shale. Medium gray (N5) calcarenites are minor and calcirudites may be present at the top of the member. The limestone beds are 1.5 to 5 inches thick and average 3 inches in thickness. The calcisiltites have a conspicuous irreglar lensing or knobby appearance in weathered sections and break down readily to olive gray (5Y4/1) and light olive gray (5Y6/1) fragments making sharp contrast with the thicker-bedded resistant calcarenites in the Hallowell Member. The Hillier Member is easily distinguished in the field, but the knobby or nodular character is not evident in drill core.

The Hillier is the **Hormotoma** and **Fusispira** zone of Raymond (1914, pp. 345-349). Although these gastropods (snails) are the most characteristic fossils of the Hillier Member, they range downward into the Hallowell Member. **Hormotoma** is also present elsewhere in the Trenton Group, particularly in the upper part of the Denmark Formation. **Conularia trentonensis** occurs profusely within the Upper Hillier along Gulf Creek at Rodman. The distinctive brachiopod **Rafinesquina deltoidea** was not observed in the Hillier, and is apparently restricted to the underlying Hallowell. The less characteristic forms have been listed by Kay (1937, p. 281).

Exposures of the Hillier Limestone are not abundant; the member is commonly obscured by glacial cover. The best places to view the Hillier are in those exposures that show the contact with the overlying Deer River Shale, but any area of Cobourg outcrop at the higher elevations generally represents a locality where the sections of the member are readily identified on a lithologic-faunal basis.

Composition

There was insufficient sampling of the Cobourg Limestone to give a true account of the chemistry of the formation though certain observations can be made.

The Cobourg was never pierced in its entirety by drill. In the bed of Gulf Creek near Rodman (Drill Hole Alf. 147, Section 14), 240 feet of Upper Trenton limestone and limy shale were penetrated. Coring began a little more than 12 feet below the top of the Cobourg, as its contact with the overlying Deer River Shale could be observed in the cliff exposure bordering the creek. The drill undoubtedly passed through rock assigned to the Cobourg and down into the Denmark Limestone, but there were no lithologic changes observed in the core sufficiently distinct to permit recognition of the units and, unlike the Henderson Harbor locality (Drill Hole Alf. 148, Section 15), there was no sharp chemical boundary either (see Table 20). The Denmark and Cobourg limestones must remain undifferentiated here. An average analysis of the entire sequence shows 83.43 percent carbonate, of which 79.96 percent is $CaCO_3$ and 3.47 percent is $MgCO_3$ (1.66 percent MgO).

The highest few feet of limestone in Drill Hole Alf. 148 that were assigned to the Cobourg Formation contain an average of 75.83 percent $CaCO_3$ and 3.47 percent $MgCO_3$, indicating that lowest Cobourg at this locality is less pure than the Denmark below and also less pure than the combined average of the Denmark and Cobourg formations at Gulf Creek. These figures, however, compare favorably with the analyses of individual 10-foot sections at or about the same stratigraphic position in Drill Hole Alf. 147. The Cobourg, in fact, appears to vary considerably in purity; it seems to contain the greatest amount of calcium carbonate near the middle of the formation. It is interesting to note that an average analysis of the combined Denmark and Cobourg penetrated in Drill Hole Alf. 148 is nearly identical with that in Drill Hole Alf. 147 (Tables 20, 21, and 28).

Maximum-minimum values of the common oxides are given in Table 29.

Geologic Sections

The following sections have been measured and described from drill core and natural exposures. With the exception of Sections 15 through 17, they are arranged from east to west across the county (Plate I). A few sections of less vertical extent which show contact relations are included in the appropriate place within the text. The figures in Column I are the thicknesses of the individual subunits. The figures in Column II give the cumulative thickness above the base of the section. Colors are according to the Rock-Color Chart (p. 10).

1. This section was measured in the small abandoned quarry which is located 200 feet west of N.Y. Highway 26 and 1100 feet south-southeast of the main intersection in West Carthage, NW/4 Carthage, N.Y. quadrangle.

	I		II	
	Ft.	In.	Ft.	In.
Lowville Formation				
5. Medium dark gray (N4) to olive gray (5Y4/1), thickly laminated to very thin-bedded calcilutite; weathers to intermediate between medium light gray (N6) and light gray (N7), dark yellowish orange (10YR6/6), pale yellowish orange (10YR8/6), and moderate reddish brown (10R4/6); beds are a ¼ inch to ½ inch thick, the surfaces are plane except at the base where they conform to the undulatory stromatoporoid horizon below.	2	0	14	8
4. Conspicuous medium dark gray (N4) to medium gray (N5) stromatoporoid layer with slight overall olive tinge; weathers intermediate between medium light gray (N6) and light gray (N7).	0	8	12	8
3. Medium dark gray (N4), locally sandy, cross-bedded calcarenite; weathers to medium dark gray and medium gray (N5); contains occasional small aggregates of calcite.	2	3	12	0
2. Medium dark gray (N4) calcilutite; weathers medium dark gray to medium gray (N5); small aggregates of calcite grains are abundant.	0	9	9	9

	I		II	
	Ft.	In.	Ft.	In.
1. Medium dark gray (N4), thin- to medium-bedded calcilutite and minor calcisiltite; weathers medium dark gray to medium gray (N5) and light olive gray (5Y6/1); limestone beds are 3 to 12 inches thick.	9	0	9	0

Floor of quarry.

2. This section was described and measured from drill core (Alf. 140) obtained along the bank of Lake Creek 0.1 mile west of the Jefferson-Lewis County line and 0.55 miles northeast of School No. 11, NE/4 Copenhagen, N.Y. quadrangle.

	I		II	
Shoreham Formation				
5. Olive gray (5Y4/1) calcisiltite to fine calcarenite interbedded with olive black (5Y2/1) limy shale[8]; core broken and discolored; the subunit is thickly laminated to thinly laminated to thinly bedded, individual beds range from 1/8 inch to 1½ inches thick; contains large specimens of **Prasopora orientalis** Ulrich and fragments of brachiopods.	2	6	147	7
Kirkfield Formation: 80 feet 2½ inches thick				
4. Medium gray (N5) to intermediate between olive gray (5Y4/1) and light olive gray (5Y6/1), very thin- to thick-bedded coarse calcarenites; olive black (5Y2/1) to dark gray (N3), thinly laminated to thin-bedded calcilutites and limy shales; and minor medium dark gray (N4) very thin- to thin-bedded calcisiltites; the calcarenites compose 45 to 50 percent of the formation, whereas the calcilutites and limy shales make up about 35 percent, and the calcisiltites make up 10 to 15				

[8]Colors of the weathered surfaces are obtainable in drill core.

	I Ft.	I In.	II Ft.	II In.
percent of the formation; individual beds are characterized by undulatory surfaces and range from a ¼ inch to 15 inches in thickness; the calcarenites are ½ inch to 15 inches thick, the limy shales and calcilutites range from paper-thin laminae to 2 inches in thickness with occasional zones 5 to 15 inches thick, and the calcisiltites are from ½ inch to 3 inches thick; the thicker zones of calcilutite frequently contain "nodules" or "pods" of calcisiltite up to 2 inches in diameter; 7 feet 7 inches below the top of the formation the beds have an apparent dip of nearly 45 degrees; elsewhere in the succession they are nearly horizontal; from 7 feet to 11 feet below the top the rock appears to be brecciated; the formation appears to be only slightly fossiliferous in drill core, it contains a few small forms of **Prasopora, Isotelus** sp., unidentifiable fragments of brachiopods, and crinoid stem fragments.	80	2½	145	1

Rockland Formation: The complete formation was not penetrated, but correlation on Plate I suggests a thickness of about 69 feet.

Napanee Member: 62 feet 11½ inches

	I Ft.	I In.	II Ft.	II In.
3. Similar to Kirkfield above, but with noticeable increase of calcilutite (55 to 60 percent) at the expense of the calcarenites; contains two prominent beds of calcarenite, each 8 inches thick, beginning 8 inches and 8 feet 5 inches above the base of the subunit; transitional upward to typical Kirkfield lithology.	21	10½	64	10½
2. Olive black (5Y2/1) to dark gray (N3), very thin- to medium-bedded calcilutites; medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded calcisiltites; intermediate between olive gray (5Y4/1) and light olive gray (5Y6/1), thin-bedded calcarenites; and minor amounts of black (N1) to grayish black (N2), thinly laminated, limy shale partings; the calcilutites make up about 40 percent, the calcisiltites 45 to 50 percent, and the calcarenites 10 to 15 percent of the subunit; on the average, the beds are thinner than in the Kirkfield Formation; the calcilutites range from ½ inch to 12 inches thick, the calcisiltites range from ½ inch to 8 inches thick, with continuous runs up to 31 inches long; and the calcarenites range from 2 to 4 inches thick; the limy shale is less abundant upward, and the calcisiltites also decrease in quantity higher in the subunit at the expense of the calcarenites; fragments of small rugose (horn) corals and small brachiopods were noted.	41	1	43	0

Selby Member

	I Ft.	I In.	II Ft.	II In.
1. Medium dark gray (N4) fine calcisiltite.	1	11	1	11

Bottom of hole.

3. This section was measured from quarry exposures and drill core (Alf. 141) obtained in the Town of Champion quarry, which is located 1 mile east of Champion Huddle, NE/4 Copenhagen, N.Y. quadrangle. Beds dip 3 degrees southwest, N. 30 degrees W.

Chaumont Formation

	I Ft.	I In.	II Ft.	II In.
93. Medium dark gray (N4), thin-bedded, cherty calcilutite and fine calcisiltite; weathers to light gray (N7); bedding surfaces wavy and uneven, spaced 1 to 4 inches apart; bedding surfaces are accentuated by moderate yellowish brown (10YR5/4) wavy argillaceous seams, 1/8 to ¼ inch thick, which separate the individual beds; grayish black (N2) to dark gray (N3) chert is present as irregular nodules elongated parallel to bedding; the chert weathers very light gray (N8) and a few nodules are characterized by a conspicuous rim of anhedral black calcite; contains **Tetradium fibratum** Safford, small horn corals, brachiopods, and orthoceracones; many of the forms are partly or wholly silicified.	6	6½	228	2

	I Ft.	I In.	II Ft.	II In.
92. Medium dark gray (N4), fossiliferous calcilutite to calcisiltite; weathers to intermediate between light olive gray (5Y6/1) and yellowish gray (5Y8/1); bedding surfaces are wavy and uneven; individual beds are mostly indistinct, but undulatory; moderate yellowish brown (10YR5/4) argillaceous seams show up the wavy character of some bedding surfaces; silicified fragments of fossils are abundant.	2	9½	221	7½

Lowville Formation: 121 feet 10 inches

Lowville **sensu-stricto:** 80 feet 11 inches

	I Ft.	I In.	II Ft.	II In.
91. Medium gray (N5), **Phytopsis**-bearing, medium-bedded calcilutite; weathers light gray (N7); beds average 6 to 8 inches thick; in addition to the characteristic calcite-filled worm boring **Phytopsis tubulosa,** the subunit contains **Tetradium cellulosum.**	1	8½	220	8
90. Dark gray (N3), thin-bedded calcilutite to fine calcisiltite; weathers to intermediate between medium light gray (N6) and light gray (N7); locally it weathers moderate yellowish brown (10YR5/4) to grayish orange (10YR7/4); beds are plane and distinct, surfaces 1 to 4 inches apart; moderately fossiliferous; some layers are more fossiliferous than others; contains abundant **Tetradium,** cephalopods, and gastropods; the subunit is particularly fossiliferous 5½ feet below the top.	6	8	218	11½
89. As 90, but beds mostly indistinct; prominent layering surfaces 3 to 8 inches apart.	1	10	212	3½
88. As 91.	1	11	210	5½
87. Medium dark gray (N4), very thin- to thin-bedded calcilutite; weathers light gray (N7); limestone beds separated by dark yellowish orange (10YR4/4) to pale yellowish orange (10YR6/6) argillaceous seams, a ¼ to ½ an inch thick.	1	0	208	6½
86. Olive black (5Y2/1) to medium dark gray (N4), knobby, stromatoporoid-bearing calcilutite to calcisiltite; weathers to intermediate between medium light gray (N6) and light gray (N7); gives off a petroliferous odor when freshly broken; contains a few small gastropods.	1	7	207	6½
85. Medium dark gray (N4), thin- to medium-bedded calcilutite; weathers light gray (N7): bedding surfaces plane, 1 to 6 inches inches apart; characterized by **Tetradium** sp. and **Phytopsis tubulosa; T.** are particularly abundant in the highest 10 inches, calcite-filled **P.** predominate in the lowest half.	1	11½	205	11½

Base of quarry wall. The quarry floor is marked by two prominent sets of vertical joints: N. 75 degrees E., surfaces spaced an average of 10 feet apart and N. 70 degrees W., surfaces spaced 2 to 20 feet apart. A less prominent set of vertical joints strikes N. 20 degrees E., joint surfaces 2 to 20 feet apart.

The following subunits have been described and measured from drill core begun at quarry floor.

	I Ft.	I In.	II Ft.	II In.
84. Medium dark gray (N4) to medium gray (N5), thickly laminated to thin-bedded calcilutite; faintly mottled with a slight brownish tinge when wet; numerous wavy, paper-thin, dark gray (N3) shaly seams, spaced ¼ inch to 4 inches apart, along which the core separates readily; prominent stylolites occur 4 and 4½ feet below the top of the subunit; contains a few **Phytopsis.**	6	0	204	0
83. As 84, but wavy shale partings are thicker and more abundant; the partings range from paper thin to ¼ inch thick and are spaced ¼ inch to 2 inches apart; small aggregates of calcite grains up to ½ inch in diameter are present; a prom-				

	I		II	
	Ft.	In.	Ft.	In.
inent stylolite occurs 2 feet 9 inches below the top of the subunit.	5	4	198	0
82. Medium dark gray (N4) to medium gray (N5) fine calcisiltite which contains well-rounded quartz grains of sand size; sand grains are disseminated throughout the subunit but are most abundant in the upper half; small aggregates of calcite are abundant; occasional undulose, paper-thin shale partings.	1	4	192	8
81. As 82, but without quartz sand grains.	0	8	191	4
80. Medium dark gray (N4) to medium gray (N5) calcisiltite; bedding not apparent; stylolitic in highest 10 inches.	1	10	190	8
79. Medium dark gray (N4) fossiliferous calcilutite; occasional paper-thin, wavy dark gray (N3) shale partings; **Phytopsis** and **Tetradium** abundant; breaks with a hackly fracture.	1	10	188	10
78. Medium dark gray (N4), thinly laminated to thin-bedded calcilutite; abundant wavy, paper-thin dark gray (N3) shale partings spaced 1/16 of an inch to 4 inches apart; contains **Phytopsis**, but not as abundantly as in subunit above.	4	7	187	0
77. Medium dark gray (N4) to medium gray (N5) calcilutite; occasional plane, paper-thin dark gray (N3) shale partings; a few well-rounded quartz grains of sand size occur 2 to 7 inches below the top of the subunit; zone of dark gray limy shale, ½ inch thick, occurs 2 feet 5 inches below the top; occasional **Phytopsis.**	4	2	182	5
76. Missing.	0	3	178	3
75. As 77, but without quartz sand grains; zones of limy shale, ½ an inch thick, 2 inches and 9 inches below top of subunit.	0	11	178	0
74. Medium dark gray (N4) to medium gray (N5), very thin- to thin-bedded calcisiltite; wavy, paper-thin, dark gray (N3) shale partings spaced an average of 1 inch apart.	2	1	177	1
73. Medium gray (N5) coarse calcisiltite with abundant quartz grains of sand size; occasional wavy, paper-thin dark gray (N3) shale partings; scattered small aggregates of calcite.	1	5	175	0
72. Medium dark gray (N4) to medium gray (N5) calcilutite, occasionally becoming calcisiltite; few paper-thin dark gray (N3) shale partings.	1	6	173	7
71. Grayish black (N2) limy shale.	0	10	172	1
70. As 72.	2	4	171	3
69. As 73, but with more shale partings; highest 8 inches appears conglomeratic, giving a mottled appearance to the core.	1	6	168	11
68. Medium gray (N5) to medium light gray (N6), very thin- to medium-bedded coarse calcisiltite which contains scattered quartz grains of sand size; sand grains are most prominent in the lowest 6 inches; very few paper-thin shale partings.	4	6	167	5
67. Medium dark gray (N4) to medium gray (N5), very thin- to thin-bedded calcilutite; occasional wavy, paper-thin dark gray (N3) shale partings; stylolite near base.	1	1	162	11
66. As 68.	2	11	161	10
65. As 67, but without stylolite.	1	6	158	11
64. Medium dark gray (N4), thickly-laminated to thin-bedded calcilutite; slightly coarser in grain than 65 and 67; wavy, paper-thin dark gray (N3) shale partings spaced ½ inch to 1½ inches apart.	2	0	157	5
63. Medium dark gray (N4) to medium gray (N5), thickly laminated to medium-bedded calcilutite; grain is slightly coarser in lowest 2 feet; contains very few quartz grains of sand size; scattered small aggregates of calcite become abundant 4 feet				

	I Ft.	I In.	II Ft.	II In.
1 inch and 5 feet 11 inches below the top of the subunit; grayish black, (N2) slightly limy shale partings, paper thin to ½ inch thick, are spaced a ¼ inch to 5 inches apart; stylolites occur 4½ feet, 10½ feet, and 11 feet 9 inches below the top; conglomeratic 5 feet 3 inches below top; minor pyrite mineralization 6 feet 11 inches below top; calcite aggregates may represent **Phytopsis.**	13	9	155	5
62. Medium gray (N5) to medium light gray (N6) calcisiltite containing scattered quartz grains of sand size; few wavy, paper-thin dark gray (N3) shale partings; occasional small aggregates of calcite.	1	11	141	8
Pamelia-Lowville transition: 40 feet 11 inches				
61. As 62, but with pale red (10R6/2) mottling; sand grains more abundant.	0	5	139	9
60. Medium gray (N5) to medium light gray (N6), very thin-bedded calcisiltite containing scattered quartz grains of sand size; the subunit is characterized by wavy, intermediate between dark greenish gray (5G4/1) and greenish gray (5G6/1) shale partings, 1/16 inch to 1/8 inch thick, which are spaced ½ inch to 1 inch apart.	2	8	139	4
*59. Medium light gray (N6) calcisil*tite with wavy greenish gray (5G6/1) shale partings which give the subunit an overall greenish gray cast; quartz grains of sand size are moderately abundant, with the heaviest concentrations at the top and 9 inches below the top of the subunit; minor pyrite mineralization 6 inches below the top.	1	8	136	8
58. Medium gray (N5) to medium light gray (N6) calcilutite; few wavy, paper-thin dark gray (N3) shale partings; minor **Phytopsis.**	1	2	135	0
57. Medium gray (N5), very thin- to medium-bedded, fine calcisiltite, locally becoming calcilutite with small aggregates of calcite or **Phytopsis;** occasional, plane and slightly wavy, paper-thin dark gray (N3), sometimes dark greenish gray (5G4/1) shale partings; stylolitic in lower half; pyrite mineralization 2 feet 2 inches, 3 feet 1 inch and 3 feet 11 inches below top of subunit.	5	8	133	10
56. Medium dark gray (N4) to medium gray (N5) thin- to thick-bedded calcilutite; dark gray (N3) shale partings, ¼ an inch to ½ inch thick, occur 2 feet 3 inches and 2 feet 5 inches below the top of the subunit; occasional stylolites.	3	6	128	2
55. Medium gray (N5) thickly laminated to thin-bedded calcilutite with abundant quartz grains of sand size; dark gray (N3) shale partings up to ¼ inch thick.	2	2	124	8
54. Medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded calcilutite; quartz grains of sand size disseminated throughout, but with the heaviest concentrations in layers in the highest 3 feet; occasional dark gray (N3) shale partings up to ½ inch thick; stylolites common; contains small aggregates of calcite which presumably fill the worm-boring **Phytopsis.**	9	7	122	6
*53. Medium light gray (N6) to light gray (N7), fine calcareous dolo*misiltite, with faint moderate reddish orange (10R6/6) mot*tling 7 inches below the top* and at the base of the subunit; occasional dark gray (N3) shale partings up to ½ inch thick; calcite grains of sand size are scattered throughout the middle of the subunit; one stylolite in middle.	3	1	112	11
52. Intermediate between medium dark gray (N4) and medium gray (N5) to medium light gray (N6), thickly laminated to medium-bedded calcisiltite and calcilutite; the calcilutites are a shade darker than the calcisiltites; dark gray (N3) shale				

	I Ft.	I In.	II Ft.	II In.
partings, 1/16 inch to an 1/8 inch thick, are spaced an 1/8 inch to a ¼ inch apart in 1 to 3 inch thick zones throughout; quartz grains of sand size are scattered through the subunit but abundant in a 2 inch thick zone, 8 feet 2 to 8 feet 4 inches below the top.	11	0	109	10
Pamelia Formation: 95 feet 2 inches				
51. Distinctive medium light gray (N6) dolomisiltite to fine dolomarenite with a greenish gray (5G6/1) cast; quartz grains of sand size are disseminated throughout the subunit, but are particularly evident in the lowest 9 inches; prominent paper-thin dark gray (N3) shale partings 4 feet 1 inch and 4 feet 4 inches below the top.	4	10	98	10
50. Intermediate between greenish-gray (5G6/1) and light-greenish-gray (5G8/1) coarse dolomisiltite which is mottled pale red (10R6/2) from 1 foot 5 inches to 2 feet 8 inches below the top of the subunit; scattered quartz grains of sand size above mottled zone.	3	9	94	0
49. Medium gray (N5) to medium light gray (N6), thickly laminated to medium-bedded calcisiltite; dark gray (N3) shale partings, 1/16 inch to 1/8 of an inch thick, are spaced 1/8 inch to 12 inches apart.	5	4	90	3
48. Medium gray (N5) to medium light gray (N6), greenish gray with quartz grains of sand size.	0	8	84	11
47. As 49.	0	5½	84	3
46. Greenish gray (5G6/1) to intermediate between greenish gray and light greenish gray (5G8/1) dolomisiltite and fine dolomarenite with quartz grains of sand size.	1	7½	83	9½
45. As 46, but mottled pale red (10R6/2) and without quartz sand grains.	1	8	82	2
44. As 46.	2	9	80	6
43. Medium light gray (N6) calcilutite and fine calcisiltite; occasional stylolites; small aggregates of calcite in upper half.	3	9	77	9
42. Light gray (N7) to intermediate between greenish gray (5G6/1) and light greenish gray (5G8/1) dolomisiltite.	0	8	74	0
41. Medium gray (N5), thickly laminated to very thin-bedded calcilutite; dark gray (N3) shale partings, paper thin to 1/16 inch thick; quartz sand grains abundant 3 feet 1 inch below the top of subunit.	4	11	73	4
40. Medium light gray (N6) dolomisiltite with greenish gray (5G6/1) mottling.	1	5	68	5
39. Medium gray (N5) calcisiltite, locally dolomitic.	4	9	67	0
38. Greenish gray (5G6/1), thin- to medium-bedded dolomisiltite; local pale red (10R6/2) mottling, particularly from 3 feet 8 inches to 4 feet 2 inches, and from 5 feet to 5 feet 4 inches below the top of the subunit; occasional dark greenish gray (5G4/1) shale partings; contains a few sand grains composed of quartz.	8	5	62	3
37. Medium gray (N5) to intermediate between dark greenish gray (5G4/1) and greenish gray (5G6/1) calcisiltite; color darkens downward; occasional dark gray (N3) shale partings; a few stylolites occur in the zone from 1 foot 10 inches to 2 feet 1 inch below the top of the subunit.	5	9	53	10
36. Medium dark gray (N4), thickly laminated to medium-bedded calcilutite; dark gray (N3) shale partings, paper thin, spaced ¼ inch to 12 inches apart; occasional small aggregates of calcite **(Phytopsis?)**.	7	5	48	1
35. Medium gray (N5) to medium light gray (N6) fine dolomisiltite with faint greenish gray				

	I Ft.	I In.	II Ft.	II In.
(5G6/1) mottling; dark gray (N3) shale parting; 1/8 inch thick, at top; 1 stylolite, 2 inches below the top of the subunit.	0	11	40	8
34. Light gray (N7) to very light gray (N8) fine dolomisiltite with light greenish gray (5GY8/1) cast; abundant well rounded quartz grains of sand size.	0	9	39	9
33. Light gray (N7) to intermediate between greenish gray (5GY6/1) and light greenish gray (5GY8/1) dolomisiltite; locally speckled pale red (10R6/2); dark gray shale layer, ½ thick, 3 feet 9 inches below top of the subunit; few small calcite grains near base.	4	9	39	0
32. Medium dark gray (N4) calcilutite.	0	3	34	3
31. As 33, but with small grains of yellowish calcite from 1 foot 6 inches to 1 foot 9 inches below top; minor pyrite 1 foot 5 inches below top.	3	8	34	0
30. As 32.	0	7	30	4
29. Medium light gray (N6) dolomisiltite with an overall faint greenish gray (5G6/1) cast, locally becoming pale green (10G6/2); contains a few 1-inch bands of medium dark gray calcisiltite.	2	5	29	9
28. Medium light gray (N6) and greenish gray (5G6/1) dolomisiltite with rounded quartz grains of sand size.	0	10	27	4
27. Greenish gray (5G6/1) dolomisiltite; rounded quartz grains of sand size in lowest 13 inches; minor pyrite mineralization.	2	10	26	6
26. Medium gray (N5), locally pale green (10G6/2) calcisiltite with abundant well-rounded quartz sand grains.	0	11	23	8
25. Greenish-gray (5G6/1) dolomisiltite, becoming grayish-blue green (5BG5/2) downward; scattered well-rounded quartz grains of sand size.	0	9	22	9
24. Medium light gray (N6) calcareous sandstone.	0	10	22	0
23. Intermediate between greenish-gray (5G6/1) and light greenish-gray (5G8/1) dolomisiltite, with occasional well-rounded quartz grains of sand size.	0	4	21	2
22. Light gray (N7) to intermediate between greenish-gray (5G6/1) and light greenish-gray (5G8/1) dolomisiltite.	1	8	20	10
21. Medium gray (N5) calcilutite.	0	10	19	2
20. Medium gray (N5) calcisiltite.	0	2	18	4
19. Dark greenish-gray (5G4/1) to greenish-gray (5G6/1) dolomisiltite.	2	5	18	2
18. Dark greenish-gray (5G4/1) dolomisiltite with moderately abundant, well-rounded quartz sand grains.	0	6	15	9
17. Greenish-gray (5G6/1) dolomisiltite becoming dark greenish-gray (5G4/1) downward; locally speckled pale red (10R6/2).	2	9	15	3
16. Dark gray (N3) argillutite with moderately abundant well-rounded quartz grains of sand size.	0	8	12	6
15. Greenish-gray (5G6/1) dolomisiltite with abundant well-rounded quartz grains ot sand size.	0	1	11	10
14. As 16.	0	1	11	9
13. As 15.	0	1	11	8
12. As 16.	0	9	11	7
11. As 15.	1	1	10	10
10. Medium gray (N5) calcisiltite with abundant quartz grains of sand size.	1	0	9	9
9. As 15, but 4 to 5 inches of core was lost.	1	3	8	9
8. As 10.	0	4	7	6
7. As 15.	0	3	7	2
6. As 10.	0	6	6	11
5. As 15.	0	4	6	5
4. Medium light gray (N6) calcisiltite; mottled greenish gray (5G6/1) near base; contains a few well-rounded quartz grains of sand size.	1	0	6	1

	I Ft.	I In.	II Ft.	II In.
3. Greenish gray (5G6/1) to intermediate between greenish gray and light greenish-gray (5G8/1) dolomisiltite; contains abundant, well-rounded quartz grains of sand size and a few small inclusions of pale reddish-brown (10R5/4) feldspar.	1	1	5	1
2. Basal conglomerate; greenish-gray (5G6/1) arenaceous dolomisiltite containing inclusions of gneiss up to 2 inches in diameter.	0	4	4	0
Precambrian				
1. Prophyroblastic hornblende-biotite gneiss containing pale reddish-brown (10R5/4) feldspar; dusky-green (5G3/2) hornblende; quartz rare.	3	8	3	8

Bottom of hole.

