

CHAZY GROUP IN THE ST. LAWRENCE LOWLAND

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I N T R O D U C T I O N

General statement:

This thesis contains the results of an investigation into the stratigraphy and paleontology of the early Middle Ordovician Chazy group in the St. Lawrence Lowland. As such, it forms part of a series of studies of the Ordovician formations in this region, carried out by graduate geology students at McGill University. It follows the work of Harris (1933) and Okulitch (1934) on the Black River group, and that of Byrne (1958) on the Beekmantown group. Despite the excellent accessibility of the best exposures in the vicinity of Montreal, the Chazy group here, as a unit by itself, has not previously been studied in detail.

Field work was done in the autumn of 1959 and during the summers of 1960 and 1961. The laboratory investigations were conducted at McGill University during the intervening winters. The study material comprises: 1) outcrops and quarries; 2) a large number of samples from the collection made by T.H. Clark for the Quebec Department of Mines (now Department of Natural Resources) during his mapping of the St. Lawrence Lowland, and stored at the Redpath Museum, McGill University; 3) specimens belonging to the Redpath Museum; 4) cores stored at the Department of Natural Resources Pilot Plant in Quebec City; 5) type fossil specimens in the collections of the Geological Survey of Canada; and 6) the writer's own collection.

Location:

Rocks of the Chazy group crop out along a 150-mile long belt between Orwell, Vermont, and Joliette, Quebec. They can be traced up the Ottawa Valley to Arnprior, 130 miles west of Montreal, and possibly to the Brent Crater (Gilmour Lake), 142 miles northwest of Ottawa (Caley and Liberty, 1957, p.238). They occur near St. Dominique, 33 miles east of Montreal, and at the Mingan Islands in the Gulf of St. Lawrence, 570 miles northeast of Montreal. Chazy rocks have also been recognized in the subsurface of the St.

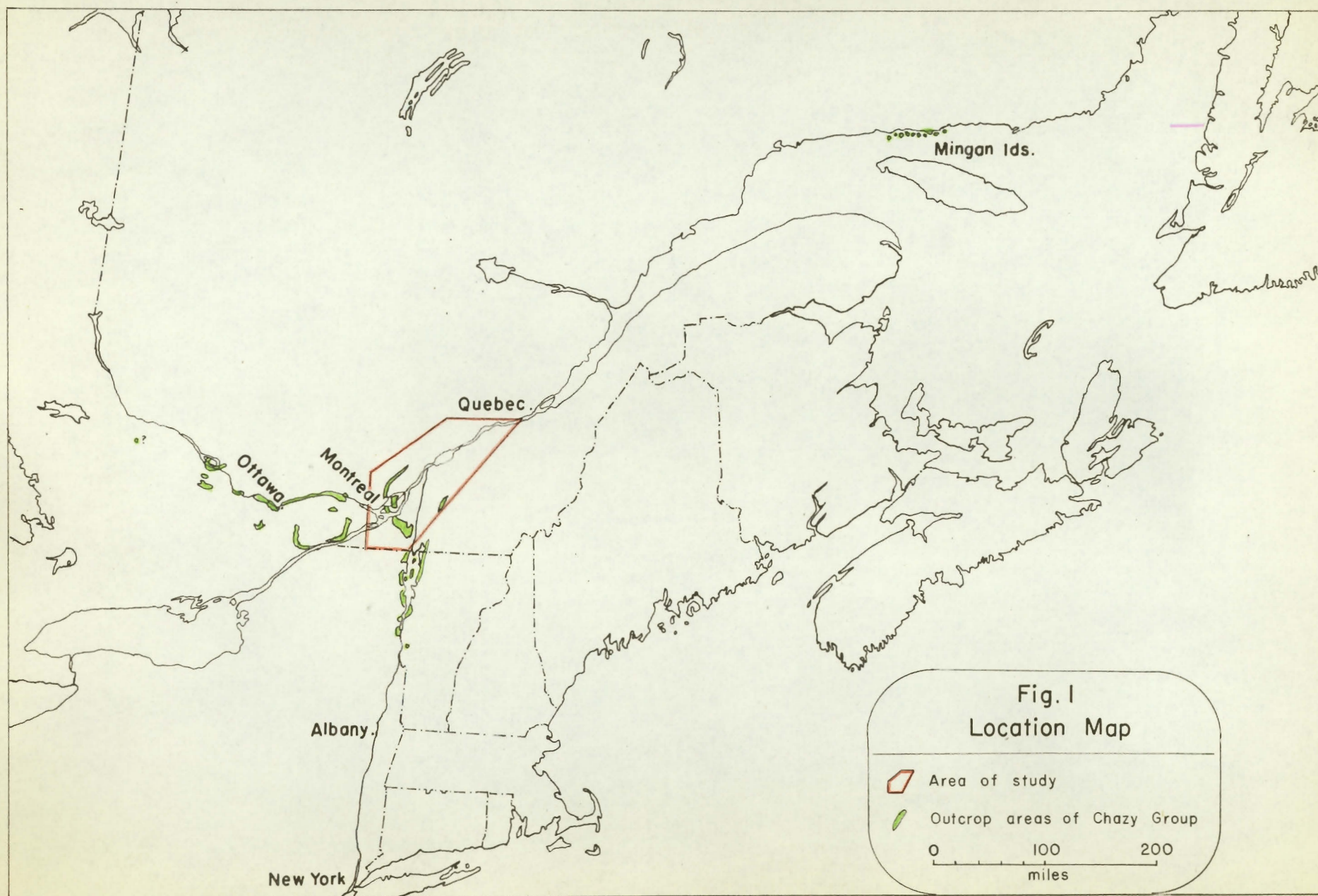
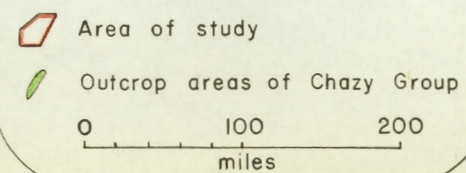


Fig. 1
Location Map



Lawrence Valley, between Batiscan, Quebec, and the International Boundary.

The St. Lawrence Lowland is a northeasterly trending flat area, underlain by gently dipping, locally folded and faulted Upper Cambrian and Ordovician sedimentary rocks. Considerable topographic relief is provided only by an easterly trending line of isolated mountains, the Monteregian Hills. The valley is wedged between the crystalline rocks of the Laurentian Upland on the northwest and the folded lower Paleozoic rocks of the northern Appalachians on the east. The Precambrian of the Frontenac axis and the Adirondacks form the southern limits. The Oka axis divides the outcrop belts of the Ottawa and St. Lawrence Valleys.

The location of the area of study in relation to the Chazy outcrop belts is shown in Fig. 1.

Historical:

The name Chazy limestone was applied by Emmons (1842) to exposures at Chazy Village in northeastern New York. Detailed lithologic descriptions of the type section and other sections were given by Brainerd and Seely (1888, 1896). Brainerd (1891) divided the section at Valcour Island, New York, into three units: A (lower), B (middle), and C (upper), for which Cushing (1905) proposed the substage (formation) names Day Point limestone, Crown Point limestone, and Valcour limestone. These three correspond roughly to the faunal divisions of Orthambonites? exfoliatus, Maclurites magnus, and Rostricellula plena, established by Raymond (1905, 1906).

Oxley and Kay (1959) divided the Day Point formation into 4 members: Head, Scott, Wait, and Fleury, in ascending order. They separated the Valcour formation into 2 members, the Hero (lower) and the Beech (upper). No new subdivision of the Crown Point was made. Other studies of Chazy rocks in Vermont are those of Erwin (1957) and Welby (1961).

A great many more papers concerning the stratigraphy and paleontology of the Chazy in the Champlain Valley have been published. For an extensive annotated bibliography of papers prior to 1905 the work by Raymond (1906) should be consulted.

The first work on the Chazy group in the St. Lawrence Lowland was that carried out by Billings and Logan in the early days of the Geological Survey of Canada. Billings described, identified, and classified many of the Chazy fossils from Montreal and surroundings (1858, 1859a, 1859b, 1865). Logan (1863) gave in detail an excellent account of the character of the Chazy in the St. Lawrence Lowland, in the Ottawa Valley, and at the Mingan Islands. In addition, he provided the first maps (1865) to show the distribution of these rocks in Canada, on the scale of 125 miles to the inch.

Ells (1896, 1900) published more material on the Chazy of southern Quebec and produced a geological map on the scale of 4 miles to the inch. This map, on which the Chazy outcrop pattern differs slightly from Logan's map, was used for many years by later authors.

Ami (1896) appended faunal lists to Ells' report. These lists are not followed by critical comments. In a later paper (1900) he described the distribution of the Chazy without adding anything new.

Adams and LeRoy (1904) briefly mentioned the Chazy group. They presented subsurface data derived from many wells drilled on the Island of Montreal, and added a geologic map (part of Ells' map) to their report.

Raymond, in a series of many papers, described the faunas of the Chazy in the Champlain and Ottawa Valleys, and named the Aylmer formation (1912). In some of his publications references to the St. Lawrence valley occur. In his paper of 1906 he furnished fossil lists which he had compiled from the lists of previous authors. This publication is now still the most important reference concerning the standard section of the Chazy at Valcour Island, New York.

Parks (1914) wrote on the economic and technical aspects (crushing strength, shearing strength, porosity, density, and other properties) of building and ornamental stones of Canada, including those of some of the limestones of the Chazy group. In another report (1931) he mentioned the Chazy, but added nothing new.

Maddox (1931a, 1931b) gathered information concerning the Chazy in the subsurface and its thickness at several localities.

Goudge (1935) made a detailed chemical study of the limestones in Quebec, and published a large number of partial analyses. He further provided detailed petrologic descriptions and other data related to limestone economics.

McGerrigle (1938) mapped Chazy rocks in the Lachute map-area and described a section of the Aylmer formation at Grenville, where it is in disconformable contact with the underlying Beauharnois dolomite.

A.E. Wilson (1932) studied the stratigraphy and fauna of the Aylmer 'formation' and divided it (1937, 1946) into a lower Rockcliffe formation (shales and sandstones) and an upper St. Martin formation (mainly limestone).

The Chazy conularids were described and illustrated by Sinclair (1942), the ostracods by Carter (1957), and the coral bioherms by MacGregor (1954). Helen Belyea (1952) examined well cores and cuttings, presented descriptions of these, and illustrated her report by graphic logs and a correlation (fence) diagram.

The long-range geologic mapping program of the Quebec Department of Natural Resources, carried out by T.H. Clark for more than 20 years, has resulted in many publications, in some of which the Chazy group has received special treatment (1944b, 1952, 1955, 1960). The papers are concerned with distributional and petrologic data, and the listing of fossil species. Their scope does not include systematic paleontology.

Exposures in the St. Dominique area near St. Hyacinthe were investigated by Usher (1947), Kay (1958) and Clark (1961).

Acknowledgments:

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The Quebec Department of Mines graciously allowed the examination of its collections stored at McGill University, and of its core depository at its Pilot Plant in Quebec City.

The writer is much indebted to officers of the museums who lent type and other fossil specimens for the special study of Bolboporites americanus, in particular Mrs. A.J. Turnham and Mrs. L.S. Stevenson of the Redpath Museum, Drs. P.M. Kier and G.A. Cooper of the United States National Museum, and C.F. Kilfoyle of the New York State Museum. Dr. T.E. Bolton, Curator of the paleontology type collections of the Geological Survey of Canada at Ottawa, gave permission to examine Billings' type material. Thanks are also due Professor Gerhard Regnéll of Lund University, Sweden, for written discussions, and for sending a copy of an unpublished manuscript on Bolboporites. Dr. L.F. Hintze of Brigham Young University, Utah, gave information concerning the occurrence of this genus.

Professor Adolf Seilacher of the University of Göttingen, Germany, was helpful with written discussions on ichnofossils. Dr. R.H. Flower of the New Mexico Institute of Mining and Technology kindly identified the rather poorly preserved cephalopods of the collections. Dr. G.R. Webber of McGill University aided in suggesting a convenient method for estimating calcite-dolomite ratios in carbonate rocks, and in providing an unpublished paper containing the determinative graph which is reproduced at the end of this thesis.

Mr. R.S. Dean, investigating the mineralogy of shales in the St. Lawrence Lowland, studied the clay mineralogy of beds in the type section of the Beaconsfield member (new) of the Laval formation, in a joint effort with the writer. His results are incorporated in Fig. 14.

Many of the photographs of fossils were taken with the

excellent equipment very kindly lent by Mr. G.E. Pajari. Photographs of two crinoids were supplied by the Geological Survey of Canada.

Mr. Howard Darling of Peru, New York, acted as guide during the visit at Valcour Island, and provided boat transportation on Lake Champlain.

Thanks are expressed to the managers and foremen of the various quarries for permitting the writer to examine and sample the quarry sections.

Yet, foremost and particular thanks are directed to Dr. T.H. Clark for originally suggesting this interesting thesis topic, for access to his field notes, maps, unpublished manuscripts, and the use of his private library, for his delightful company on many field trips, of which the one to the standard section of the Chazy at Valcour Island was most successful, and for his continued interest, discussions, and beneficial hints throughout the study period.

G E N E R A L G E O L O G Y *

Stratigraphy

The St. Lawrence Lowland is underlain by a series of Cambrian and Ordovician sedimentary rocks 8,000 to 9,000 feet thick, which rest on a Precambrian basement of very irregular topography. The oldest Paleozoic rocks are the pebble conglomerates and quartz arenites of the Potsdam group (Upper Cambrian). This group is extremely variable in thickness, ranging from zero in the north central part to a maximum of about 2,000 feet in the southwestern part of the Lowland.

The Potsdam is succeeded unconformably by the Lower Ordovician Beekmantown group, consisting of quartz arenites and dolomitic sandstones of the March formation, and the overlying Beauharnois dolomite. This group is 1,400 feet thick in wells at St. Hubert, but thins rapidly towards the Laurentian Upland in the northwest. In the southeastern part of the Lowland the next sediments to be deposited were the dolomite and lithographic limestones of the Beldens formation, with a maximum thickness of about 275 feet in the St. Hyacinthe area. This formation is not known near Montreal.

The region was then inundated by the Chazy sea, and shales, sandstones, and shaly limestones formed contemporaneously with coarse-grained calcarenite shoals and lenses, and local coral bioherms. This assemblage constitutes the Laval formation, which is about 300 feet thick in the Montreal area. During the regression of the Chazy sea and the return of the sea during Black River time 20 feet of dolomitic shales, dolomites, and quartz sandstones with local mudcracks and ripple marks accumulated, making the Pamelia formation.

Above the Pamelia are 50 feet of Black River beds, the Lowville calcilutites and the Leray calcarenites. Deposition of 600 to 2,000 feet of Trenton limestones and shales then took place, before the Utica black shales were laid down.

* Data mostly from Clark (1947, 1952, 1955, 1956) and Cady (1960).

Effects of uplifts in the Taconic Mountains are reflected in the sedimentary record by the silting-up of the basin from the east. The calcareous shales and fine-grained sandstones of the Lorraine group formed, and, finally, the more than 2,000 feet thick marine shales and limestones and non-marine deltaic deposits of the Richmond brought the Ordovician sedimentary events to a close.

The highly disturbed Ordovician rocks immediately west of 'Logan's Line' are all grouped under the St. Germain Complex (Clark, 1947). They include mainly Trenton-Utica-Lorraine rocks.

There is no record of Silurian sedimentary rocks, but fossiliferous limestone fragments in the St. Helen's Island diatrema breccia indicate that the Lower Devonian sea extended to the Montreal area. Since the Devonian the region has presumably undergone long continued erosion.

At some time during the Cretaceous the Monteregian intrusives penetrated the Lowland, along a tectonic zone of weakness that is the eastern extension of the Ottawa graben.

Glaciers overrode the rocks several times during the Pleistocene, and tills accumulated, while varved clays and silts were brought down in glacial lakes (Gadd, 1960). The glacial debris was followed by postglacial marine clays and shallow-water sands laid down in the Champlain Sea. Aeolian sands and alluvium were the last sediments to accumulate.

A résumé of the bedrock stratigraphy is given in Table 1.

Structure

The Paleozoic rocks are folded into a long, curved, synclinal fold, the axis of which runs more or less parallel to the St. Lawrence River on its south side, between the International Boundary and Quebec City (Fig. 2). On the northwestern border of the Lowland are 6 northeastward-trending, en échelon faults, along which the sedimentary rocks have dropped down with respect to the Precambrian of the Laurentians. Several eastward-trending high-angle faults of

moderate throw, and a multitude of associated smaller faults occur in the Montreal region. These are most probably related to the tectonics of the Ottawa graben.

The beds on the northern shore of the St. Lawrence River dip fairly uniformly to the southeast with angles averaging 2° . At Montreal and east of there the beds are more undulating.

The eastern boundary of the Lowland is formed by a complex zone of highly deformed sedimentary rocks, which is the extension of the Champlain Thrust, here known as 'Logan's Line'. It is the zone where the thrust sheets from the Appalachians met and overrode the subhorizontal rocks of the St. Lawrence Lowland geological sub-province during the Taconic orogeny. In the St. Hyacinthe area some of the miogeosynclinal carbonate beds have been caught up by the thrusting and brought to the surface. This slice includes a Chazy sequence, the St. Dominique formation, as well as stratigraphically lower and higher limestones. West of the thrust the sedimentary rocks are tightly folded, overturned, and highly cleaved (St. Germain Complex).

The Monteregian intrusions have contact-metamorphosed and locally deformed the enclosing sedimentary rocks.

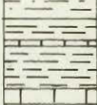
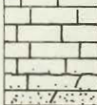
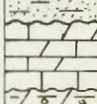
SYSTEM		GROUP	FORMATION		Lithology	Thickness
SERIES			Member			
CRETACEOUS			MONTEREGIAN INTRUSIVES			
O R D O V I C I A N	CINCINNATIAN	RICHMOND	BÉCANCOUR RIVER			2,000' +
			Carmel River	non - marine		
		PONTGRAVÉ RIVER	marine		170'	
			LORRAINE	NICOLET RIVER		
	St. Hilaire					
	Chambly					
	Breault					
	MOHAWKIAN	UTICA	LACHINE - LOTBINIÈRE			300' - 1,000'
		TRENTON	TETREAUVILLE - GRONDINES			500' - 2,000'
			Terrebonne			
			MONTREAL - ST. CASIMIR - NEUVILLE			
			DESCHAMBAULT			
		OUAREAU - FONTAINE - ST. ALBAN			0' - 90'	
BLACK RIVER		LERAY			50' ±	
		LOWVILLE				
CHAZYAN		CHAZY	PAMELIA			20'
	LAVAL - ST. DOMINIQUE					
	Beaconsfield St. Martin Ste. Thérèse		St. Dominique Is. Joliette St. Dominique ss.			
CANADIAN	BEEKMANT'N	BELDENS			0' - 275'	
		BEAUHARNOIS				
		MARCH				
CAMBRIAN	CROIXIAN	POTSDAM	POTSDAM		0' - 2,000'	
PRE-CAMBRIAN		GRENVILLE				

TABLE I.

Bedrock stratigraphy of the St. Lawrence Lowland.

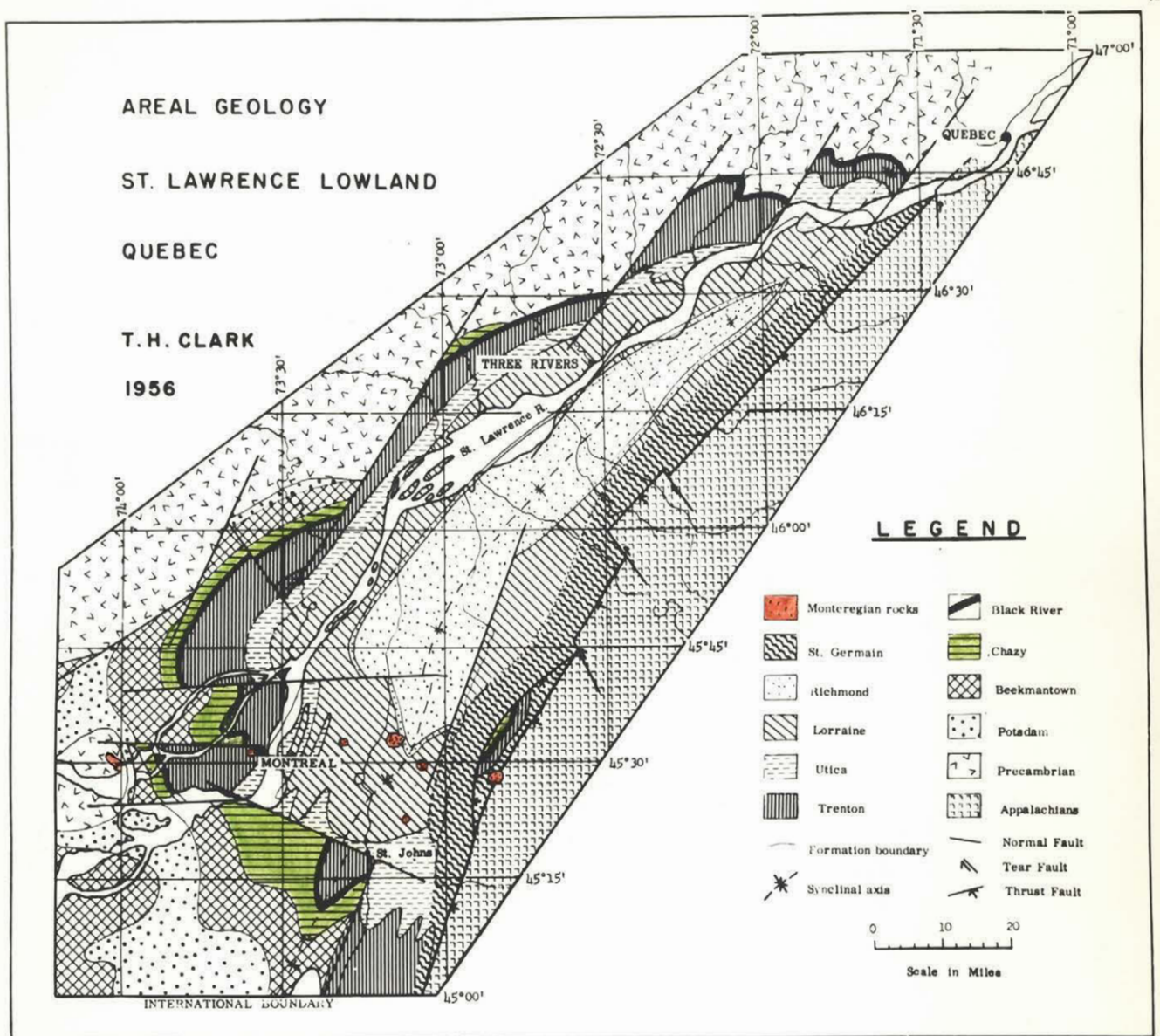


Fig. 2.

(After Clark, 1956. Chazy pattern northwest of Three Rivers and geology near Oka slightly modified.)

STRATIGRAPHY OF THE CHAZY GROUP

Definition of Chazy Group (Southern Quebec)

The designation 'Chazy group' is used in this thesis for the sedimentary units of southern Quebec which overlies the Beekmantown group and underlies the Black Riveran part of the Pamela formation. As such, the group includes the rocks referred to as 'Chazy formation' or 'Chazy limestone' by authors in general, as well as terms of more restricted usage, namely:

- St. Martin formation (Wilson, 1937, pp.46, 54; 1946, p.19. Cooper, 1956, p.16)
- Laval formation (Clark, 1944, p.29; 1952, p.43; 1956, p.278. Belyea, 1952, p.12)
- Caughnawaga member (Clark, 1944, p.29)
- Ste. Thérèse member (Clark, 1944, p.29; 1952, p.43; 1955, p.7)
- St. Martin member (Clark, 1952, p.44; 1955, p.8; 1956, p.278)
- Joliette member (Clark, 1956, p.278)
- St. Dominique formation
- St. Dominique limestone } (Clark, 1955, p.9; 1956, p.278. Kay, 1958, p.82.
- St. Dominique sandstone }
- Beaconsfield member (new).

Also included is most of the poorly fossiliferous Pamela formation, a unit which in the Montreal area was studied by Okulitch and was considered to be entirely of Black Riveran age (Okulitch, 1934, 1936; Clark, 1952). The presence of what is believed to be Rostricellula plena (Hall) just below the topmost bed at Pointe Claire (Locality 39)* suggests that this formation, at Montreal and vicinity, belongs to the Chazy rather than to the Black River group, at least in part.

Excluded from the Chazy group is the Beldens formation, formerly regarded as Chazy (Cady, 1945, p.524, 550-554; Belyea, 1952, p.12; Clark, 1955, p.10; 1956, p.278). Part of the Beldens in Vermont is now known to contain brachiopods and trilobites of Canadian affinities (Kay, 1958, p.79), and hence this formation is grouped with the Beekmantown.

In order to give the reader a picture of the stratigraphic subdivisions of the Chazy of southern Quebec as they are at present understood by the writer the following table is presented (Table 2).

* Localities are numbered consecutively from 1 to 52. For location see Correlation Chart (Fig. 20) and map in pocket.

TABLE 2

Proposed subdivision of the Chazy of southern Quebec,
with a list of the characteristic fossils.

GROUP	Formation	Member	Faunal assemblage zone	Characteristic fossils
BL. RIV		Upper		
	Pamelia	Lower	pelecypods	<i>Ctenodonta</i> sp., cf. <i>C. parvidens</i> <i>Modiolopsis parviuscula</i>
Y		Upper Laval beds	<i>Rostricellula plena</i>	Shaly limestones: <i>Lingulella?</i> sp. <i>Palaeoglossa?</i> belli <i>Mimella transversa</i> <i>Rostricellula plena</i> <i>Cyclora?</i> sp. Dolomitic shales and shaly dolomites: <i>Lingulella?</i> sp. Pelecypods
Z		coral bioherms		
A		Middle Laval shaly limestone and calcarenite beds	<i>Bolboporites americanus</i>	Calcarenites: Branching Trepostomata <i>Mimella borealis</i> <i>M. vulgaris</i> <i>Rostricellula raymondi</i> <i>Sphenotreta acutirostris</i> Trilobite fragments <i>Eurychilina</i> spp. Smooth ostracods <i>Cheirocrinus forbesi</i> <i>Palaeocystites tenuiradiatus</i> <i>Bolboporites americanus</i> <i>Blastoidocrinus carchariaedens</i> <i>Malocystites murchisoni</i> Coral bioherms: <i>Billingsaria parva</i> <i>Eofletcheria incerta</i> Bryozoans
H		St. Martin		
C		Lower Laval quartz - sandy beds		Shaly limestones: Bryozoans <i>Mimella borealis</i> <i>M. vulgaris</i> <i>Rostricellula raymondi</i> Orthocone cephalopods <i>Cheirocrinus forbesi</i> <i>Bolboporites americanus</i> <i>Malocystites murchisoni</i> Quartz sandstones, siltstones, shales: <i>Hudsonospongia?</i> <i>infundibulosa</i> <i>Lingulella?</i> sp. <i>Orthambonites</i> Orthocone cephalopods <i>Palaeophycus ancoraforme</i>

Laval Formation

General:

For many years after Logan's (1863) original description the Chazy rocks in the Montreal area were considered to be mainly comprised of limestone, with subordinate amounts of shale, totalling 100 - 150 feet in thickness (Ells, 1896; Parks, 1914, 1931; Goudge, 1935). However, a thickness of 785 feet was reported by Adams and LeRoy (1904, p.550) at the Turkish Bath well (near the site of the modern Place Ville Marie) in Montreal. They, nevertheless, assigned only 300 feet to the Chazy as an average for the Montreal district.

Another indication of a greater thickness came with the drilling of the L'Assomption Experimental Farm well by the Canadian government, in 1929. The records of this well were briefly mentioned by Maddox (1931a, p.57D; 1931b, p.90D), who identified 360 feet as Chazy and considered this to be representative of the thickness of the Chazy group in this region. The cuttings from this well were later restudied by Belyea (1952, pp.35-36); she assigned only 260 feet to the Chazy, including a 70-foot sandstone section at the base.

The misconception that the group is dominantly limestone was also exposed by Clark (1952, p.38) after a geological survey of the Montreal area, and a detailed examination of the core of the Mallet well, which represents a nearly complete section. He found (p.40) that less than half of the Chazy section is composed of limestone, and divided (p.43) the sequence into four parts:

- | | | |
|-----|----------|--|
| (d) | 62 feet | Mostly shaly limestone with some pure limestone
(including uppermost 10 feet missing from core) |
| (c) | 64 feet | Pure or nearly pure limestone |
| (b) | 112 feet | Shale and impure limestone |
| (a) | 42 feet | Sandstone with considerable shale and a little
impure limestone |
| | _____ | |
| | 280 feet | Total thickness. |

These four parts grade into one another, and for this reason he found it appropriate to consider the entire assemblage as a formation, characterized chiefly by calcareous shales and shaly

limestones, and proposed the term 'Laval formation' (initially mentioned, but not defined, in Clark, 1944, p.29) for its development in Laval County, Ile Jésus.

The basal 42 feet of sandstone were designated 'Sainte Thérèse member'. The relatively pure calcarenite beds of part (c) are what is commonly called 'Chazy limestone', and were identified as the 'St. Martin member'. Names were not given to the other two units, i.e. parts (b) and (d), because their lithologic character is very variable and indistinct (see Fig. 17).

An examination of many quarry sections, outcrops, and several well cores has confirmed that using 'Laval formation' for the local Chazyan assemblage below the Pamelia is very practical. It is a lithostratigraphic term, applied to a sequence of very variable and gradational lithologies, and free from bio- and time-stratigraphic connotations. However, the practice of subdividing the Laval formation on the basis of Ste. Thérèse and St. Martin members has not proved to be entirely satisfactory with regard to detailed stratigraphy. This two-member model is much too simple to permit a good understanding of the complexities involved.

Although the Ste. Thérèse sandstone member can be recognized in cores of several wells, its boundaries, especially the top one, are by no means very definite. In the Mallet well type section there are shale and carbonate beds in the top part of the Ste Thérèse, and units of quartz-sandy beds in part (b), reflecting the gradational nature of the division boundary. The section 126 - 136 feet above the base of the Ste. Thérèse member is a very fine-grained, micaceous, calcareous quartz arenite. Thus, the beds of sandstone in the Mallet well almost reach to the base of part (c), the calcarenite unit. Hence the usefulness of the term 'Ste. Thérèse member' is somewhat limited. (A sandstone bed in the lower part of the Laval formation need not necessarily be a correlative of the Ste. Thérèse member -part (a)- of the Mallet well section.) Elsewhere, quartz sandstone beds occur between calcarenite beds typical of the St. Martin member (e.g., Bédard Quarry, locality 40).

It has been found that the sandstones and shales, interbedded with the calcarenite units, occur in several horizons in what is about the lower half of the Laval formation in the Montreal area. Because of the gradational nature of the beds all the lower sandstones are here informally referred to as 'Lower Laval quartz-sandy beds' (see Table 2, p.14). They therefore include the Ste. Thérèse member -part (a)- as well as the sandstone beds interlayered with shales and limestones of part (b), and also those within some calcarenites in other localities.

The coarsely crystalline calcarenite, generally cross-bedded, is readily recognized wherever it is encountered. Yet, instead of having just one 'St. Martin member', such as is found in the Mallet well, many quarries and wells contain two or even more units of similar calcarenite, intercalated with shaly limestones and shales (e.g., Bédard Quarry and Quonto-International No.1 Mascouche well). In other words, there are two or more 'St. Martin members'. Consequently, it is evident that the meaning of the term 'St. Martin member' must be modified so as to apply to any unit in the Laval formation consisting of massive calcarenite beds, unless one is willing to give a different name to each separate calcarenite lens or bed. To follow the latter course would only lead to complications and confusion. The calcarenite horizons are banks, lenses, and massive beds, often laterally discontinuous, which are intertongued and interlayered with the predominantly shaly and silty units, and vice versa. They thus represent a distinct facies at various horizons and localities within the Laval formation, and the St. Martin 'member' is synonymous with St. Martin 'facies'.

The work carried out by the writer has shown that a suitable subdivision of the Laval formation can be made with the use of fossils (see Table 2, p.14). Two main biostratigraphic units were recognized: 1) an upper division in which Rostricellula plena (Hall) and Lingulella? sp. are very abundant, almost to the exclusion of any other fossils, and 2) a lower, pre-Rostricellula plena division characterized by Bolboporites americanus Billings.

Of the two, the Rostricellula plena assemblage zone is the more consistent. It encompasses mainly shaly limestones, shales, and dolomitic horizons, the Beaconsfield member (new lithostratigraphic unit), but also includes some massive beds of the calcarenite facies. The nature of the lower contact of this zone has not been ascertained, as critical sections are not available; it may be gradational or may be sharp. The upper contact has been placed at the top of the highest unit in which this brachiopod occurs abundantly, below the first dolomite bed of the Pamela formation. The zone is not intended as a 'range zone' (Amer. Comm. Stratigraphic Nomenclature, 1961, p.656), for, although Rostricellula plena was collected near the top of the Pamela (Locality 39), this fossil is not generally found in the quartz-silty dolomitic facies of the Pamela.

The assemblage zone of Bolboporites americanus, which embraces many varied lithologies, can be subdivided into biolithostratigraphic units (see Table 2, p.14): a) shaly limestones and calcarenites with Mimella borealis (Billings), Rostricellula raymondi Cooper, Sphenotreta acutirostris (Hall), ostracods, Bryozoa, and echinoderms; b) bioherms with colonial tabulate corals and Bryozoa; and c) interbedded shales and sandstones with but minor limestone seams, featuring sponges and ichnofossils (tracks and burrows), of which Palaeophycus ancoraforme n.sp. is the most abundant. As these three subdivisions are intricately interlayered they have only limited local significance.

A relation seems to exist between the abundances of specimens of Mimella and of Rostricellula raymondi (R. orientalis of older papers). Mimella specimens are common in the lower horizons where R. raymondi is absent or rare. In the higher horizons the ratio of Rostricellula to Mimella frequencies becomes much larger, and in the highest beds Rostricellula predominates. Such a relationship has also been observed by Wilson (1932, p.384) in the Aylmer formation (Chazy of the Ottawa Valley).

Distribution and thickness:

The areal distribution of the Chazy in Quebec was first shown on a map made by Logan (1865). Ells (1896) published a map on which the outcrop pattern of the Chazy differs somewhat from that of Logan's map. The map of 1896 has been used since by other authors to show the general geology, namely Adams and LeRoy (1904), Parks (1914, 1931), Goudge (1935), and Clark (1939).

With a more detailed knowledge of the local geology due to the mapping by Clark for the Quebec Department of Mines in the late 1930's, the shapes of the outcrop areas of Ells' map in the Montreal area were revised (Clark, 1944a, p.27). These changes were incorporated into the map of Dresser and Denis (1944), as were slight changes in the Lacolle map-area, following the work previously carried out by Clark for the Geological Survey of Canada. Further refinements in the shape of the Chazy outcrop belts have been made in the Glasgow - St. Lin area (Clark, 1960), in the St. Jean area (Clark, 1955), and in the St. Hyacinthe area (Usher, 1947; Kay, 1958, p.72; Clark, 1961).

Numerous deep wells drilled for oil and gas in southern Quebec have yielded cores and cuttings. Generalized logs of these have been published in "The Mining Industry of the Province of Quebec", the annual reports of the provincial government, between 1951 and 1961. In these logs only the stratigraphic horizons represented and their thicknesses are given. The data on wells drilled up to the end of 1958 were summarized by DeBlois (1959), and a map showing the location of the wells was compiled by Simard (1959) and added to the report by DeBlois. In this publication 31 wells are mentioned as containing Chazy (excluding the St. Philippe No.1 well), and 10 wells in which the Chazy is not recognized between older and younger stratigraphic units. Since the publication of this summary the generalized logs of four additional wells containing Chazy were brought out (Quebec Department of Mines, 1961, pp.35-38).

Belyea (1952) gave detailed logs of wells, 7 of which have Chazy control. She presented a fence diagram showing the extent of the Chazy. The basal 90 feet in the St. Philippe No.1 well were

assigned by her (p.103) to the Chazy, but according to Clark (ms.) this is Deschambault (Trenton), and it is considered as such here.