4. This section was measured on the east wall of the quarry which is located in Camp Drum about 850 feet west of the LeRaysville Cemetery, immediately south of the Camp Drum-Evans Mills Road, SE/4 Black River, N.Y. quadrangle.

Lowville Formation

Lowville sensu-stricto

	I Ft.	I In.	II Ft.	II In.
12. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, thickly laminated to thin-bedded calcilutite and fine calcisiltite; weathers medium light gray (N6); dark gray (N3) limy shale is present in thin beds an 1/8 inch to 3 inches thick; small grains of calcite are moderately abundant; occasional quartz grains of sand size; contains a few small cup corals.				
11. Medium dark gray (N4), fossiliferous calcirudite; matrix calcisiltite with small fragments of calcilutite from subunit below; weathers medium gray (N5) to medium light gray (N6); brecciated character obvious only on a weathered surface; contains Bryozoa, brachiopods, gastropods, small orthoceracones, and crinoid stem fragments.	0	5	33	3
10. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, thinly laminated to very thin-bedded calcilutite; weathers light gray (N7); abundant paper-thin, dark gray (N3) limy shale partings, particularly in the uppermost few inches; contains a few small pods of limonite up to ¼ inch in diameter.	3	2	32	10
9. Dark gray (N3) to medium dark gray (N4), thickly laminated to thin-bedded calcilutite and calcisiltite; weathers medium light gray (N6) to light gray (N7); locally appears brecciated on a weathered surface; dark gray (N3) wavy shale partings, paper thin to ¼ inch thick, spaced an 1/8 inch to 4 inches apart; fossils not common; contains a few small brachiopods and ostracodes; occasional aggregates of calcite grains up to ¾ inch in diameter.	6	4	29	8
8. Dark gray (N3) to medium dark gray (N4), thin- to medium-bedded calcilutite and minor calcisiltite; weathers medium light gray (N6) to light gray (N7); limestone beds are 1 to 12 inches thick, with an average of 4 inches; dark gray (N3), paper-thin limy shale partings; calcite grains of sand size disseminated throughout subunit; contains small coiled gastropods, small cepahlopods and ostracodes.	1	10	23	4
7. As 8, but with an increase of the shale partings to about 20 percent of the subunit.	1	10	21	6
6. Identical to 8, but with zones of breccia, 6 to 10 inches thick, evident on the weathered surface; fossils appear to be concentrated in the brecciated zones.	7	4	19	8
Pamelia-Lowville transition				
5. Medium dark gray (N4), thin- to medium-bedded, slightly dolomitic calcisiltite; weathers light olive gray (5Y5/2); dark greenish-gray (5GY4/1) shale partings; contains quartz grains of sand size.	3	0	12	4

	I Ft.	I In.	II Ft.	II In.
4. Intermediate between dark gray (N3) and medium dark gray (N4), thickly laminated to thin-bedded calcilutite and calcisiltite, and calcirudite; weathers medium light gray (N6); brecciated character evident on weathered surface only; limestone beds are ¼ inch to 3 inches thick and separated by paper-thin, dark gray (N3) shale partings which weather to light olive gray (5Y6/1); the surfaces of some partings are mud-cracked; prominent layers are 4 to 15 inches thick; contains ostracodes.	4	0	9	4
3. Medium dark gray (N4) to medium gray (N5) dolomisiltite; weathers intermediate between moderate yellowish brown (10YR5/4) and grayish orange (10YR7/4).	1	0	5	4
2. As 4, but locally very slightly dolomitic; contains scattered sand-sized calcite grains.	4	4	4	4
1. Floor of quarry. Base of section. Medium gray (N5) calcilutite; weathers medium light gray (N6); cut by 2 sets of vertical joints: N. 73 degrees E., surfaces spaced an average of 4 feet apart, and N. 79 degrees E., surfaces spaced 2 to 8 feet apart.				

5. This section was measured from cliff and stream exposures on the northern slope located immediately north of Ridge Road, 0.75 mile east of Woodwards Side Hill, NW/4 South Rutland, N.Y. quadrangle. The base of the section begins 52 feet 6 inches above the valley floor. Colors of weathered surfaces were not obtained because of profuse growth of lichen.

Shoreham Formation

	I Ft.	I In.	II Ft.	II In.
8. Medium gray (N5) thin-bedded calcarenite and medium dark gray (N4) to medium gray, thin-bedded calcisiltite with minor paper-thin, dark gray (N3) limy shale partings; limestone beds range from 1 to 5 inches thick with an average of 2 to 3 inches; the calcarenites are highly fossiliferous; contain ubiquitous Trenton brachiopods; a portion of the cephalic brim of **Cryptolithus** cf. **quadrillineus** in the highest foot.	12	0	108	5

Kirkfield Formation: 80 feet 5 inches

	I Ft.	I In.	II Ft.	II In.
7. Medium gray (N5) to intermediate between medium gray and medium light gray (N6), thin- to medium-bedded coquinal calcarenites and medium gray, thin-bedded, barren calcisiltites separated by plane and wavy, dark gray (N3) limy shale partings; the limy shale is not evident having weathered back to form narrow reentrants parallel to bedding surfaces of the limestones; the calcarenites measure 1½ to 8 inches thick, with an average of 4 inches in thickness; the calcisiltites are 1 to 2 inches thick and compose 10 to 15 percent of the entire subunit; the fossils present are typical of the Trenton fauna with brachiopods the dominant element; included are **Dinorthis, Paucicrura, Sowerbyella** and **Strophomena;** also noted were trilobite fragments and crinoid stem fragments; **Prasopora orientalis** is fairly common in the uppermost 5 feet of the subunit.	30	1	96	5
6. As 7, but without the calcisiltites; contains a few high-spired gastropods (**Hormotoma ? sp.**).	11	3	66	4
5. As 7; calcisiltites increase slightly in quantity to account for about 15 percent of the subunit; weathered surfaces locally stained dark yellowish orange (10YR6/6); contains the long-ranging Trenton trilobite **Isotelus.**	16	5	55	1
4. Dark gray (N3) limy shale with very thin interbeds of medium gray (N5) calcarenite; cut by prominent set of vertical joints which strike N. 88 degrees W.	1	1	38	8
3. As 5.	15	0	37	7
2. Medium gray (N5), thin- to medium-bedded calcisiltite; dark gray (N3) limy shale partings as in 7; limestone beds are 2 to 8 inches thick with an average of 4 to 5 inches; fossiliferous coarse calcisiltite beds, 5 inches thick, occur at the top and 1 foot above the base of the subunit; other calcisiltites are barren.	6	7	22	7

	I Ft.	I In.	II Ft.	II In.
Rockland Formation				
Napanee Member				
1. Medium dark gray (N4), very thin- to medium-bedded, very fine calcisiltite and coarse calcilutite with thin interbeds of medium gray (N5) calcarenite; beds are ½ to 5 inches thick, with an average thickness of 2½ inches; considerably thinner-bedded than any of the subunits above; limestone beds separated by dark gray (N3) limy shale as in 7; layering coincides with bedding; the calcarenites account for about 35 percent of the subunit and are moderately fossiliferous; the brachiopods **Sowerbyella** and **Paucicrura,** and crinoid stem fragments predominate.	16	0	16	0
Base of section				

6. This section was measured in the falls and bed of the small westward-flowing stream 1,000 to 2,000 feet northwest of School No. 7, East Watertown, NW/4 South Rutland, N.Y. quadrangle.

	I Ft.	I In.	II Ft.	II In.
Denmark Formation				
6. Covered.				
5. As 4 below, but limy shales increase in quantity to make up 30 to 35 percent of the subunit and the calcilutites disappear.	3	4	57	11
4. Medium gray (N5) to medium light gray (N6), fine to coarse calcarenites with the coarsest layers having a pale yellowish-brown (10YR6/2) cast, medium gray (N5) calcisiltites, very minor medium dark gray (N4) to medium gray calcilutites, and plane, dark gray (N3) limy shale partings; the calcarenites compose 50 to 55 percent, the calcisiltites and calcilutites combined make up 35 to 40 percent, and the limy shales account for 10 to 15 percent of the subunit; limestone beds range from ½ inch to 9 inches thick with an average thickness of 3 inches, bedding surfaces are plane and smooth; the limy shales range in thickness from paper-thin partings to zones measuring ½ inch; ubiquitous Trenton brachiopods are common, "nests" of small **Prasopora** are locally common, and both large and small forms of branching Bryozoa are fairly abundant throughout the succession.	29	7	54	7
Shoreham Formation: 20 feet 6 inches				
3. Medium dark gray (N4) to medium light gray (N6), very thin- to medium-bedded limestone, ranging from coarse calcisiltite to coarse calcarenite with fine calcarenite and calcisiltite predominating; the limestone beds are separated by wavy, dark gray (N3) limy shale partings (compose 30 percent of subunit), paper thin to ½ inch thick, and measure ½ inch to 5 inches, with an average of 1 to 2 inches thick; bedding surfaces are wavy and give a pinch and swell character to the beds; thus a thin limestone layer may grade laterally into limy shale and back again into limestone; the coarser limestones are fossiliferous; the long-ranging Trenton brachiopods such as **Paucicrura** and **Sowerbyella** are common; **Prasopora** is present, and a fragment of a large orthoceracone, 3 inches in diameter, was noted 9 feet above the base of the subunit.	20	6	25	0
Kirkfield Formation				
2. Medium dark gray (N4) to intermediate between medium gray (N5) and medium light gray (N6), thin- to medium-bedded calcarenites and calcisiltites separated by minor but prominent limy shale partings (compose 10 percent of subunit); limestones measure 1 to 8 inches and average 4 to 5 inches thick; the coarser calcarenites are thickest and almost coquinal, containing such typical brachiopods as **Paucicrura ("Dalmanella"), Sowerbyella,** and **Dinorthis,** small **Prasopora,** and abundant crinoid stem fragments.	4	6	4	6

	I Ft.	I In.	II Ft.	II In.
1. Covered				

Base of section

7. This section was described and measured from the cliff exposure along the north bank of the Black River immediately west of the bridge on N.Y. Highway 3 and opposite the City of Watertown filtration plant, NE/4 Watertown, N.Y. quadrangle.

	I Ft.	I In.	II Ft.	II In.
Chaumont Formation				
6. Medium dark gray (N4), medium-bedded calcilutite to fine calcisiltite; weathers light gray (N7); beds indistinct but appear to average 4 or 5 inches in thickness, surfaces irregular; contains small horn corals, brachiopods, cephalopods, and crinoid stem fragments; from 1 to 2 feet below the top of the subunit are several specimens of the cephalopod **Actinoceras**.	10	2	32	1
5. Medium dark gray (N4), thin- to medium-bedded calcilutite to fine calcisiltite with many irregular nodules of dark gray (N3) chert arranged in layers and elongated parallel to bedding; limestone weathers light gray (N7) to very light gray (N8); beds average 4 to 5 inches thick; chert layers are spaced 1 to 8 inches apart; limestone beds not delineated by chert are generally indistinct; subunit is sparsely fossiliferous.	5	2	21	11
4. Medium dark gray (N4), noncherty, thin-bedded calcisiltite; weathers light gray (N7); individual beds are generally indistinct except where thin veins of white calcite, an 1/8 inch to 1 inch thick, parallel and cut across the beds to outline small irregular blocks; the subunit is typified by silicified fossils, particularly small brachiopods, occasional cephalopods, and the horn coral **Enterolasma** sp.; water, from the small canal 10 feet to the north, issues from the base of the subunit to wet the Lowville Limestone below and clearly mark the plane of contact between the two formations.	3	1	16	9
Lowville Formation				
3. Medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded calcilutite; weathers light gray (N7); beds are ½ an inch to 6 inches thick; prominent layering surfaces are 1½ to 8 inches apart; streaks and blotches of coarse white calcite are common; moderately fossiliferous, contains **Phytopsis**, fragments of small gastropods and Bryozoa.	4	6	13	8
2. Medium light gray (N6), very thin- to medium-bedded calcirudite (calcilutite fragments in coarse calcisiltite matrix); weathers intermediate between medium light gray (N6) and light gray (N7); bedding surfaces slightly wavy, ½ inch to 6 inches apart; beds average 3 inches thick; prominent layering surfaces 4 to 12 inches apart; moderately fossiliferous, contains abundant Bryozoa and occasional ostracodes.	1	11	9	2
1. Medium dark gray (N4) to olive gray (5Y4/1), thin- to thick-bedded calcilutite and locally fine calcisiltite; weathers medium light gray (N6); bedding surfaces wavy, 1 to 12 inches apart; prominent layers 8 inches to 3 feet thick; contains **Phytopsis**, Bryozoa, small brachiopods, gastropods, and cephalopods; many of the forms weather a distinctive dark yellowish orange (10YR6/6) or grayish orange (10YR7/4).	7	3	7	3

Base of section. Rock in stream bed is described below.

Medium dark gray (N4) to olive gray (5Y4/1) fine calcisiltite; weathers light olive gray (5Y6/1); bedding surfaces characterized by many small solution pits; some surfaces exhibit polygonal outlines suggesting mud cracks.

8. This section was described and measured from drill core (Alf. 144) obtained on Gotham Hill at the city limits of Watertown, 300 feet southwest of Gotham Street and 8,100 feet southeast of Public Square, NE/4 Watertown, N.Y. quadrangle.

	I		II	
	Ft.	In.	Ft.	In.
Denmark Formation				
31. Medium light gray (N6), thin- to medium-bedded calcarenite interbedded with minor amounts of medium gray (N5) calcisiltite and dark gray (N3) limy shale; calcarenite beds are 2 to 12 inches thick, surfaces wavy; the thicker beds occur 1 to 2 feet, 3 feet 4 inches to 4 feet, 4 feet 2 inches to 4 feet 8 inches, and 7 feet 1 inch to 8 feet 1 inch below the top of the subunit; calcisiltite beds are thin; the limy shale partings are paper-thin to 1/8 of an inch thick and occur singly and in zones; when found between beds of calcarenite the partings are wavy, elsewhere in the subunit they are plane; a few fragments of small brachiopods were noted in the calcarenites.	8	1	260	3
Shoreham Formation: 24 feet 1 inch				
30. Approximately equal amounts of thin- to medium-bedded medium light gray (N6) calcarenite and medium gray (N5) calcisiltite, and minor wavy, dark gray (N3) limy shale partings; limestone beds range from 3 to 7½ inches thick, but with an average thickness half that of basal Denmark above; the limy shale ranges from paper-thin partings to zones ¼ inch thick; contains **Prasopora** and long-range Trenton brachiopod **Parastrophina(?).**	7	1	252	2
29. Interbedded fine to coarse, medium dark gray (N4) to medium gray (N5) calcisiltite, medium light gray (N6) to pale yellowish-brown (10YR6/2) calcarenite, and dark gray (N3) limy shale; the brownish tinge of the calcarenites appears restricted to the larger calcite grains which gives to the rock an overall yellowish-brown cast; the limy shale composes about 25 percent of the subunit, the limestones account for the balance with the coarse calcisiltites and calcarenites predominating; limestone beds measure 1 to 4 inches, averaging 3 inches in thickness; the limy shale is present as partings, paper-thin to 1 inch thick and occurs in well-defined, plane and wavy zones, 1/16 to 1½ inches thick; the subunit is moderately fossiliferous; ubiquitous Trenton fauna is common to the limestones but none are coquinal; crinoid stem fragments are present in the limy shale.	17	0	245	1
Kirkfield and Rockland Formations: 107 feet 2 inches.				
28. Interbedded medium dark gray (N4) to medium gray (N5) fine to coarse calcisiltite, medium light gray (N6) to pale yellowish-brown (10YR6/2) calcarenite, and dark gray (N3) limy shale; limestone beds are 1 to 11 inches thick; throughout the succession there are nine beds of coarse calcisiltite and calcarenite which measure more than 8 inches thick; the limy shale makes up about 20 percent of the subunit and is present as partings, paper thin to 1 inch thick, which occur in zones a 1/16 inch to 3½ inches thick; the partings are mostly plane; fossils generally not evident in core but appear to be restricted to calcarenites; the fauna is typically Trenton.	42	1	228	1
27. Interbedded medium dark gray (N4) to medium gray (N5) calcisiltite and calcilutite, and minor amounts of medium light gray (N6) calcarenite; base of subunit marked by prominent 8-inch thick calcarenite; otherwise as 28. The change from Rockland to Kirkfield lithology takes place in this subunit but the contact is not easily distinguished. The sequence is transitional upward to the Kirkfield Formation.	35	6	186	0
26. Interbedded medium dark gray (N4) to medium gray (N5) calcisiltite and calcilutite, and dark gray (N3) limy shale; no calcarenite; ½-inch zone of barite (or strontianite) in limy				

	I Ft.	I In.	II Ft.	II In.
shale 3 feet 4 inches below the top and minor pyrite mineralization 7 feet 2 inches below the top of the subunit; thickness of limestone and limy shale comparable to 27 and 28.	22	6	150	6
25. Medium dark gray (N4) to intermediate between medium dark gray and medium gray (N5), thin-bedded calcisiltite, locally mottled and flected brownish gray (5YR4/1), and minor plane, paper-thin dark gray (N3) shale partings; the calcisiltite locally coarsens to very fine calcarenite; the sequence is transitional upward from highest Chaumont lithology to typical Rockland lithology.	7	1	128	0
Chaumont Formation: 25 feet 1 inch				
24. Intermediate between medium dark gray (N4) and medium gray (N5) and brownish-gray (5YR4/1), thin-bedded, uniformly-textured calcisiltite and minor calcilutite, and wavy dark gray (N3) limy shale partings; the shale partings are paper thin, 1 to 4 inches apart, and separate the limestone beds; the core does not readily break parallel to the shale partings, as is typical of the Trenton rocks, so that the sequence appears more massive; occasional stylolites; no fossils seen.	19	8	120	11
23. As 24, but with brownish-gray (5YR4/1) chert in small irregular nodules elongated parallel to the bedding surfaces.	2	8	101	3
22. As 24, but with occasional small aggregates of calcite grains.	2	9	98	7
Lowville Formation				
Lowville **sensu-stricto:** 89 feet 10 inches				
21. Intermediate between medium gray (N5) and medium light gray (N6) fine calcisiltite to calcilutite and paper-thin dark gray (N3) limy shale partings; abundant **Phytopsis.**	0	11	95	10
20. Intermediate between medium dark gray (N4) and medium gray (N5), thickly laminated to very thin-bedded fine calcisiltite containing wavy, paper-thin dark gray (N3) limy shale partings spaced 1/8 inch to 1 inch apart; few **Phytopsis.**	1	5	94	11
19. Intermediate between medium gray (N5) and medium light gray (N6), thinly laminated to thin-bedded calcilutite to fine calcisiltite containing paper-thin, dark-gray (N3) shale partings spaced a 1/16 inch to 2½ inches apart; occasional **Phytopsis.**	1	3	93	6
18. Medium dark gray (N4) to medium gray (N5) calcisiltite, minor intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray calcilutite, and very minor medium gray (N5) calcarenite with a brownish-gray (5YR4/1) cast 3 feet 11 inches to 4 feet 5 inches below the top of the subunit; mostly wavy, dark gray (N3) limy shale partings, paper-thin to 1/8 inch thick, separate the limestone beds and are spaced a 1/16 inch to 3 inches apart; the shale partings are particularly abundant 9 feet 10 inches to 10 feet 4 inches below the top of the sequence, causing the core to break into many thin discs; occasional **Phytopsis** in the finer-grained limestones.	14	11	92	3
17. Medium dark gray (N4) to olive gray (5Y4/1), thickly laminated to thin-bedded calcilutite; paper-thin, dark gray (N3) limy shale partings are spaced 1/8 inch to 2 inches apart; occasional **Phytopsis.**	3	5	77	4
16. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, thickly laminated to medium-bedded calcisiltite; locally abundant, plane and wavy, dark gray limy shale partings, paper-thin to a ¼ inch thick, spaced an 1/8 inch to 9 inches apart.	12	4	73	11
15. Medium dark gray (N4) to medium gray (N5), **Phytopsis**-bearing calcilutite.	0	6	61	7

	I Ft.	I In.	II Ft.	II In.
14. Intermediate between dark gray (N3) and medium dark gray (N4), thickly laminated to medium-bedded calcisiltite and minor medium gray (N5) calcarenite; wavy paper-thin dark gray (N3) limy shale partings are spaced a ¼ inch to 8 inches apart; small aggregates of calcite, perhaps filling the worm boring **Phytopsis**, are occasionally found.	7	6	61	1
13. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, thickly laminated to thin-bedded calcilutite; distinct plane, paper-thin dark gray (N3) shale partings which are limy and spaced 1/8 inch to 3 inches apart; contains **Phytopsis.**	8	11	53	7
12. Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, thickly laminated to thin-bedded calcisiltite and calcilutite; wavy, dark gray limy shale partings, paper-thin to ¼ inch thick, are spaced 1/8 inch to 2 inches apart; occasional **Phytopsis** in the calcilutites.	5	1	44	8
11. Intermediate between medium dark gray (N4) and medium gray (N5), thickly laminated to thin-bedded calcilutite; wavy, paper-thin dark gray (N5) limy shale partings, 1/8 inch to 2 inches apart; grayish-black (N2) limy shale zone from 2 feet 5 inches to 2 feet 6 inches below top of subunit.	3	2	39	7
10. Medium dark gray (N4) to intermediate between medium dark gray and medium gray (N5) calcisiltite; occasional wavy, paper-thin dark gray (N3) limy shale partings; scattered quartz grains of sand size; minor pyrite mineralization at top of subunit.	1	8	36	5
9. Intermediate between medium dark gray (N4) and medium gray (N5) calcilutite; wavy, paper-thin, dark gray (N3) limy shale partings; slight pyrite mineralization.	0	5	34	9
8. As 10, but without pyrite.	1	7	34	4
7. As 10, but without pyrite and vaguely rudaceous or conglomeratic; conglomerate fragments are a faint greenish gray (5G6/1), which gives the subunit a slightly mottled appearance.	0	2	32	9
6. As 8.	2	0	32	7
5. Intermediate between medium dark gray (N4) and medium gray (N5), thickly laminated to thin-bedded calcisiltite and minor calcilutite; wavy, dark gray (N3) limy shale partings, paper thin to 1/8 inch thick, spaced 1/8 inch to 2 inches apart; contains rounded quartz grains of sand size in the coarser limestone beds; occasional **Phytopsis** in the calcilutites.	8	4	30	7
4. Medium dark gray (N4), thickly laminated to medium-bedded calcilutite with minor amounts of medium gray (N5) calcisiltite and fine calcarenite; wavy and plane, dark gray (N3) limy shale partings, paper-thin to 1/8 inch thick, spaced 1/8 inch to 11 inches apart and locally concentrated into zones 1 inch thick; occasional **Phytopsis.**	13	10	22	3
3. Medium dark gray (N4) calcisiltite; occasional wavy, paper-thin dark gray (N3) limy shale partings; contains quartz grains of sand size.	2	5	8	5
Pamelia-Lowville transition				
2. Medium gray (N5), thickly laminated to very thin-bedded calcisiltite which is locally greenish-gray (5GY6/1) and slightly dolomitic; plane and wavy, intermediate between dark greenish-gray (5G4/1) and greenish-gray shale partings, 1/16 inch to 1/8 inch thick, spaced ½ inch to 1 inch apart; rounded quartz grains of sand size are scattered throughout the subunit.	4	0	6	0
1. Medium dark gray (N4) to intermediate between medium dark gray and medium gray (N5), thinly laminated to very thin-bedded calcisiltite and minor coarse cal-				

	I Ft.	I In.	II Ft.	II In.
cilutite; wavy, paper-thin dark gray (N3) limy shale partings, 1/16 inch to ½ an inch apart; occasional quartz grains of sand size.	2	0	2	0

Bottom of hole

9. This section was described and measured from core obtained by drilling (Alf. 146) on the south bank of a small westward-flowing stream immediately east of N.Y. Highway 37, 3.5 miles north of Watertown, SE/4 Brownville, N.Y. quadrangle. Drilling began 12 feet 2 inches below the Lowville-Chaumont contact.

Lowville Formation: 131 feet 10 inches

Lowville **sensu-stricto:** 69 feet 3 inches measured in core; 12 feet 2 inches to Chaumont Formation; 81 feet 5 inches in total thickness.