An outcrop map with location of wells is given at the end of the paper (in pocket). An isopach map of the Laval formation is presented on p.21 (Fig. 3). The thicknesses shown are those appearing in publications. Except for three wells the cores were not critically studied by the writer, partly because cores or cuttings were not accessible. Geophysical logs were not available.

As can be seen on the isopach map, there is an irregular distribution with some peculiar characteristics. In the northeastern part the thicknesses range from 0 to more than 970 feet over a very short distance, and isopach 'holes' appear near Three Rivers. In the Montreal region and towards Lac St. Pierre the thickness is more constant, ranging from 205 to 390 feet. South of St. Jean the thicknesses again become anomalous, ranging from 450 to more than 670 feet. The general trend of the isopach lines is in a north-westerly direction, but there are complications. It may be that much of the sandstone logged as Chazy (DeBlois, 1959, pp.3-4) in the lower parts of the wells in the northeastern area is actually older than the Chazy. On the other hand, if it is Chazy, the great thickness of sandstone probably represents an accumulation in a trough along faults, probably striking northwesterly, as suggested by the distribution of wells where the Chazy thickness is zero. However, without good guide fossils, this problem is not settled.

The isopach 'holes' may be interpreted as hills of Precambrian or other pre-Chazy rocks which stood in the Chazy sea, either below sea level, or projecting above the surface of the sea. Twin peaks of anorthosite of one of these hills are possibly represented by the exposures of Precambrian at Cartierville (Clark, 1952, p.15). The latter were covered before the end of Laval deposition, as inferred from the small outcrop size and the distribution of the Chazy rocks. The thickness of the Chazy is very variable, and possibly there are many more such peaks which stood in the Chazy sea, and remain to be found by further drilling.

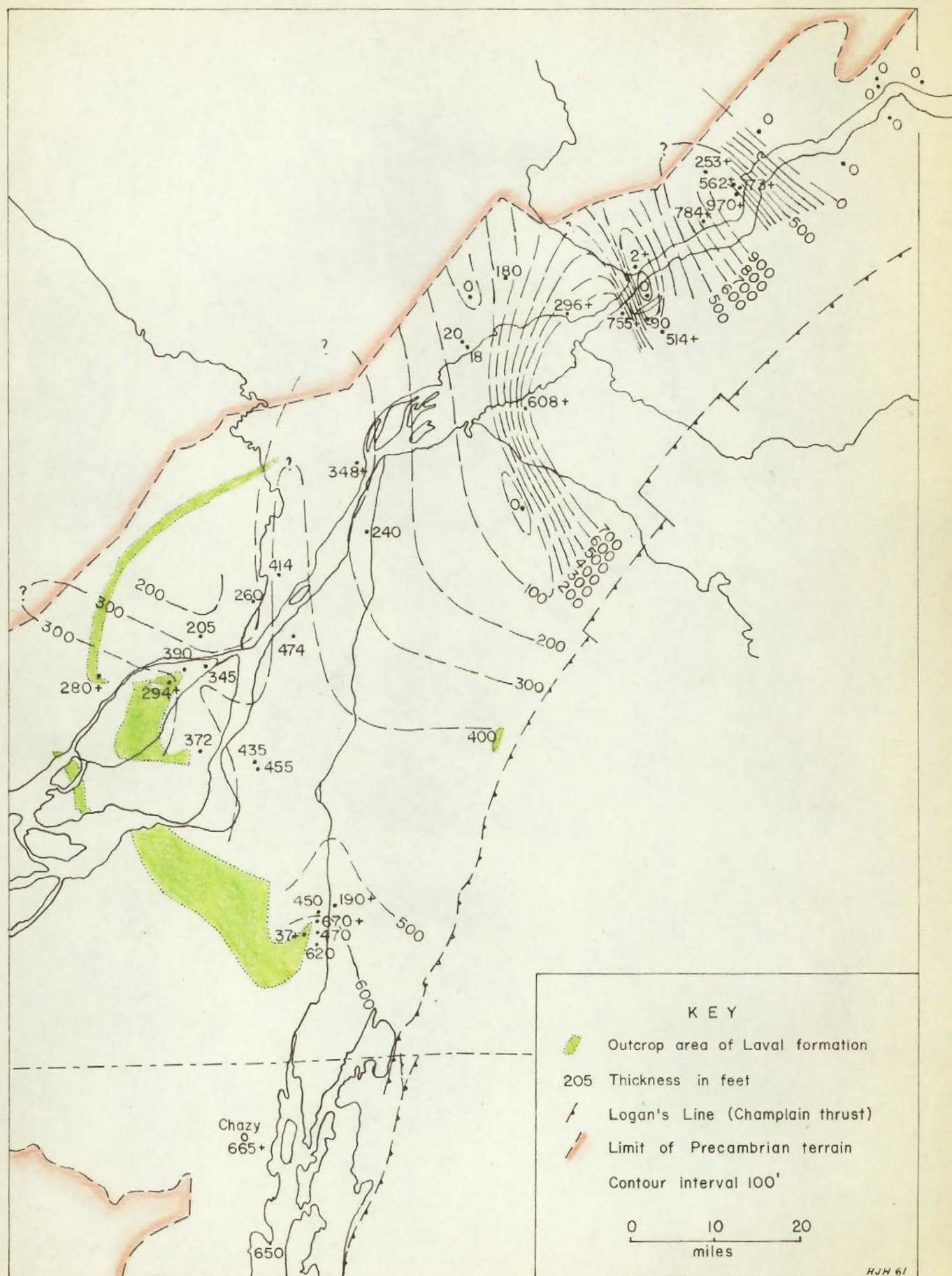


Fig. 3 Isopach map of Laval formation

The thickness of the Chazy group increases southward, to 890 feet on Valcour Island, and then decreases to 306 feet at Crown Point, and to 60 feet at Orwell, Vermont. Isopachs for the Lake Champlain region were given by Oxley and Kay (1959, pp.822-823). It should be noted that the total thickness in the Chazy Village - Plattsburg area increases towards the west.

The Chazy in the Ottawa Valley is about 200 feet thick and thins to the west (Wilson, 1946, pp.18-20). At the Mingan Islands it is about 150 feet thick (Twenhofel, 1938, p.15).

Lower contact:

The lower contact of the Laval formation is nowhere exposed in outcrops or quarries, and as a result this boundary has not been investigated in detail in the St. Lawrence Valley. At only one place, the small village of St. Jacques Nord, 9 miles west-southwest of Joliette, Beekmantown rocks are in close proximity to the Chazy at the surface, although the contact itself is covered.

Byrne (1958), who studied the Beekmantown group in the St. Lawrence Valley, arrived at the conclusion (p.43) that the contact between the Beauharnois and the Laval "is unconformable, though there is no significant break visible in the Mallet Well". The evidence from other wells seems to substantiate the view that this contact is disconformable. It is also disconformable in the Ottawa Valley, as the investigations of Wilson (1937, p.48; 1946, p.17) and McGerrigle (1938, p.46) have shown.

In the Quonto-International No.1 Mascouche well and in some other wells the basal Chazy consists of several feet of coarse-grained, well sorted, carbonate-cemented quartz arenite with a characteristic coquina of Lingulella? sp. In other wells this lithology is absent, and in these it is quite difficult to place the boundary because of the variable nature of the lithologies.

The existence of a significant break between the Beekmantown and the Chazy is best shown by the fauna, as already demonstrated by previous authors with regard to the Ottawa Valley (see Wilson,

1937, pp.48-54). Rocks of the Beekmantown group in the St. Lawrence Valley are generally not very fossiliferous. They contain, however, in some places a varied gastropod fauna with Lecanospira and with high-spined genera such as Hormotoma, which have not been recognized in the Chazy. The brachiopods and trilobites of the two units also show no affinities. The first abundant fauna to appear in the miogeosynclinal environment of the Ordovician in southern Quebec seems to have developed during Chazyan time. Many new groups of animals appeared for the first time in the St. Lawrence Valley region: Scyphozoa, Anthozoa, Bryozoa, Cystoidea, Blastoidea, and Crinoidea. The Paracrinoidea and the Pelecypoda are known from the Beekmantown only by a few sporadic occurrences, but are well represented in the Chazy.

The existence of a considerable lapse of time represented by the contact between Canadian and Chazyan rocks elsewhere has been inferred by G.A. Cooper and B.N. Cooper (see G.A. Cooper, 1956, p.7), who recognize a post-Canadian, pre-Chazyan interval -the Whiterock stage- on the basis of brachiopod faunas found in Nevada. This stage has also been recognized by Flower (1957, p.7), based on a study of cephalopods. The term has been accepted by Kay (1960, p.30). In Quebec this stage is confined to the hiatus which is delineated by the disconformity at the base of the Chazy.

It should be mentioned that at least one striking similarity exists between the fossils of the Beekmantown and the Chazy, and that is the ichnofossil Palaeophycus (Hall). In the Beekmantown at Beauharnois and at Ste. Anne de Bellevue there appear in great profusion criss-crossing straight, rodlike bodies, which Billings (1865, p.98) named 'Palaeophycus Beauharnoisensis'. Very similar structures occur in the lower quartz-sandy horizons of the Laval formation in the Lagacé Quarry at St. Martin (Locality 25) and at other localities, to which the name Palaeophycus ancoraforme has been given.

In the southeastern part of the St. Lawrence Valley the eastward thickening wedge of the Beldens formation lies below the Laval and above the Beauharnois (Clark, 1955). The Beldens does not

occur in the Montreal area, and may possibly be cut out by pre-Laval erosion, or by non-deposition, or by facies change within the Beekmantown. The westward wedging-out of this formation is a problem outside the scope of this thesis.

Lower Laval quartz-sandy beds (including Ste. Thérèse, Joliette, and St. Dominique sandstone members:

The lower part of the Bolboporites assemblage zone consists mainly of light to medium grey quartz arenites and greenish grey illite shales, but as a whole it is an extremely variable sequence of lithologies, with gradations into dolomitic shales and calcarenites. The sandstone beds are carbonate-cemented, although a carbonate-clay matrix is prevalent in some units. The cementing minerals weather out easily and their loss renders the rocks friable. This may partly account for the paucity of outcrops of the sandstone units in the Montreal region. Another reason is the presence of a multitude of thin shale beds interlayered with the mostly medium- to fine-grained arenites, which precludes the formation of any massive outcrops (see Pl. 1, Fig. 8).

In some areas a characteristic coarse-grained to conglomeratic quartz arenite with a Lingulella? coquina lies at the base of the Laval formation. This has only been seen in well cores.

Towards the north and northeast of the Montreal area there is an increase in the quartz grain content and also in grain size, both of which are related to the position of the shoreline of the Chazy sea. The rocks in the Laurentides map-area and at Joliette (the Joliette sandstone member of the Laval formation) are more massively bedded, partly cross-bedded, and shale beds are absent or unimportant in size. These rocks occupy a higher stratigraphic position in the Bolboporites zone than the sandstones further south. Much coarse-grained clastic carbonate (recrystallized calcareous skeletons) is present, and most gradations between quartz arenite and quartz-sandy calcarenite can be seen. These beds are further discussed in the section on the St. Martin member.

Westwards from Montreal the sandstones and shales increase

in thickness relative to the remainder of the Chazy succession, until at Ottawa most of the Chazy is shale and sandstone, the Rockcliffe formation of Wilson (1937, p.46; 1946, p.18).

In the St. Dominique area, 33 miles east of Montreal, the lower sandstones (St. Dominique sandstone member of the St. Dominique formation) are brownish grey to dark grey, cross-laminated, and contain many shale partings. These partings are colored by bright red to orange hydrous iron oxides, from which no distinct X-ray diffraction pattern was obtained. The sandstones comprise roughly the lower third of the Chazy group at St. Pie Hill (Locality 52), and are calcareous, especially in the upper parts where they are interbedded with dark grey calcarenites.

The lower quartz-sandy beds have their lithologic equivalents in the Champlain Valley: the Head and Wait members of the Day Point formation (Oxley and Kay, 1959, p.825). At the Mingan Islands conglomerate and shale are present in the lower parts of the Chazy (Twenhofel, 1938). However, these are not necessarily all of the same age.

The detrital minerals are of many kinds, and those identified by optical and X-ray diffraction methods are given below.

Inorganic

Apatite RR
Corundum C
Magnetite R
Microcline C
Microperthite R
Muscovite, and clays - chiefly illite (X-ray) AA
Plagioclase A
Potash feldspar (X-ray) A
Quartz AA
Tourmaline R
Zircon R

Organic

Calcite AA
Phosphate A

KEY:

AA = very abundant (major constituent)
A = abundant
C = common
R = rare
RR = very rare, found locally

The largest part of the coarse inorganic detrital minerals is quartz. This indicates considerable mineralogical sorting. Much

of the quartz in the Laurentides map-area and at Joliette is well-rounded (Fig. 4), probably multicycle, and derived to some extent from Beekmantown and Potsdam sandstones.

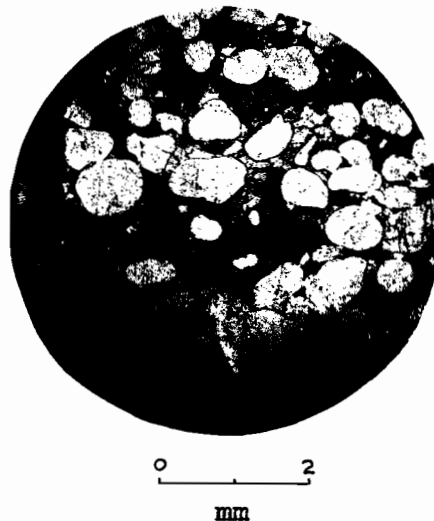


Fig. 4.

Photomicrograph, Joliette sandstone member; Joliette, Quebec.
Well-rounded, carbonate-cemented quartz grains
and organic fragments (bryozoans and echinoderms).

The varied accessory minerals come from several provenances, most or all of which are located in the Grenville geological province of the Canadian Precambrian shield.

The minerals listed on p.25 are those commonly found in sedimentary rocks, and the only unusual one in the list is corundum. It was found in the fine-grained quartz sandstone beds in the Cap St. Martin region, where it makes up about 1 percent of the rock. Corundum is derived from silica-deficient igneous and metamorphic rocks, such as occur in certain regions of the Grenville province. It is especially abundant in alkali syenites in the area around Bancroft, Ontario.

The fauna in the lower sandstones and shales is benthonic, as demonstrated by the abundance of ichnofossils and sessile sponges, but a few others also occur (e.g., orthocone cephalopod fragments). The characteristic fossils are listed in Table 2, p.14.

Middle Laval shaly limestone and calcarenite beds:

Another highly variable sequence of beds occupies approximately the middle third of the Laval formation. This is the upper part of the Bolboporites zone, of predominantly shaly limestone and calcarenite lithologies. Nearly all gradations exist between shale and calcarenite, with the more common mixture being 50 - 70 percent calcarenite. Where the intermediate stages are developed a characteristic 'lumpy' bedding is present, resembling sedimentary boudinage (Pl.1, figs. 4,6,7). This is due to irregular, oblate, or elongated aggregates, 1 - 2 inches across, of biogenic calcarenite or calcisiltite within shale beds which may be silty or dolomitic.

Inasmuch as nearly all intermediate gradations are encountered as a result of the accumulation of varying proportions of the end members, any subdivision of the unit is artificial. The only subdivision useful for mapping has already been established. This is the 'St. Martin member', which comprises the calcarenite end member of the series. It is treated in the next section.

The shale-calcarenite series is complicated further by the presence of other minerals, chiefly coarse clastic quartz. Dolomite and pyrite also occur in variable proportions, but these minerals are not detrital as far as could be determined. The euhedral dolomite is practically always confined to shale seams or patches, or very thin clay films (microstylolites).

In many layers a bryozoan shaly dolomite or dolomitic shale is developed, in which branching trepostomatous bryozoans constitute nearly half of the rock (Pl. 1, Fig. 5).

The fossils in the shaly limestones are the same as those found in the calcarenites, with the exception of a few species, notably the ostracods and Sphenotreta acutirostris (Hall) (see list in Table 2, p.14). These animals probably did not thrive in the muddy water environment.

St. Martin member:

Wilson (1937, p.54) used the name 'St. Martin formation' for the exposures at Cap St. Martin (see Wilson 1946, p.17). Without properly defining it, she gave the following description (1937, p.54): "The St. Martin consists of arenaceous shales interbedded with thin bands of more calcareous material and some dolomite." This is with reference to the Ottawa Valley and that part of the Chazy which overlies the Rockcliffe sandstone. She went on to state that "to the east [towards Montreal] the St. Martin becomes thicker and the limestone members become more prominent." A type section was not described.

In a later publication Wilson (1946, pp.19-20) described a limited section of rocks under 'St. Martin formation', from "about one mile east of where Green Creek crosses the Ottawa-Montreal highway" (7 miles E.N.E. of the Alexandra bridge joining Ottawa and Hull). The section is only about 20 feet thick and contains much shale and dolomitic material. It is near the western edge of the outcrop belt of the Chazy calcarenites, and the rocks are not typical of the massive calcarenite units of the Laval formation in the Cap St. Martin area — the St. Martin member (Clark, 1952, p.44) and the undefined Caughnawaga member (Clark, 1944a, p.29).

A measured type section at Cap St. Martin has never appeared in any publication, nor have any thicknesses at that locality been given. Consequently, the term 'St. Martin formation', used in Wilson's sense, has no formal status (see Amer. Comm. Stratigraphic Nomenclature, 1961), and should be removed from the list of formal stratigraphic names. The term 'Laval formation' was defined properly (Clark, 1952, p.43) and is used here so as to include Wilson's 'St. Martin formation', as well as the lower sandy beds of the Chazy of southern Quebec.

The St. Martin member, as used in Clark's sense (1952), refers to a calcarenite development which occurs as a 64-foot unit in the Mallet well, and was thought to be representative of a continuous horizon. 'St. Martin member', as now understood by the writer, refers to massive beds of the calcarenite facies which are

scattered through the Laval formation. The member occurs predominantly in the Bolboporites zone, but is also developed in the Rostricellula plena zone.

There are many good quarry exposures of the calcarenite members in the Laval formation (stratigraphic sections at the principal localities are given in a succeeding chapter). The sections at Cap St. Martin and at near by Village Bélanger comprise 50 to 65 feet of nearly massive crystalline limestone, the typical St. Martin member. These are minimum thicknesses, as the top boundaries are formed by the Pleistocene glaciated erosion surface. The thickest section of calcarenite was observed in the St. Francis Quarry (Locality 30) on Côte Vertu Boulevard, St. Laurent. Here 130 feet of calcarenite are vertically continuous, except for two shaly limestone and three shaly dolomite beds which are interbedded and make up less than 20 feet of the whole section.

Cross-bedding is a characteristic of the calcarenite members of the Laval formation, and is most conspicuous in massive beds (Fig. 5). In many of the cross-bedded units fine- to medium-grained quartz is scattered throughout. Except for the small species, such as the ostracods, and some of the more durable ones, such as the brachiopods, the skeletons are fragmentary. This is especially true of the trilobites, with which difficulties are encountered in identification. The cross-bedding and the fragmental state of the fossils both indicate that strong currents existed in the Chazy sea.

The direction of dip of the foreset beds, which is the direction of sediment transport, is not always consistent in any one outcrop or quarry. The observations made at 11 localities are summarized in Fig. 7. A current-rose diagram with angular intervals of 18° was constructed to group the various vectors. While this shows considerable scatter, two main peaks are evident: one in a northwesterly direction, and a larger one in a southeasterly direction. This bimodal pattern might suggest that the main directions of transport followed a setting of reversible currents, such as could be expected from strong tides. The shoreline would in this case be



Fig. 5.

Medium-scale cross-bedding in quartz-sandy calcarenite.
Road cut on Montée St. Aubin, near cloverleaf exit 7 of the
Laurentian Autoroute (Locality 25). View in N.W. direction.
Yardstick at left gives scale.



Fig. 6.

Slump structure in quartz-sandy calcarenite.
Outcrop at water tower of St. Martin village.
(Locality 25). View in S.E. direction.

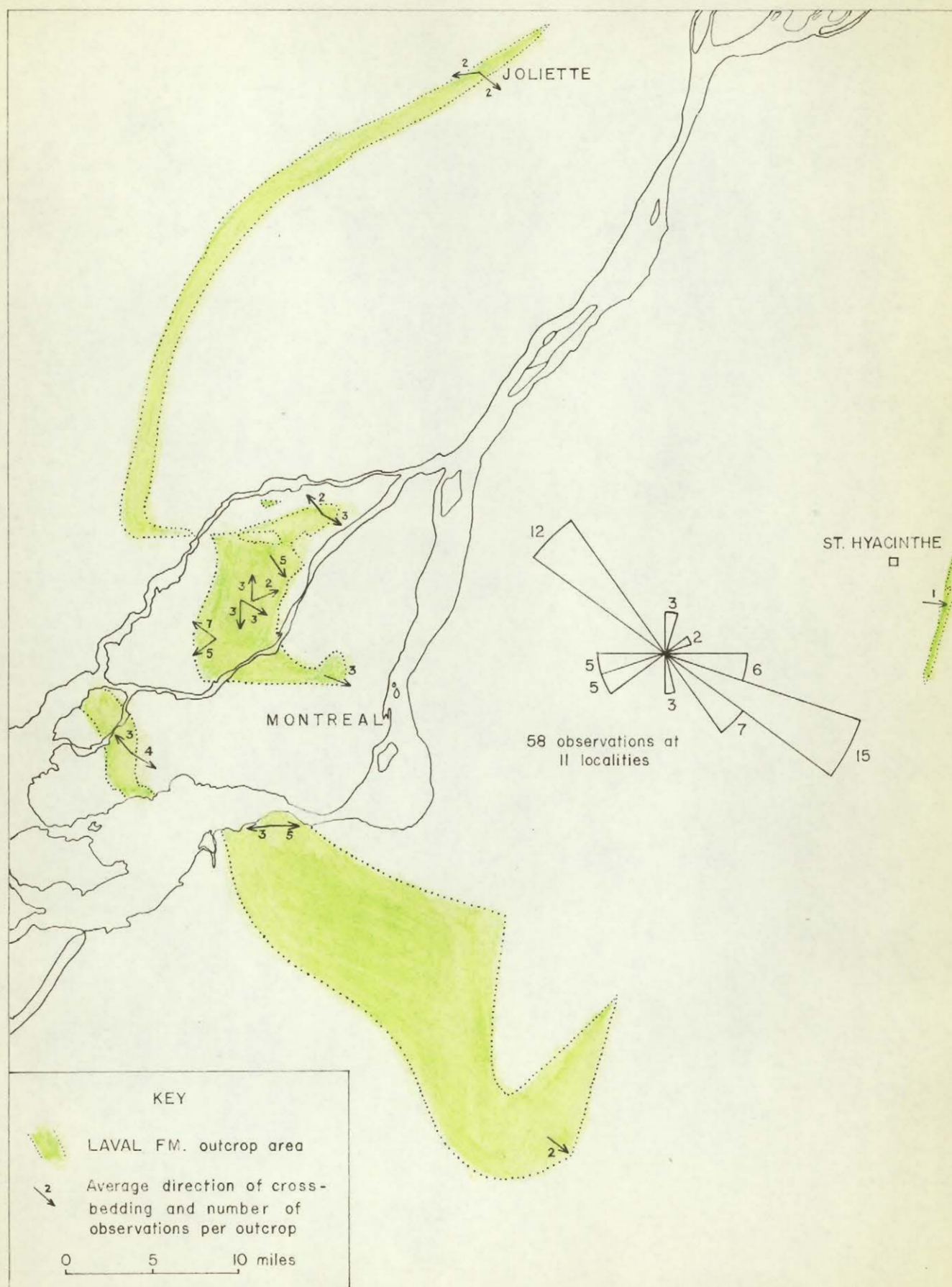


Fig. 7. Cross-bedding in LAVAL FORMATION.

more or less perpendicular to the direction of cross-bedding, i.e., northeastward-trending. One should note, though, that more than half of the northwestward-pointing cross-bedded units (7 out of 12) occur at one locality, in the St. Martin area, and that if the remainder only is taken into consideration, there is a strong peak for the southeasterly direction. In this case the main direction of transport is from the northwest to the southeast. The cross-bedding could be that of a delta or could be due to longshore currents, or both, and hence the direction of sediment transport may be perpendicular or parallel to the shore.

A slump structure (Fig. 6) was found in the outcrop on which the onion-shaped water tower of the village of St. Martin is erected (Locality 25). It is within a poorly fossiliferous and very quartz-rich calcarenite which is overlain by very calcareous, cross-bedded quartz arenite. The deformation is confined to a bed 1 foot thick, and was evidently originated by some force which caused the water-logged, unconsolidated material to slide from its original position along a steep slope (foreset bed), and in the process distorted the adjoining sediment. There are several forces which could account for making an unconsolidated layer unstable: submarine tremors, powerful waves, great sedimentary load, tilting of sea floor, etc. Since this was the only structure of its kind to be observed, the force must have been local, and the most reasonable explanation seems to be that too great a load accumulated on an unstable slope, causing the water-logged sediment to slide away.

Oolitic limestones, mostly of dark grey color, are well developed locally where lutitic material, highly saline water, and the action of currents favoured their formation. They were found in the upper parts of the Bolboporites zone, and it is perhaps no mere coincidence that coral bioherms occur at the same horizons. In thin sections the ooliths are seen to be composed of a nucleus, often some shell fragment, surrounded by an agglutinated (and chemically precipitated), concentric structure of very fine-grained clayey carbonate. The ooliths range in size up to 2 mm., but most are

about 1 mm. across.

Coquinal and coquinoïdal limestones are found at many places. They are common in the earliest calcarenite layers in which Mimella borealis is very abundant. The highest calcarenite layers are in places also coquinal, forming a Rostricellula plena graveyard (e.g., Locality 6). Actually, the greater part of the calcarenites is composed of crystallized echinoderm fragments, and thus constitutes an echinoderm coquina.

Brownish, yellow-weathering, sugary dolomitic patches and streaks, up to 2 or 3 cm. across, are scattered through some of the calcarenite beds (e.g., Locality 12). Goudge (1933, p.56) analyzed several of these patches chemically, and determined that they usually contain a much higher content of "impurities such as silica, iron, sulphur, and compounds of sodium and potassium" than the surrounding calcarenite.

Another very common structure in the calcarenites is the development of dark grey to black stylolite seams which traverse the rock with a subhorizontal trend. Microstylolites are also visible in thin section (Fig. 8). These seams follow closely the calcite grain boundaries, and represent deformed shaly laminae and surfaces of pressure-solution activity.



0 5 10
mm

Fig. 8.

Photomicrograph of microstylolites in calcarenite. Grains and cement are calcite. St. Martin member, 60 feet above bottom of Billet Quarry (Locality 23).

Within the calcarenites of the upper parts of the Bolboporites zone, and possibly the lower parts of the Rostricellula plena zone, some of the earliest coral bioherms developed. The deposits flanking these structures are fairly steeply dipping, coarse-grained, fragmental limestones, some containing material derived from the bioherms. These reefs are described in the next section.

In some places, previous investigators have noticed that coarse crystals of calcite and uncrystallized bryozoans have a pink color. This phenomenon is not confined to one horizon, but does occur at several levels within massive calcarenites (e.g., Locality 40). In some large crystals, such as the deltoid plate of Blastoidocrinus, one can observe that only partial coloring exists, and that there are no sharp boundaries between the pink and the uncolored parts of the crystal. An examination by X-ray fluorescence has shown the presence of manganese in the crystal structure, and this may be responsible for the coloration. The substitution of manganese for calcium took place while the echinoderm fragments crystallized from three-dimensional meshwork lattices into single coarse crystals; it is a post-depositional feature, related to the process of lithification.

An exception to this is in the St. Lin area (Locality 8). Here a calcarenite is in contact with a trap sill (Logan, 1863, p. 133; Goudge, 1935, p. 82), although today the colored limestone is only found as loose blocks (Clark, 1960, p. 25). The whole rock has a brownish red color, slightly darker than the pink color of the manganese-bearing calcite crystals of the Montreal area. The coloration at St. Lin is due to the impregnation of the rock with clay-sized grains of hematite pigment, probably resulting from the near by intrusion.

Blebs of yellowish green sphalerite were collected at two localities (25 and 37). They range from 8 mm. to 2 cm. in diameter. Their large size and lack of weathering features points to an authigenic (post-depositional?) origin of these bodies. The enrichment of zinc and sulfur in these blebs is not clearly understood.

Where these bodies were found there is no evidence of faulting or veining, so that they are not due to hydrothermal activity. They probably originated at some time during diagenesis, before lithification was complete and the pore space was eliminated by carbonate cementation. Similar sphalerite blebs are found in the Deschambault (lower Trenton) limestone.

Abundant purple fluorite occurs at the bottom center of the St. Francis Quarry (Locality 30). Together with calcite it is concentrated along seams, although parts of the calcarenite host rock is also impregnated with fluorite. A near by fault zone, striking 103° , suggests that the mineralization is related to the faulting, probably resulting from the interaction of rising fluorine vapours or solutions with the calcite of the country rock.

The chemical composition of limestones of the Laval formation as well as detailed petrologic descriptions for many localities were given by Goudge (1935). Most analyses show a high CaCO_3 content, with MgCO_3 being generally less than 10 percent. For further data his publication should be consulted.

The fauna of the calcarenite members is very varied; yet it is scarce in some localities. More than half of the species listed in the correlation table (Fig. 20) have been found in the calcarenite horizons exposed in the Laval, Lachine, St. Jean, and Lacolle map-areas. The more characteristic ones are included in Table 2, p.14.

In the Laurentides map-area the calcarenites appear more quartz-sandy, and at Joliette in the Sorel map-area many or most of the beds are calcareous quartz arenites. After treatment of these rocks with 10-percent, cold HCl, insoluble residues comprise up to 66 percent. Cross-bedding is present, but is not as pronounced as on Ile Jésus. The fauna is also somewhat different from that of the Montreal area, and indicates that the beds belong to a horizon somewhere near the top of the Bolboporites zone and at the base of the Rostricellula plena zone. Among others it contains the following species: Rostricellula plena (Hall), Sphenotreta acutirostris (Hall), Dorytreta? arduamarginata n.sp., Bucania sulcatina (Emmons), and Pliomerops canadensis (Billings). The last two species occur in

common association just below the Rostricellula plena zone in the Champlain Valley (Raymond, 1908, p.196).

Much of the calcarenite in the St. Jean and Lacolle map-areas is argillaceous, of dark grey color, and very poor in terrigenous detritus. At St. Dominique the calcarenite beds are also of dark color and contain much shaly material. The faunas at these localities are different from those in the Montreal area (see Correlation Chart, Fig. 20).

Bioherms:

Four coral bioherms in the Laval formation were studied and discussed in detail by MacGregor (1954), and the northernmost of these was described by Clark (1960, pp.26-27).

These structures appear to be confined to a stratigraphic position near the top of the Bolboporites zone. They have been recognized only in outcrops, and their distribution is, no doubt, very patchy. The outcrops described by MacGregor and an additional one (at Locality 49) not described by him are the only ones known, and seem to lie along a northwest-trending line. Whether this is significant or whether this is just coincidental with the shape of the outcrop belt is not established. It is well to note, however, that this trend is nearly parallel to that of the isopach lines.

The bioherms are composed of coral and bryozoan colonies, with interskeletal accumulations of calcilutite that is commonly dolomitized and weathers light bluish green with a brownish tinge. They occur as 5 - 10 feet high ridges, up to 700 feet long, and 30 - 100 feet wide, and may be in sharp contact with flanking calcarenite beds or exhibit a gradational contact (Figs. 9, 10). The flanking beds have a comparatively steep dip (up to 15°) close to the bioherm and are more gently dipping 10 feet or more away.

The south end of the reef at Locality 49 shows a channel-fill structure (Figs. 11, 12). A branching channel several inches wide and 2 to 3 inches deep is cut into the light bluish grey limestone. It is filled with dark grey calcarenite with bryozoans and other



Fig. 9.

Two bioherms, separated by steeply dipping calcarenite beds, and joined at the top. The structures seem to have grown towards the right. Meunier Quarry (Locality 12). View looking N.W. Yardstick at lower left gives scale.



Fig. 10.

Close-up of bottom of a bioherm. Floor is comprised of deformed calcarenite, and is covered by rubbly weathering bioherm. Meunier Quarry (Locality 12). N.W. wall of quarry. 25-cent coin at center right gives scale.



Fig. 11.

Reef channel filling (dark grey) at Locality 49.
Brunton compass at top center points due north.

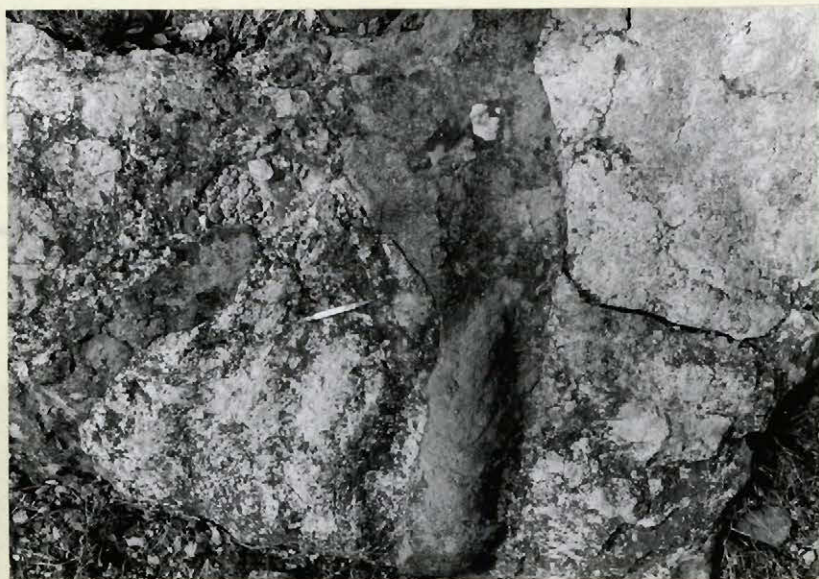


Fig. 12.

Vertical close-up view of the branched channel shown in Fig. 11.
Note sharp contacts and darker color of the filling.
Pencil at center points due north.

faunal debris. Channel fillings have also been reported from the Champlain Valley (Oxley and Kay, 1959, p.835). These structures strongly suggest that the reefs were near the ocean surface, in the intertidal zone, and perhaps experienced subaerial erosion on their tops during low tide.

The conclusions reached by MacGregor (1954) seem reasonable. They are that the reefs accumulated on an ocean floor less than 150 feet deep, in clear, silt-free, agitated, and circulating waters with a temperature between 65° and 70°F. (18° and 21°C).

A fairly simple fauna is found in the bioherms proper. It consists of either of the corals Billingsaria parva (Billings) and Eofletcheria incerta (Billings), or both, and various forms of encrusting and branching bryozoans.

The order of appearance of the reef builders can be determined at the Meunier Quarry (Locality 12), where several bioherm lentils are exposed. It is as follows. The floor of the reef body is calcarenite with Rostricellula raymondi Cooper, Malocystites murchisoni Billings, and bryozoans. The first (lowermost) fossils of the reef are small scattered patches of encrusting bryozoans. These are followed by discontinuous thin layers of Billingsaria parva which encrust the earlier bryozoans and parts of the calcarenite floor. There are only several thin layers, and these are overlain by light bluish green, dolomitic calcilutite, in which pockets of Eofletcheria incerta coralla are randomly distributed. It is not known whether this sequence is duplicated elsewhere.

Another type of bioherm, with attendant biostrome, consists of the bryozoan shaly dolomites and dolomitic shales containing fairly thick lenses or mats of branching trepostomatous bryozoans. These were encountered at many places and at various horizons, and they are also easily recognized in well cores (Pl. 1, Fig. 5). The colonies are found in fine-grained, sugary, dolomitic beds, which weather orange, and apparently do not contain any other kinds of fossils.