	I Ft.	I In.	II Ft.	II In.
45. Medium gray (N5) **Phytopsis**-bearing calcilutite.	6	11	230	0
44. Medium dark gray (N4) coarse calcilutite to fine calcisiltite; occasional plane, paper-thin dark-gray (N3) shale partings.	2	10	229	1
43. Medium dark gray (N4) to intermediate between medium dark gray and medium-gray (N5) coarse calcisiltite or fine calcarenite which is mottled dark yellowish-brown (10YR4/2); occasional plane, paper-thin, dark-gray (N3) shale partings.	2	8	226	3
42. Intermediate between medium dark gray (N4) and medium gray (N5), thickly laminated to thin-bedded calcilutite; plane, paper-thin, dark gray (N3) shale partings 1/8 inch to 3 inches apart.	1	8	223	7
41. Medium dark gray, thickly laminated to thin-bedded calcisiltite of very uniform texture; paper-thin, dark gray (N3) shale partings 1/8 inch to 4 inches apart and in zones ¼ inch thick.	9	8	221	11
40. Medium dark gray (N4), very thin- to medium-bedded, **Phytopsis**-bearing calcilutite; plane and wavy, paper-thin, dark gray shale partings ½ inch to 6 inches apart; calcarenite from 5 feet to 5 feet 3 inches and 5 feet 10 inches to 6 feet 3 inches below the top of the subunit.	6	5	212	3
39. Intermediate between medium dark gray (N4) and medium gray (N5) to intermediate between medium gray and medium light gray (N6), thinly laminated to thin-bedded calcilutite and minor medium gray to medium light gray calcisiltite; abundant plane and wavy, paper-thin dark gray (N3) shale partings spaced a 1/16 inch to 3 inches apart.	8	10	205	10
38. Medium dark gray (N4) to medium gray (N5), thickly laminated to medium-bedded calcilutite and calcisiltite; locally abundant plane and wavy dark gray (N3) shale partings, paper-thin to 1/8 inch thick, spaced 1/8 inch to 6 inches apart; occasional **Phytopsis** in the calcilutite.	6	0	197	0
37. Medium gray (N5) to intermediate between medium gray and medium light gray (N6), thin- to medium-bedded, **Phytopsis**-bearing calcilutite; paper-thin dark gray (N3) shale partings in zones up to a ¼ inch thick; partings 2 to 7 inches apart.	1	6	191	0

36. Intermediate between dark gray (N3) and medium dark gray (N4) to intermediate between medium dark gray and medium gray (N5), thickly laminated to medium-bedded calcilutite and calcisiltite with minor medium gray fine calcarenite (N.B. What is logged in the Lowville core as calcarenite may well weather to fine breccia or limestone conglomerate); from 3 feet 1 inch to 4 feet below the top of the subunit, the limestone exhibits a faint dark greenish gray (5GY4/1) overtone to the basic gray color; plane and wavy dark-gray (N3) shale partings, paper-thin to 1/8 of an inch thick, are spaced 1/8 inch to 12 inches apart; partings in the calcilutites tend to be more

	I Ft.	I In.	II Ft.	II In.
plane and commonly occur in zones up to 1½ inches thick; occasional stylolites.	4	0	189	6
35. Missing.	1	2	185	6
34. As 36, but without local greenish gray.	23	7	184	4
Pamelia-Lowville transition: 50 feet 5 inches				
33. As 36, including occasional rounded quartz grains of sand size and local greenish-gray (5GY6/1) mottling; shale partings are an average of 1 to 2 inches apart.	2	8	160	9
32. Intermediate between medium dark gray (N4) and medium gray (N5) to intermediate between medium gray and medium light gray (N6), thinly laminated to medium-bedded calcisiltite and coarse calcilutite with a greenish-gray (5G6/1) cast; minor intermediate between dark gray (N3) and medium dark gray calcilutite; dark-gray to greenish-gray, paper-thin shale partings spaced 1/16 inch to 8 inches apart; the partings are greenish-gray mostly in the upper portion of the subunit and grade downward into dark gray.	15	11	158	1
31. Medium dark gray (N4) to intermediate between medium gray (N5) and medium light gray (N6), very thin- to medium-bedded calcilutite; mostly plane, dark gray (N3) shale partings, paper-thin to ¼ of an inch thick, spaced ¾ inch to 12 inches apart; thin vertical veins of white calcite are common 3 feet 8 inches to 3 feet 11 inches from the top; two horizontal bands of fibrous gypsum, each 1½ inches thick, occur 13 feet 7 inches and 14 feet 1 inch below the top of the subunit; the gypsum fibers are perpendicular to layering.	15	1	142	2
30. Medium gray (N5) to medium light gray (N6), thickly laminated to medium-bedded calcisiltite; paper-thin dark gray (N3) shale partings are spaced 1/8 inch to 9 inches apart with an average spacing of 3 to 4 inches.	5	1	127	1
29. Medium dark gray (N4) to medium gray (N5), thickly laminated to thin-bedded calcilutite and calcisiltite; paper-thin dark gray shale partings, locally very abundant, are spaced ¼ inch to 3 inches apart with an average spacing of about 3 inches.	11	8	122	0
Pamelia Formation: 107 feet 1 inch				
28. Greenish gray (5G6/1), locally dark greenish gray (5G4/1), thin- to thick-bedded dolomisiltite mottled pale red (10R6/6) and light green (10G6/2); very few paper-thin, dark greenish-gray shale partings; rounded quartz grains of sand size are scattered throughout the sequence; the subunit is moderately calcareous in the highest and lowest 3 inches.	10	7	110	4
27. Medium gray (N5) calcisiltite with occasional paper-thin dark gray (N3) shale partings.	1	1	99	9
26. Intermediate between medium dark gray (N4) and medium gray (N5), thin-bedded calcilutite; dark-gray (N3) shale partings, 1/8 inch thick, are spaced 1 to 4 inches apart; occasional **Phytopsis.**	2	2	98	8
25. Intermediate between medium gray (N5) and medium light gray (N6) to medium light gray, thickly laminated to medium-bedded calcisiltite; occasional paper-thin dark gray (N3) shale partings ¼ inch to 7 inches apart with an average spacing of 4 to 5 inches.	5	10	96	6
24. Greenish-gray (5G6/1) dolomisiltite; paper-thin dark greenish-gray (5G4/1) to dark gray (N3) shale partings; contains rounded quartz grains of sand size.	1	4	90	8
23. Medium dark gray (N4) calcisiltite.	0	5	89	4
22. Intermediate between medium gray (N5) and medium light gray (N6) to medium light				

Unit	Description	I Ft.	I In.	II Ft.	II In.
	gray, thin- to thick-bedded calcisiltite; occasional paper-thin dark gray (N3) shale partings 1 inch to 2½ feet apart, with an average spacing of 12 to 15 inches.	9	10	88	11
21.	Intermediate between medium dark gray (N4) and medium gray (N5) to medium gray, very thin- to medium-bedded calcilutite; dark gray (N3) shale partings, paper-thin to an 1/8 inch thick, spaced ½ inch to 12 inches apart.	4	2	79	1
20.	Greenish-gray (5G6/1), slightly calcareous dolomisiltite.	1	0	74	11
19.	Medium dark gray (N4) to intermediate between medium dark gray and medium gray (N5), thickly laminated to thin-bedded calcisiltite; plane, paper-thin, dark gray (N3) shale partings ¼ inch to 3 inches apart.	2	9	73	11
18.	Medium gray (N5) and greenish-gray (5G6/1) dolomisiltite.	1	2	71	2
17.	Medium gray (N5) and greenish-gray (5G6/1) calcisiltite; 1 inch thick seam of white calcite 3 to 4 inches below the top of the subunit.	0	10	70	0
16.	Intermediate between medium gray (N5) and medium light gray (N6) to medium light gray, medium-bedded calcisiltite; paper-thin dark gray (N3) shale partings are 5 to 12 inches apart; stylolites are locally abundant, 6 were noted from 2 feet 2 inches to 4 feet 2 inches below the top of the subunit.	8	3	69	2
15.	Dark greenish-gray (5G4/1) to greenish-gray (5G6/1) dolomisiltite which is mottled grayish-red (10R4/2); the color become medium dark gray (N4) to medium gray locally as the dolomisiltite becomes more calcareous; paper-thin, dark greenish-gray shale is found in zones 2 to 3 inches thick in the middle of the subunit.	5	11	60	11
14.	Dark gray (N3) to medium dark gray (N4), thickly laminated to thin-bedded calcilutite; plane, paper-thin dark gray (N3) shale partings, spaced 1/8 inch to 4 inches apart, with an average of 3 to 3½ inches; 1/8 inch thick gypsum seam which is parallel to bedding occurs 5 feet 7 inches below the top of the subunit.	13	10	55	0
13.	Intermediate between medium gray (N5) and medium light gray (N6) and greenish-gray (5GY6/1) dolomisiltite with 3 zones of dark greenish-gray (5G4/1) shale up to 3 inches thick; rounded quartz grains of sand size scattered throughout the sequence but abundant in the highest 15 inches of the subunit and from 2 feet 10 inches to 3 feet below the top.	6	7	41	2
12.	Medium dark gray (N4) calcilutite; minor paper-thin dark gray (N3) shale partings.	0	9	34	7
11.	Intermediate between medium gray (N5) and medium light gray (N6), thickly laminated to medium-bedded calcisiltite with overall greenish-gray (5GY6/1) cast; paper-thin dark gray (N3) shale partings are spaced 1/8 of an inch to 10 inches apart with an average of 6 to 7 inches between them.	3	9	33	10
10.	Intermediate between dark gray (N3) and medium dark gray (N4) to medium dark gray, locally dolomitic calcisiltite; occasional zones of dark gray to dark greenish-gray (5G4/1) shale up to 1 inch thick.	3	3	30	1
9.	Dark greenish-gray (5G4/1) to greenish-gray (5G6/1), thinly-laminated to thin-bedded dolomisiltite which is locally flecked pale red (10R6/2); abundant paper-thin dark greenish-gray shale partings, a 1/32 inch to 2 inches apart.	4	4	26	10
8.	Greenish-gray (5GY6/1) calcisiltite.	0	8	22	6
7.	As 8, but with rounded quartz grains of sand size; the lowest ½ inch is medium dark gray (N4) shale containing fragments of greenish-gray (5GY6/1) calcisiltite.	0	3	21	10

	I Ft.	I In.	II Ft.	II In.
6. Intermediate between medium dark gray (N4) and medium gray (N5), thin-bedded calcilutite with minor calcisiltite, mottled grayish-green (5G5/2) from 1 foot 6 inches to 1 foot 8 inches below the top of the subunit; paper-thin, dark gray (N3) shale partings are spaced 2 to 3 inches apart; zones of rounded quartz grains of sand size occur 1 foot 3 inches to 1 foot 4 inches and 2 feet 3 inches to 2 feet 4 inches below the top of the sequence.	3	10	21	7
5. Intermediate between medium dark gray (N4) and medium gray (N5) to greenish-gray (5GY6/1) calcilutite with a few thin interbeds of greenish-gray dolomisiltite which is flecked grayish-red (10R4/2); two prominent zones of dark gray (N3) shale occur 1 foot 2 inches to 1 foot 4½ inches and 3 feet 7 inches to 3 feet 11 inches below the top of the subunit; abundant quartz grains of sand size from 1 foot 4½ inches to 1 foot 5 inches and 5 feet 10 inches below the top.	7	½	17	9
4. Dark gray (N3) limy shale with disseminated quartz sand grains and thin seams of calcareous sandstone, 1/8 inch to ¼ inch thick.	0	7	10	8½
3. Intermediate between medium dark gray (N4) and medium gray (N5) to medium gray calcareous sandstone with an overall faint greenish-gray (5GY6/1) east.	1	10½	10	1½
2. Greenish-gray (5G6/1) sandy dolomitic limestone and dolomitic sandstone which is locally speckled pale red (10R6/2) and light olive gray (5Y6/1); from 2 feet 6 inches to 3 feet below the top of the subunit and in the lowest 7 inches, the rounded quartz grains are up to 3/8 of an inch in diameter, both clear and milky varieties; transitional downward to the Theresa Formation.	5	0	8	3

Theresa Formation

	I Ft.	I In.	II Ft.	II In.
1. Dark gray (N3) to medium dark gray (N4), fine- to medium-grained, saccharoidal sandstone characterized by very pale orange (10YR8/2) banding and mottling.	3	3	3	3

Bottom of hole

10. This section was described and measured from exposures along the bank and in the bed of the Black River immediately below the dam at Glen Park, NW/4 Watertown, N.Y. quadrangle.

Chaumont Formation

	I Ft.	I In.	II Ft.	II In.
4. Medium dark gray (N4), thin- to medium-bedded calcilutite to fine calcisiltite; weathers light gray (N7) to very light gray (N8); irregular dark gray (N3) chert nodules are elongated parallel to bedding and arranged in layers 2 to 10 inches apart; the individual beds of limestone are generally indistinct, except where bounded by chert, but the surfaces appear to be uneven, 3 to 5 inches apart; contains brachiopods and cephalopods.	9		25	3
3. Medium gray, thin-bedded calcilutite to fine calcisiltite; weathers light gray (N7) to yellowish gray (5Y8/1); noncherty, but contains a few silicified fossil fragments.	1	8	16	3

Lowville Formation

	I Ft.	I In.	II Ft.	II In.
2. Medium dark gray (N4) to olive gray (5Y4/1), very thin- to thin-bedded calcilutite; weathers medium light gray (N6) to light gray (N7); locally rudaceous with fragments of calcilutite in a calcisiltite or fine calcarenite matrix; limestone beds ½ inch to 3 inches thick, with an average of 2 inches thick; contains small horn corals, small gastropods, and **Phytopsis**; **Phytopsis** common in the calcilutite; the fossils may occasionally weather to a distinctive grayish-orange (10YR7/4), particularly near the base.	10	8	14	7

	I Ft.	I In.	II Ft.	II In.
1. Medium gray (N5), thin-bedded calcilutite; color of weathered surface obscured by muddy film; beds 1½ to 4 inches thick; prominent layering surfaces 2 to 10 inches apart; minor **Phytopsis.**	3	11	3	11

Base of section at river level. Bed rock in the river is dark gray (N3) to medium dark gray (N4) agrillaceous calcilutite.

11. This section was described and measured from drill core (Alf. 142) and road cut and quarry exposures on the north side of the old Brownville-Limerick road, 2.3 miles southeast of Limerick, SE/4 Dexter, N.Y. quadrangle. Subunits 66 and 67, exposed in the road cut, are after Kay (1937, p. 253). Subunits 61 through 64 are exposed in the face of the small abandoned quarry, but drilling was begun immediately northeast of the quarry in subunit 63. The uppermost 3 feet 7 inches of core are, therefore, exposed in the quarry face.

Kirkfield Formation

	I Ft.	I In.	II Ft.	II In.
67. Bluish gray, buff-weathering, thin-bedded shaly limestone containing **Encrinurus cybeliformis** and other fossils; exposed to top of the hill.	6	0	325	10

Rockland Formation: 63 feet 1 inch

Napanee Member: 56 feet

	I Ft.	I In.	II Ft.	II In.
66. Light gray, thin-bedded limestone with shaly, plane partings, with some coarse textured beds, one arbitrarily considered the top having ripple marks of 2 foot wave length, trending east; in a bed less than 2 feet below its top, **Triplecia cuspidata** is common, and the fossil is frequent through the subjacent 10 feet.	27	6	319	10
65. Unexposed.	28	6	292	4

Selby Member: 7 feet 1 inch

	I Ft.	I In.	II Ft.	II In.
64. Medium dark gray (N4), very thin- to thin-bedded calcisiltite; weathers light gray (N7); slightly wavy, paper-thin, dark gray (N3) limy shale partings, ½ to 3 inches apart; limestone beds are ½ inch to 4 inches thick, surfaces more even than in subunit below; contains **Paucicrura** and crinoid stem fragments.	1	7	263	10
63. Medium dark gray (N4), medium light gray (N6)-weathering, thin-bedded calcisiltite and fossiliferous calcarenite; wavy, paper-thin, dark gray (N3), limy shale partings; bedding surfaces wavy, 1 to 4 inches apart; contains **Paucicrura rogata, Doleroids ottawanus, mesotrypa,** and **Prasopora** which are up to 2 inches in diameter.	2	11	262	3
62. Medium dark gray (N4), thickly laminated to thin-bedded, barren calcisiltite; weathers medium light gray (N6); beds are 1/8 an inch to 2 inches thick.	0	8	259	4
61. Medium dark gray (N4), thin- to medium-bedded calcisiltite and calcarenite; weathers medium light gray (N6); wavy, paper-thin, dark gray (N3) limy shale partings; limestone beds 3 to 10 inches thick; contains **Doleroides;** base marked by a 3-inch thick calcarenite.	1	11	258	8

Chaumont Formation: 25 feet 5½ inches

	I Ft.	I In.	II Ft.	II In.
60. Dark gray (N3) to medium dark gray (N4), massive-looking, medium-bedded calcisiltite, becoming flecked with brownish gray (5YR4/1) downward; occasional wavy, paper-thin, dark gray limy shale partings; transitional to Rockland.	3	11	256	9
59. Medium dark gray (N4), brownish gray (5YR4/1)-flecked calcisiltite and coarse calcilutite; wavy paper-thin, dark gray (N3) limy shale partings; limestone beds 2 to 8 inches thick.	17	11	252	10
58. Brownish-gray (5YR4/1) chert.	0	1	234	11
57. As 59.	0	2½	234	10
56. As 58.	0	1	234	7½
55. As 59.	1	5	234	6½
54. Medium dark gray (N4) calcilutite and minor calcisiltite.	1	7	233	1½
53. Dark gray (N3) shaly limestone.	0	1½	231	6½
52. As 54.	0	1½	231	5

	I Ft.	I In.	II Ft.	II In.
Lowville Formation: 123 feet 3½ inches				
Lowville **sensu-stricto**: 72 feet ½ inch				
51. Medium gray (N5), thin-bedded, **Phytopsis**-bearing calcilutite; paper-thin, wavy, dark gray (N3) shale partings, 1 to 4 inches apart.	1	6½	231	3½
50. Medium dark gray (N4), thickly laminated to medium-bedded calcisiltite; wavy, paper-thin, dark-gray (N3) shale partings, 1/8 inch to 6 inches apart; prominent layering surfaces 7 to 12 inches apart; occasional small aggregates of calcite grains (**Phytopsis?**).	9	5	229	9
49. As 51.	1	2½	220	4
48. Medium dark gray (N4) calcilutite and minor calcisiltite; contains a few **Phytopsis.**	3	0	219	1½
47. As 50.	2	½	216	1½
46. Medium gray (N5) calcilutite; occasional **Phytopsis.**	1	1	214	1
45. Medium gray (N5) calcisiltite; **Phytopsis** rare.	0	10	213	0
44. Medium dark gray (N4), very thin- to medium-bedded calcilutite and minor calcisiltite; prominent zones of dark gray (N3) shale from 3 to 9 inches, 8 feet 6 inches to 9 feet 2 inches, and 11 feet 4 inches to 12 feet below the top of the subunit; paper-thin, dark gray shale partings are present throughout the sequence but are not as wavy as those in the upper part of the formation; limestone beds are ½ inch to 6 inches thick; minor pyrite mineralization is common in the shaly zones, but it is particularly notable from 8 feet to 10 feet 2 inches below the top of the subunit; contains a few rounded quartz grains of sand size 1 foot 2 inches above the base.	52	11	212	2
Pamelia-Lowville transition: 51 feet 3 inches				
43. Medium dark gray (N4) calcisiltite, locally mottled pale green (10G6/2); paper-thin dark gray (N3) shale partings account for 10 percent of the subunit; scattered quartz grains of sand size.	6	1	159	3
42. Medium gray (N5) dolomisiltite, locally mottled greenish-gray (5G6/1); paper-thin, greenish-gray shale partings.	1	10	153	2
41. Medium dark gray (N4) to medium gray (N5), thickly laminated calcisiltite with paper-thin dark gray (N3) shale partings spaced ¼ inch apart.	0	6	151	4
40. Medium dark gray (N4) to medium gray (N5), thin-bedded calcilutite with paper-thin dark gray (N3) shale partings spaced 3 to 4 inches apart.	2	10	150	10
39. As 41.	1	3	148	0
38. As 40.	2	5	146	9
37. As 41.	0	11	144	4
36. As 40.	0	10	143	5
35. As 41.	1	2	142	7
34. As 40.	7	6	141	5
33. As 41.	1	1	133	11
32. As 40.	8	1	132	10
31. Medium light gray (N6), medium-bedded dolomisiltite; paper-thin, dark gray shale partings 10 inches apart.	1	6	124	9
30. Medium gray (N5) to medium light gray (N6), medium-bedded calcisiltite; dark gray (N3) shale partings, 1/8 inch thick, spaced 5 to 6 inches apart.	4	0	123	3
29. Medium gray (N5) to medium light gray (N6), thin-bedded calcilutite; paper-thin, dark gray (N3) shale partings an average of 4 inches apart; occasional stylolites.	1	10	119	3
28. Medium dark gray (N4) to medium gray (N5), thinly-laminated to thin-bedded calcisiltite with minor zones of calcilutite; abundant paper-thin, dark gray (N3) shale partings spaced a 1/16 inch apart to 3 inches apart; spacing averages an 1/8 inch to ¼ inch in the calcisiltite, 3 inches in calcilutite.	9	5	117	5
Pamelia Formation: 108 feet plus				
27. Greenish-gray (5G6/1), medium-bedded, medium to coarse dolomisiltite; paper-thin, dark gray shale partings; prominent zone of				

Unit	Description	I Ft.	I In.	II Ft.	II In.
	dark gray (N3) shale, 1 foot 8 inches to 2 feet 7 inches below the top of the subunit; contains rounded quartz grains of sand size.	5	3	108	0
26.	As 27, but mottled pale red (10R6/2) and shale partings are greenish-gray (5G6/1) and pale red; large crystal of calcite 2 feet 9 inches below top of subunit.	6	0	102	9
25.	Medium dark gray (N4) to medium gray (N5), thinly laminated to thin bedded calcilutite; dark gray (N3) shale partings, paper-thin, spaced a 1/16 inch to 4 inches apart.	3	8	96	9
24.	Greenish-gray (5G6/1) dolomisiltite with prominent shaly zone 1 foot 1 inch to 1 foot 6½ inches below the top of the subunit.	2	10	93	1
23.	Medium gray (N5), thickly laminated to thin-bedded calcisiltite becoming coarser, greenish-gray (5G6/1), and mottled pale red (10R6/2) downward; paper-thin, dark gray (N3) shale partings are ¼ inch to 3 inches apart.	3	2	90	3
22.	Greenish-gray (5G6/1), thickly laminated to thick-bedded dolomisiltite mottled pale red (10R6/2); becomes dark greenish-gray (5G4/1) with grayish-red (10R4/2) mottling from 8 feet 1 inch to 8 feet 6 inches below the top of the subunit; dark greenish-gray shale partings, paper-thin to an 1/8 inch thick, are spaced 1/8 inch to 3 feet apart; a 6 inch zone which is medium gray (N5) and more calcareous occurs 1 foot 11 inches to 2 feet 5 inches below the top of the sequence; quartz sand grains scattered throughout succession.	14	10	87	1
21.	Medium dark gray (N4) to medium gray (N5), thickly laminated to thin-bedded calcilutite; dark gray (N3) shale partings are ¼ inch thick; partings are particularly abundant from 2 feet 1 inch to 2 feet 5 inches below the top of the subunit.	3	3	72	3
20.	Greenish-gray (5G6/1) dolomisiltite mottled pale red (10R6/2).	0	8	69	0
19.	Medium gray (N5), thin- to medium-bedded calcisiltite; paper-thin, dark gray (N3) shale partings.	2	7	68	4
18.	Greenish-gray (5G6/1) dolomisiltite with rounded quartz grains of sand size.	2	6½	65	9
17.	Medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded calcilutite and calcisiltite; slightly dolomitic from 2 feet 3½ inches to 2 feet 4½ inches below th top of the subunit; dark gray (N3) shale partings an 1/8 inch to a ¼ inch thick; occasional stylolites.	7	9½	63	2½
16.	Greenish-gray (5G6/1) and medium gray (N5), thickly laminated to medium-bedded dolomisiltite locally mottled pale red (10R6/2); paper-thin, dark greenish-gray (5G4/1) and dark gray (N3) shale partings spaced 1/8 inch to 12 inches apart.	7	8	55	5
15.	Medium dark gray (N4), thickly laminated to medium-bedded calcisiltite and minor calcilutite; grayish-black (N2) to dark gray (N3) shale partings, a 1/16 of an inch to 1/8 inch thick, are spaced 1/8 inch to 6 inches apart.	13	4	47	9
14.	Medium dark gray (N4) to greenish-gray (5G6/1) and greenish-gray to dark greenish-gray (5GY4/1) dolomisiltite; moderately calcareous 2 feet 1 inch to 3 feet 7 inches below the top of the subunit; abundant grayish-black (N2) shale partings from 2 feet 10½ inches to 3 feet 2½ inches below the top.	6	6	34	5
13.	Medium dark gray (N4) to medium gray (N5) calcisiltite with a grayish-black (N2) to dark gray (N3) shale zone, 6 to 10 inches below the top of the subunit.	2	7	27	11
12.	Greenish-gray (5G6/1) locally dolomitic calcisiltite; contains quartz grains of sand size scattered throughout.	2	3	25	4
11.	Medium dark gray (N4) to medium gray (N5) calcisiltite.	1	4	23	1
10.	Greenish-gray (5G6/1 and 5GY6/1) and dark greenish-gray				

	I Ft.	I In.	II Ft.	II In.
(5GY4/1), medium-bedded, locally dolomitic calcisiltite with pale red (10R6/2) and grayish red (10R4/2) mottling; minor dark greenish-gray shale partings; scattered quartz grains of sand size.	7	9	21	9
9. Medium gray (N5) calcisiltite.	1	7	14	0
8. Greenish-gray (5G6/1), slightly dolomitic calcisiltite; scattered quartz grains of sand size.	1	3	12	5
7. Greenish-gray (5G6/1), medium-bedded dolomisiltite with faint pale red (10R6/2) mottling.	4	7	11	2
6. Grayish-red (5R4/2), medium-bedded dolomisiltite with grayish green (5G5/2) mottling.	3	1	6	7
5. Grayish-green (5G5/2) dolomisiltite.	0	8	3	6
4. Dark greenish-gray (5GY4/1), sandy dolomisiltite and dolomitic sandstone; abundant rounded quartz grains of sand size making up about 35 to 40 percent of the subunit.	0	4½	2	10
3. Dark greenish-gray (5GY4/1), sandy dolomisiltite with some pale red (10R6/2) mottling; 10 to 20 percent of quartz sand grains.	0	7	2	5½
2. As 4.	0	11	1	10½
1. Greenish-gray (5G6/1) to grayish-blue-green (5BG5/2) sandy dolomisiltite with some pale red (10R6/2) mottling; 25 to 30 percent of quartz sand grains.	0	11½	0	11½

Bottom of hole. Very close to the base of the Pamelia Formation.