Upper Laval beds - Beaconsfield member:

At the top of the Laval formation there occurs a predominantly argillaceous skeletal brachiopodal calcisiltite, which becomes more and more dolomitic towards the top. It is a lithofacies unit in the Rostricellula plena assemblage zone, and is essentially free from coarse terrigenous detritus, although quartz siltstone beds can be found.

The type section is at the Pointe Claire Quarry on St. Charles Road in Beaconsfield (Locality 38) and is described in the next chapter. The base of the member was not observed. The upper boundary was placed at the 65.5' level, at the top of the last bed in which Rostricellula plena is common, and at the base of the first massive bed of dolomite typical of the Pamelaia. The minimum thickness of the member at the type section is thus 65.5 feet.

One can recognize the member at several other places and in well cores by the fact that it is a variable shaly limestone of fine to medium grain and carries Rostricellula plena. It should be remembered that the unit may locally be replaced by a calcarenite development (St. Martin calcarenite in the Rostricellula plena zone), and therefore be absent at certain levels or localities.

At the base of the quarry of the type section there are ripple marks striking 135°, with wave lengths of 6 to 12 inches and low amplitude (Fig. 13). This is the only known occurrence of this type of structure within the Laval formation. Although this unique observation is statistically not significant, one should, nevertheless, note that the strike of the ripples is parallel to the trend of the main cross-bedding direction, and the trend of the isopach lines.

The fauna of the Beaconsfield member is quite restricted in that the largest number of fossil specimens (coquina in some places) is made up of but two species: Rostricellula plena (Hall) and Palaeoglossa? belli (Billings) (or Lingulella? sp.; see section on paleontology). In the upper, dolomitic layers pelecypods are common. The gradational nature of the upper contact is next discussed.



Fig. 13.

Ripple marks in the Beaconsfield member.
Bottom of Pointe Claire Quarry, Beaconsfield. View in S.E. direction.
Yardstick just below center of picture gives scale.

Upper contact:

The Laval - Pamela contact in the Montreal area has been a matter of speculation and uncertainty. Okulitch (1936, p.127) interpreted it as a disconformity at the base of the rusty weathering, silty carbonate beds and on top of a dark brownish grey, dolomitic shale, in the St. Vincent de Paul Quarry. This was also viewed as the boundary between the Chazy and Black River groups, although he found no diagnostic fossils within the Pamela to support his interpretation at that time. Later authors have consistently followed Okulitch's interpretation without adverse criticism.

Because of the uncertainty of the boundary in the Devito Quarry and in the Pointe Claire Quarry, the writer undertook a detailed study of the change in lithology and in fauna from the upper part of the Beaconsfield into the Pamela. As the Pamela is a predominantly dolomitic sequence and the Chazy is mainly calcareous, it was thought best to approach the lithologic aspect of the problem on the basis of calcite-dolomite ratios. To this end,

the determination of these ratios depended on some rapid method of estimating the relative percentages of calcite and dolomite. The method selected was that used by Webber (1957), which is based on X-ray diffraction (see Appendix 1). The results of the study of the section at the Pointe Claire Quarry are all summarized in Fig. 14. It is evident that dolomite is well developed in several layers below the top of the Beaconsfield, and that the top part of the Pamela is calcareous dolomite. There is a preference for dolomite to form in shaly or sandy beds.

The variations in the position of the 2θ peaks (peak shift) indicate an apparently non-systematic vertical variation of the ionic substitution in both calcite and dolomite, but these variations follow a nearly identical pattern. The 2θ values for calcite (104) are all greater than that for pure calcite (i.e., greater than 29.40°). The maximum peak shift for calcite is about $0.2^\circ 2\theta$, which corresponds to about 5 percent of diadochy in terms of carbonate of some other ion, probably magnesium (see Gulbrandsen, 1960a, p.96).

Peak shifts in the dolomite from the standard ($d = 2.887\text{\AA}$; $2\theta = 30.97^\circ$) are, with one exception, towards a smaller 2θ value, indicating substitution of some ion with a radius greater than that of magnesium ($0.78\text{\AA}$) in the magnesium positions, or greater than that of calcium ($1.06\text{\AA}$) in the calcium positions in the crystal lattice. From crystal chemistry considerations, the latter is unlikely because ions larger than calcium, such as strontium or barium, would have stabilized the structure in the orthorhombic system (aragonite structure), with consequent loss of the dolomite (112) peak. It is more likely that substitution of the magnesium by a larger ion has occurred, and probably it is calcium.

The nearly identical pattern of the peak shifts is explained by interrelated ionic substitution; beds in which the calcite has the most diadochous magnesium, the dolomite has the least diadochous calcium, and vice versa.

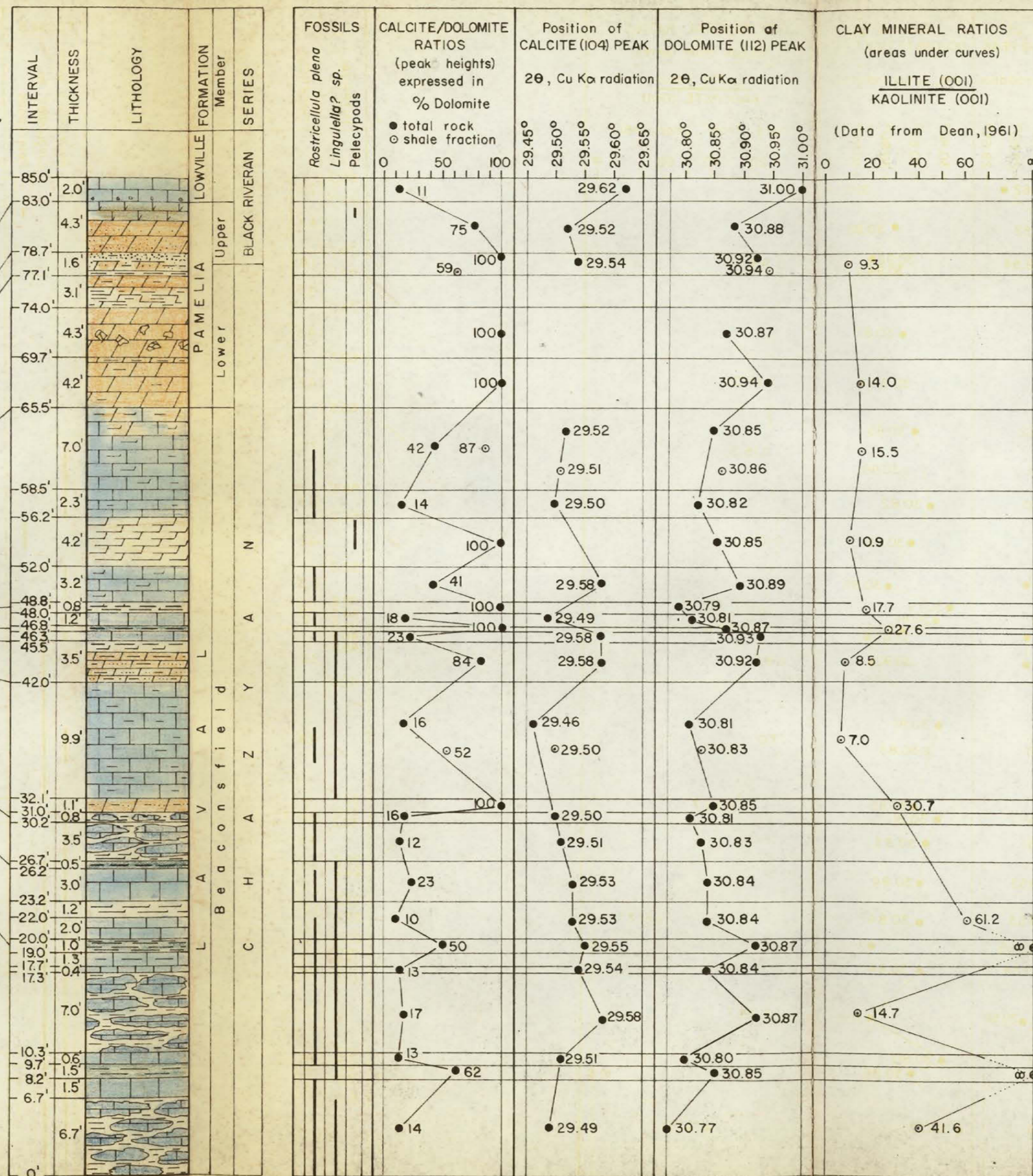
The clay minerals, which were studied in detail by Dean (1961) in a joint effort with the writer, show a tendency for kaolinite to increase with respect to illite in the higher parts (Fig. 14).

Fig. 14.

POINTE CLAIRE QUARRY SECTION, BEACONSFIELD



VIEW OF CHAZY - BLACK RIVER SECTION,
CENTRAL PART OF SOUTHEAST WALL OF QUARRY



The guide fossil for the Beaconsfield, Rostricellula plena, occurs above the first few dolomite beds. The shale facies fossil Lingulella? sp. was not observed above the 46.3' level. Pelecypods are present in dolomitic shale below the uppermost Rostricellula plena layer, and again at the top of the Pamelia.

In the Devito Quarry the situation is similar, only more helpful, because the beds there have been exposed to weathering for a long time, and hence the fossils are more easily found. Lingulella? sp., Rostricellula plena, and pelecypods were found to continue from the Beaconsfield into the Pamelia.

From these observations one can conclude that the contact is gradational, that the change from Laval to Pamelia deposition was gradual, with many fluctuations of the conditions of sedimentation in the species-poor Beaconsfield, and with the foreshadowing of Pamelia-type dolomitic sedimentation already in late Beaconsfield time. Nevertheless, one can place the boundary arbitrarily at the top of the last bed rich in Rostricellula plena, which in the Pointe Claire Quarry happens to coincide with the base of a dolomite bed. At the Devito Quarry the position of the boundary is not so readily evident, because the rocks are more shaly, and the basal dolomite bed is very thin and separated from a Rostricellula plena bed by 3.5 feet of silty, dolomitic shale (see description of stratigraphic section). The boundary has been arbitrarily placed at the base of the dolomite bed at 18.8', because the Rostricellula plena layer at 13.8' - 15.3' lies between beds of similar lithology.

The contact at the St. Vincent de Paul Quarry is placed arbitrarily at the base of a shale bed (Bed No. 6 of Okulitch, 1936, p.126), rather than on top of it, as Okulitch has done. The reason for this is that this shale more closely resembles the dark brownish grey, dolomitic shales of the Pamelia in the Devito Quarry, than it does to the olive green, silty, dolomitic shales in which beds of lumpy-bedded shaly limestone with Rostricellula plena occur (see Fig. 21 for correlation of the contacts).

Pamelia Problem

The Pamelia formation was named by Cushing (1908, p.158) for exposures of blue and dove limestone and magnesian limestone, and basal sandstone and green shale, near Pamelia, Jefferson County, New York, on the southwestern limits of the Adirondacks. The lower parts of these beds are the 'Depeauville' of Emmons (1840, p.324). In the type area the Pamelia is unconformably underlain by the Theresa formation, but further southeast it lies on Precambrian rocks. Cushing thought the Pamelia occupied a stratigraphic position between the middle and upper Chazy.

Since Cushing's original paper the opinions on the position of the Pamelia have been varied. In two later papers Cushing (1910, 1911) mentioned that the Pamelia cannot be successfully correlated with any of the Chazy in the Lake Champlain area, either lithologically or faunally. Raymond (1911, p.189) set forth his opinion that Logan's (1863) Chazy in the Ottawa Valley is actually composed of two formations, a lower one (Aylmer formation) of upper Chazyan age, and an upper one which he correlated with the Pamelia, and which he assigned to the Black River. He followed this classification in later papers (1912, p.353; 1913, p.143). Since then, several other authors have considered the Pamelia of New York to be of Chazyan age, or of Black Riveran age (for summaries see Young, 1943, p.151; Wilmarth, 1957, pp.1594-1595).

Wilson (1932) reviewed the Pamelia problem in the Ottawa Valley and found (p.138) that the Pamelia there can be divided into two parts: 1) a lower sandy phase with thin rusty brown weathering layers of dark limestone, in places coarsely crystalline, and in other places fine-grained dolomite; 2) an upper phase of mainly grey limestones and thick beds of fine-grained dolomitic material, both interbedded with considerable amounts of shale and occasional layers of sandy material.

The two phases also carry different faunas (Wilson, 1932, pp.139-144). The lower one contains obscure pelecypods, gastropods,

some ostracods, and fragments of a Lingulella?, all of which are, however, neither diagnostic of the typical Chazy, nor of the typical Black River. The upper phase carries gastropods, pelecypods, ostracods, fucoids (ichnofossils?), Tetradium, and Bathyurus extans (Hall), characteristic of the Black River. Thus, the actual evidence for a correlation of the Pamelia with the Black River has been found only in the upper part of the Ottawa Valley section.

A comprehensive study of the Black River stratigraphy and faunas in New York and Ontario was made by Young (1943). He referred (p.152) to Wilson's paper which cites as chief evidence for a Black River age the presence of Bathyurus extans, and stated that in New York Bathyurus sp., cf. B. extans has been found only in the lower divisions. Young compared the Ottawa Valley section with the type Pamelia in New York, and concluded that, while there are some differences in the range of faunas of the two areas, the lithologies are so similar as to make their equivalency fairly certain. He favoured a post-Chazyan age of the Pamelia.

Raymond (1912, p.353) thought that the Pamelia did not extend further east than L'Orignal, and hence that it is absent at Montreal. Okulitch (1934; 1936, p.127) recognized about 10 feet of rusty weathering dolomitic beds at Montreal that lie between Tetradium-bearing Lowville and beds rich in Rostricellula, and correlated them with the Pamelia of the Ottawa Valley. These beds are exposed in several quarries, and an outcrop also occurs in the Ouareau River at Les Dalles, in the northeast corner of the Laurentides map-area.

Okulitch (1936) saw no break between the Chazy (Laval fm.) and the Pamelia (p.128), and none between the Pamelia and the Lowville (p.129). He further said (p.128) that on a faunal basis there was no connection between the Laval and Pamelia seas, as the fauna of the Pamelia "shows close relationship with that of the Lowville, whereas it is totally different from that of the Chazy." This is a somewhat strong statement, considering that the fauna of the Pamelia, as he found it in the Montreal area, consisted only of

Lingulella sp. indet. Okulitch (1934, p.61) originally correlated the Pamelia of Montreal with that of the Ottawa Valley purely on lithologic grounds, whereas he assigned a Black Riveran age to the Montreal Pamelia with fossils that do not occur there and which Wilson had found only in the upper part of the Ottawa Valley Pamelia. This correlation is not very sound, because it assumes that the Pamelia (lithostratigraphic unit) is a time-stratigraphic unit. However, later Okulitch (1939, p.84) studied the 8-foot section of Pamelia at the Ouareau River, from which he reported Rhynchotrema increbescens, Strophomena sp., cf. S. corrugata, and unidentifiable gastropods. Unfortunately, these specimens could not be located, but others from the same locality are poorly preserved, and the Rhynchotrema increbescens might just as well be Rostricellula plena (see discussion in section on paleontology, under R. plena). Previously, Parks (1930, p.21) was unable to come to a conclusion as to which one of the two it was.

About 3 feet below the top of the Pamelia in the Ouareau River section is a 3-inch layer of coarsely crystalline calcarenite with pelecypods and smooth ostracods, which seems to have been overlooked by previous workers. The layer lies just below a zone of sandstone that is very coarse-grained at about 2.5 feet below the top of the Pamelia. The strophomenid brachiopod collected by Okulitch was not found by the writer.

The present work has demonstrated a similarity between the top of the Beaconsfield and the Pamelia. An examination of the section at the Devito Quarry (see stratigraphic section described, and Fig.21) will show that the faunas overlap, and as mentioned in the previous section (p.44), the lithologies also overlap. Furthermore, the occurrence of Rostricellula plena near the top of the Pamelia in the Devito Quarry is good evidence in itself for the Chazyan age of that part of the Pamelia in which it occurs.

The fauna of the Pamelia of Montreal and vicinity as established by the present study consists of the following :

Lingulella? sp.
Rostricellula plena (Hall)
R. sp.
Ctenodonta sp., cf. C. parvidens Raymond
Modiolopsis parviuscula Billings
Michelinoceras sp.
 gastropods
 smooth ostracods.

It is similar to that found in the upper part of the species-poor Beaconsfield member, and dissimilar to the Tetradium- and Bathyrurus-bearing Lowville limestone.

One can correlate the Pamelia of Montreal with that of the Ottawa Valley. The writer thinks that the Chazy - Black Riveran time-stratigraphic boundary (also biostratigraphic boundary) in the Ottawa Valley lies within the Pamelia, instead of at its base, and that most of the Pamelia at Montreal is correlative with the lower phase described by Wilson (1932). At Montreal this boundary is almost at the top of the Pamelia, and the upper phase, as developed further west, has minimal representation. In the Devito Quarry the uppermost bed (Bed No. 7 of Okulitch, 1936, p.123) is a shale 1 inch thick, which in places grades into coarse-grained quartz arenite lenses. This layer, directly below which the Rostricellula occurs, probably represents all of the upper phase as developed in the Ottawa Valley. In the Pointe Claire Quarry and in the St. Vincent de Paul Quarry the uppermost bed is a dolomitic calcilutite, very similar to the overlying Lowville except for its orange weathering color. No fossils have been obtained yet from this besides two or three pelecypod fragments. Inasmuch as this bed is at both localities directly underlain by quartz sandstone, which probably represents an unconformity, the writer is inclined to regard it as the equivalent of the upper phase of the Ottawa Valley Pamelia. The upper layers in the St. Vincent de Paul Quarry are very sandy and silty, and one can observe ripple marks (Fig. 15), mudcracks, and intraformational shale pebble conglomerate, which indicates at least short periods of emergence. These layers represent the most likely horizon at which to place an unconformity. The ripple marks (oscillation type) strike north,



Fig. 15.

Oscillation ripple marks in dolomitic sandstone, with mudcrack fillings. Brunton compass points due north. Upper part of 32.1'-35.1' interval (Pamelia) in St. Vincent de Paul Quarry; central part, southwest wall.



Fig. 16.

Dolomite patches (with elephant-hide weathering) in uppermost St. Dominique limestone at St. Pie Hill, close to S.W. corner of orchard on E. side of hill.

have wave lengths of 2 to 3 inches, and low amplitudes.