12. This section was described and measured from core obtained by drilling (Alf. 143) on the east side of the small water-filled quarry located 0.75 mile southeast of Rosiere, NW/4 Chaumont, N.Y. quadrangle.

	I Ft.	I In.	II Ft.	II In.
Rockland Formation:				
41. Medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded limestone, ranging from coarse calcilutite to calcarenite, and grayish-black (N2) to dark gray (N3) limy shale; the calcisiltite makes up from 60 to 70 percent and the limy shale from 25 to 30 percent of the subunit; calcilutite and calcarenite are present in minor amounts; limestone beds are ½ inch to 12 inches thick; the limy shale is found as paper-thin partings which occur singly and in zones ranging from ½ inch to 2½ inches thick; very few fossils were seen; contains small fragments of brachiopods, particularly in the coarser limestones, and small **Prasopora.**	38	7	250	0
40. Olive gray (5Y4/1) to medium gray (N5), fossiliferous calcarenite; contains brachiopod and trilobite fragments.	0	5	211	5
Chaumont Formation: 20 feet				
39. Medium-dark gray (N4) to medium gray (N5), medium-bedded calcisiltite which is locally flecked brownish gray (5YR4/1); occasional paper-thin, wavy dark-gray (N3) limy shale partings.	2	9	211	0
38. Medium gray (N5), thin- to medium bedded calcisiltite and minor calcilutite which are locally flecked brownish gray (5YR4/1); dark gray (N3) limy shale partings, wavy and paper-thin, are spaced 2 to 8 inches apart; occasional stylolites.	13	3	208	3
37. Brownish-gray (5YR4/1) chert in small irregular nodules elongated parallel to bedding.	0	1	195	0
36. As 38.	0	11	194	11
35. Medium gray (N5) calcilutite and minor calcisiltite.	3	0	194	0
Lowville Formation: 121 feet 2 inches				
Lowville **sensu-stricto:** 68 feet				
34. Medium light gray (N6), **Phytopsis**-bearing calcilutite.	1	0	191	0
33. Medium dark gray (N4), thickly laminated to medium-bedded calcisiltite; wavy, paper-thin, dark-gray (N3) shale partings, 1/8 inch to 6 inches apart; prominent layering surfaces are 7 to 12 inches apart; occasional **Phytopsis.**	4	4	190	0
32. Medium gray (N5) to medium light gray (N6) calcisiltite; minor paper-thin, wavy dark gray (N3) shale partings.	0	11	185	8

	I Ft.	I In.	II Ft.	II In.
31. Medium-dark-gray (N4) to medium-gray (N5), **Phytopsis**-bearing calcilutite; minor zones of dark gray (N3) shale up to a ¼ inch thick.	1	5	184	9
30. Medium dark-gray (N4) to medium gray (N5), thinly-laminated to medium-bedded calcilutite and minor medium gray to intermediate between medium gray and medium light gray (N6) calcisiltite; locally abundant, wavy shale partings, paper-thin to 1/8 inch thick, spaced 1/16 inch to 5 inches apart; minor **Phytopsis** in the calcilutite.	15	3	183	4
29. Light olive gray (5Y6/1) to olive-gray (5Y4/1), thin- to medium-bedded calcilutite which is locally mottled dark gray (N3); occasional wavy, paper-thin dark gray shale partings; minor **Phytopsis.**	3	0	168	1
28. Intermediate between medium dark gray (N4) and medium gray (N5) to medium light gray (N6), thinly laminated to medium-bedded calcilutite and minor calcisiltite; abundant plane and wavy, paper-thin, dark gray (N3) shale partings, spaced 1/16 inch to ¾ inch apart, in the highest 2 feet 10 inches and from 6 feet 1 inch to 7 feet 4 inches below the top of the subunit; 4 inches of core are missing from 5 feet 6 inches to 5 feet 10 inches below the top.	8	10	165	1
27. Medium dark gray (N4) to medium gray (N5) calcilutite; highest 4 inches has greenish-gray (5GY6/1) calcilutite fragments in medium dark gray to medium gray coarse calcilutite and fine calcisiltite matrix giving a mottled appearance.	0	10	156	3
26. Medium dark gray (N4) to medium light gray (N6), thickly laminated to medium-bedded calcilutite and minor calcisiltite; plane and wavy, paper-thin, dark gray (N3) shale partings in zones an 1/8 inch to 2 inches thick, spaced an 1/8 inch to 6 inches apart; few **Phytopsis** in calcilutites.	7	7	155	5
25. Medium light gray (N6), **Phytopsis**-bearing calcilutite; occasional stylolites.	1	9	147	10
24. Intermediate between dark gray (N3) and medium dark gray (N4) to medium gray (N5), thinly laminated to medium-bedded calcilutite and minor calcisiltite; paper-thin, dark gray (N3) and grayish-black (N2) shale partings are locally abundant, spaced 1/16 of an inch to 7 inches apart; a prominent zone of grayish-black shale is present from 6 feet 11 inches to 7 feet 7 inches below the top of the subunit; minor pyrite mineralization is found 11 feet 11 inches and 21 feet 10 inches below the top of the sequence; a few rounded quartz grains of sand size occur in the lowest 6 inches.	23	1	146	1
Pamelia-Lowville transition: 53 feet 2 inches.				
23. Medium dark gray (N4) to medium gray (N5), thickly-laminated to medium-bedded calcisiltite which is faintly mottled greenish gray (5GY6/1); paper-thin, dark gray (N3) shale partings make up 10 to 15 percent of subunit; rounded quartz grains of sand size erratically disseminated throughout.	6	7	123	0
22. Greenish-gray (5GY6/1) to medium light gray (N6) dolomisiltite containing a few rounded quartz grains of sand size.	1	10	116	5
21. Medium dark gray (N4) to medium gray (N5) calcilutite with minor calcisiltite and rudaceous zones at several intervals; thickly laminated to thin-bedded; paper-thin, dark gray (N3) shale partings, spaced 3 to 4 inches apart in the calcilutite and an average of ¼ inch apart in the calcisiltite; very minor rounded quartz grains of sand size.	24	8	114	7
20. Medium gray (N5) to medium light gray (N6), locally greenish-gray (5GY6/1) dolomisiltite;				

	I Ft.	I In.	II Ft.	II In.
few paper-thin, dark-gray (N3) shale partings.	2	8	89	11
19. Medium gray (N5) to intermediate between medium gray and medium light gray (N6), thickly laminated to medium-bedded calcisiltite; dark gray (N3) shale partings, paper-thin to an 1/8 of an inch thick, spaced an 1/8 inch to 5 inches apart; occasional stylolites.	6	11	87	3
18. Intermediate between medium gray (N5) and medium light gray (N6) dolomisiltite.	0	9	80	4
17. Medium dark gray (N4) to medium gray (N5), thinly-laminated to medium-bedded calcisiltite and calcilutite; paper-thin dark gray (N3) shale partings spaced a 1/16 inch to 7 inches apart.	9	9	79	7
Pamelia Formation				
16. Greenish-gray (5G6/1), locally medium light gray (N6) and somewhat calcareous, thin- to thick-bedded dolomisiltite which is mottled by pale red (10R6/2) from 10 feet 10 inches to 12 feet 10 inches and from 13 feet 10 inches to 14 feet 6 inches below the top of the subunit; occasional dark greenish-gray (5G4/1) and dark gray (N3) paper-thin shale partings.	16	0	69	10
15. Medium gray (N5) to medium light gray (N6), thinly laminated to thick-bedded calcilutite and fine calcisiltite; pale red (10R6/2) from 7 feet 3 inches to 8 feet 1 inch below the top of the subunit; paper-thin dark gray (N3) shale partings are spaced a 1/16 inch to 13 inches apart and locally occur in zones up to an inch thick.	10	5	53	10
14. Medium dark gray (N4) to medium light gray (N6) dolomisiltite and very minor calcisiltite; the lighter grays are mottled greenish-gray (5G6/1) and pale red (10R6/2).	5	3	43	5
13. Dark greenish-gray (5G4/1) to intermediate between greenish-gray (5G6/1) and light greenish-gray (5G8/1), thin- to medium-bedded dolomisiltite which is mottled pale red (10R6/2) from 3 feet 2 inches to 5 feet 7 inches below the top of the subunit; occasional paper-thin dark greenish-gray shale partings; locally abundant quartz grains of sand size.	8	9	38	2
12. Medium gray (N5) to medium light gray (N6) dolomisiltite.	1	10	29	5
11. Intermediate between medium dark gray (N4) and medium gray (N5) calcisiltite.	2	1	27	7
10. Medium dark gray (N4) shale.	0	1	25	6
9. Intermediate between medium gray (N5) and medium light gray (N6) to medium light gray calcilutite with a mottled appearance; occasional dark gray (N3) shale partings.	1	7	25	5
8. Medium gray (N5), thickly-laminated to medium-bedded calcisiltite; dark gray (N3) shale partings, paper-thin, spaced 1/8 inch to 12 inches apart; occasional stylolites.	5	4	23	10
7. Medium light gray (N6) calcilutite; abundant stylolites spaced ½ inch to 8 inches apart.	3	10	18	6
6. Medium gray (N5) calcisiltite.	2	11	14	8
5. Medium gray (N5) dolomisiltite.	0	11	11	9
4. Greenish-gray (5GY6/1) dolomisiltite.	2	5	10	10
3. Intermediate between medium dark gray (N4) and medium gray (N5) calcisiltite; occasional paper-thin dark gray (N3) shale partings.	1	3	8	5
2. Greenish-gray (5G6/1), thin- to medium-bedded dolomisiltite; minor medium gray (N5) calcareous zones; occasional paper-thin dark greenish-gray (5G4/1) and dark gray (N3) shale partings.	5	10	7	2
1. Intermediate between medium dark gray (N4) and medium gray (N5) to medium gray calcisiltite.	1	4	1	4

Bottom of hole.

13. This section was described and measured from core obtained by drilling (Alf. 145) immediately east of the dirt road that parallels the east side of Wilson Bay, Town of Cape Vincent, NW/4 Cape Vincent South, N.Y. quadrangle.

	I Ft.	I In.	II Ft.	II In.
Kirkfield Formation				
12. Interbedded medium gray (N5) to intermediate between medium gray and medium light gray (N6) calcarenite with a yellowish-brown (10YR6/2) cast, medium dark gray (N4) to medium gray calcisiltite, and dark gray (N3) limy shale; the calcarenites predominate, making up 70 to 80 percent of the subunit; the calcisiltites and limy shales each make up 10 to 15 percent of the subunit; the limestone beds are from ¼ inch to 8 inches thick, with an average thickness of 3 inches; the calcarenites are thickest, the calcisiltites attain a maximum thickness of 5½ inches; the limy shale is present as plane and wavy paper-thin partings which occur singly and in zones up to 2 inches thick; fossils are scarce, a few fragments of the typical long-ranging Trenton brachiopods, such as **Paucicrura** and **Sowerbyella** were noted in the calcarenite layers.	7	0	155	5
11. Rock types and colors as 12, but limy shale accounts for 15 to 20 percent of the subunit, and the calcarenites and calcisiltites are present in equal amounts; the limestone beds are generally thinner, ranging from ¼ inch to 5 inches thick; the calcarenites are the thickest but only two beds reach the maximum thickness; the average thickness of the limestone layers is about 2 inches; the limy shale is present as plane and wavy paper-thin partings which occur singly and in zones up to 3½ inches thick; a few brachiopod fragments were noted in the coarser limestones.	24	9	148	5
10. Rock types and colors as 12, but calcarenites make up 65 to 70 percent, calcisiltites 20 to 25 percent, and limy shales 10 percent of the subunit; limestone beds are ½ inch to 9 inches thick, with an average thickness of 3 to 4 inches; the calcarenites are thickest, with particularly prominent beds occurring in the uppermost 9 inches, from 10 feet 9 inches to 11 feet 5 inches, 17 feet 11 inches to 18 feet 7 inches, 23 feet 5 inches to 24 feet 1 inch, 24 feet 7 inches to 25 feet 2 inches, and 29 feet 9 inches to 30 feet 4 inches below the top of the subunit; the limy shale is present as plane and wavy, paper-thin partings which occur singly and in zones up to 3 inches thick; fossils scarce and apparently restricted to the calcarenites; drill crew reported gas show for a few feet beginning 8 feet 3 inches below the top of the sequence; the flow was sufficiently strong to support a flame at the top of the drill pipe string; the limy shale from this zone had a very strong petroliferous odor when freshly broken, but it soon disappeared.	31	2	123	8
Rockland Formation: 57 feet 2 inches				
9. Rock types and colors as in subunits above, but with a notable increase of calcisiltite at the expense of the calcarenite; the calcarenite is without the yellowish-brown (10YR6/2) cast; the calcisiltites make up 45 to 50 percent, the calcarenites 40 to 45 percent and the limy shales 10 percent of the subunit; the sequence is transitional upward from typical Rockland lithology below to Kirkfield lithology above.	20	7	92	6
8. Interbedded medium gray (N5) calcisiltite, medium dark gray (N4) coarse calcilutite, dark gray (N3) limy shale, and very minor medium gray calcarenite; the calcisiltite accounts for 70 percent, the calcilutite 15 to 20 percent, the limy shale 10 percent and the calcarenite less than 5 percent of the subunit; there are no thick prominent limestone layers; beds are from ½ inch to 6 inches thick with				

	I Ft.	I In.	II Ft.	II In.
an average thickness of 2½ to 4 inches; the limy shale is present as mostly plane, paper-thin partings, which occur singly and in zones up to ½ inch thick; drill crew reported 13 inches of ground up core somewhere between 26 feet 6 inches and 31 feet 11 inches below the top of the subunit; this interval was represented by grayish-black (N2) to dark gray (N3) calcilutite or limy shale which was ground into fine sand and silt having a very strong petroliferous odor.	19	2	71	11
7. As 8, but calcarenite increases to 15 percent of total limestone.	17	5	52	9

Chaumont Formation: 20 feet 9 inches

	I Ft.	I In.	II Ft.	II In.
6. Intermediate between medium-dark gray (N4) and medium gray (N5), brownish-gray (5YR4/1)-flecked, "clean-looking", thin-bedded, medium to fine calcisiltite and calcilutite; medium calcisiltite predominates; wavy, paper-thin dark gray (N3) limy shale partings, spaced 1 to 4 inches apart; core does not split readily parallel to the partings; occasional stylolites.	16	3	35	4
5. As 6, but with brownish-gray (5YR4/1) chert in irregular nodules elongated parallel to bedding.	1	5	19	1
4. Rock types and colors as 6, but with a few small aggregates of calcite grains; minor silicification.	3	1	17	8

Lowville Formation

Lowville **sensu-stricto**

	I Ft.	I In.	II Ft.	II In.
3. Intermediate between medium gray (N5) and medium light gray (N6), **Phytopsis**-bearing fine calcisiltite and calcilutite; minor wavy, paper-thin dark gray (N3) limy shale partings.	0	11	14	7
2. Medium gray (N5), **Phytopsis**-bearing calcilutite with occasional wavy, paper-thin dark gray (N3) limy shale partings.	1	3	13	8
1. Interbedded medium dark gray (N4) to medium gray (N5) calcisiltite, minor intermediate between dark gray (N3) and medium dark gray to medium dark gray calcilutite, minor medium gray calcarenite and dark gray limy shale; thinly laminated to thin-bedded; prominent calcarenites, with a slight yellowish-brown (10YR-6/2) tinge, are present from 1 inch to 3 inches, 2 feet 11 inches to 3 feet 1 inch, and 3 feet 7 inches to 3 feet 8 inches below the top of the subunit; the shale partings, paper-thin to ¼ inch thick, are spaced 1/16 inch to 3 inches apart; occasional **Phytopsis** in the finer limestones.	12	5	12	5

Bottom of hole.

14. This section was described and measured from cliff exposures and drill core (Alf. 147) obtained in Gulf Creek, 2,500 feet east of Rodman, NE/4 Rodman, N.Y. quadrangle.

Deer River Shale

	I Ft.	I In.	II Ft.	II In.
17. Intermediate between dark gray (N3) and medium dark gray (N4), extremely fissile, argillaceous shale which breaks down to characterisitic chips, 1 by 1½ by 1/8 inch thick, on weathering; the base of the subunit (and of the formation) is frequently marked by small concretions and crystals of marcasite (particularly upstream), but at this locality the base is masked by the shale chips falling down from above; contains the trilobite **Triarthrus eatoni** (Hall); at the site of Alf. 147, the Utica shale composes the upper two-thirds of the cliff face forming the valley wall.	20 plus			

Cobourg Formation

16. Medium dark gray (N4), olive gray (5Y4/1) to light olive gray (5Y6/1)-weathering, calcisiltite in lensing or knobby beds (bouldery limestone), 1½ inches to 5 inches thick, separated by zones of dark gray (N3) shale, ½ to 2 inches thick, which becomes more abundant upward; contains occasional specimens of orthoceracone cephalo-

	I Ft.	I In.	II Ft.	II In.
pods and trilobites, partiuclarly **Isotelus** sp.	5	0	252	4
15. Medium dark gray (N4), olive gray (5Y4/1) to light olive gray (5Y6/1)-weathering coarse calcisiltite and calcarenite in distinctive knobby layers, 1½ inches to 5 inches thick with an average thickness of 3 inches, which often weather to rubbly fragments; the limestone beds are separated by zones of dark gray (N3) limy shale, ½ inch to 2 inches thick; moderately fossiliferous; contains Bryozoa, brachiopods, gastropods, trilobites and crinoid stem fragments; the complete fauna has been listed by Kay (1933, Table III, p. 7).	7	4	247	4
Bed of Gulf Creek and base of cliff section. The subunits below have been described and measured from the drill core.				
Cobourg and Denmark Formations				
14. Intermediate between dark gray (N3) and medium dark gray (N4), very thin- to very thick-bedded coarse calcisiltite with minor interbeds of dark gray to medium gray (N5) calcilutite and medium gray calcarenite; the limestone beds are separated by wavy partings and thin plane zones of dark gray limy shale, but there are often long runs of limestones without shale intercalations; the calcisiltites account for 80 to 90 percent of the subunit and range in thickness from ½ inch to 42 inches, with an average of 5 to 7 inches; the calcilutites and calcarenites range from 1 to 3 inches thick but generally measure less than 2 inches; the zones of limy shale are 1/8 inch to ¼ inch thick; drillers reported a small show of gas at the base of the subunit; many small brachiopods are present within the limestone layers.	38	0	240	0
13. Rock types, color and fauna as 14, but the calcarenites become more abundant (40 to 50 percent of the subunit) so that the calcisiltites and calcarenites are present in approximately equal proportions; the dark gray (N3) limy shale partings are somewhat more abundant; the limestone beds are 1½ to 5 inches thick, with an average thickness of 3 inches.	43	11	202	0

	I Ft.	I In.	II Ft.	II In.
12. Medium dark gray (N4) calcisiltite and medium gray (N5) to intermediate between medium gray and medium light gray (N6) calcarenite which is characterized by a slight pale yellowish-brown (10YR6/2) cast; the limestone beds are ½ inch to 5 inches thick, with an average thickness of 2 inches, and separated by wavy, paper-thin dark gray (N3) limy shale partings and plane zones of medium dark-gray argillaceous calcilutite, 1/8 inch to 2½ inches thick; the sequence is transitional upward from subunit 11 to subunit 13.	17	0	158	1
11. Intermediate between medium gray (N5) and medium light gray (N6) to medium light gray, thickly laminated to medium-bedded, medium to coarse calcarenite with overall faint pale yellowish brown (10YR6/2) cast; limestone beds are 1/8 inch to 6½ inches thick, with an average thickness of 2 to 3 inches, and separated from one another by zones of dark gray (N3) to medium dark gray (N4) limy shale and argillaceous calcilutite, 1/8 inch to 5 inches thick and averaging ½ inch to 1 inch thick; a few unidentifiable fragments or brachiopods occur in the limestone.	36	4	141	1
10. As 11, but with the introduction of small amounts of medium dark gray (N4) to medium gray (N5) calcisiltite and calcilutite at the expense of the calcarenite.	5	8	104	9
9. Dark gray (N3) to medium dark gray (N4) calcilutite.	1	0	99	1
8. As 10.	22	0	98	1
7. Medium gray (N5) to medium-light gray (N6), fine calcarenite.	0	11	76	1

	I Ft.	I In.	II Ft.	II In.
6. Interbedded medium dark gray (N4) calcilutite and medium gray (N5) to intermediate between medium gray and medium light gray (N6) calcisiltite in approximately equal amounts; limestone beds are ½ inch to 6½ inches thick and separated from one another by zones of dark gray (N3) limy shale ¼ inch to 4 inches thick, with an average thickness of 1 to 1½ inches; the shale is more prominent than in any of the subunits above; contains brachiopods.	24	4	75	2
5. Predominantly dark gray (N3) limy shale in beds 1/8 inch to 2 inches thick and dark gray calcilutite in beds 2 to 6 inches thick; minor amounts of medium gray (N5) calcarenite and calcisiltite, ½ inch to 3 inches thick; distinctive subunit.	10	10	50	10
4. Intermediate between medium gray (N5) and medium light gray (N6) calcarenite and medium gray calcisiltite in beds ½ inch to 5 inches thick; limestone beds separated from one another by plane partings, and thin zones of dark gray (N3) limy shale ¼ an inch to 4 inches thick, with an average thickness of 1 inch or less; the line of division between subunits 4 and 5 is arbitrary, the amount of limy shale gradually diminishes downward in the section; occasional brachiopods in the calcarenite.	34	8	40	0
3. As 4, but with wavy, dark gray (N3) shale partings.	2	0	5	4
2. Intermediate between medium gray (N5) and medium light gray (N6), fine calcarenite.	1	2	3	4
1. As 3.	2	2	2	2

Bottom of hole.

15. This section was described and measured from core obtained by drilling (Alf. 148) on the southeast side of the harbor road, 3,500 feet northeast of the center of the village of Henderson Harbor, NW/4 Henderson, N.Y. quadrangle. The drilling began approximately 270 feet above sea level.

	I Ft.	I In.	II Ft.	II In.
Cobourg Formation				
17. Medium gray (N5) calcarenite, very minor intermediate between medium dark gray (N4) and medium gray calcilutite, and olive gray (5Y4/1) to light olive gray (5Y6/1) thin, limy shale partings which darken to olive black (5Y2/1) near the base of the subunit; the limestones are locally stained dark yellowish orange (10YR6/6) in the highest 5 feet; the calcarenite beds range from 1½ inches to 5 inches thick; the calcilutites are 1 to 2 inches thick and occur from 6 inches to 8 inches, 1 foot 11 inches to 2 feet, and 7 feet 9 inches to 7 feet 11 inches below the top of the sequence; 80 percent core recovery.	8	1	220	0
16. Medium gray (N5) to medium light gray (N6), fossiliferous calcarenite with a faint pale yellowish brown (10YR6/2) cast, very minor medium dark gray (N4) to medium gray calcisiltite and calcilutite; the limestone beds are separated by zones of dark gray (N3) limy shale, 1/8 inch to 4½ inches thick; the calcarenites compose about 60 percent of the subunit and occur in beds ½ to 8 inches thick, with an average thickness of 5 to 6 inches; the finer limestones account for 15 percent and the limy shales 25 percent of the subunit; calcisiltites are ¼ inch to 2 inches thick; calcilutites are ½ inch to 3½ inches thick; calcarenites are fossiliferous.	15	7	211	11
15. Rock types and colors as 16 but without calcilutites; calcarenites compose 65 to 70 percent, calcisiltites 10 percent and limy shales 20 to 25 percent of the subunit; the calcarenites range from ¼ inch to 6½ inches in thickness, the calcisiltites range from ¼ inch to 1 inch in thickness, and the limy shales are 1/8 inch to 2 inches thick; calcarenites fossiliferous.	3	10	196	4

	I Ft.	I In.	II Ft.	II In.
14. Medium gray (N5) to medium light gray (N6) coquinal calcarenite with an overall pale yellowish-brown (10YR6/2) cast	0	9	192	6
Denmark Formation: 169 feet 8 inches				
13. Rock types and colors as 16 but with a slight increase of the finer limestones and a decrease in the average thickness of the calcarenites; calcarenites make up 60 percent, calcilutites 15 percent, calcisiltites 10 percent and limy shales 15 percent of the subunit; the calcarenites range from ½ inch to 6 inches in thickness with an average thickness of 2 inches; calcilutites are 1 to 5½ inches thick; calcisiltites are ¼ inch to 3 inches thick; and the limy shales are 1/8 inch to 2 inches thick; the top of the Denmark Formation is arbitrarily located; it is placed at the first appearance of persistent thicker calcarenites upward.	11	2	191	9
12. Medium gray (N5) to medium light gray (N6), fossiliferous calcarenite.	0	8	180	7
11. Medium gray (N5) to medium light gray (N6), moderately fossiliferous, thin- to medium-bedded calcarenite and thin interbeds of dark gray (N3) limy shale; calcarenite beds are 2 to 6 inches thick; zones of limy shale are ½ inch to 1½ inches thick.	1	1	179	11
10. Medium dark gray (N4), medium-bedded calcilutite with thin interbeds of medium gray (N5) to medium light gray (N6) calcarenite, and dark gray (N3) limy shale; the calcilutite beds are 3 to 10 inches thick with an average thickness of 8 to 10 inches; the calcarenites are 1 to 3 inches thick; the limy shale ranges from plane and wavy paper-thin partings to plane zones 1½ inches thick; subunit has a distinctive appearance because of the persistent thicker-bedded calcilutites.	4	6	178	10
9. Medium gray (N5) to medium light gray (N6), very thin- to medium-bedded, fossiliferous calcarenite with a pale yellowish-brown (10YR6/2) cast; medium dark gray (N4) to medium gray, thickly laminated to thin-bedded calcisiltite; and dark gray (N3) limy shale; the calcarenites range from ½ inch to 11½ inches thick, with an average thickness of 3 to 4 inches, and account for 70 percent of the subunit; the calcisiltites are a ¼ inch to 3½ inches thick and make up 5 to 10 percent of the subunit; the limy shales are 1/8 inch to 2 inches thick and make up 20 to 25 percent of the subunit.	8	2	174	4
8. Intermediate between dark gray (N3) and medium dark gray (N4) calcilutite.	0	7	166	2
7. Succession of medium gray (N5) to medium light gray (N6), thickly laminated to medium-bedded, fossiliferous, fine to coarse calcarenite separated by dark gray (N3) limy shale in wavy paper-thin partings and zones, 1/8 inch to 3/8 of an inch thick, and minor very thin beds of medium dark gray (N4) calcisiltite and calcilutite; the calcarenites range from ¼ inch to 9 inches, with an average thickness of 2 to 3 inches, and make up 80 percent of the subunit; the limy shale makes up 5 percent of the subunit, and the finer-grained limestones, ¼ inch to 1 inch thick, compose the remainder of the sequence.	53	6	165	7
6. As 7, but calcarenites are ½ inch to 5 inches thick, with an average thickness of 2½ inches, and the limy shale is present in plane zones, 1/8 inch to 2 inches thick; contains a moderate number of **Prasopora** in the lower half of the succession; sequence is transitional upward to the subunit above; drill crew reported a gas show from 22 to 37 feet below the top.	47	3	112	1
5. Medium dark gray (N4) calcilutite.	1	3	64	10
4. As 6; occasional **Prasopora**.	2	10	63	7

	I Ft. In.	II Ft. In.
3. Distinctive medium light gray (N6), pale yellowish-brown (10-YR6/2)-speckled, very thin- to medium-bedded, fossiliferous calcarenite; medium dark gray (N4), very thin- to medium-bedded calcilutite and fine calcisiltite; and thin zones of dark gray (N3) limy shale; the calcarenites are ½ inch to 10½ inches thick, with an average thickness of 3 to 4 inches, and make up 45 to 50 percent of the subunit; the calcilutites are 1 to 10 inches thick, with an average thickness of 3 to 5 inches, and make up 20 to 25 percent of the subunit; the calcilsiltites are 1 to 4 inches thick, with an average thickness of less than 2 inches, and account for 10 to 15 percent of the subunit; and the shaly zones are 1/8 inch to 4 inches thick, with an average thickness of ¼ inch, and make up 20 percent of the subunit; **Prasopora** are present throughout the succession; a gas show, 10 feet 9 inches below the top, blew water 20 feet above the surface of the ground.	25 7	60 9
2. Medium dark gray (N4) to medium gray (N5), very thin- to medium-bedded, fine calcarenite to medium calcilutite with interbeds of medium dark gray calcilutite and dark gray (N3) limy shale; the coarser limestones ½ inch to 6 inches thick, with an average thickness of 2 to 3 inches, and make up 55 to 60 percent of the subunit; the calcilutites are ½ inch to 9½ inches thick, with an average thickness of 4 to 5 inches, and account for 15 to 20 percent of the subunit; the limy shale is present as paper-thin partings and zones, 1/8 inch to 5 inches thick, with an average thickness of less than 1 inch; the shale partings and zones are wavy, which imparts to the limestone beds a marked pinch and swell character; the calcarenites are sparsely fossiliferous in drill core; **Paucicrura** and **Prasopora** are present.	13 1	35 2

Shoreham Formation

	I Ft. In.	II Ft. In.
1. Medium gray (N5) to medium light gray (N6), very thin- to thin-bedded, moderately fossiliferous, fine to medium calcarenite; medium gray, very thin- to thin-bedded calcisiltite; medium dark gray (N4), very thin- to thin-bedded calcilutite; and dark gray (N3) limy shale; the calcarenites are ½ to 4 inches thick, with an average thickness of 1½ to 2 inches, and make up 60 percent of the subunit; the calcisiltites are ½ inch to 2 inches thick and make up 10 percent of the subunit; the calcilutites are also ½ inch to 2 inches thick and account for 10 to 15 percent of the subunit; and the limy shale, present in zones 1/8 inch to 1½ inches thick, accounts for 15 to 20 percent of the subunit; contains many specimens of the distinctive bryozoan, **Prasopora orientalis,** some of which are 3½ inches in diameter.	22 1	22 1

Bottom of hole.

16. This section was described and measured from exposures along the bed of Stony Creek where it crosses U.S. Highway 11 at Talcott Falls, SW/4 Watertown, N.Y. quadrangle. The top of the falls marks the upper limit of the section.

Cobourg and Denmark Formations

	I Ft. In.	II Ft. In.
12. Broken and jumbled section because of fault; apparently as subunits 9 and 11.	10 0	132 11
11. As 9.	8 6	122 11
10. Medium gray (N5), medium light gray (N6)-weathering, thin- to medium-bedded, sparsely fossiliferous fine calcarenite and calcisiltite; occasional beds of coarse coquinal calcarenite as in subunit 9; and thin intercalactions of dark gray (N3) limy shale; limestone beds are 1 to 12 inches thick and account for 70 to 80 percent of the subunit.	35 6	114 4
9. Medium gray (N5), medium light gray (N6)-weathering, thin- to medium-bedded, me-		

	I		II	
	Ft.	In.	Ft.	In.
dium to coarse coquinal calcarenite with intercalations of dark gray (N3) limy shale; limestone beds are 1 to 12 inches thick and account for 75 to 80 percent of the subunit.	11	0	78	10
8. Medium dark gray (N4) to medium gray (N5), thin-bedded non coquinal calcarenite; medium dark gray to medium gray, very thin- to thin-bedded calcisiltite; and dark gray (N3) limy shale; the calcarenites become fewer in number, finer in texture, and light olive gray (5Y6/1) to pale yellowish-brown (10YR6/2) upward, whereas the calcisiltites increase in quantity upward; limestones compose 70 to 75 percent of the subunit; prominent pararipples with a 2-foot wave length and 5-inch amplitude are present from 1 foot 6 inches to 2 feet, at 6 feet 7 inches, and from 17 to 18 feet below the top of the subunit; contains several **Prasopora,** some of which are 2½ inches in diameter, in lowest 10 feet; otherwise, fauna as in subunit 1.	26	6	67	10
7. Dark gray (N3) to medium dark gray (N4), very thin- to thin-bedded barren calcisiltite; weathers medium gray (N5).	1	9	41	4
6. As 4, but the fine calcisiltites occasionally exhibit cross bedding on the weathered edges, and a few of the thin-bedded calcarenites are coquinal.	5	6	39	7
5. Covered interval.	19	4	34	1
4. As 2, but with 5 to 10 percent of barren, fine calcisiltite in beds ½ inch to 1 inch thick.	3	4	14	9
3. Covered interval.	2	2	11	5
2. Medium dark gray (N4) to olive gray (5Y4/1), thin- to medium-bedded coarse calcisiltite to coarse calcarenite, with the finer textures predominating, and dark gray (N3) limy shale; the color of the weathered surfaces is obscured by lichen; the limestone beds have wavy surfaces, are 2½ inches to 8 inches thick, with an average thickness of 3 to 4 inches, and compose 80 to 85 percent of the subunit; the limy shale is present as wavy, paper-thin partings and wavy thin zones, 1/16 inch to ¼ inch thick, and accounts for the balance of the subunit; the limestones are moderately fossiliferous but not coquinal, brachiopods dominate.	3	9	9	3
Camp Member.				
1. Medium dark gray (N4) to medium gray (N5), medium light gray (N6) to light-gray (N7)-weathering, thin-bedded coquinal calcarenite; minor medium dark gray to medium gray, medium light gray weathering, very thin- to thin-bedded fossiliferous calcisiltite; and wavy and plane paper-thin partings and very thin zones of dark gray (N3) limy shale; the limestone beds are ½ inch to 3½ inches thick; the calcarenites are thickest, measuring 2 to 3½ inches; bedding surfaces are mostly plane; the more prominent wavy surfaces are characterized by pararipples of 5-inch amplitude and 2-foot wave length; the limestones make up 65 to 70 percent of the subunit, the balance is limy shale; brachiopods dominate the fauna, particularly, **Rafinesquina, Sowerbyella,** and **Hesperorthis.** The subunit is cut by a prominent set of vertical joints, N. 78 E.	5	6	5	6
Base of section.				

Structure

The structure of the limestones in Jefferson County is remarkably uncomplicated, both regionally and in detail. The single predominant feature is the southwestward regional dip of 1 to 2 degrees. Jointing is present in all the rocks, particularly in the limestones of the Black River Group. No large folds or major faults were noted.

Joints

Several sets of joints cut the Jefferson County limestones. The most prominent joint directions in their order of importance are: N. 65-75° E., N. 45-55° W., N. 25-35° E., and N. 10-20° W. The major joint sets are very constant in strike over wide areas but, locally, other sets become important and may even predominate. Joint planes other than vertical are rare. A statistical study of the joints has shown that there is no significant change in attitude within age or locality. The joints are spaced a few inches to more than 20 feet apart. Joint separation in the more prominent sets is generally less than 10 feet, and often less than 5 feet. On bared limestone surfaces, solution has widened many of the joint cracks as much as several feet, particularly in the Chaumont Formation. Much of the water falling on the Chaumont terrace passes downward through these cracks to underground drainage. Chaumont Limestone is more soluble than upper Lowville Limestone, and the chief underground flow within the area is on the upper surface of the Lowville Formation. This subsurface drainage is responsible for many contact springs and caves at the Lowville-Chaumont contact. Joints are indicated on the geologic maps.

Folds

The limestones exhibit various degrees of folding, most of it slight. Broad gentle warps with a maximum dip of 6 or 7 degrees are locally common. Folds of this type are readily detected along the banks of the Black River, particularly between Watertown and Brownville, where any rock layer at water level (Lowville or Chaumont Limestone) can be seen to gradually dip below or rise above the water line up- or down-stream. Gentle folds on the top surface of the Cobourg Limestone are well displayed in the bed of Fish Creek (NW/4 Rodman quadrangle) and along the north Branch of Sandy Creek.

A small, asymmetrical fold ridge (4 feet in amplitude) which trends N. 56° W. occurs 0.5 mile due south of Depeauville (SW/4 Clayton quadrangle). It is exposed in a small cut on the west side of the Depeauville-Reynold Corner road. The south limb is steeper. A northeast-dipping high angle thrust fault of very slight displacement which strikes parallel to the ridge may be seen in the road cut, but it could not be seen elsewhere. A similar fold in the field immediately southwest of N.Y. Highway 12 a little more than 1 mile southeast of Depeauville strikes N. 77° W. It appears to represent the eastward continuation of the first fold ridge, giving the fold a slightly arcuate appearance in plan. The structure is the result of lateral compression of relatively incompetent beds sliding on more competent strata. This type of phenomenon (ice pressure ridge) is often found on glaciated surfaces and is due to pressure and movement of the overriding ice.

A few folds with dips unusually steep (up to 35 degrees) for the area have been reported (Cushing, 1910, p. 115) in the older limestones. One of these is found in the Lowville Formation 1 mile west of Sanford Corners (SW/4 Black River quadrangle). The evidence (glacial striae, etc.) suggests that the fold is probably the result of postglacial uplift, i.e., readjustment of the rock to the upward movement of the land following the removal of the ice sheet.

Faults

Faults of considerable magnitude have not been noted. The fairly accurate mapping which the frequency of rock exposures makes possible indicates that no such faults are present. Several faults of relatively minor displacement are present but remarkably scarce.

County Line Fault

In the valley of Lake Creek, 500 to 1,000 feet west of and parallel to the Jefferson-Lewis County line (NE/4 Copenhagen quadrangle and NW/4 Carthage quadrangle), is a possible fault. Except for unusually steep dips (45 degrees) and breccia in the Kirkfield core recovered from

Drill Hole Alf. 140 (Section 2), dips of 18 degrees in the Lowville beds exposed in the bed of Lake Creek at the village of West Carthage swimming pool (NW/4 Carthage quadrangle), and the map pattern, there is little direct evidence on which to go. A sharp monoclinal fold could produce a similar pattern, but the dips necessary to bring about this type of structure are lacking. The map pattern suggests movement of a pivotal nature, with the fulcrum at the southwest end of the fault, i.e., the northwest side of the fault apparently moved up differentially, with the greatest upward movement in the northeast thereby giving the appearance of strike-slip movement, but with a distinct variation in the width of the outcrop belts on either side of the fault plane. A fault with similar movement and producing a similar map pattern is well exposed in the valley of Stony Creek (Stony Creek Fault) about 4 miles to the southeast in Lewis County.

Other Faults

Minor faults are present along the Black River south of Herring(s) (SE/4 Deferiet quadrangle). The average trend of the faults is about N. 45° W., varying from N. 37° W. to N. 66° W., and they are nearly vertical. The displacements, as indicated by drag, striations, and relative movements of the beds seem to be predominantly vertical, with minor strike-slip and reverse components on some of the faults. Variations in the directions of movement on the fault planes can be seen clearly. The major result of the faulting is that a northwest-elongated block has been pushed upward in the flat-lying beds. A series of step faults bound the horst-like structure on each side. The stratigraphic throw on each of the faults is slight, but the combined maximum displacement is about 50 feet. Marcasite, which has been partly altered to limonite, and calcite mark the fault lines in several places.

In the abandoned New York Central Railroad cut a few yards east of N.Y. Highway 179 (NE/4 Chaumont quadrangle) there is a small northwest-trending normal fault which dips 49 degrees to the northeast. The northeast block has dropped just enough to preserve a small outlier of Rockland limestone in the belt of Chaumont Limestone.

Cushing (1910, p. 120) described a fault in the Pamelia Formation 2 miles east of Perch Lake (probably near Lowell Creek, NW/4 Black River quadrangle) which displaces the strata about 20 feet. This fault was not found. Another small fault occurs in the Cobourg Formation at Talcott Falls (Section 16).

Development Possibilities

General Statement

Carbonate rocks have a great many uses, all of which depend on certain physical, chemical or physical-chemical requirements. No attempt is made herein to discuss all of these uses and their requirements. Construction consumes the bulk of the carbonate rocks quarried, principally in the building and maintenance of highways. Cement and agricultural limestone, in that order, are next in importance. Stone used as aggregate is primarily dependent upon certain physical properties, whereas carbonates suitable for cement and agricultural limestone depend largely on their chemical content.

Tests and Specifications

All aggregate stone used in the construction of highways under the jurisdiction of New York State is subjected to a variety of tests by the New York State Department of Transportion. Bureau of Materials; crushed limestone is no exception.[9] These tests include Specific Gravity (density), Absorption, Abrasion, Soundness and Freeze-Thaw.

Density and absorption determinations yield weight per unit volume and information on the amount of water-penetrable voids in the stone. The latter test is of value in determining the durability of the limestone on exposure to freezing action. Abrasion tests measure the resistance of the crushed stone to wear by rotating a sized and weighed sample of aggregate in a special steel cylinder for a set time. Two methods of determining the amount of abrasion are used; these are the Deval Abrasion Test and the Los Angeles Abrasion Test, but the Deval is the official State test for deciding on the suitability of the stone in this regard. The tests differ in design of apparatus and duration. The Los Angeles Test utilizes an abrasive charge of steel balls along with the stone and is, therefore, more severe, which results in a greater percent of loss or wear. The Soundness Test measures the resistance of the rock to disintegration and it, too, is an aid in determining the durability of limestone exposed to freezing action. The tests consists of immersing a sized and weighed sample of aggregate in a saturated sodium sulfate solution and the drying of it in an oven. The New York State Department of Transportation now uses a magnesium sulfate instead but the procedures are similar. This immersion and drying procedure is repeated through a required number of cycles. The sample is resized and the loss subtracted from 100 gives soundness in percent. The Freeze-Thaw Test involves the placing of a representative sized and weighed sample in a 10 percent solution of NaCl (sodium chloride or salt) for 24 hours, after which the receptacle containing the sample is placed in a freezing chamber at -10° F. until the salt solution is frozen solid, but not for less than 16 hours. The sample is put through 25 freeze-thaw cycles. This test is also a measure of the rock's resistance to disintegration. It is required only of crushed stone used in Portland cement concrete where surfaces are exposed.

[9]Excepting calcitic dolostone containing not less than 30 percent $MgCO_3$ or dolostone which may be crushed to make artificial sand, carbonates may not be used as fine aggregate, i.e., crushed stone fine enough to pass ¼-inch screen.

In addition to meeting the specifications of the tests described above, crushed stone must be clean, durable sharp-angled fragments of rock of uniform quality throughout. There cannot be more than 30 percent of crushed particles that are flat or elongated to the degree of 3:1, and not more than 10 percent to the degree of 5:1. There are also specific requirements governing the amounts and kinds of deleterious substances that may be present.

The New York State Department of Transportation uses three gradings for acceptable rocks and designates the quality Types A, B, and C as follows:

TESTS	TYPES A	TYPES B	TYPES C
Deval Abrasion Test Percent loss maximum by weight	4.0	5.7	6.5
Magnesium Sulfate Soundness Test Percent loss at 10 cycles maximum by weight	1.0	10.0	12.0
Freeze-Thaw Test Percent loss at 25 cycles maximum by weight*	3.0	3.0	------

*For exposed portland cement concrete surfaces.

More detailed information concerning tests and specifications can be obtained from the District Engineer, N.Y. State Department of Transportation Office, Watertown, New York, or from the Department of Transportation, Bureau of Materials, State Campus, Albany 12226.

The results of density, absorption and sodium sulfate sounds tests performed on Jefferson County samples by the Research Department of the State University of New York College of Ceramics are described in the section by Wayne E. Brownell (p. 74).

Any commercial development of the limestones for aggregate stone, whether in this county or elsewhere in New York State, will be required to have the rock product meet the State specifications. The Jefferson County limestones must not only be subjected to further physical tests to determine their suitability, but the soundness test employed in this study is no longer the New York standard. In addition, the results of the sodium sulfate soundness tests tabulated elsewhere in this report are based on but a few localities, particularly with respect to the Trenton limestones. Furthermore, these results are based on the testing of drill core, which are often not the same as the results obtained from the crushed stone product. Many limestones, particularly those of the Trenton Group, contain thinly laminated beds and seams of limy shale in varying amounts. This shale is often the cause of failure. It has been found that during the processing of rock in a quarry operation, where the stone passes through several stages, such as initial blasting, secondary breaking or crushing, mechanical shaking and screening, the effect of the much greater impact by explosives and large-scale industrial equipment usually is to rid the finished product of most of the easily abraded shale to yield a stone of acceptable quality. The limited action of equipment used in the laboratory is not enough to cause sufficient separation of the undesirable material. The results of the soundness tests are, therefore, open to question.

The chemical analyses in Tables 13 through 29 are sufficiently complete to determine the suitability of the limestone for those uses that have specific chemical requirements. Useful conversion factors that apply to the chemical data are given in Table 30 (p. 87).

Technological and Economic Considerations

A rock quarry is developed when there is a demand for a certain type of rock product (or products) and there is sufficient stone with the appropriate physical and/or chemical requirements to meet this demand. The operation may be permanent or temporary, in the latter instance, for example, to supply crushed stone for a highway construction job.

The success of a commercial quarry operation is governed by numerous technological and economic factors.

Technological factors involve geologic and topographic considerations. Plainly, a deposit of stone satisfying the requirements of the planned uses must be found. Such work is facilitated by referring to the geologic maps which delineate those areas within the county where the limestones form the surface rock. Once the area in which the desired rock occurs is known, the configuration of the land surface becomes significant in the choice of a site. The deposit should be located topographically so that natural drainage will not involve excessive pumping to keep the operation water free, that sufficient level or nearly level land exists on which to erect the plant required for the particular operation, and that haulage roads will have sufficently low grades (optimum less than 8 percent). Hills or ridges of suitable limestone that stand above their surroundings are, therefore, favored for quarry sites. There should be an adequate water supply to satisfy the particular needs of the operation.

The nature of the overburden is extremely significant. The cost of stripping cover material varies greatly, depending on its character and thickness. In general, stripping costs for unconsolidated overburden are less than those for rock overburden, which requires drilling and blasting. It is difficult to place a precise limit on the thickness toleration for either type of cover because unusually thick deposits of unwanted material have been stripped where the need for the rock below was sufficiently great. In practice, stripping costs for unconsolidated overburden more than 12 to 15 feet thick are considered high enough to reject quarry sites for aggregate stone and other low-priced rock products. In Jefferson County each of the limestone formations forms the surface rock in belts sufficiently wide so that there is no need to consider removal of consolidated overburden except under conditions of selective quarrying. Unconsolidated overburden more than 12 to 15 feet thick are is most areas but the thickness varies considerably from place to place.

The character of the stone and its structure are also very important. The nature and attitude of layering and jointing greatly influence the effects of blasting, the size and shape of the broken stone and the ease of operation, including the maintenance of a good working face and a smooth and level quarry floor. The deposit should be as uniform as possible in terms of its physical properties and its composition, particularly if the rock is to serve as raw material for the manufacture of cement or other essentially chemical applications. For such uses, interbedded, impure rock materials are cause for rejection. The acceptability of any rock sequence depends largely on the use to which the rock is to be put.

The successful development of a quarry is also governed by a number of economic considerations such as land values, local zoning regulations, location, accessibility, transportation facilities, market distance, and power supply.

The value of the land and zoning regulations should be such that enough property can be obtained economically for plant construction, storage facilities, and future expansion. A site too close to a developed area can result in damage to nearby structures as a result of blasting and dust. Certain types of rock products, such as crushed stone, are relatively low priced, large volume commodities which prohibit long truck or rail hauls to the consumer. All suppliers of rock products, particularly those with more favorable cost-price balance, could benefit over a long haul by taking advantage of less costly water transportation available on Lake Ontario and the St. Lawrence River. The expense of building an access road to any specific locality from a public highways should not be a major concern. The county has a fine network of all-weather roads.

Methods for Estimating Quantity of Stone

The volume of stone available for immediate and future needs must be determined before a quarry is developed. Various data may be used for calculating the amount of stone.

The specific gravity of carbonate rock averages about 2.68; it is seldom lower than 2.60 nor higher than 2.85. Specific gravities of the limestones in Jefferson County range from 2.52[10] to 2.74, averaging 2.676 or 2.68.

The quantity of rock in any given area may be expressed in terms of cubic measure, usually cubic yards, or short tons (2,000 pounds), though there has been a decided preference toward reporting quantity on a tonnage basis in recent years. Limestone with a specific gravity of 2.68 weighs 167.7 pounds per cubic foot, but common practice is to use the figure of 160 pounds per cubic foot, which takes into account losses from quarrying and handling. If stone is crushed, an allowance of 50 percent should be made for the spaces between the rock particles. The quantity of limestone available (or that in reserve) can be determined in the following ways:

T = Tonnage

1) lbs./cu. ft. (160) x vol. cu. ft. (length x width x thickness) = Thickness
   2,000

2) Vol. cu. ft. (length x width x thickness) x .08 = T
3) 1 cu. yd. = 27 cu. ft. = 2.2 tons
   Vol. cu. ft. (length x width x thickness) x 2.2 = T

4) 43,560 sq. ft./acre = 1 acre-foot = 3,500 tons/acre-foot[11] (length x width x 3,500) x thickness = T
   43,560

[10] Two samples out of 195 had a specific gravity less than 2.60; these reflect the presence of numerous quartz sand grains in the lower portion of the Pamelia Formation.

[11] This figure takes into consideration losses from quarry and handling.

Potential Quarry Sites

No attempt is made in the following discussion to recommend any particular locality as meeting all requirements for commercial development. It is difficult to find any single site that completely satisfies the many technological and economic factors. The limestone sampling and the analyses of the sampled units are believed to be representative of the rock units from which the samples were obtained. The area of study is large, however, and the choice of a site or sites to obtain a specific sequence of rock for testing was selective. More detailed geologic study and testing are necessary to prove out a particular area.

This report serves to outline the distribution of the carbonate units within Jefferson County and to single out several localities as potential quarry sites. There are others. In fact, there are few areas where a quarry could not be opened although the rock should meet the physical and/or chemical requirements and the political and economic conditions should be satisfactory.

The test results suggest that the commercial potential of the Jefferson County limestones is not great, particularly with respect to uses based on physical criteria and, accordingly, it is difficult to single out any particular unit or units for specific development. The altogether different results often obtained from commercially processed materials, selective quarrying procedures, new methods of processing, and reblending techniques may serve to yield an acceptable product. Therefore, sites are chosen that collectively represent all of the formations in the carbonate succession, with emphasis on the technological considerations. Many of the economic factors could change for one reason or another.

Potential quarry sites are shown on the geologic maps by black arrows. They are described in the pages that follow by alphabetical arrangement of the topographic quadrangles (Fig. 1) in which they are located. **Those sites marked by an asterisk (*) in the text are preferred locations.** The rock units present at each locality are listed, but the reader is referred to the text and the geologic sections for a detailed description of these rocks. Because the limestones are so nearly flat, no mention is made of the structure unless some significant departure from the regional dip exists. The attitudes of the joints, however, are given where possible, as this information is more precise than the range of values given for dip and strike in the section devoted to joints. The figure or figure range for the height of the working face refers to the maximum height for an open-face quarry, that is, one in which the face is developed above the general surface of the land and the stone is shot down to plant level. If a pit quarry is developed below the general level of the surrounding terrain, a higher vertical face can be had, and its height would be determined by the thickness of the acceptable stone and a workable vertical dimension. The composition of the individual rocks units at a given site can be estimated by consulting the chemical analyses for the appropriate portion of the rock sequence in the Tables.

The sites are as follows:

1. ADAMS QUADRANGLE
   None recommended.
2. BARNES CORNERS QUADRANGLE
   None recommended.
3. BLACK RIVER QUADRANGLE
   None recommended; largely U.S. Military Reservation.
4. BROWNVILLE QUADRANGLE
   There are several localities available for possible development. Most sites involve the Lowville and Chaumont limestones in the southern half of the map area.

SITE 4A (*)

Location – Along north margin of SW/4, 1.5 miles due south of N.Y. Highway 12 and 3.5 miles due north of the village of Brownville, Town of Brownville.

Elevation – 400 to 450 feet.

Rock Units – Lowville and Chaumont limestones.

Overburden – Variable drift cover, generally thin, with bedrock occasionally exposed. Vegetation included grass, brush, and in part of the area, dense woods.

Working Face – Depends on rock desired, up to 50 feet.

Accessibility – All-weather secondary road for 1.5 miles to N.Y. Highway 12.

Joints – N. 12-28° W.; N. 14° E.; N.67-70° E.

Remarks – There are 3 other possible site locations in the general vicinity; all are east of the locality described above within an area measuring 1 by 2 miles.