At St. Pie Hill the uppermost beds of the Chazy are rich in dolomitic patches and lenses (Fig. 16), and at La Carrière (Locality 51) more massive, unfossiliferous, dolomitic beds appear between St. Dominique calcarenite beds and the Lowville limestone. Neither of these dolomitic horizons can be identified with the Pamela, but it is noteworthy that the top of the Chazy at these two localities is also very dolomitic.

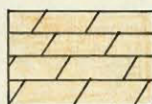
Lastly, one should not fail to mention that^{at} the top of the uppermost Chazy on the north end of Valcour Island, New York, there are 17 feet of orange weathering "tough, arenaceous magnesian limestone, passing upwards into fine-grained sandstone" (Brainerd, 1891; Brainerd and Seely, 1896. Section also quoted in Cushing, 1905, p.367; Raymond, 1906, p.506; Whitcomb, 1941, p.75). This is Raymond's C₁₀ layer (1906, p.521). It carries the Chazy ostracod Eurychilina latimarginata, the only recognizable fossil found by Raymond in this layer. During the present investigation the writer was able to examine this rock, and was impressed by the strong lithologic resemblance to the Pamela of Montreal. The correlation with the Montreal Pamela does not appear to have been suggested in the literature before, although it fits well into the general picture. Of course, such a correlation has very significant consequences, as it throws new light on the relationship between the Chazy and Black River groups on a regional scale, and these are incorporated into a correlation diagram (Fig. 23). As is suggested, the rocks correlated with the type section Pamela, that is, the 'Ottawa Valley Pamela' and the 'Montreal Pamela', appear to be time-transgressive (strictly speaking, 'faunizone-transgressive', for fossils were the basis on which series and stages were established). This conclusion would lend support to the hypothesis of Winder (1960) that Pamela-Lowville-Chaumont-Trenton form a sequence of contemporaneous facies, at least as far as the Black River is concerned. The Pamela represents the near-shore clastics and restricted lagoonal carbonates, the Lowville the sheltered, near-normal marine calcareous muds, and the Chaumont the biogenic calcarenite accumulations in open marine shallow waters.

Stratigraphic Sections, Montreal and Vicinity

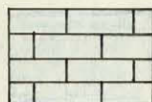
In this part of the thesis the descriptions of 10 important quarry sections are given, as well as the graphic logs of 3 wells in which the Chazy record is well preserved. Graphic logs of 3 of the quarry sections appear elsewhere in the text (Figs. 14 and 21).

The symbols used in all columnar sections are given below:

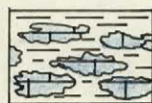
KEY TO COLUMNAR SECTIONS



Dolomite: consistent units; includes all shaly and silty varieties



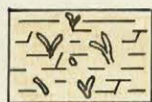
Limestone: massive calcarenite units (St. Martin members)



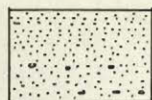
Shaly limestone: lumpy bedding; all varieties between calcarenite and shale end members



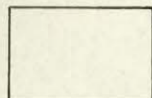
Shale: pure, dark greenish grey, fissile



Bryozoan dolomitic shale and shaly dolomite: weathering to orange color



Quartz sandstone and siltstone



No record

Intermediate or mixed rock types shown by combination of patterns.

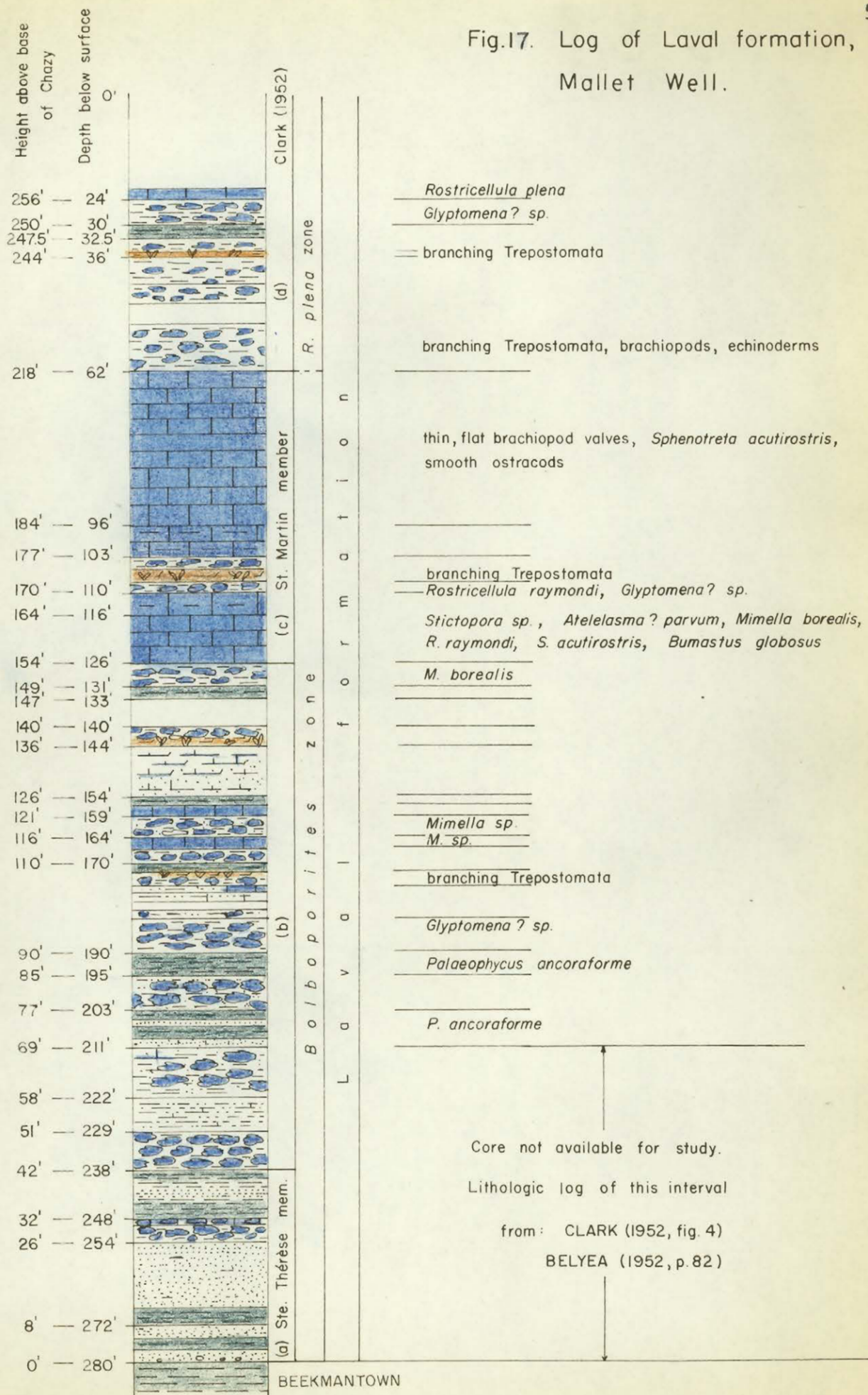
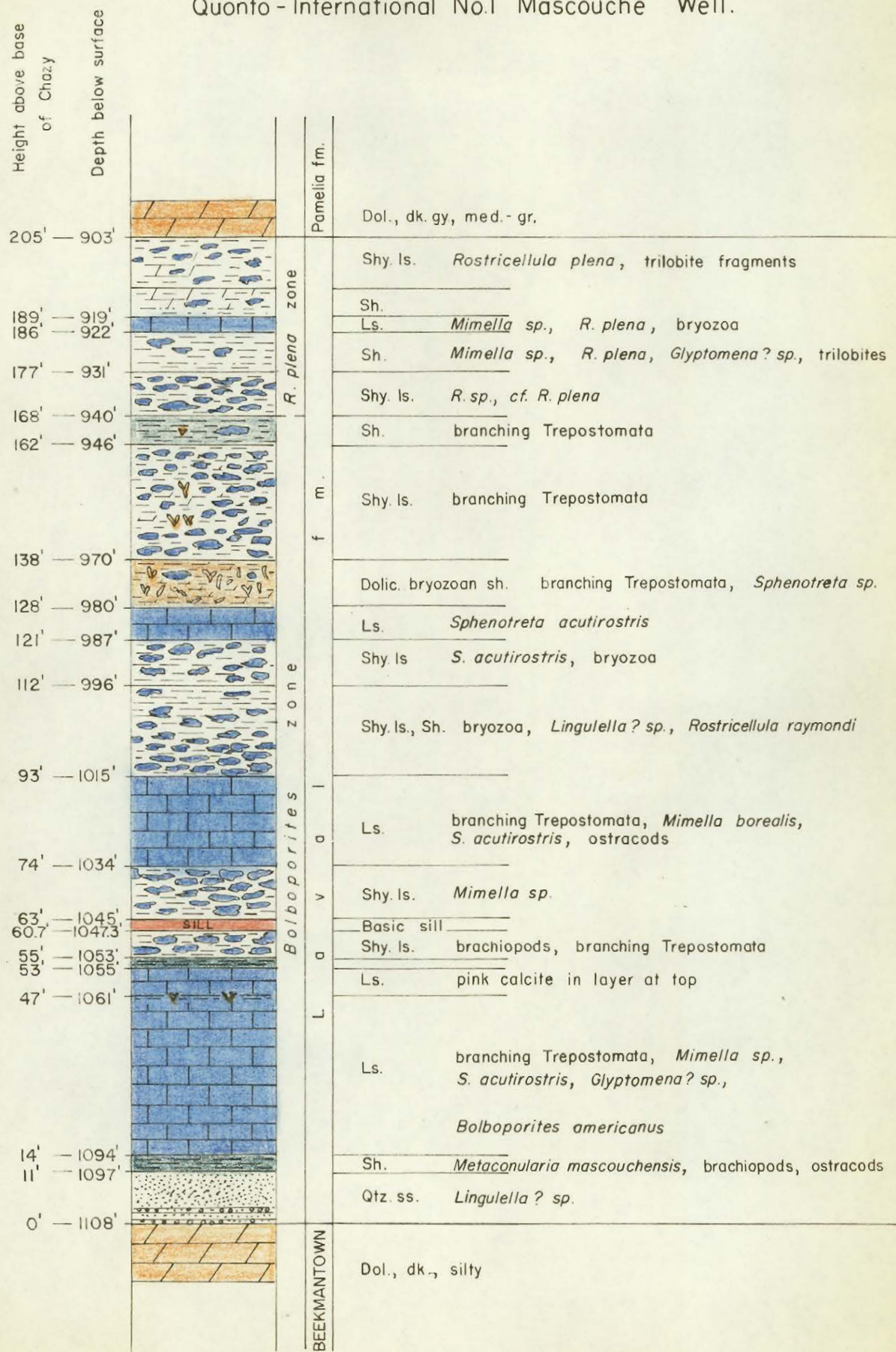
Fig.17. Log of Laval formation,
Mallet Well.

Fig.18. Log of Laval formation,
Quonto - International No.1 Mascouche Well.



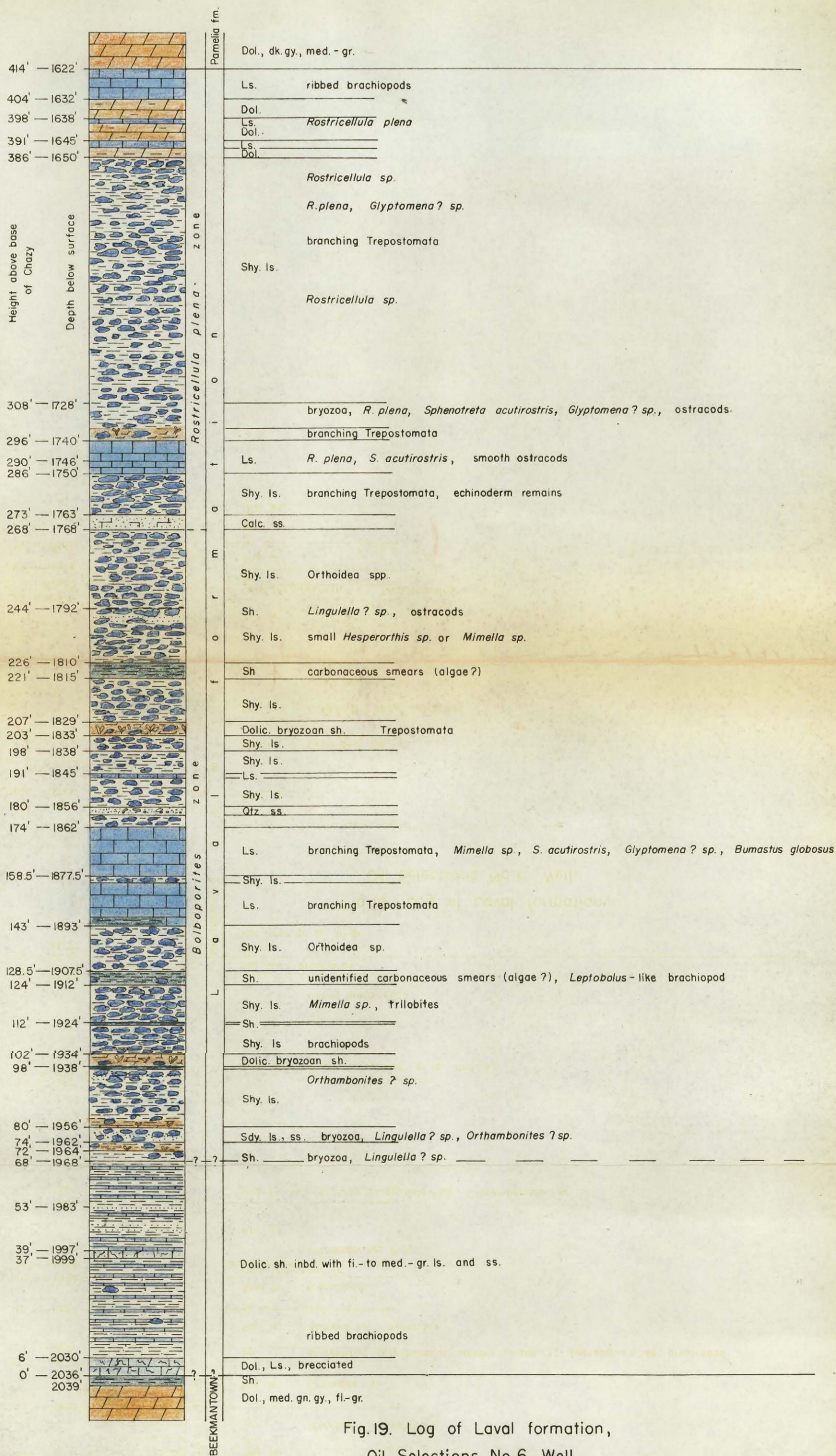


Fig. 19. Log of Laval formation,
Oil Selections No. 6 Well.

LAGACÉ QUARRY Section, St. Martin.

(LAVAL 7E-3, 8)

(Locality 25, in part)

L A V A L F O R M A T I O N

Interval	Thickn.	Top of quarry
98.5'-114'	15.5'	Quartz-sandy limestone, medium grey, coarse- to medium-grained, crystalline, medium- to thick-bedded; cross-bedding distinct. Unit forms top of quarry as well as outcrops in vicinity of quarry. branching Trepostomata <u>Phylloporina aspera</u> (Hall) <u>Mimella</u> sp. <u>Sphenotreta acutirostris</u> (Hall) trilobite fragments smooth ostracods <u>Bolboporites americanus</u> Billings
96'-98.5'	2.5'	Shaly limestone, dark medium grey; coarse-grained, lumpy-bedded calcarenite, in beds 3 - 5 inches thick, separated by shale layers up to 1" thick.
87'-96'	9'	Quartz sandstone, fine-grained, intimately mixed with greenish shale; carbonate cement. <u>Hudsonospongia? infundibulosa</u> n.sp. <u>Mimella borealis</u> (Billings) <u>Palaeophycus ancoraforme</u> n.sp. <u>Rusophycus grenvillense</u> Billings unidentified trails (Pl. 11, Fig. 6)
84'-87'	3'	Shale, dark greenish grey, micaceous, fissile. Unit forms upper thin dark marker bed in quarry.
69'-84'	15'	Shaly limestone, dark grey; lumpy-bedded calcarenite in shaly beds, silty towards top. <u>Mimella</u> sp.
58'-69'	11'	Limestone, medium grey, coarse-grained, crystalline, some pink calcite crystals. Unit best developed on S. side of quarry, wedges out to the N., where only 3' occur at this horizon.
39.5'-58'	18.5'	Shale and shaly limestone, dark grey, silty, lumpy-bedded calcarenite. Near bottom of unit several 3-inch to 5-inch calcarenite beds. Thin layers of very fine-grained quartz sandstone. <u>Mimella borealis</u> (Billings) <u>M. vulgaris</u> (Raymond) <u>Palaeophycus ancoraforme</u> n.sp. <u>Phymatoderma?</u> sp.

36.5'-39.5'	3'	Shale, dark greenish grey, even fissility, very poor in silt fraction. Unit forms lower thin dark marker bed in quarry.
18.8'-36.5'	17.7'	Shaly limestone, dark grey; lumpy-bedded calcarenite in beds 3 to 12 inches thick. Amount of shale increases towards top. Laminae of coarse silt scattered throughout. <u>Mimella</u> sp. <u>Bolboporites americanus</u> Billings <u>Palaeophycus ancoraforme</u> n.sp. <u>Petalonia soleaformis</u> n.gen. and sp.
11.0'-18.8'	7.8'	Quartz sandstone, very fine-grained, intimately interbedded with siltstone and dark greenish grey shale. One 6-inch dark grey calcisiltite bed with <u>Mimella</u> sp. at 16'. Two 3-inch dark grey, fine-grained calcarenite layers at top of unit, separated by a 2-inch shale seam. <u>Mimella</u> sp. <u>Bolboporites americanus</u> Billings <u>Palaeophycus ancoraforme</u> n.sp.
0'-11.0'	11.0'	Limestone, medium to dark grey, coarse-grained; interbedded with dark greenish grey shale seams at intervals 9.3'-9.4' 7.8'-8.1' 5.5'-5.8' 4.9'-5.1' 4.3'-4.4' 2.0'-2.4' Pyrite specks common. Frosted quartz grains present. At 10.0' and at 11.0' are 1-inch layers of dense aphanitic material with conchoidal fracture, which also occurs in nodules where layers are discontinuous. <u>Lingulella?</u> sp. <u>Mimella</u> sp. <u>Orthambonites</u> sp.
		Base of quarry

BÉDARD QUARRY Section, Caughnawaga.