SITE 4B

Location – SW/4, 2.2 miles northeast of Brownville, immediately north of Pettit Cementery and west of Military Road, Town of Brownville.

Elevation – 380 to 415 feet.

Rock Units – Upper Lowville and Chaumont limestones.

Overburden – Essentially none; little or no soil cover with grass.

Working Face – 30 feet.

Accessibility – 1,000 feet from all-weather road connecting with N.Y. Highway 12E at Brownville (2.3 miles) and Route 12 (0.75 mile).

Joints – N. 48° W.; N. 28° E.

SITE 4C

Location – Southeast corner of SE/4, either side of U.S. Highway 11, Town of Pamelia.

Elevation – 450 to 500 feet.

Rock Units – Upper Lowville and Chaumont limestones.

Overburden – Variable drift cover, slight; grass and brush.

Working Face – 45 to 50 feet.

Accessibility – Bisected by U.S. Highway 11, 2.5 miles northeast of Watertown city center.

Joints – N. 48-53° W.; N. 29° E.; N. 69-71° E.

SITE 4D

Location – SE/4, east and west of N.Y. Highway 37, 5 miles north of Watertown, in Town of Pamelia.

Elevation – 420-480 feet (west side) and 460-500 feet (east side).

Rock Units – Lowville Limestone.

Overburden – Variable drift cover, slight; grass with some brush.

Working Face – 40 to 55 feet.

Accessibility – Bisected by N.Y. Highway 37; Interstate 81 located 1,500 to 2,000 feet west.

Joints – N. 50° W.; N. 10° E.; N. 64° E.

5. **CAPE VINCENT NORTH QUADRANGLE**

None recommended.

6. **CAPE VINCENT SOUTH QUADRANGLE (*)**

Location – Central part of north half, west wall of valley of Mud Creek between N.Y. Highway 12E and Pleasant Valley Road, Town of Cape Vincent.

Elevation – 265 to 325 feet.

Rock Unit – Kirkfield Limestone.

Overburden – Variable drift cover, generally less than 3 to 5 feet; grass and some brush.

Working Face – 60 feet.

Accessibility – Conveyor belt to Mud Bay and barge transportation, a distance of less than 0.5 mile; 1 mile from N.Y. Highway 12E.

Joints – N. 65-75° E.; N. 4° W. to N. 21° E.

Remarks – Operation would require relocation of northeast-southwest secondary road; many connecting roads in vicinity.

7. **CARTHAGE QUADRANGLE**

Location – Jefferson-Lewis County line, but mostly in Lewis County (Town of Denmark), 2 miles southwest of Carthage.

Elevation – 785 to 825 feet.

Rocks Units – Upper Lowville and Chaumont limestones.

Overburden – Virtually none.

Working Face – 35 feet.

Accessibility – Borders N.Y. Highway 26.

Joints – N. 77° W.; N. 37° W.; N. 68° E.

8. **CHAUMONT QUADRANGLE**

There are three potential sites in the Chaumont Quadrangle; one is in the Black River limestones, the other two are in rocks of the Trenton Group.

SITE 8A

Location – NE/4, between N.Y. Highway 179 and Chaumont River, Town of Lyme, 0.5 mile north of village of Chaumont.

Elevation – 260 to 300 feet.

Rock Units – Lowville and Chaumont limestones.

Overburden – Slight drift cover; occasional brush and trees. Rock exposed over broad area.

Working Face – 40 feet.

Accessibility – Borders N.Y. Highway 179. Water transport via Chaumont River to Lake Ontario.

Joints – N. 21° E.; N. 67° E.

Remarks – Limited tonnage; easterly expansion prevented by N.Y. Highway 179. Area extends along strike into neighboring Dexter Quadrangle. Powerline crosses area.

SITE 8B

Location – SE/4, Town of Brownville.

Elevation – 260 to 320 feet.

Rock Units – Kirkfield Limestone, possibly some Shoreham Limestone.

Overburden – Slight glacial cover; scattered brush and trees.

Working Face – 25 to 60 feet, becoming higher as development progresses eastward.

Accessibility – Barge from Guffin Bay, Lake Ontario; all-weather road to N.Y. Highway 12E via Luther Hill.

Remarks – Summer camps along lakeshore.

SITE 8C

Location – SW/4, Town of Lyme, 0.25 mile north of village of Point Peninsula.

Elevation – 260 to 310 feet.

Rock Units – Kirkfield Limestone and basal Shoreham Limestone.

Overburden – Variable glacial drift; maximum thickness not known.

Working Face – 40 to 50 feet.

Accessibility – Water transport via Guffin Bay and Chaumont Bay. Long truck haul via all-weather roads to Chaumont, Dexter, or Watertown.

9. CLAYTON QUADRANGLE

Several possible sites occur within the Clayton Quadrangle.

SITE 9A

Location – SW/4, 1 to 1.5 miles west and west-northwest of Depeauville, Town of Clayton.

Elevation – 340 to 400 feet.

Rock Units – Lowville Limestone (including the Pamelia-Lowville transition) with thin cap of Chaumont Limestone to south.

Overburden – Variable drift cover, generally slight; bedrock exposed over much of area. Open, vegetation mostly grass and brush; occasional trees.

Working Face – 50 feet.

Accessibility – N.Y. Highway 12, 0.5 to 1 mile northeast.

Joints – N. 61-70° W.; N. 10-20° W.; N. 53-86° E.

SITE 9B (Three areas in close proximity to one another)

Location – SW/4 and SE/4, Town of Clayton, along Chaumont River from vicinity of Depeauville to 0.8 mile northeast. One site is located along west bank, immediately south of N.Y. Highway 12; another occurs along the west bank 0.5 mile north; and the third is 0.75 mile northeast, along the east bank.

Elevation – 280 feet (river level) to 380 feet.

Rock Units – Pamelia Formation, locally with thin cap of basal Lowville (Pamelia-Lowville transition) limestone.

Overburden – Variable drift cover on terraces; rock exposed in valley walls. Vegetation includes grass, brush and, in places, dense woods.

Working Face – Variable, depending on choice of locality. The site south of Depeauville could have an open face 80 to 100 feet high; the site north and west of Depeauville, 50+ feet; and the site east of the river, a face 80+ feet high. The easternmost site would involve destruction of a little-used dead end dirt road leading to a small abandoned quarry and town dump.

Accessibility – N.Y. Highway 12, 0.2 to 0.8 mile, depending on choice of site.

Joints – N. 50-51° W.; N. 47-62° E.

SITE 9C

Location – NW/4, southeast wall of valley of French Creek, 3 miles south-southwest of village of Clayton and the St. Lawrence River, Town of Clayton; 1.5 miles west of N.Y. Highway 12.

Elevation – 300 to 380 feet.

Rock Unit – Pamelia Formation.

Overburden – Glacial drift, 1 to 3 feet; bedrock crops out over much of area. Vegetation mainly grass and brush on terrace; trees at edge of terrace and along steep north-facing slope.

Working Face – 75 feet.

Accessibility – N.Y. Highway 12, 1.5 miles to east via excellent all-weather road. Water transportation facilities at Clayton.

Joints – N. 47-70° W.; N. 10° W. to N. 7° E.; N. 56-79°E.

10. COPENHAGEN QUADRANGLE

SITE 10A (*)

Location – NE/4; Town of Champion, 2 miles southwest of Carthage-West Carthage. Site is just inside Jefferson County line, 0.25 to 1 mile north of Drill Hole Alf. 140.

Elevation – 820 to 1,000 feet.

Rock Units – All limestones from Lowville through Denmark.

Overburden – Variable drift cover; Chaumont terrace has generally less than 3 feet of drift, with occasional clusters of trees and brush. Slopes covered with trees and brush.

Working Face – Dependent on rock units to be quarried. The Lowville-Chaumont sequence permits a face of 40 to 45 feet. The Trenton limestones permit a face of 100+ feet.

Accessibility – All-weather road joining N.Y. Highways 26 and 3 at West Carthage and Carthage.

Joints – N. 75-86° W.; N. 20-25° W.; N. 70-75° E.

SITE 10B

Location – NE/4; 1 mile southeast of Champion, Town of Champion.

Elevation – 1,100 to 1,200 feet.

Rock Unit – Cobourg Limestone.

Overburden – Variable glacial drift; brush, occasional trees.

Working Face – up to 100 feet.

Accessibility – All-weather roads to N.Y. Highways 26 (2.5 miles) and 3 (3 miles) at West Carthage and Carthage.

11. DEFERIET QUADRANGLE

None recommended; area largely U.S. Military Reservation. Extensive cover of glacial materials, mainly glaciofluvial sands.

12. DEXTER QUADRANGLE

SITE 12A

Location – NW/4, in Town of Lyme, 1.5 miles northeast of village of Chaumont between N.Y. Highway 179 and Morris Tract Road.

Elevation – 310 to 335 feet.

Rock Units – Lowville and Chaumont limestones.

Overburden – Thin glacial cover, generally 0 to 3 feet; local patches of dense brush, areas of heavy woods to north.

Working Face – 20 to 25 feet.

Accessibility – Excellent roads to N.Y. Highway 12E at Chaumont; conveyor belt to Chaumont River and barges.

Joints – N. 50-70° W.; N. 72° E.

Remarks – Only the basal portion of the Chaumont Limestone is present in this area.

SITE 12B

Location – SE/4; side hill immediately east of Drill Hole Alf. 142, 2.3 miles southeast of Limerick, Town of Brownville.

Elevation – 340 to 420 feet.

Rock Units – Rockland and Kirkfield limestones. Chaumont and Lowville limestones by deepening into pit quarry.

Overburden – Variable drift cover, slight; brush and trees on side hill.

Working Face – 75 to 80 feet.

Accessibility – All-weather road to N.Y. Highway 12E, 1 mile away.

Joints – N. 45° W.; N. 19° W.; N. 57° E.

SITE 12C (*)

Location – SW/4; east and west of Perch River inlet, 1.75 miles west of Dexter, Town of Brownville.

Elevation – 280 to 345 feet.

Rock Units – Rockland and Kirkfield limestones.

Overburden – Variable drift cover; grass and local patches of brush; no trees.

Working Face – 50 to 60 feet.

Accessibility – Good all-weather roads to N.Y. Highway 12E via Doanes Hill (2 miles) or via Dexter (2.25 miles); N.Y. Highways 12F and 179 at Dexter. Water transportation via Black River Bay.

13. ELLISBURG QUADRANGLE

None recommended. Outcrops are rare; area covered by extensive blanket of glacial drift, including both till and fluvial materials.

14. HENDERSON QUADRANGLE

SITE 14A (*)

Location – NW/4; area bounded by Henderson Bay and White's Bay, 1.5 miles west of village of Henderson Harbor, Town of Henderson.

Elevation – 250 to 340+ feet.

Rock Units – Denmark-Cobourg Limestone, probably that part of sequence representing Cobourg Limestone.

Overburden – Variable drift cover. Rock forms cliff section at lake edge. Local patches of dense brush and woods.

Working Face – 85 to 90 feet.

Accessibility – Excellent opportunity for water transportation via Henderson Bay; all-weather road joining N.Y. Highway 3, 2 miles from site.

Remarks – Summer cottages at lake edge along eastern portion of area.

SITE 14B

Location – NE/4; 1.25 miles east of village of Henderson Harbor, Town of Henderson.

Elevation – 340 to 430 feet.

Rock Units – Denmark-Cobourg Limestone, probably that part of sequence representing Cobourg Limestone.

Overburden – Dense tree cover.

Working Face – 85 to 90 feet.

Accessibility – 1 mile south of N.Y. Highway 3.

15. HENDERSON BAY QUADRANGLE

SITE 15A (*)

Location – SW/4, on tip of peninsula, Town of Henderson.

Elevation – 250 to 340 feet.

Rock Units – Denmark-Cobourg Limestone, that part of sequence representing Cobourg Limestone.

Overburden – Variable drift cover, generally slight. Rock crops out in cliff section at lake edge. Local patches of brush and woods.

Working Face – 85 to 90 feet.

Accessibility – Excellent site for water transport via Lake Ontario. Secondary road to all-weather road connecting with N.Y. Highway 3 at Aspinwall Corners, a distance of about 4 miles.

SITE 15B

Location – SE/4, 4.5 miles northeast of village of Henderson, Town of Henderson. See Site 19E, Sackets Harbor Quadrangle.

16. LAFARGEVILLE QUADRANGLE

Location – SW/4, general area bisected by Carter Street, 1 mile east of N.Y. Highway 180 and 3.5 miles south of Lafargeville, Town of Orleans.

Elevation – 380 to 430 feet.

Rock Unit – Pamelia Formation.

Overburden – Variable drift cover; hay fields, local patches of brush and occasional trees. Bedrock locally exposed.

Working Face – 50 feet.

Accessibility – All-weather road to N.Y. Highway 180.

17. POINT PENINSULA QUADRANGLE (*)

Location – SE/4; tip of Stony Point, Town of Henderson.

Elevation – 250 to 340 feet.

Rock Unit – Cobourg Limestone.

Overburden – Essentially none; rock at surface over most of area; brush and grass.

Working Face – 85 to 90 feet.

Accessibility – Excellent site for transportation by water via Lake Ontario.

Joints – N. 68° W.; N. 2-35° W.; N. 65-70° E.

Remarks – Abandoned U.S. Military Reservation rifle range.

18. RODMAN QUADRANGLE

Location – NW/4; 0.5 mile east of Whitford Corners; 1 mile northwest of village of Rodman, Town of Rodman.

Elevation – 680 to 780 feet.

Rock Unit – Cobourg Limestone.

Overburden – Variable, heavy drift cover in many portions of the region, which appears to be considerably thinner in the vicinity of the site. Bedrock is exposed in places. Grass and brush, patches of trees locally.

Working Face – 90+ feet.

Accessibility – Area bisected by N.Y. Highway 177, 2.5 miles to U.S. Highway 11 and Interstate 81 at Adams Center.

Joints – N. 35° W.; N. 64-80° E.

Remarks – Site is 1.5 miles northwest of Drill Hole Alf. 147.

19. SACKETS HARBOR QUADRANGLE

Most of the eastern and southeastern portions of the map area are covered by extensive blanket of glacial drift. The maximum thickness of the cover is not known.

SITE 19A (*)

Location – NW/4; north of Black River Bay, 2 miles north of Sackets Harbor. The site is in the Town of Brownville.

Elevation – 260 to 340 feet.

Rock Unit – Kirkfield Limestone.

Overburden – Variable drift cover; local patches of trees. Area mainly open gentle slope.

Working Face – Up to 75 or 80 feet; height of face will increase as opening is developed to northwest.

Accessibility – Excellent for transportation of raw material by water via Lake Ontario. All-weather road to N.Y. Highway 12E (3.5 miles) and Dexter (5 miles).

SITE 19B

Location – NW/4, south of Black River Bay, 1 mile northeast of village of Sackets Harbor, Town of Hounsfield.

Elevation – 250 to 300 feet.

Rock Unit – Kirkfield Limestone.

Overburden – Thick sand cover in southeastern portion near Muskelonge Bay; elsewhere, variable drift, generally thin, and grass with local patches of brush.

Working Face – 35+ feet.

Accessibility – Water transport via Lake Ontario. Secondary road joins area with N.Y. Highway 3 which is 0.75 mile away.

Remarks – Geology identical to site 19A but much less stone available.

SITE 19C (*)

Location – NE/4, between N.Y. Highway 3 and Old Military Road, 3 miles northeast of Sackets Harbor, in Town of Hounsfield.

Elevation – 330 to 380 feet.

Rock Unit – Kirkfield Limestone.

Overburden – Variable drift cover; open hill side with brush and scattered trees.

Working Face – Up to 45 or 50 feet.

Accessibility – Borders N.Y. Highway 3 at Baggs Corners.

SITE 19D

Location – Central NE/4; 1.3 miles south of the Watertown Municipal Airport.

Elevation – 360 to 420 feet.

Rock Units – Kirkfield and Shoreham limestones.

Overburden – Variable drift cover. Vegetation mainly brush; occasional trees. Bedrock exposed in places.

Working Face – Up to 50 or 60 feet.

Accessibility – ½ mile north of N.Y. Highway 3.

SITE 19E

Location – SW/4, general area in Town of Henderson, 1 to 1.5 miles northwest and west of village of Smithville.

Elevation – 370 to 450+ feet.

Rock Units – Denmark-Cobourg limestone, that part of sequence representing Cobourg Limestone.

Overburden – Variable drift cover; bedrock exposed in cliff section. Brush and grass, local patches of woods.

Working Face – 75 to 80 feet.

Accessibility – ½ mile to 1 mile east of N.Y. Highway 3.

Remarks – Drill Hole Alf. 147 located at Smithville.

SITE 19F

Location – SW/4, 2 miles northeast of Smithville, Town of Adams.

Elevation – 460 to 540 feet.

Rock Units – Denmark-Cobourg limestone; that portion of sequence representing Cobourg Limestone.

Overburden – Variable drift cover; grass and brush; occasional trees.

Working Face – 75+ feet.

Accessibility – 2.5 miles east of N.Y. Highway 3.

SITE 19G

Location – SE/4, 2 miles east of Smithville, Town of Adams.

Elevation – 400 to 530 feet.

Rock Units – As 19F.

Overburden – As 19F, but with dense tree cover along a portion of the cliff section.

Working Face – 100+ feet.

Accessibility – 3 to 3.5 miles via South Harbor Road to Interstate 81 and U.S. Highway 11 at Adams Center.

SITE 19 H (*)

Location – SE/4, 0.75 mile southeast of North Adams, Town of Adams.

Elevation – 440 to 580 feet.

Rock Units – as 19F.

Overburden – Some drift; no trees.

Working Face – up to 140 feet.

Accessibility – 1 mile to Interstate 81 and U.S. Highway 11 at Adams Center.

20. SANDY CREEK QUADRANGLE

None recommended.

21. SAWMILL BAY QUADRANGLE

SITE 21A

Location – NE/4, bounding St. Lawrence River, 1 mile northeast of Sawmill Bay, Town of Cape Vincent.

Elevation – 250 to 330 feet.

Rock Unit – Pamelia Formation.

Overburden – Slight drift cover; bedrock exposed over large portion of area. Mostly open fields with grass and brush; occasional trees.

Working Face – Up to 75 feet.

Accessibility – Water transportation via the St. Lawrence River; also bounds N.Y. Highway 12E.

Joints – N. 52-80° W.; N. 8-12° E.; N. 88° E.

SITE 21B

Location – NE/4, mid-section of eastern margin.

Elevation – 310 to 370 feet.

Rock Unit – Pamelia Formation.

Overburden – Glacial drift, including glaciofluvial sand locally; dense tree cover.

Working Face – 60 feet; a 50-foot natural face is exposed as a result of removal of sand from same terrace.

Accessibility – 0.25 mile from N.Y. Highway 12E and 2.25 miles southwest of Clayton.

Joints – N. 52° W.; N. 12° E.; N. 88° E.

SITE 21C

Location – SW/4, 1.75 miles east of Riverview, Town of Cape Vincent.

Elevation – 325 to 340 feet.

Rock Units – Lowville and Chaumont limestones.

Overburden – Variable drift cover; rock exposed over large portions of area. Dense tree cover in local patches.

Working Face – 15+ feet.

Accessibility – All-weather roads in every direction.

Joints – N. 46-65° W.; N. 7° W. to N. 25° E.; N. 74-75° E.

Remarks – Pit quarry necessary to obtain adequate face.

SITE 21D

Location – SW/4, area just north of School No. 11, 3.6 miles southeast of Riverview, Town of Cape Vincent.

Elevation – 340 to 350 feet.

Rock Units – Chaumont Limestone exposed; Lowville Limestone below.

Overburden – Slight cover of glacial drift; considerable bedrock exposed. Some brush; occasional trees.

Working Face – Pit quarry must be developed.

Accessibility – All-weather roads in every direction.

Joints – N. 46° W.; N. 7° W. to N. 26° E.; N. 74° E.

SITE 21E

Location – SE/4, 1.5 miles east of village of St. Lawrence, Town of Cape Vincent.

Elevation – 280 to 380 feet.

Rock Units – Pamelia and Lowville formations; lower portion of Lowville representing Pamelia-Lowville transition.

Overburden – Variable drift; dense brush and tree cover.

Working Face – up to 100 feet.

Accessibility – Hard surface gravel road leading to all-weather paved roads in all directions.

Joints – N. 46° W.; N. 17° W. to N. 31° E.; N. 83° E.

SITE 21F

Location – SE/4, west side of Three Mile Creek.

Elevation – 350 to 370 feet.

Rock Units – Lowville and Chaumont limestones.

Overburden – Slight glacial drift cover; brush; occasional trees.

Working Face – 20 feet; pit operation recommended.

Accessibility – All-weather roads in every direction.

22. SOUTH RUTLAND QUADRANGLE

SITE 22A

Location – NW/4; Woodwards Side Hill (Section 5), Town of Rutland.

Elevation – 560 to 700 feet.

Rock Units – Rockland, Kirkfield and Shoreham limestones.

Overburden – Variable drift cover, slight; brush and trees. Rock exposed in many portions of hillside.

Working Face – 100+ feet.

Accessibility – 1 mile to N.Y. Highway 3 and the village of Black River.

SITE 22B

Location – NW/4, Ruthland Hollow, south side of Rutland Hollow Road, Town of Rutland.

Elevation – 700 to 980 feet.

Rock Units – Denmark-Cobourg limestone.

Overburden – Variable drift cover, brush and trees.

Working Face – Variable; convenient height in preferred portion of section.

Accessibility – Rutland Hollow Road, 2.5 to 3 miles east of Watertown.

SITE 22C

Location – NE/4, east-west belt through center of map area paralleling Rutland Hollow Road, between Miser Hill Road (on west) and Staplin Road (on east), Town of Rutland.

Elevation – 800 to 1,020 feet, but not in a single area.

Rock Units – Denmark-Cobourg Limestone.

Overburden – Variable drift cover; local brush and patches of dense woods.

Working Face – Dependent on rock quality and convenient working height.

Accessibility – All-weather road east and west; 3.5 to 4 miles east of Watertown.

SITE 22D (*)

Location – NE/4; 1 mile east of Rutland Center, Town of Rutland.

Elevation – 1,000 to 1,090 feet.

Rock Units – Denmark-Cobourg limestone, that part of sequence representing the Cobourg Limestone. Hillier Member at top of section.

Overburden – Glacial cover of varying thickness. Some brush; few trees.

Working Face – 80 to 90 feet.

Accessibility – Access into State Street leading west into Watertown.

SITE 22E

Location – SW/4, 0.25 mile southwest of Burrs Mills, Town of Rutland.

Elevation – 880 to 1,000 feet.

Rock Units – Denmark-Cobourg limestone; that part of sequence representing Cobourg Limestone.

Overburden – Variable drift cover, ranging from less than 2 feet to unknown thickness. Some brush; few trees.

Working Face – 100+ feet.

Accessibility – 0.5 mile south of N.Y. Highway 12.

23. **STONY POINT QUADRANGLE**
Southern extension of Site 17.

24. **THERESA QUADRANGLE**
None recommended.

25. **WATERTOWN QUADRANGLE**

SITE 25A (2 sites in the general area)

Location – NW/4, in Town of Hounsfield between N.Y. Highways 12F (on the north) and 3 (on the south).

Elevation – 380 to 500 feet.

Rock Units – Upper Rockland Limestone, Kirkfield Limestone and Shoreham Limestone.

Overburden – Variable drift cover with grass, brush and occasional trees.

Working Face – 60 feet in the Upper-Rockland-Kirkfield sequence; 35 to 40 feet in the Upper Kirkfield-Shoreham strata.

Accessibility – The area is bisected by a good all-weather road which connects with N.Y. Highway 12F (0.5 mile) and N.Y. Highway 3 (0.75 mile). Watertown city center is 3 miles due east.

SITE 25B (*)

Location – SE/4; east and west of Dry Hill Road along northwest-facing slope of Dry Hill in Town of Watertown, 1.5 miles south-southwest of the community of Watertown Center.

Elevation – 620 to 850 feet; terraced at 700 to 720 feet.

Rock Units – Denmark-Cobourg Limestone.

Overburden – Variable drift and brush. Local patches of woods, but generally free of heavy concentration of trees.

Working Face – 60 to 100 feet, depending on location.

Accessibility – Dry Hill Road joins with U.S. Highway 11 at Watertown Center. Any operation along west side of Dry Hill Road would be less than 0.5 mile from U.S. Highway 11.

Analyzing and Testing of Samples

by Wayne E. Brownell

The samples of limestones of Jefferson County were taken by diamond-core drilling at the locations previously described in this report. AX cores were drilled; afterwards they were examined by the geologist. When the logging of the cores was completed, they were divided into 10-foot sections for arbitrary samples. The cores were then split, one half being preserved as a permanent record, the other half being used for analysis and testing. Several pieces about 1-inch in diameter were removed from the sample and set aside for the sulfate-soundness test, density determination, and absorption measurements. The remainder of each sample was crushed, pulverized, and quartered for chemical analyses. These physical and chemical tests were made by the Research Department of the State University of New York College of Ceramics at Alfred University, Alfred, New York.

Absorptions and densities were determined for all the samples. The procedures for these tests were closely related. After a thorough washing to remove dust and any other coating from the surface of the pieces, the samples were dried to constant weight at a temperature of 110° C.; then they were immersed in water at 20° C. for a period of 24 hours. The pieces of limestone were removed from the water and rolled in an absorbent cloth until the visible film of water was removed. The pieces were individually weighed in the saturated condition. After weighing, the limestone pieces were placed in a wire basket and their weight while suspended in water measured. The samples were then dried to a constant weight at a temperature of 110° C., cooled to room temperature, and weighted. From these weights, the absorption and density of each limestone sample were calculated. The results of these calculations are recorded on Tables 4 through 12.

The sulfate-soundness test was considered a measure of the durability of the limestone for use as road ballast or constructional aggregate. For this test, 9 fragments of limestone rock, each approximately 1 inch in diameter, were used. The sample was thoroughly washed and dried to constant weight at 110° C. After weighing, each piece was placed in a separate galvanized wire basket. These baskets were used to immerse the samples in a sodium sulfate solution with a specific gravity between 1.151 and 1.174 for 18 to 20 hours. The samples and solution were maintained at a temperature of 21° ± 1° C. for the entire immersion period. At the end of this immersion period, the samples were removed and placed in a drying oven at 110° C. The process of alternate immersion and drying was repeated for 10 cycles. After each cycle, the fragments of limestone were visually examined for cracking, flaking, splitting, or disintegration. After the final drying, the samples were washed and weighed to determine the percentage loss in weight. If the percent of weight loss was 5 percent or greater, the sample was considered to have failed in this test. The results obtained with this test are also given in Tables 4 through 12. These results should be interpreted as an indication to the durability of the rock. Before any formation is selected for use, it should be tested more completely on a larger scale and magnesium sulfate soundness tests should be made. The sodium sulfate results are an approximate guide to soundness and for this reason they are included in the Tables 4 through 12.