(LACHINE 8C-2)

(Locality 40, in part)

L A V A L F O R M A T I O N

Interval	Thickn.	Top of quarry
61'-90'	29'±	Limestone, medium grey to light brownish grey, coarse-grained, crystalline, massive-bedded, conspicuously cross-bedded in places; local shale seams and lenses of conglomeratic quartz sand grains. Pink calcite crystals scattered throughout. Unit forms top of quarry, has yielded most of the fossils from Caughnawaga. branching Trepostomata <u>Phylloporina aspera</u> (Hall) <u>Atelelasma? parvum</u> (Wilson) <u>Glyptomena? sp.</u> <u>Glyptorthis transversa</u> Cooper <u>Hesperorthis sp.</u>, cf. <u>H. ignicula</u> (Raym.) <u>Mimella borealis</u> (Billings) <u>Rostricellula raymondi</u> Cooper <u>Schizambon duplicimuratum</u> Hudson <u>Sphenotreta acutirostris</u> (Hall) <u>Basilicus marginalis</u> (Hall) <u>Bumastus globosus</u> (Billings) <u>Isotelus sp.</u> <u>Eurychilina sp.</u> smooth ostracods <u>Bolboporites americanus</u> Billings <u>Palaeocystites tenuiradiatus</u> (Hall) <u>Palaeocrinus striatus</u> Billings <u>Blastoidocrinus carchariaedens</u> Billings
57'-61'	4'	Shaly limestone, dark medium grey, quartz-silty, dolomitic, orange-weathering, lumpy-bedded. Lumps of calcisiltite and calcarenite. Abundant bryozoans. Basal 1' contains considerable amount of large frosted quartz grains. trepostomatous bryozoans <u>Mimella borealis</u> (Billings) <u>Rostricellula pristina</u> (Raymond) <u>R. raymondi</u> Cooper
54'-57'	3'	Shale, dark greenish grey, rusty weathering bedding joints; very few silty laminae. Unit weathers recessively.
52'-54'	2'	Limestone, brownish grey, coarse-grained, crystalline, quartz-sandy; scattered pink calcite crystals. <u>Mimella sp.</u> trilobite fragments

49'-52'	3'	Quartz siltstone, greenish grey, with abundant shale seams and dolomitic material, brownish grey weathering. <u>Hudsonospongia? infundibulosa</u> n.sp. <u>Palaeophycus ancoraforme</u> n.sp. cystid fragments
46'-49'	3'	Quartz siltstone, shaly, dolomitic, grading upwards into intimately interbedded rusty orange-weathering dolomite and dark grey calcarenite seams.
44'-46'	2'	Limestone, dark grey, coarse-grained, crystalline, silty
36'-44'	8'	Shaly quartz sandstone, greenish grey, fine-grained, micaceous, dolomitic, calcarenitic in southern part of the quarry (facies change). <u>Palaeophycus ancoraforme</u> n.sp. <u>Phymatoderma?</u> sp.
13.3'-36'	22.7'	Limestone, medium grey, coarse-grained, crystalline, massive-bedded, cross-bedding pronounced. Basal 5' quartz-sandy, with micaceous shale seams; remainder of unit has few shale seams. bryozoans <u>Glyptomena?</u> sp. <u>Mimella borealis</u> (Billings) trilobite fragments smooth ostracods <u>Bolboporites americanus</u> Billings
3.5'-13.3'	9.8'	Quartz sandstone, very fine-grained, micaceous, interbedded with greenish grey, silty shale; weathering olive brown, in contrast to overlying grey-weathering unit. 1-inch shale layer at top of interval. Reddish brown weathering bedding joints. <u>Mimella borealis</u> (Billings) <u>Bolboporites americanus</u> Billings <u>Palaeophycus ancoraforme</u> n.sp. <u>Phymatoderma?</u> sp.
0'-3.5'	3.5'	Quartz-sandy limestone, brownish grey to grey, coarse-grained, replete with brachiopod fragments (<u>Mimella</u>) which weather to a rusty color. Sporadic pink calcite crystals near top. <u>Mimella borealis</u> (Billings) <u>Sphenotreta acutirostris</u> (Hall) trilobite fragments <u>Palaeophycus ancoraforme</u> n.sp.
		Base of quarry

BEAUDRY QUARRY Section, Rang St. Elzéar.

(LAVAL 8C-14)

(Locality 18)

L A V A L F O R M A T I O N

Interval	Thickn.	Top of quarry
12.2'-34.0'	21.8'	Limestone, medium grey, coarse-grained, crystalline, massive, cross-bedded. Thin shale parting planes; a few pink calcite crystals. <u>Mimella borealis</u> (Billings) <u>Rostricellula raymondi</u> Cooper smooth ostracods <u>Bolboporites americanus</u> Billings
11.2'-12.2'	1.0'	Shale, dark greenish grey, with scattered small calcarenite lenses.
9.9'-11.2'	1.3'	Dolomitic shale, abundant bryozoans; brownish grey, finely granular in patches. Unit weathers yellowish brown. branching trepostomatous bryozoans
4.0'-9.9'	5.9'	Shaly limestone, dark medium grey; coarse-grained calcarenite seams, in 3-inch to 1-foot beds, irregularly interbedded with dark shale. <u>Mimella coquina</u> in places. <u>Mimella borealis</u> (Billings) <u>Rostricellula pristina</u> (Raymond) <u>R. raymondi</u> Cooper <u>Bolboporites americanus</u> Billings <u>Malocystites murchisoni</u> Billings
0'-4.0'	4.0'	Shale, dark greenish grey, rusty parting planes in places, very thin-bedded, fissile, slightly micaceous. bryozoans <u>Lingulella?</u> sp. <u>Orthambonites</u> sp. <u>Valcourea strophomenoides</u> (Raymond) <u>Eurychilina</u> sp.
		Base of quarry

CAP ST. MARTIN QUARRY Section, Cap St. Martin.

(LAVAL 7D-9)

(Locality 22, in part)

L A V A L F O R M A T I O N
S t . M a r t i n m e m b e r (type area)

Interval	Thickn.	Top of quarry
51.2'-76.0'	24.8'	Limestone, medium grey, coarsely crystalline, cross-bedded on large scale, quartz-silty in places; lowest 2' are rich in orange-weathering dolomite patches. Most of the fossils in topmost 7'. <u>Mimella</u> sp. <u>Rostricellula raymondi</u> Cooper <u>Sphenotreta acutirostris</u> (Hall) <u>Bumastus globosus</u> (Billings) <u>Eurychilina</u> sp. smooth ostracods <u>Malocystites murchisoni</u> Billings
49.0'-51.2'	2.2'	Shale, medium grey, containing masses of Bryozoa and lenses of calcarenite. Unit weathers dark and recessively, and forms good marker bed in the quarry. Some orange-weathering dolomite patches. branching Trepostomata <u>Mimella</u> sp. <u>Bolboporites americanus</u> Billings
41.2'-49.0'	7.8'	Limestone, medium grey, coarsely crystalline, with a few thin, wavy shale seams, stylonitic. Many frosted quartz sand grains scattered throughout, some small bryozoan patches. Small vug (2 cm. across) filled with crystalline calcite and pyrite. Top 0.8' weathers darker and contains black granules up to 3 mm. across and is irregularly cross-laminated; the base of this layer may mark a small unconformity. branching Trepostomata <u>Sphenotreta acutirostris</u> (Hall) <u>Malocystites murchisoni</u> Billings
41.0'-41.2'	0.2'	Shale, greenish grey, calcareous, recessive weathering.
31.6'-41.0'	9.4'	Limestone, medium grey, coarsely crystalline, massive, in beds 1' to 4' thick, cross-bedded in lower parts. <u>Sphenotreta acutirostris</u> (Hall) <u>Bolboporites americanus</u> Billings

30.4'-31.6'	1.2'	Shale, medium grey, silty, dolomitic, fissile. Contains lenses or beds of medium-grained, brownish grey limestone.
24.0'-30.4'	6.4'	Limestone, medium grey, interbedded orange-weathering dolomite layer and patches. Bottom 1.8' cross-bedded calcarenite.
15.0'-24.0'	9.0'	Limestone and fine-grained quartz sandstone, intimately interbedded, greenish grey to dark grey, dolomitic, brownish grey weathering, much shaly material; massive-bedded, yet thinly laminated. Thin section shows rock to be composed of carbonate, quartz, and 1 percent corundum. Abundant cystid plates and columnals. <u>Hudsonospongia? infundibulosa</u> n.sp. bryozoans <u>Mimella borealis</u> (Billings) <u>Glyptomena?</u> sp. gastropod <u>Cheirocrinus forbesi</u> (Billings) <u>Palaeophycus ancoraforme</u> n.sp.
6.0'-15.0'	9.0'	Quartz siltstone and sandstone, with lumpy-bedded grey, coarsely crystalline limestone; shaly material abundant. bryozoans <u>Mimella</u> sp.
0'-6.0'	6.0'	Limestone and quartz siltstone, brownish grey to dark grey, fine-grained, dolomitic, abundant shaly partings. <u>Mimella</u> sp.
		Base of quarry

BILLET QUARRY Section, Village Bélanger.

(LAVAL SE-15)

(Locality 23, in part)

L A V A L F O R M A T I O N
S t. M a r t i n m e m b e r

Interval	Thickn.	Top of quarry
28.2'-75'±	47'±	Limestone, medium grey, coarsely crystalline, some layers dark grey, scattered pink calcite crystals; cross-bedding common; yellowish brown weathering dolomitic patches and streaks in 30'-40' interval. At 60' the calcarenite has strong petroliferous odour when freshly fractured, but rock gives no fluorescence in ultraviolet light. Thin section shows rock to be composed of carbonate-cemented crystallized grains, predominantly echinoderm remains. Fossils poorly preserved. Microstylolites (Fig. 8, p.33). <u>Sphenotreta acutirostris</u> (Hall) <u>Bolboporites americanus</u> Billings
28.0'-28.2'	0.2'	Shale, dark greenish grey, recessive weathering.
8.0'-28.0'	20.0'	Limestone, medium grey, coarsely crystalline, lower 15' quartz-sandy, cross-bedded. bryozoans <u>Mimella borealis</u> (Billings) <u>Rostricellula raymondi</u> Cooper <u>Sphenotreta acutirostris</u> (Hall) trilobite fragments <u>Bolboporites americanus</u> Billings
0'-8.0'	8.0'	Shaly sandstone with limestone patches, greenish grey, fine-grained, very fossiliferous. Great abundance of nearly complete, fragile specimens indicates fossils are autochthonous. <u>Solenopora</u> sp. <u>Hudsonospongia? infundibulosa</u> n.sp. branching and encrusting Trepostomata <u>Carinophylloporina</u> sp. <u>Phylloporina</u> sp. <u>Lingulella?</u> sp. <u>Mimella borealis</u> (Billings) <u>Rostricellula raymondi</u> Cooper trilobite fragments <u>Bolboporites americanus</u> Billings <u>Cheirocrinus forbesi</u> (Billings) <u>Canadocystis barrandi</u> (Billings) <u>Palaeophycus ancoraforme</u> n.sp.
		Base of quarry

MONTREAL CUT STONE QUARRY Section, St. François de Sales.

(LAVAL 9B-11)

(Locality 12, in part; westernmost quarry)

L A V A L F O R M A T I O N

Interval	Thickn.	Top of quarry
8.5'-36.5'	28.0'	Limestone, medium grey, coarsely crystalline, thin- to medium-bedded, oölitic near bottom; some shaly, dolomitic seams in lower half, and a 1.5-foot magnesian bed at 32'. Much cross-bedding in massive beds; orange-weathering, sugary, dark brownish grey blebs scattered through rock. Thin black stylolites in the calcarenite. No well preserved fossils. bryozoans <u>Bolboporites americanus</u> Billings cystid plates and columnals
6.3'-8.5'	2.2'	Dolomitic shale and shaly dolomite, dark brownish grey, orange-weathering, silty, very fossiliferous. branching and encrusting Trepostomata <u>Stictopora</u> sp. <u>Mimella borealis</u> (Billings) <u>M. vulgaris</u> (Raymond) <u>Rostricellula raymondi</u> Cooper <u>Valcourea strophomenoides</u> (Raymond) <u>Malocystites murchisoni</u> Billings
0'-6.3'	6.3'	Shaly limestone, brownish grey to medium grey, coarsely crystalline; fragmental and oölitic limestone in 1- to 3-inch beds, separated by half-inch dolomitic shale seams; lumpy bedding. Some cross-bedding in the calcarenite. Oölitic content decreases to the east, is replaced by skeletal material. Top part of unit is locally biohermal. bryozoans <u>Lingulella?</u> sp. <u>Mimella vulgaris</u> (Raymond) <u>Rostricellula raymondi</u> Cooper <u>Valcourea strophomenoides</u> (Raymond) <u>Archinacella propria</u> Raymond gastropods cephalopod <u>Isotelus</u> sp. <u>Vogdesia bearsi</u> Raymond
		Base of quarry

ST. FRANCIS QUARRY Section, Côte Vertu Boulevard, St. Laurent.

(LAVAL 8F-5,6)

(Locality 30)

L A V A L F O R M A T I O N

Interval	Thickn.	Top of quarry
109'-130'	21'	Limestone, medium grey, coarse-grained, quartz-silty, orange-weathering dolomitic patches and dark shale partings; thick-bedded, some thin beds where shale abundant; cross-bedding. Top 2' have typical jagged weathering surface. Encrusting bryozoan colonies in dolomitic layer at 124'-125'. branching and encrusting Trepostomata <u>Mimella transversa</u> Cooper <u>Rostricellula</u> sp. <u>Multicostella platys</u> (Billings) <u>Glyptomena?</u> sp. <u>Bumastus globosus</u> (Billings)
100.5'-109'	8.5'	Limestone, medium grey, coarse-grained, medium-to thick-bedded, weathering grey, few shaly seams, many bryozoans in lower part. branching Trepostomata <u>Rostricellula raymondi</u> Cooper <u>Sphenotreta acutirostris</u> (Hall) trilobite fragments <u>Malocystites murchisoni</u> Billings
93'-100.5'	7.5'	Shaly dolomite, dark brown, fine-grained, weathering yellowish brown, replete with bryozoans; 3-inch layer at base full of brachiopods. branching Trepostomata <u>Rostricellula raymondi</u> Cooper
89'-93'	4'	Limestone, medium grey, coarsely crystalline, medium-bedded, somewhat cross-bedded.
86'-89'	3'	Shaly limestone, dark grey; medium-grained calcarenite irregularly interbedded with dark dolomitic shale.
75'-86'	11'	Limestone, medium grey, coarsely crystalline, medium-bedded, slightly cross-bedded, scattered orange-weathering, dolomitic shale patches; dolomitic at base.
71'-75'	4'	Shaly limestone, dark brownish grey, dolomitic, lumpy bedding, 0.2' shale bed at base.

65'-71'	6'	Limestone, medium grey, coarsely crystalline, medium- to thin-bedded, distinct cross-bedding. <u>Mimella borealis</u> (Billings)
60.5'-65'	4.5'	Limestone, medium grey, coarse-grained, scattered blebs and stringers of rusty weathering material; this unit is one massive bed, shows cross-bedding.
60.2'-60.5'	0.3'	Shale, dark grey, silty and dolomitic, unidentifiable fossils.
47.2'-60.2'	13'	Limestone, medium grey, coarse-grained; intimately interlayered fine-grained, rusty weathering dolomite patches. A 1-foot bed at the top is nearly all dolomite. trilobite fragments
44'-47.2'	3.2'	Dolomite, greenish grey, fine-grained, silty, orange-weathering; basal 1.5' portion has up to 10 percent grey calcarenite patches; upper portion has widely scattered calcarenite patches. Poorly fossiliferous.
0'-44'	44'	Limestone, medium to dark grey, coarsely crystalline, medium- to thick-bedded (3"-2'), some cross-bedding. Interval 12'-30' is more shaly and of dark grey color. Some pink calcite crystals in basal 12'. Lowermost part of quarry is in center, where there is a zone rich in purple fluorite and white calcite, probably related to a major fault crossing the southern part of the quarry with attitude 103°T. 64°S., vertical separation 15 feet, north wall moved up. branching Trepostomata <u>Mimella borealis</u> (Billings) <u>Rostricellula</u> sp. <u>Sphenotreta acutirostris</u> (Hall) <u>Glyptomena?</u> sp.
		Base of quarry

POINTE CLAIRE QUARRY Section, Beaconsfield.