The chemical analyses were made by conventional techniques. The analyst was Elmer L. Prew, member of the staff at the College of Ceramics. Sulfur and carbon were determined with a Leco analyzer. Sodium and potassium oxides were determined by precipitation with zinc uranyl acetate and chloroplatanic acid, respectively.

The potential for the industrial use of the limestones of Jefferson County is not great. Most of the formations are too impure for most known uses. Blending of rock units of differing compositions adds some flexibility to potential uses. The Chaumont Formation warrants special mention because it is the purest limestone in the county. It is rather unfortunate that its thickness in this area is only about 20 feet. This was the only stone to pass the sulfate-soundness test which indicated that it might be useful for road ballast. The Chaumont Limestone could also be quarried for metallurgical fluxing stone, agricultural limestone, and Portland cement manufacturing. The chemical compositions of the Kirkfield, Lowville-Pamelia transition, and the Pamelia indicate that they might be employed as a natural cement rock. Some sections of the Pamelia are relatively high in magnesia, but on the average, the composition would probably be favorable for the production of natural cement.

Chemical Analyses

The complete chemical analyses of the limestones penetrated by Drill Holes Alf. 140-148 are given in Tables 13 through 21, which are arranged in order according to the stratigraphic sections. The core samples from each hole were analyzed in 10-foot sections downward with no regard for the formational boundaries. It is, therefore, difficult to obtain a precise analysis for any particular rock unit. The position of the formational boundary within a specific 10-foot section may be determined by referring to the appropriate stratigraphic section in the text. The whole numbers in the left column of the tables refer to the 10-foot section; viz., 1. spans the interval from 0 to 10 feet, 2. the interval from 10 to 20 feet below the top of the hole, etc. The letters NR in place of a percentage figure mean "Not Reported."

The composition of the Black River and Trenton limestones by formation is given in Tables 22 through 28. Johnsen prepared these tables by averaging appropriate data from the detailed chemical analyses and omitting those samples which contained a contact between two rock units. Within each table, the columns are arranged from west to east to correspond with Plate I.

A summary of important chemical information for the purpose of rapid evaluation of each rock unit is presented in Table 29. Maximum and minimum chemical values are given for all samples in Jefferson County by formation. Because each of the limestones is relatively uniform throughout the area of study, these values will serve to indicate the range of composition that can be expected at any site when sampled in 10-foot sections. Samples including a contact between two formations were omitted in the preparation of this summary.

Useful conversion factors that apply to the chemical data appear in Table 30.

Table 4

Physical Properties of Alf. 140 (Section 2)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Sodium Sulfate Soundness Pass or Fail
1	2.67	0.4	7.8	Osh 2'6"
2	2.66	0.6	4.0	
3	2.69	0.3	0.7	
4	2.68	0.4	40.2	Ok
5	2.68	0.4	11.3	
6	2.69	0.3	1.1	
7	2.69	0.3	0.2	
8	2.68	0.4	1.6	
9	2.67	0.5	19.4	82'8½"
10	2.67	0.3	12.9	
11	2.68	0.3	18.9	
12	2.68	0.3	10.7	Or
13	2.68	0.3	7.5	
14	2.67	0.3	3.5	
15	2.65	0.8	25.4	

Table 5

Physical Properties of Alf. 141 (Section 3)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Sodium Sulfate Soundness Pass or Fail
1	2.69	0.3	11.1	
2	2.69	0.4	13.5	
3	2.70	0.3	21.1	
4	2.68	0.9	79.4	01
5	2.66	1.0	71.4	
6	2.68	0.5	31.8	
7	2.67	0.4	30.5	64'3"
8	2.69	0.7	12.8	
9	2.71	0.3	9.8	Op-01
10	2.73	0.5	11.2	
11	2.67	1.0	79.1	105'2"
12	2.72	0.7	15.4	
13	2.61	1.7	40.4	
14	2.66	1.7	0.4	
15	2.67	1.9	23.6	
16	2.70	0.6	25.3	Op
17	2.60	2.2	35.5	
18	2.61	2.5	62.5	
19	2.57	3.3	79.4	
20	2.52	3.1	100.0	

Table 6

Physical Properties of Alf. 144 (Section 8)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Sodium Sulfate Soundness Pass or Fail
				Od
1	2.69	0.4	11.4	8'0"
2	2.67	0.8	23.8	Osh
3	2.65	0.8	22.8	
4	2.64	1.0	38.7	32'2"
5	2.68	0.4	2.5	
6	2.66	0.6	10.5	
7	2.66	0.5	4.6	Ok
8	2.67	0.6	16.2	
9	2.65	0.8	22.1	
10	2.64	1.0	21.3	
11	2.65	0.8	15.3	Or
12	2.66	0.8	26.3	
13	2.69	0.1	0.0	
14	2.68	0.2	0.0	139'4"
15	2.68	0.3	0.0	Och
16	2.68	0.3	0.0	
17	2.69	0.3	1.1	164'5"
18	2.70	0.2	0.0	
19	2.70	0.2	0.3	
20	2.69	0.3	0.2	01
21	2.69	0.4	0.3	
22	2.69	0.6	25.5	
23	2.66	0.9	20.5	
24	2.69	0.6	4.3	
25*	2.67	0.7	24.0	

*Hole drilled to depth of 260'3"; the lowest 10'3" were not tested for density, absorption or soundness. The Lowville *sensu-stricto* (01)-Lowville-Pamelia transition (Op-01) contact occurs at 254'3".

Table 7

Physical Properties of Alf. 146 (Section 9)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Sodium Sulfate Soundness Pass or Fail
1	2.69	0.4	0.9	
2	2.69	0.5	18.3	
3	2.68	0.6	43.8	01
4	2.69	0.5	22.7	
5	2.69	0.5	36.3	
6	2.68	0.6	9.0	
7	2.69	0.5	11.1	69'3"
8	2.67	0.8	11.7	
9	2.70	0.3	0.6	Op-01
10	2.70	0.2	2.3	
11	2.74	0.6	0.0	
12	2.70	0.5	11.5	119'8"
13	2.70	0.9	10.6	
14	2.70	0.8	2.3	
15	2.67	0.9	10.3	
16	2.73	0.4	1.1	
17	2.71	1.1	32.6	Op
18	2.67	1.5	87.0	
19	2.67	0.7	25.6	
20	2.69	1.2	49.6	
21	2.68	1.3	55.1	
22	2.67	1.5	82.4	
23	2.67	1.0	46.2	226'9"
				Ot

Table 8

Physical Properties of Alf. 142 (Section 11)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Pass or Fail
				Or
1	2.68	0.3	0.0	3'3"
2	2.69	0.2	0.0	Och
3	2.67	0.3	0.3	28'8½"
4	2.70	0.2	0.8	
5	2.69	0.3	1.8	O1
6	2.69	0.3	13.2	
7	2.70	0.2	13.6	
8	2.68	0.6	1.9	
9	2.68	0.6	11.3	
10	2.66	0.9	5.7	100'9"
11	2.67	0.8	3.1	
12	2.68	0.5	1.1	Op-OL
13	2.71	0.4	0.5	
14	2.74	0.3	0.0	
15	2.70	0.6	26.4	
16	2.68	1.1	1.9	152'
17	2.67	1.3	2.2	
18	2.68	1.1	25.2	
19	2.63	1.7	53.9	Op
20	2.72	0.7	10.9	
21	2.68	1.3	56.3	
22	2.69	1.1	52.2	
23	2.70	1.0	36.1	
24	2.70	0.7	23.1	
25	2.65	1.5	69.4	
26	2.61	2.0	74.3	

Table 9

Physical Properties of Alf. 143 (Section 12)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Pass or Fa
1	2.66	0.7	20.7	Or
2	2.67	0.8	23.7	
3	2.66	0.8	26.6	
4	2.68	0.5	22.1	39'
5	2.67	0.4	0.0	Och
6	2.68	0.4	0.1	59'
7	2.69	0.4	0.0	
8	2.69	0.5	22.9	
9	2.68	0.4	3.0	O1
10	2.69	0.5	20.1	
11	2.70	0.4	9.4	
12	2.70	0.3	34.4	
13	2.68	0.5	42.7	127'
14	2.68	0.8	9.9	
15	2.70	0.3	1.2	
16	2.73	0.4	7.6	Op-O1
17	2.74	0.6	11.5	
18	2.71	0.6	20.8	
19	2.63	2.1	42.8	180'2"
20	2.64	1.9	13.9	
21	2.72	0.6	13.8	
22	2.67	1.6	39.8	Op
23	2.69	1.2	18.4	
24	2.74	0.3	0.0	
25	2.73	1.2	30.6	

Table 10

Physical Properties of Alf. 145 (Section 13)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Pass or Fail
1	2.67	0.7	13.2	
2	2.65	1.0	33.6	
3	2.64	1.5	12.5	Ok
4	2.65	1.0	45.8	
5	2.65	0.8	22.6	
6	2.66	1.0	35.9	
7	2.66	0.7	13.4	62'11"
8	2.67	0.8	9.7	
9	2.65	0.8	23.2	Or
10	2.66	0.9	37.7	
11	2.67	1.0	5.4	
12	2.66	0.6	10.9	114'1"
13	2.68	0.3	0.0	Och
14	2.68	0.4	11.3	134'10"
15*	2.68	0.6	17.3	O1

* Hole bottomed at 155'5" Lowest 5 feet of core not tested.

Table 11

Physical Properties of Alf. 147 (Section 14)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Pass or Fail
1*	2.67	0.6	9.6	
2	2.67	0.7	35.2	
3	2.68	0.5	0.4	
4	2.68	0.6	20.3	
5	2.69	0.3	0.4	
6	2.69	0.3	1.6	
7	2.68	0.6	3.1	
8	2.69	0.3	12.0	
9	2.67	0.6	41.0	
10	2.68	0.6	52.4	
11	2.66	0.9	38.6	
12	2.67	0.9	33.9	
13	2.69	0.7	12.5	Od-Oco
14	2.68	0.7	16.6	
15	2.69	0.6	30.9	
16	2.68	0.5	29.7	
17	2.66	0.9	31.8	
18	2.68	0.6	21.3	
19	2.68	0.6	49.5	
20	2.66	0.6	69.1	
21	2.68	0.7	37.4	
22	2.66	0.8	27.4	
23	2.66	0.8	41.4	
24	2.67	0.8	40.5	

*Hole began 16'4" below Deer River Shale-Cobourg Limestone (Oco) contact.

Table 12

Physical Properties of Alf. 148 (Section 15)

Sample No.	Density	Absorption (%)	Sodium Sulfate Soundness % Loss	Pass or Fail
1	2.66	0.9	31.9	Oco
2	2.66	0.9	49.6	
3	2.67	0.6	23.4	28'3"
4	2.66	0.9	36.1	
5	2.67	0.8	37.0	
6	2.66	0.9	47.4	
7	2.68	0.5	27.8	
8	2.67	0.7	41.8	
9	2.68	0.5	19.3	
10	2.67	0.5	31.4	
11	2.67	0.6	51.0	
12	2.69	0.5	25.8	Od
13	2.68	0.5	23.9	
14	2.68	0.4	7.2	
15	2.68	0.6	31.2	
16	2.68	0.5	8.8	
17	2.69	0.5	6.7	
18	2.68	0.5	14.6	
19	2.67	0.7	34.5	
20	2.66	0.8	26.0	197'11"
21	2.68	0.5	14.5	Osh
22	2.68	0.6	2.6	

Table 13

Chemical Analysis of Alf. 140 (Section 2) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	5.7	3.8	1.0	0.12	1.6	46.5	0.02	0.05	0.23	1.9	8.0	39.3	37.5
2	6.1	4.3	1.2	0.11	1.5	45.7	0.02	0.05	0.21	2.1	10.3	38.6	36.1
3	6.6	3.8	1.3	0.11	1.5	47.1	0.02	0.04	0.24	1.8	10.3	38.2	35.4
4	7.5	3.9	1.3	0.10	1.6	45.8	0.02	0.05	0.39	1.6	11.4	38.1	35.7
5	6.5	4.6	1.3	0.11	1.6	46.9	0.03	0.07	0.22	1.4	9.1	39.1	37.2
6	4.9	2.9	1.2	0.12	1.9	47.8	0.03	0.05	0.22	1.3	8.3	39.5	36.4
7	4.3	2.8	1.1	0.11	1.8	49.0	0.03	0.06	0.20	1.5	7.9	39.6	36.5
8	4.5	2.8	1.2	0.10	1.7	48.2	0.02	0.05	0.32	1.4	7.8	39.8	37.1
9	9.5	3.9	1.6	0.10	1.6	43.6	0.02	0.05	0.29	2.5	14.2	36.8	34.4
10	7.3	3.9	1.5	0.12	2.1	44.0	0.03	0.07	0.27	1.6	13.1	37.6	35.1
11	13.5	4.0	1.6	0.11	1.7	43.0	0.02	0.05	0.23	1.7	14.8	35.3	33.1
12	6.8	2.6	1.5	0.12	1.7	48.1	0.04	0.08	0.19	1.8	7.6	39.0	37.5
13	10.1	2.9	1.4	0.11	1.5	45.6	0.03	0.08	0.23	1.7	11.2	37.9	35.4
14	12.7	3.3	1.5	0.11	1.9	43.3	0.02	0.04	0.23	1.9	14.1	36.5	34.2
15	13.1	3.8	1.7	0.12	1.8	42.6	0.02	0.06	0.26	2.0	14.2	35.7	33.3

Table 14

Chemical Analysis of Alf. 141 (Section 3) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	3.7	1.3	0.87	0.06	1.7	50.8	0.03	0.10	0.19	1.4	4.1	41.3	39.6
2	2.8	1.4	0.84	0.09	1.6	51.0	0.03	0.09	0.23	1.1	4.7	41.1	39.5
3	7.0	3.1	1.1	0.07	1.2	47.8	0.04	0.09	0.22	1.8	8.5	39.3	37.6
4	14.2	6.1	1.4	0.09	3.3	39.0	0.03	0.09	0.21	2.1	18.6	34.7	32.7
5	9.7	4.8	1.3	0.09	2.0	44.3	0.04	0.10	0.27	1.9	12.4	37.1	35.5
6	5.6	2.2	1.1	0.10	1.4	49.4	0.04	0.09	0.24	1.8	6.6	39.9	37.9
7	20.0	8.1	1.4	0.07	2.5	35.3	0.02	0.05	0.21	1.9	26.1	31.3	29.7
8	10.0	4.2	1.3	0.05	3.0	43.3	0.04	0.09	0.30	2.1	13.1	37.5	34.8
9	4.8	1.9	0.99	0.08	3.4	47.1	0.04	0.10	0.27	1.1	5.8	41.3	39.3
10	4.9	2.1	1.1	0.09	7.9	42.1	0.04	0.09	0.25	1.2	6.2	41.4	39.7
11	17.4	7.9	1.4	0.07	4.6	34.1	0.03	0.09	0.20	1.3	23.3	33.0	31.8
12	11.4	4.1	1.7	0.06	6.4	34.8	0.04	0.09	0.25	2.5	13.4	37.9	34.8
13	26.4	9.7	1.3	0.08	3.6	28.9	0.04	0.10	0.25	2.3	33.5	28.6	26.4
14	3.2	1.1	0.89	0.09	4.9	44.2	0.04	0.09	0.29	2.2	3.6	43.1	41.3
15	16.7	7.7	1.6	0.06	9.2	26.1	0.04	0.09	0.27	3.5	19.5	34.0	31.9
16	6.2	2.3	1.0	0.09	4.1	45.5	0.05	0.11	0.07	2.3	6.8	40.3	38.3
17	12.2	5.4	1.5	0.09	9.9	35.0	0.06	0.14	0.17	2.9	2.97.6	34.6	32.8
18	19.9	7.7	2.8	0.08	11.3	24.5	0.06	0.15	0.12	2.4	10.6	32.0	28.6
19	26.0	9.9	3.4	0.08	9.5	22.3	0.04	0.10	0.10	2.1	14.0	27.3	25.7
20	52.4	10.8	3.2	0.09	4.5	13.0	0.06	0.14	0.14	2.2	60.2	15.0	13.3

Table 15
Chemical Analysis of Alf. 144 (Section 8) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	6.8	2.4	1.1	0.08	1.2	48.1	0.02	0.05	0.26	1.6	10.3	39.7	NR
2	11.1	3.8	1.5	0.08	1.6	43.2	0.02	0.04	0.21	2.2	15.1	36.8	NR
3	11.3	3.4	1.6	0.09	1.9	43.5	0.08	0.21	0.23	2.4	14.4	36.5	NR
4	13.6	3.4	1.2	0.09	1.8	42.7	0.02	0.05	0.25	2.1	13.2	35.8	NR
5	7.7	2.8	1.2	0.08	1.8	46.7	0.02	0.04	0.24	3.2	11.7	38.6	NR
6	10.7	2.8	1.2	0.08	1.8	44.6	0.01	0.03	0.19	1.9	13.0	37.6	NR
7	10.8	2.4	1.1	0.09	1.8	43.9	0.01	0.03	0.18	3.3	14.0	37.6	NR
8	13.2	3.2	1.2	0.08	2.0	42.2	0.01	0.03	0.25	2.3	17.7	35.9	NR
9	13.2	3.1	1.0	0.09	1.7	41.8	0.02	0.03	0.27	2.5	17.9	36.3	NR
10	16.8	3.8	1.8	0.16	2.2	40.2	0.03	0.08	0.09	2.4	22.7	32.8	NR
11	14.3	4.2	1.5	0.15	2.4	41.2	0.03	0.08	0.17	1.9	20.5	34.6	NR
12	13.8	3.1	1.2	0.17	1.8	42.6	0.03	0.06	0.18	2.2	18.9	34.9	NR
13	9.6	0.98	0.76	0.19	1.2	48.0	0.02	0.05	0.14	1.7	11.9	37.5	NR
14	1.4	0.13	0.45	0.11	0.58	54.2	0.05	0.11	0.12	1.4	2.4	42.8	NR
15	0.76	0.09	0.33	0.25	0.69	55.2	0.02	0.07	0.21	1.8	1.3	42.1	NR
16	3.1	0.06	0.60	0.14	1.5	51.9	0.05	0.11	0.21	2.4	4.1	40.1	NR
17	2.7	0.35	0.85	0.20	1.0	52.1	0.04	0.10	0.25	1.7	4.0	42.3	NR
18	3.6	1.0	0.50	0.16	1.6	50.8	0.05	0.12	0.22	2.2	5.7	41.8	NR
19	5.0	1.7	0.88	0.16	1.6	50.2	0.03	0.08	0.21	2.3	7.3	39.2	NR
20	5.2	1.8	0.92	0.16	1.4	49.9	0.04	0.09	0.34	1.8	7.9	39.6	NR
21	5.9	2.1	1.2	0.16	1.1	49.0	0.04	0.10	0.26	1.2	9.1	39.8	NR
22	6.7	2.4	1.2	0.16	1.5	48.3	0.04	0.11	0.21	1.4	12.3	38.8	NR
23	12.3	4.1	1.3	0.16	1.5	43.9	0.02	0.05	0.20	1.6	15.3	35.8	NR
24	8.1	3.8	1.4	0.16	1.7	45.9	0.02	0.05	0.23	1.4	10.5	37.0	NR
25	10.4	2.9	1.2	0.16	1.3	45.3	0.02	0.06	0.19	1.6	11.5	36.7	NR

Table 16
Chemical Analysis of Alf. 146 (Section 9) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	2.7	0.13	1.0	0.17	0.75	52.3	0.01	0.03	0.15	1.2	4.7	41.6	NR
2	2.3	0.37	0.66	0.17	0.70	49.9	0.01	0.04	0.10	2.6	5.0	41.6	NR
3	5.1	1.7	1.0	0.16	1.0	49.1	0.01	0.03	0.10	2.3	9.0	39.8	NR
4	5.8	1.6	1.1	0.17	0.79	47.5	0.01	0.02	0.14	3.2	9.6	39.4	NR
5	5.7	3.5	1.4	0.17	1.1	49.1	0.02	0.07	0.23	2.5	7.4	37.0	NR
6	8.6	3.3	1.4	0.17	1.1	45.3	0.03	0.07	0.20	2.7	11.4	37.5	NR
7	5.2	1.7	1.0	0.17	1.1	47.3	0.02	0.05	0.12	4.9	7.3	37.5	NR
8	18.6	6.7	1.5	0.17	1.9	35.6	0.02	0.06	0.23	3.9	21.4	31.5	NR
9	5.0	3.5	1.1	0.19	1.5	46.4	0.03	0.08	0.23	2.7	10.7	38.4	NR
10	3.2	1.5	0.96	0.19	2.5	49.7	0.03	0.07	0.20	1.3	5.3	41.6	NR
11	3.5	1.5	1.0	0.19	2.8	45.4	0.01	0.04	0.24	3.5	5.2	41.4	NR
12	7.6	3.3	1.1	0.18	4.8	42.5	0.02	0.04	0.23	1.6	9.5	38.8	NR
13	27.6	9.5	0.24	0.19	9.8	22.2	0.08	0.19	0.44	2.9	36.6	28.4	NR
14	7.7	1.7	1.3	0.22	5.7	42.2	0.06	0.16	0.23	3.1	11.9	39.2	NR
15	38.5	9.6	2.5	0.19	6.0	18.5	0.07	0.18	0.66	3.7	50.1	21.3	NR
16	4.5	1.8	1.0	0.19	5.5	44.3	0.11	0.28	0.23	2.8	7.3	41.1	NR
17	4.3	1.6	1.4	0.19	8.1	41.8	0.10	0.26	0.38	2.8	7.1	40.8	NR
18	13.3	6.6	1.7	0.17	7.1	34.3	0.08	0.19	0.41	2.7	21.0	34.8	NR
19	4.6	1.1	1.4	0.20	2.6	45.5	0.19	0.26	0.45	2.9	6.8	41.0	NR
20	13.0	5.6	1.9	0.20	8.9	33.4	0.11	0.28	0.45	2.9	15.6	34.9	NR
21	19.4	8.4	3.0	0.20	5.8	30.3	0.04	0.11	0.38	2.8	22.5	30.9	NR
22	20.9	9.4	3.9	0.21	3.4	29.7	0.13	0.32	0.35	2.7	24.0	29.4	NR
23	73.3	9.3	2.6	0.19	2.4	3.1	0.17	0.44	0.35	2.6	85.9	6.1	NR

Table 17

Chemical Analysis of Alf. 142 (Section 11) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	0.98	0.18	0.50	0.12	0.19	54.7	0.02	0.05	0.39	1.1	1.9	43.3	41.1
2	0.52	0.04	0.44	0.12	0.24	55.1	0.01	0.04	0.27	1.6	1.3	43.5	42.2
3	1.5	0.12	0.44	0.14	0.28	53.6	0.04	0.09	0.40	1.5	2.5	43.0	41.1
4	2.4	0.70	0.66	0.14	0.13	53.1	0.03	0.08	0.51	1.9	4.3	42.0	40.4
5	3.3	1.1	0.57	0.25	0.18	52.5	0.02	0.05	0.50	1.5	5.7	41.5	39.4
6	3.0	1.2	0.62	0.13	0.27	53.1	0.03	0.09	0.35	0.89	5.2	41.4	40.8
7	6.9	2.7	1.3	0.13	1.2	48.4	0.04	0.10	0.52	1.5	12.0	38.4	37.5
8	8.1	3.1	1.8	0.12	1.5	46.4	0.04	0.09	0.53	1.6	14.6	37.8	36.6
9	7.2	2.9	1.4	0.16	1.1	48.2	0.03	0.08	0.68	1.5	12.1	38.3	36.6
10	5.1	2.1	1.1	0.19	1.3	50.3	0.03	0.08	0.26	0.96	8.6	39.8	38.3
11	19.9	4.1	1.9	0.14	2.7	37.1	0.04	0.10	0.57	2.3	25.9	31.5	30.7
12	11.6	2.6	1.4	0.13	2.3	42.5	0.04	0.09	0.85	2.2	16.5	36.3	34.1
13	4.8	0.96	1.1	0.24	2.8	49.0	0.03	0.08	0.47	0.85	6.8	41.1	39.6
14	3.0	0.8	0.86	0.11	5.5	46.7	0.17	0.41	0.17	1.6	5.3	42.7	40.4
15	6.3	2.3	0.85	0.11	4.5	43.7	0.14	0.33	0.41	1.9	9.6	40.3	38.9
16	19.1	7.3	0.22	0.11	5.9	32.5	0.15	0.37	0.37	2.8	27.3	32.0	30.8
17	12.8	6.0	1.3	0.09	7.4	34.4	0.11	0.27	0.32	1.6	14.6	36.4	33.4
18	16.6	4.6	1.2	0.10	6.4	33.5	0.16	0.39	0.54	2.2	19.0	35.0	33.2
19	33.9	10.6	2.1	0.11	3.8	20.8	0.35	0.98	0.56	3.9	35.4	24.1	21.1
20	3.7	1.2	0.72	0.10	5.4	45.2	0.15	0.38	0.42	1.7	4.3	42.1	40.2
21	9.8	4.8	0.14	0.09	8.4	35.4	0.13	0.32	0.88	2.6	10.7	38.2	36.0
22	11.0	5.2	0.14	0.09	5.0	39.0	0.14	0.35	0.61	2.1	13.2	37.0	35.1
23	6.2	2.2	0.97	0.09	3.5	46.1	0.15	0.37	0.65	1.6	14.6	40.0	37.3
24	14.9	5.4	1.7	0.09	4.0	36.5	0.13	0.33	0.28	1.8	16.8	35.0	32.4
25	21.5	9.0	3.7	0.11	2.8	31.7	0.11	0.27	0.38	2.1	24.2	29.3	26.1
26	36.7	12.9	4.2	0.10	2.9	19.3	0.10	0.26	0.42	2.9	38.4	20.4	18.6

Table 18

Chemical Analysis of Alf. 143 (Section 12) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	10.1	1.1	1.0	0.12	2.1	45.9	0.03	0.07	0.55	1.4	12.4	38.6	37.3
2	11.3	2.7	1.3	0.09	2.3	44.5	0.03	0.07	0.38	1.0	14.5	37.3	36.5
3	8.3	2.3	0.85	0.09	2.1	47.1	0.05	0.13	0.32	1.0	10.8	39.5	38.3
4	4.3	0.11	1.4	0.09	1.2	49.8	0.05	0.11	0.30	1.8	6.3	41.5	39.6
5	0.95	0.46	0.41	0.10	0.59	53.2	0.04	0.10	0.46	1.7	2.0	43.3	41.5
6	1.7	0.37	0.41	0.10	0.69	52.8	0.04	0.09	0.46	1.2	2.8	42.9	40.2
7	3.4	1.4	0.59	0.09	1.6	50.3	0.03	0.06	0.37	1.5	4.8	41.9	39.4
8	5.0	1.8	0.75	0.09	3.0	47.9	0.03	0.07	0.53	1.2	7.2	40.7	39.2
9	4.6	2.0	0.69	0.09	1.4	49.1	0.04	0.09	0.50	1.2	6.6	41.0	38.8
10	5.9	2.4	0.89	0.09	1.8	47.3	0.02	0.06	0.50	1.8	8.6	40.2	39.1
11	8.1	3.6	1.3	0.10	1.6	45.1	0.02	0.05	0.55	1.8	11.7	38.2	36.2
12	7.8	3.6	1.1	0.09	1.6	45.0	0.02	0.06	0.46	1.9	11.1	38.9	36.6
13	6.7	1.1	1.1	0.10	1.7	47.8	0.02	0.06	0.23	2.2	10.1	39.0	36.9
14	21.1	2.5	1.8	0.11	6.1	29.7	0.14	0.36	0.42	3.9	30.4	34.1	32.0
15	6.2	1.0	0.87	0.10	2.5	47.3	0.04	0.12	0.26	2.1	10.1	39.5	36.8
16	4.0	1.7	0.94	0.09	4.9	48.2	0.05	0.13	0.20	2.1	5.0	38.4	35.9
17	4.3	1.7	0.95	0.09	8.2	43.7	0.06	0.15	0.40	1.5	5.6	39.1	37.2
18	7.7	3.1	1.0	0.11	6.8	37.5	0.21	0.51	0.57	3.8	9.2	39.5	36.6
19	24.4	7.3	2.3	0.17	9.8	22.9	0.24	0.60	0.40	2.6	32.3	29.7	26.4
20	11.8	4.5	1.5	0.22	9.9	33.6	0.08	0.20	0.47	3.2	12.9	34.8	32.2
21	6.5	2.3	1.1	0.20	2.6	41.6	0.38	0.95	0.57	3.0	7.7	40.3	37.8
22	22.1	9.7	2.2	0.23	9.7	22.6	0.05	0.13	1.1	3.4	29.4	28.9	27.2
23	5.7	3.2	0.94	0.21	5.5	44.3	0.27	0.67	0.09	2.0	6.5	37.2	34.8
24	4.3	1.4	1.0	0.08	6.7	44.5	0.03	0.08	0.10	2.2	4.7	41.2	39.7
25	13.4	5.6	1.6	0.19	10.4	28.5	0.37	0.93	0.14	2.8	13.1	36.6	35.2

Table 19

Chemical Analysis of Alf. 145 (Section 13) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	7.5	3.3	1.3	0.16	1.7	47.0	0.03	0.09	1.2	1.4	9.2	38.0	NR
2	8.9	3.3	1.5	0.16	1.7	46.4	0.02	0.07	0.79	1.3	10.4	37.2	NR
3	11.1	5.1	1.9	0.17	1.9	42.7	0.03	0.08	0.48	1.2	12.6	35.0	NR
4	11.9	4.2	1.7	0.17	2.4	42.8	0.03	0.08	0.62	2.2	13.0	35.5	NR
5	11.2	3.1	1.4	0.17	2.0	44.4	0.02	0.07	0.45	2.3	12.5	36.5	NR
6	5.9	2.4	1.3	0.15	1.5	49.3	0.04	0.10	0.42	1.3	7.3	39.1	NR
7	9.4	3.1	1.3	0.16	1.9	46.4	0.03	0.08	0.60	1.3	11.4	37.6	NR
8	7.5	2.5	1.2	0.16	1.9	47.9	0.03	0.08	0.48	1.3	9.2	38.8	NR
9	9.5	2.7	1.2	0.17	2.0	45.8	0.04	0.11	0.26	1.2	10.2	37.6	NR
10	9.1	2.4	1.1	0.18	1.9	46.0	0.03	0.09	0.21	1.8	10.0	37.5	NR
11	8.4	2.3	1.0	0.17	2.0	46.5	0.04	0.10	0.21	1.0	8.7	38.1	NR
12	6.1	1.4	0.9	0.18	1.3	49.5	0.03	0.09	0.19	1.9	6.6	39.2	NR
13	1.5	0.44	0.4	0.16	0.72	54.2	0.03	0.08	0.15	1.4	3.4	42.4	NR
14	3.2	0.51	0.63	0.18	0.87	52.7	0.04	0.10	0.17	1.1	5.1	41.7	NR
15	4.5	1.9	0.86	0.18	2.4	48.4	0.03	0.08	0.24	1.0	7.2	40.4	NR
16*													

*Drill hole bottomed at 155 feet 5 inches. The analysis of the lowest 5 feet 5 inches of core was not reported.

Table 20

Chemical Analysis of Alf. 147 (Section 14) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	11.4	4.6	1.4	0.20	1.7	43.2	0.14	0.35	0.38	2.2	18.9	35.5	NR
2	11.8	4.2	1.3	0.20	1.8	43.3	0.12	0.30	0.32	2.6	20.0	35.4	NR
3	8.5	3.0	1.2	0.20	1.6	46.6	0.13	0.33	0.41	2.2	15.5	36.2	NR
4	9.0	3.2	1.2	0.20	1.5	45.4	0.26	0.66	0.36	2.6	12.5	37.0	NR
5	4.6	1.4	0.93	0.20	1.5	49.4	0.07	0.18	0.29	1.7	8.0	40.3	NR
6	4.2	1.4	1.0	0.20	1.6	47.7	0.30	0.74	0.28	1.6	7.3	40.8	NR
7	4.8	1.5	0.95	0.20	1.6	50.1	0.27	0.66	0.30	2.3	7.5	37.6	NR
8	4.2	1.5	0.76	0.20	1.7	53.6	0.28	0.71	0.31	1.8	6.7	35.2	NR
9	5.7	1.8	1.6	0.20	1.5	53.8	0.23	0.58	0.29	2.0	9.3	32.9	NR
10	7.3	2.7	1.4	0.20	1.6	51.4	0.43	1.4	0.30	1.9	11.6	32.4	NR
11	9.2	3.8	1.5	0.03	1.9	43.8	0.41	1.0	0.44	2.6	13.6	36.6	NR
12	13.2	6.3	2.0	0.04	1.8	40.4	0.48	1.2	0.43	2.2	19.4	33.6	NR
13	9.5	4.3	1.5	0.04	1.6	43.7	0.39	1.0	0.42	3.2	14.2	36.2	NR
14	12.0	5.5	1.5	0.04	1.7	42.1	0.32	0.80	0.26	2.8	17.4	34.8	NR
15	10.4	5.7	1.5	0.03	1.9	43.6	0.37	0.91	0.27	2.6	15.4	33.4	NR
16	13.3	5.9	1.7	0.03	1.7	41.0	0.40	0.99	0.25	1.6	19.4	33.9	NR
17	11.4	5.1	1.5	0.04	1.6	42.2	0.29	0.73	0.31	2.0	17.0	35.0	NR
18	10.4	5.5	1.3	0.04	1.5	41.9	0.23	0.58	0.26	1.8	15.4	35.8	NR
19	9.1	5.8	1.4	0.04	1.4	42.5	0.23	0.57	0.21	3.8	15.1	36.1	NR
20	12.1	6.7	1.6	0.03	1.9	41.0	0.28	0.70	0.27	2.5	18.1	34.5	NR
21	10.7	7.8	1.6	0.03	1.7	41.6	0.31	0.78	0.29	2.0	17.8	34.7	NR
22	11.8	8.6	1.9	0.03	1.7	39.7	0.14	0.36	0.25	2.5	19.7	33.4	NR
23	5.1	6.7	1.3	0.02	1.4	45.8	0.19	0.47	0.23	1.1	11.5	37.7	NR
24	7.9	5.1	1.5	0.04	1.9	44.2	0.17	0.42	0.22	2.0	13.6	36.8	NR

Table 21

Chemical Analysis of Alf. 148 (Section 15) in Percent

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	CaO	Total S	SO_3	Na_2O	K_2O	Insoluble Residue	Ignition Loss	CO_2
1	9.6	3.4	1.3	0.02	1.5	46.4	0.05	0.23	0.52	2.1	12.4	35.9	NR
2	14.1	5.3	1.9	0.02	1.8	41.4	0.04	0.11	0.63	2.2	19.6	33.6	NR
3	14.8	6.1	2.2	0.02	1.7	40.1	0.16	0.40	0.65	3.2	21.0	30.2	NR
4	9.4	3.8	1.7	0.02	1.6	45.3	0.08	0.20	0.71	2.0	13.6	35.2	NR
5	8.4	4.2	1.5	0.02	1.9	44.7	0.07	0.18	0.86	2.2	13.4	35.9	NR
6	9.5	3.7	1.5	0.02	1.6	45.4	0.09	0.22	0.83	3.3	13.7	33.7	NR
7	7.4	3.4	1.3	0.02	1.4	47.3	0.04	0.10	0.73	2.0	9.3	37.2	NR
8	8.2	3.6	1.5	0.02	1.9	46.2	0.05	0.11	0.81	2.2	11.2	36.4	NR
9	8.8	3.9	1.5	0.02	1.5	46.3	0.04	0.10	0.59	1.9	12.2	36.1	NR
10	6.6	3.0	1.2	0.02	1.3	48.6	0.05	0.11	0.64	2.3	8.5	37.6	NR
11	7.4	2.9	1.3	0.02	1.3	48.0	0.05	0.11	0.61	2.4	9.4	37.0	NR
12	5.8	2.2	1.3	0.02	1.4	49.9	0.06	0.16	0.74	2.7	8.4	36.9	NR
13	5.9	2.2	0.98	0.01	1.7	48.6	0.02	0.05	0.29	1.6	9.3	39.6	NR
14	5.3	2.1	0.97	0.02	1.5	49.9	0.02	0.05	0.28	1.7	8.8	39.5	NR
15	9.8	3.8	1.3	0.02	1.9	45.6	0.02	0.04	0.31	1.5	14.5	36.9	NR
16	9.6	4.0	1.3	0.02	1.8	45.2	0.02	0.05	0.29	1.5	15.9	37.1	NR
17	6.4	3.0	1.1	0.03	1.7	48.0	0.01	0.03	0.28	1.6	11.8	38.7	NR
18	5.7	3.1	0.99	0.05	1.9	47.7	0.02	0.05	0.14	1.4	10.2	39.4	NR
19	6.3	3.7	0.9	0.05	1.9	46.4	0.02	0.06	0.16	1.5	11.6	39.0	NR
20	8.3	4.6	1.3	0.03	2.1	44.0	0.02	0.05	0.14	1.4	13.8	37.9	NR
21	7.5	4.7	1.2	0.04	1.8	45.9	0.01	0.03	0.16	1.5	12.4	38.1	NR
22	6.3	3.1	1.0	0.03	1.3	47.3	0.03	0.07	0.14	1.5	10.4	38.9	NR

Table 22

Average Composition of the Pamelia Formation in Percent

	Alf. 143* (Section 12)	Alf. 142 (Section 11)	Alf. 146† (Section 9)	Alf. 141 (Section 3)
SiO_2	12.6	16.93	22.5	15.2
Al_2O_3	4.86	6.29	6.29	6.2
Fe_2O_3	1.4	1.5	1.83	1.7
P_2O_5	0.19	0.10	0.196	0.08
MgO	7.8	5.1	6.29	7.1
CaO	34.0	34.0	34.2	32.8
Total S	0.2	0.15	0.097	0.44
SO_3	0.51	0.39	0.22	0.11
Na_2O	0.41	0.5	0.398	0.19
K_2O	2.74	2.3	2.93	2.4
Insol. Res.	15.23	19.86	20.29	14.7
Ign. Loss	35.5	33.6	34.18	34.5
CO_2	33.3	31.3	NR	32.4

*The analysis covers only the upper 69 feet 10 inches of the formation. The Pamelia Formation becomes increasingly siliceous downward and is most siliceous at the base.

†The average silica content is unusually high because of an extremely siliceous zone 20 feet 4 inches to 30 feet 4 inches below the top of the formation. Without this zone the average silica content is 12.8 percent.

Table 23

Average Composition of the Lowville Formation in Percent

	Alf. 143 (Section 12)			Alf. 142 (Section 11)		
	Lowville *sensu-stricto*	Pamelia-Lowville Transition	Combined Average	Lowville *sensu-stricto*	Pamelia-Lowville Transition	Combined Average
SiO_2	5.93	8.66	7.3	5.1	9.12	7.1
Al_2O_3	2.27	2.0	2.14	1.97	2.15	2.06
Fe_2O_3	0.92	1.11	1.02	1.06	1.22	1.14
P_2O_5	0.93	0.1	0.52	0.16	0.146	0.153
MgO	1.81	5.7	3.76	0.81	3.56	2.19
CaO	47.5	41.28	44.39	50.29	43.8	47.05
Total S	0.026	0.1	0.063	0.03	0.084	0.058
SO_3	0.064	0.254	0.16	0.81	0.20	0.51
Na_2O	0.45	0.37	0.41	0.479	0.494	0.487
K_2O	1.66	2.68	2.17	1.41	1.77	1.59
Insol. Res.	8.59	12.04	10.32	8.93	12.82	10.88
Ign. Loss	39.99	38.12	39.06	39.89	38.38	39.14
CO_2	38.03	35.70	36.89	38.51	36.74	37.63

Table 23 Continued

	Alf. 143 (Section 9)			Alf. 144) (Section 8)
	Lowville* *sensu-stricto*	Pamelia-Lowville Transition	Combined Average	Lowville† *sensu-stricto*
SiO_2	5.06	7.58	6.32	7.15
Al_2O_3	1.76	3.3	2.53	2.48
Fe_2O_3	1.08	1.13	1.105	1.08
P_2O_5	0.169	0.18	0.175	0.16
MgO	0.93	2.7	1.82	1.46
CaO	48.64	43.92	46.28	47.91
Total S	0.016	0.022	0.019	0.033
SO_3	0.044	0.058	0.051	0.083
Na_2O	0.15	0.226	0.188	0.232
K_2O	2.77	2.6	2.69	1.69
Insol. Res.	7.77	10.42	9.1	9.95
Ign. Loss	39.2	38.34	38.77	38.59
CO_2	NR	NR	NR	NR

*Analysis covers only the lowest 69 feet 3 inches. The entire unit measures 81 feet 5 inches at this locality.

†Analysis does not include the highest 5 feet 7 inches or the lowest 4 feet 3 inches of the unit.

Table 23 Continued

	Alf. 141 (Section 3)		
	Lowville* *sensu-stricto*	Pamelia-Lowville Transition	Combined Average
SiO_2	7.3	9.9	8.6
Al_2O_3	3.2	4.1	3.65
Fe_2O_3	1.1	1.2	1.15
P_2O_5	0.08	0.07	0.075
MgO	1.86	4.2	3.03
CaO	47.05	41.95	44.5
Total S	0.035	0.035	0.035
SO_3	0.09	0.08	0.085
Na_2O	0.23	0.26	0.245
K_2O	1.7	1.6	1.65
Insol. Res.	9.2	12.8	11.0
Ign. Loss	38.9	37.9	38.4
CO_2	37.1	35.9	36.5

*Excludes the highest 10 feet 8 inches of this unit.

Table 24

Average Composition of the Chaumont Formation in Percent

	Alf. 145 (Section 13)	Alf. 143 (Section 12)	Alf. 142 (Section 11)	Alf. 144 (Section 8)
SiO_2	2.35	1.3	1.0	1.93
Al_2O_3	0.48	0.42	0.11	0.08
Fe_2O_3	0.52	0.41	0.46	0.465
P_2O_5	0.17	0.1	0.126	0.195
MgO	0.8	0.64	0.24	1.1
CaO	53.5	53.0	54.5	53.6
Total S	0.035	0.04	0.023	0.035
SO_3	0.09	0.095	0.06	0.09
Na_2O	0.16	0.46	0.35	0.21
K_2O	1.25	1.45	1.4	2.1
Insol. Res.	4.3	2.4	1.9	2.7
Ign. Loss	42.1	43.1	43.3	41.1
CO_2	NR	40.85	41.5	NR

Table 25

Average Composition of the Rockland Formation in Percent

	Alf. 145 (Section 13)	Alf. 143* (Section 12)	Alf. 144† (Section 8)	Alf. 140+ (Section 2)
SiO_2	8.3	8.5	11.37	10.4
Al_2O_3	2.4	1.6	2.7	3.49
Fe_2O_3	1.1	1.1	1.04	1.54
P_2O_5	0.17	0.098	0.12	0.11
MgO	1.83	1.9	1.73	1.76
CaO	47.0	46.8	44.4	44.3
Total S	0.033	0.04	0.023	0.026
SO_3	0.09	0.095	0.54	0.06
Na_2O	0.33	0.39	0.19	0.24
K_2O	1.4	1.3	2.26	1.9
Insol. Res.	9.4	11.0	14.9	12.7
Ign. Loss	38.1	39.2	36.8	37.0
CO_2	NR	37.9	NR	34.7

*Analysis covers only the lowest 39 feet of the formation at this locality.
†Rockland and Kirkfield formations undifferentiated.
+Analysis covers only the highest 64 feet 10½ inches of the formation at this locality.

Table 26

Average Composition of the Kirkfield Formation in Percent

	Alf. 145* (Section 13)	Alf. 140 (Section 2)
SiO_2	9.4	5.76
Al_2O_3	3.56	3.6
Fe_2O_3	1.5	1.2
P_2O_5	0.16	0.11
MgO	1.86	1.65
CaO	45.4	47.1
Total S	0.028	0.024
SO_3	0.082	0.053
Na_2O	0.49	0.25
K_2O	1.6	1.6
Insol. Res.	10.83	9.14
Ign. Loss	36.9	39.0
CO_2	NR	36.5

*Analysis covers only the lowest 62 feet 11 inches of the formation.

Table 27

Average Composition of the Shoreham Formation in Percent

	Alf. 144 (Section 8)	Alf. 148 (Section 15)
SiO_2	11.2	6.9
Al_2O_3	3.6	3.9
Fe_2O_3	1.55	1.1
P_2O_5	0.085	0.035
MgO	1.75	1.55
CaO	43.35	46.6
Total S	0.05	0.02
SO_3	0.125	0.05
Na_2O	0.22	0.15
K_2O	2.3	1.5
Insol. Res.	14.75	11.4
Ign. Loss	36.65	38.5
CO_2	NR	NR

Table 28

Average Composition of the Denmark and Cobourg Formations in Percent

	Alf. 148* (Section 15)	Alf. 148† (Section 15)	Alf. 147+ (Section 14)
SiO_2	7.57	12.8	9.07
Al_2O_3	3.36	4.9	4.5
Fe_2O_3	1.27	1.8	1.4
P_2O_5	0.024	0.02	0.1
MgO	1.67	1.66	1.66
CaO	46.89	42.6	44.92
Total S	0.04	0.08	0.268
SO_3	0.098	0.25	0.68
Na_2O	0.49	0.6	0.31
K_2O	1.95	2.5	2.23
Insol. Res.	11.51	17.66	14.37
Ign. Loss	37.30	33.23	35.66
CO_2	NR	NR	NR

*Analysis covers the "Upper Member" of the Denmark Formation.
†Analysis covers the lowest 28 feet 3 inches of the Cobourg Formation at this locality.
+Cobourg and Denmark formations undifferentiated.

Table 29

Summary of Chemical Determination as to Formation (Maximum and Minimum) Values Given in Percent

Formation	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Cobourg-Denmark	4.2–14.8	1.4 –8.6	0.90–2.2	39.7–53.8	1.3 – 2.1
Shoreham	6.3–11.3	3.1 –4.7	1.5 –1.6	43.2–47.3	1.3 – 1.9
Kirkfield	4.3–13.6	2.4 –5.1	1.1 –1.9	42.7–49.3	1.5 – 2.4
Rockland	6.1–16.8	1.0 –4.2	0.85–1.7	40.2–49.5	1.2 – 2.4
Chaumont	0.5– 3.2	0.04–0.51	0.33–0.63	51.9–55.2	0.24– 1.5
Lowville					
Lowville *sensu-stricto*	2.3– 8.6	0.1 – 4.1	0.50–1.8	45.3–52.3	0.1 – 3.0
Pamelia-Lowville Transition	3.2–21.1	1.0 – 8.1	0.86–1.9	29.7–49.7	1.2 – 8.2
Pamelia	3.2–38.5	0.8 –12.9	0.24–4.2	18.5–49.0	2.3 –11.3

Table 30

Useful Conversion Factors for Carbonate Rocks[12]

To convert	Multiplied by
Ca to CaO	1.40
Ca to $CaCO_3$	2.50
Ca to Mg	0.61
Ca to MgO	1.01
Ca to $MgCO_3$	2.10
Mg to MgO	1.66
Mg to $MgCO_3$	3.48
Mg to Ca	1.64
Mg to CaO	2.31
Mg to $CaCO_3$	4.12
CaO to Ca	0.71
CaO to $CaCO_3$	1.78
CaO to Mg	0.43
CaO to MgO	0.72
CaO to $MgCO_3$	1.50
MgO to Mg	0.60
MgO to $MgCO_3$	2.09
MgO to Ca	0.99
MgO to CaO	1.39
MgO to $CaCO_3$	2.48
$CaCO_3$ to Ca	0.40
$CaCO_3$ to CaO	0.56
$CaCO_3$ to Mg	0.24
$CaCO_3$ to MgO	0.40
$CaCO_3$ to $MgCO_3$	0.84
$MgCO_3$ to Mg	0.29
$MgCO_3$ to MgO	0.48
$MgCO_3$ to Ca	0.48
$MgCO_3$ to CaO	0.66
$MgCO_3$ to $CaCO_3$	1.18

[12] Modified after National Limestone Institute, Inc.

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GEOLOGICAL SURVEY
James F. Davis, State Geologist

THE LIMESTONES (MIDDLE ORDOVICIAN) OF JEFFERSON COUNTY, NEW YORK

John H. Johnsen

(SOUTHERN PORTION)

EXPLANATION

MIDDLE ORDOVICAN (MOHAWKIAN)

Utica Shale — Ou — *dark gray to black graptolite-bearing fissile shale. Pyrite concretions and lenses have been noted at the shale-limestone contact.*

TRENTON GROUP

Cobourg Limestone — Oco — *upper part* (Hillier) *nodular and argillaceous medium-textured limestone, with interbeds of dark gray calcareous shale; lower part* (Hallowell) *thin-to thick-bedded occasionally crossbedded, medium-to medium-light gray, coarse-textured fossiliferous limestone with shale partings.*

Denmark Limestone — Od — *thin-to thick-bedded, occasionally crossbedded, medium-to medium-light gray, coarse-textured fossiliferous limestone with shale partings.*

Shoreham Limestone — Osh — *irregular lensing, thin-to medium-bedded, medium gray, medium-to coarse-textured limestone. The coarser limestone beds have wavy surfaces producing an irregular lensing appearance.*

Kirkfield Limestone — Ok — *medium-to thick-bedded, medium-to light gray, medium-to coarse-textured limestone; abundantly fossiliferous with obvious echinoderm columnals; frequently crossbedded.*

Rockland Limestone — Or — *thin-bedded, somewhat argillaceous medium-to dark-gray, fine-to medium-textured limestone with shale interbeds.*

BLACK RIVER GROUP

Chaumont Limestone — Och — *massive, medium-to dark-gray, fine-textured cherty limestone, weathering light gray with silicified fossils and large cephalopods.*

Lowville Limestone — Ol — *principally medium-gray, conchoidally fracturing, fine-to medium-textured limestone; light gray weathering.*

Pamelia Formation — Op — *principally greenish-gray and medium-gray conchoidally fracturing dolostone with some medium-to dark-gray limestone interbeds. Basal few feet may be more quartzose or feldspathic. Dolostones weather a conspicuous yellowish-brown.*

LOWER ORDOVICAN (CANADIAN)

Theresa Formation — O€t — *massive bedded quartzose dolostone and dolomitic sandstone with frequent cavities lined with dolomitic crystals.*

UPPER CAMBRIAN (CROIXIAN)

Potsdam Sandstone — €p — *medium-to thick-bedded tan to grayish-white quartz sandstone with siliceous and calcareous cement. Basal few feet may be conglomeratic and/or feldspathic.*

PRECAMBRIAN

p€ — *undifferentiated gneisses, marbles*

SYMBOLS

Formation contact; solid where observed, dashed where inferred.

U / D — Normal fault; solid where observed, dashed where inferred.

Area of outcrop.

Anticlinal axis.

Synclinal axis.

70 — Strike of vertical joints.

Strike and dip of bedding.

Horizontal beds.

Stone quarries.

Potential quarry site showing recommended direction of development.

Preferred quarry site showing recommended direction of development.

o Alf 142 — Drill hole; Alfred University School of Ceramics.

Principal sand and/or gravel deposits.

SCALE 1:48000

1 0 1 2 3 MILES

2000 0 2000 4000 6000 8000 10000 12000 14000 FEET

1 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 10 FEET

15° — APPROXIMATE MEAN DECLINATION 1966

NEW YORK STATE MUSEUM AND SCIENCE SERVICE
MAP AND CHART SERIES NO. 13
1970
Geologic mapping 1954-1956

MAP LOCATION

*Since this work was submitted for publication, Marshall Kay (1968, "Ordovician Formations in northwestern New York"; Naturaliste Can., v. 95, p. 1373-1378), has proposed three new formational names - - Kings Falls, Sugar River, and Denley - - for the Kirkfield, Shoreham, and Denmark, respectively. It is uncertain, however, whether these newly erected names have precisely the same stratal limits as those used in this article.

Outcroppings along Interstate 81 not shown as highway was constructed following mapping.

Williams & Heintz Map Corporation, Washington, D.C. 20027

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