(LACHINE 4B-1)

(Locality 38)

(See Fig. 14, p.43)

Interval	Thickn.	Top of measured section
83.0'-85.0'	2.0'	L O W V I L L E F O R M A T I O N
		Limestone, light grey, pure, massive, sublithographic; conglomeratic near base, grains of calcilutite 2 - 3 mm. across, minute delicate shell fragments (ostracods?). Unit weathers light grey, in contrast to underlying, orange-weathering rocks.
78.7'-83.0'	4.3'	P A M E L I A F O R M A T I O N
		Dolomite, sandstone, and limestone, light greenish grey, weathering orange, fine-grained, equigranular, in 1' - 2' beds. Much well sorted, angular quartz, the grains averaging 0.1 mm., most abundant at bottom. Towards top the dolomite grades into medium greenish grey dolomitic calcilutite. Pyrite specks common. Other silt detritus seen in thin section: plagioclase and zircon. pelecypod fragments at 82.0'
77.1'-78.7'	1.6'	Shale-dolomite-quartz sandstone, recessive weathering unit. -Shale: at base; brownish black, dolomitic, full of rounded black, phosphatic grains (pelecypod remains, in part?). -Dolomite: light green, equigranular, fine-grained, crystals 0.1 mm. across; contains rounded black, phosphatic grains; pyrite, quartz, and plagioclase present. -Quartz sandstone: near top; brownish grey, shaly; quartz grains up to 2 mm. across, but mostly less than 1 mm.; slight cross-lamination evident due to black shaly laminae. Some fine-grained, equigranular sandstone with reddish brown weathering spots. Unconformity (Black River-Chazy) in this interval, as suggested in Fig. 14.
74.0'-77.1'	4.1'	Shale, dark grey, dolomitic, and shaly dolomite, quartz-silty.
69.7'-74.0'	4.3'	Dolomite, dark brownish grey, fine-grained, granular; dolomite euhedra 0.1 mm. across; on polished surface rock shows mottling with lighter patches and brecciated appearance. Unit massive-bedded. Thin section shows the lighter, angular patches

		to be composed of pure, subhedral dolomite grain aggregates, in a matrix of slightly coarser idiomorphic dolomite, richer in clays, and also containing phosphatic splinters and quartz and plagioclase grains. This breccia resembles the 24.2'-25.1' interval of the Devito Quarry.
65.5'-69.7'	4.2'	Dolomite, dark grey, very fine-grained, even texture, dense, silty, with shale seams and pyrite specks. Lower 0.8' more resistant to weathering. No pronounced lower contact.
L A V A L F O R M A T I O N B e a c o n s f i e l d m e m. (type section)		
58.5'-65.5'	7.0'	Limestone, medium grey, very fine-grained, argillaceous, dolomitic. Quartz silt detritus. Shale laminae dolomitic, without calcite. <u>Rostricellula plena</u> (Hall)
56.2'-58.5'	2.3'	Limestone, medium grey, fine-grained, massive, argillaceous; brownish grey dolomitic shale stringers. <u>Rostricellula plena</u> (Hall)
52.0'-56.2'	4.2'	Shale, dark grey, silty, very dolomitic, massive appearance; pyrite specks. Several specimens of <u>Ctenodonta</u> sp., cf. <u>C. parvidens</u> (Raymond)
48.8'-52.0'	3.2'	Limestone, medium brownish grey, fine-grained, argillaceous, dolomitic. Abundant dolomitic shale stringers. Unit in 2 massive beds. <u>Rostricellula plena</u> (Hall)
48.0'-48.8'	0.8'	Shale, dark grey to black, brown-weathering, silty, dolomitic; fissile; fractures into thin, uneven flakes. Good marker horizon in quarry.
46.8'-48.0'	1.2'	Limestone, dark medium grey, fine- to medium-grained, argillaceous; lumpy-interbedded dark greenish grey, dolomitic shale. Very thin pyrite stringers and specks. <u>Rostricellula plena</u> (Hall)
46.3'-46.8'	0.5'	Shale, dark greenish grey, silty, slightly dolomitic, uneven fissility. Good marker bed in quarry.
45.5'-46.3'	0.8'	Limestone, brownish grey, fine-grained, argillaceous, slightly dolomitic. Shale stringers about 10 percent of rock. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
42.0'-45.5'	3.5'	Dolomite, greenish grey, equigranular, shaly and

		quartz-silty. About 5% of unit are thin laminae and streaks of quartz silt. Dolomite euhedral. Carbonate has replaced quartz along grain boundaries. Pyrite specks. Alkali feldspar detected by X-ray diffraction. The top 2 to 3 inches of unit are shale, weathering recessively, and forming the lowest of 3 closely spaced dark bands in the quarry. <u>Lingulella?</u> sp.
32.1'-42.0'	9.9'	Limestone, dark grey with brownish tinge, fine- to coarse-grained, massive-bedded, faint indication of cross-bedding; abundant dolomitic shale stringers. Crystallized fossil fragments. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall) <u>Cyclora?</u> sp. echinoderm remains
31.0'-32.1'	1.1'	Shaly dolomite, dark grey, dense, very fine-grained, quartz-silty and sandy.
30.2'-31.0'	0.8'	Shaly limestone, dark grey, lumpy-bedded. Nearly 2% pyrite as coarse crystals and as stringers. Quartz-silty, dolomitic shale patches and seams. Thin small shell fragments. This bed provides the source of the rusty brown weathering color on the S.E. wall of the quarry. <u>Rostricellula plena</u> (Hall)
26.7'-30.2'	3.5'	Limestone and shale; medium grey calcisiltite in beds 6 inches thick, lumpy-bedded in dolomitic shale seams. <u>Rostricellula plena</u> (Hall)
26.2'-26.7'	0.5'	Shale, greenish grey; even fissility. <u>Lingulella?</u> sp.
23.2'-26.2'	3.0'	Limestone, medium grey, fine-grained, argillaceous, with dolomitic shale stringers and shell fragments. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
22.0'-23.2'	1.2'	Shale, dark greenish grey, dolomitic; uneven fissility. Two 1-inch layers of hard, medium grey calcisiltite. Minute pyrite specks and sporadic quartz silt grains. <u>Lingulella?</u> sp.
20.0'-22.0'	2.0'	Limestone, medium grey, fine- to coarse-grained, argillaceous, in 3-inch beds. Abundant shell fragments.

		<u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall) echinoderm fragments
19.0'-20.0'	1.0'	Shale, dark greenish grey, quartz-silty. Small amounts of alkali feldspar detected by X-ray diffraction. Coquina of <u>Lingulella?</u> sp. A few fragments of <u>Rostricellula plena</u> (Hall).
17.7'-19.0'	1.3'	Shaly limestone, medium grey; lumpy-bedded calcisiltite in dark greenish grey shale. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
17.3'-17.7'	0.4'	Limestone, dark medium grey, fine- to coarse-grained. Some specimens of <u>Rostricellula</u> filled with white calcite crystals. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
10.3'-17.3'	7.0'	Shaly limestone, medium grey; quartz-silty calcisiltite lumpy interbedded with much greenish grey dolomitic shale. Minute pyrite specks in the shale. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
9.7' -10.3'	0.6'	Limestone, dark medium grey, fine- to medium-grained, silty shale seams and dolomitic patches. Pyrite specks. <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall)
8.2'-9.7'	1.5'	Shale, dark greenish grey, quartz-silty, very slightly dolomitic. <u>Lingulella?</u> sp.
6.7'-8.2'	1.5'	Limestone, dark medium grey, fine- to medium-grained, silty. <u>Rostricellula plena</u> (Hall)
0'-6.7'	6.7'	Shaly limestone, dark medium grey; calcarenite and calcisiltite, lumpy-bedded, with much shale; clay lumps; pyrite along veinlets. Fair amount of quartz silt detritus scattered through rock. Microstylolites. This unit forms the base of the quarry, the floor of which in the north central part shows ripple marks, striking 135°, wave length 6 to 12 inches, low amplitude. <u>Stictopora</u> sp. <u>Lingulella?</u> sp. echinoderm fragments
Bottom of quarry. Base of Beaconsfield member not exposed.		

DEVITO QUARRY Section, Pointe Claire.

(LACHINE 5B-2)

(Locality 39)

Interval	Thickn.	Top of section
34.2'-36.0'	1.8'	L O W V I L L E F O R M A T I O N
		Limestone, light grey, very fine-grained, in 2 massive beds, conglomeratic in lower part, pebbles of calcilutite, weathering light grey. <u>Tetradium celluloseum</u> (Hall)
		Disconformity
34.1'-34.2'	0.1'	P A M E L I A F O R M A T I O N
		Shale and quartz sandstone; shale is brownish black, dolomitic; sandstone occurs in local lenses, is composed of rounded coarse quartz grains, green shale flakes, some black grains.
		Disconformity
32.9'-34.1'	1.2'	Dolomite, greenish brown, fine-grained, equigranular, orange-weathering; pyrite specks. At top of unit numerous casts and molds of <u>Rostricellula plena</u> (Hall)
32.7'-32.9'	0.2'	Shale, dark brownish grey, recessive weathering. <u>Lingulella?</u> sp.
30.6'-32.7'	2.1'	Dolomite, greenish grey, fine-grained, equigranular, massive bed; orange-weathering, pyrite specks common. Quartz silt.
30.1'-30.6'	0.5'	Shale, dark brownish grey, dolomitic, recessive weathering. pelecypod
28.3'-30.1'	1.8'	Dolomite, dark greenish grey, orange-weathering, fine-grained, equigranular, quartz-silty, pyrite specks; massive bed.
26.3'-28.3'	2.0'	Shale, brownish black, dolomitic, conchoidal fissility. <u>Ctenodonta</u> sp. cf. <u>C. parvidens</u> Raymond <u>Modiolopsis parviuscula</u> Billings
25.9'-26.3'	0.4'	Dolomite and quartz sandstone; dolomite fine-grained, granular, light greenish grey to brownish grey, with scattered dark streaks, abundant very fine-grained quartz sand detritus; sandstone fine- to medium-grained, cross-laminated on very small scale. Reddish spots, green shale flakes. Unit is resistant to weathering. <u>Lingulella?</u> sp.

25.1'-25.9'	0.8'	Shale, brownish black, dolomitic, silty, limonite-rich 1-mm. layer at base. Unit recessive weathering. <u>Lingulella?</u> sp. pelecypods
24.2'-25.1'	0.9'	Dolomite, brownish to greenish grey, fine-grained, massive, orange-weathering; brecciated appearance, with angular patches up to 1 cm. long, which is best seen on weathered surface or in polished section; pyrite abundant. Unit greatly resembles 69.7'-74.0' interval of the Pointe Claire Quarry. <u>Lingulella?</u> sp.
22.5'-24.2'	1.7'	Shale, brownish black, dolomitic, uneven fissility. <u>Rostricellula</u> sp. pelecypods
22.3'-22.5'	0.2'	Dolomite, dark brownish grey, very fine-grained, argillaceous, brownish yellow weathering.
19.0'-22.3'	3.3'	Shale, brownish black, dolomitic, good but irregular fissility; clay nodules. <u>Michelinoceras</u> sp. <u>Ctenodonta</u> sp. cf. <u>C. parvidens</u> Raymond <u>Modiolopsis parviuscula</u> Billings
18.8'-19.0'	0.2'	Dolomite, dark brownish grey, very fine-grained, yellowish grey, resistant weathering.
L A V A L F O R M A T I O N B e a c o n s f i e l d m e m b e r		
15.3'-18.8'	3.5'	Shale, olive grey, very dolomitic, silty, yellowish green weathering, small black, rounded, phosphatic grains. Gradational contact with underlying unit.
13.8'-15.3'	1.5'	Shaly limestone, dark grey, fine-grained, intimately mixed with silty, dolomitic material. Unit more resistant to weathering than adjoining beds. Gradational contact with underlying unit. Small rounded black grains (some of which are pelecypod fragments (Pl. 7 Fig. 18)). <u>Lingulella?</u> sp. <u>Rostricellula plena</u> (Hall) pelecypods
9.8'-13.8'	4.0'	Silty dolomite and dolomitic shale, dark olive grey, chunky fracture, rubbly, recessive weathering. Basal 0.2' more massive dolomite.

		Small rounded black grains, some with distinct pelecypod outlines preserved. pelecypods
8.7'-9.8'	1.1'	Shale, dark brownish grey, non-calcareous, very thin-bedded, fissile.
7.5'-8.7'	1.2'	Shale, olive brown, very dolomitic, silty, chunky fracture, organic remains near base.
5.0'-7.5'	2.5'	Shaly limestone, dark brownish grey, very fine-grained, lumpy-bedded, abundant dolomitic patches. Bed is more resistant to weathering than beds above and below. <u>Rostricellula plena</u> (Hall) <u>Cyclora?</u> sp.
4.2'-5.0'	0.8'	Shale, brownish grey, slightly dolomitic.
3.3'-4.2'	0.9'	Limestone, medium brownish grey, medium- to fine-grained, few dolomitic patches, lumpy-bedded. <u>Rostricellula</u> sp.
2.5'-3.3'	0.8'	Shale, brownish grey; contains nodules of brownish grey, aphanitic limestone, 2 inches across. <u>Rostricellula</u> sp.
1.8'-2.5'	0.7'	Limestone, brownish grey, lumpy-bedded, shaly and silty.
0.5'-1.8'	1.3'	Shale, medium grey, silty, dolomitic.
0'-0.5'	0.5'	Quartz-sandy limestone, medium grey, very fine-grained.
		Base of quarry in N.E. corner.

ST. VINCENT DE PAUL QUARRY Section, St. Vincent de Paul.

(LAVAL 9D-1)
(Locality 20)

Interval	Thickn.	Top of measured section
36.0'-37.5'	1.5'	L O W V I L L E F O R M A T I O N
		Limestone, light grey, fine-grained, oolitic, silty, weathering light grey.
35.2'-36.0'	0.8'	P A M E L I A F O R M A T I O N
		Dolomitic limestone, light medium grey, fine-grained, orange-weathering, carries green shale flakes up to 1 cm. across; silty.
35.1'-35.2'	0.1'	Shale, light green.
32.1'-35.1'	3.0'	Dolomite and dolomitic sandstone, medium- to coarse grained, greenish grey. Quartz grains up to 2 mm. across; mudflakes of green color, and ripple marks (Fig. 15, p.49), striking north, and having low amplitudes and wave lengths of 2 to 3 inches. Dessication cracks filled with silt and fine-grained sandstone on top of ripple marks. Pyrite specks. Unit forms resistant, orange-weathering bed. Top part indicates emergence and represents an unconformity.
31.6'-32.1'	0.5'	Shale, greenish grey, dolomitic.
31.1'-31.6'	0.5'	Dolomite, greenish grey, fine-grained, sandy, orange-weathering.
28.8'-31.1'	2.3'	Shale, grey and brownish grey, dolomitic.
26.3'-28.8'	2.5'	Dolomite, grey and brownish grey, medium-grained, sugary, orange-weathering, silty. Unit is lowest resistant weathering Pamela bed in quarry. <u>Lingulella?</u> sp.
24.0'-26.3'	2.3'	Shale, interval very poorly exposed. Top part is of dark brownish color, middle part is very silty and dolomitic, lower part is grey. Laval-Pamelia boundary lies within this unit, probably at base of the upper shale part.
19.8'-24.0'	4.2'	L A V A L F O R M A T I O N B e a c o n s f i e l d m e m b e r
		Shaly limestone and shale, olive grey, very dolomitic, silty, lumpy-bedded, yellowish brown weathering; limestone fine-grained, coquinal, makes up about 30% of rock. <u>Rostricellula plena</u> (Hall)

19.1'-19.8'	0.7'	Shale, dark grey, fissile, homogeneous, non-calcareous, breaks into very thin flakes; contains 3 very thin (2 mm.) orange-weathering laminae; flattened brachiopod shells near the base. <u>Rostricellula</u> sp.
18.3'-19.1'	0.8'	Dolomitic and silty shale, brownish grey, with some calcareous lumps, weathering olive grey, abundant fossils. <u>Rostricellula plena</u> (Hall) <u>R. wilsonae</u> Cooper
18.0'-18.3'	0.3'	Shaly dolomite, olive grey, very fine-grained, with lumpy, calcareous patches; weathering rusty; full of brachiopod shells. <u>Rostricellula</u> spp.
Disconformity		
S t . M a r t i n m e m b e r		
4.2'-18.0'	13.8'	Limestone, medium grey, coarsely crystalline, medium- to thick-bedded, cross-bedded in middle parts; orange weathering, dolomitic patches. Topmost layer is replete with vertical, unbranched tubes filled with argillaceous dolomite, up to 7 mm. long and 1.0 - 1.2 mm. across. <u>Lingulella?</u> sp. <u>Palaeoglossa? belli</u> (Billings) <u>Rostricellula raymondi</u> Cooper <u>R. wilsonae</u> Cooper <u>Mimella</u> sp. <u>Glyptomena?</u> sp. <u>Cyclora?</u> sp. <u>Helicotoma?</u> sp. <u>Loxoplocus (Lophospira)</u> sp. trilobite fragments smooth ostracods <u>Scolithus</u> sp.
3.5'-4.2'	0.7'	Shale, dark brown to dark grey, dolomitic. <u>Lingulella?</u> sp.
3.0'-3.5'	0.5'	Dolomite, light olive grey, yellowish brown weathering, fine-grained, silty, contains limestone patches with brachiopod fragments.
0'-3.0'	3.0'	Limestone, medium grey, coarsely crystalline, dolomitic patches and streaks, cross-bedded. <u>Rostricellula</u> sp.
Base of section is water level in quarry, June 1960. About another 15' of calcarenite occurs below water level.		

C O R R E L A T I O N

Correlation Between Principal Localities in Southern Quebec

Whereas the recognition of Chazyan rocks in the St. Lawrence Lowland is comparatively easy, the problem of correlating the various outcrops with regard to their relative stratigraphic positions is beset with difficulties. Outcrops are generally small and low, and widely scattered, which precludes any tracing along particular horizons. There are no distinctive marker beds that could be used for identifying particular horizons. Moreover, the Laval formation comprises a series of very variable lithologies of limited lateral extent. The lateral lithologic (facies) changes can be observed in several quarries (e.g., Lagacé Quarry, Locality 25), and are especially conspicuous where coarse-grained calcarenite beds are involved. Furthermore, there is a recurrence of calcarenite and shale - siltstone layers at different stratigraphic levels in the same section, as suitably illustrated by several wells which have penetrated complete sections of the Chazy (see Figs. 18 and 19, pp. 53, 54).

All these facts must be incorporated in any interpretation of the local Chazy, which has often been regarded as a simple, two-fold unit, with sandstones and shales at the base, overlain by the 'St. Martin limestone'. As already mentioned on p. 28, the term 'St. Martin member' denotes a calcarenite facies which occurs repeatedly at various stratigraphic levels. It is readily recognized as such, although its fossil content must be determined before one can assign the unit to its proper stratigraphic position.

The criteria used in assigning stratigraphic positions to the different outcrops are: position in the outcrop belt (field relationships), fossil content, and lithology, in that order of importance. These correlations appear in the chart on p. 76 (Fig.20).

Of all the outcrops, the ones in the Laurentides, Laval, and Lachine map-areas are the most readily assignable to a horizon, because exposures and fossils are abundant. The positions in the

[illegible]

Lacolle and St. Jean map-areas are more difficult to obtain because diagnostic fossils are not too abundant, and outcrops are widely spaced.

The St. Dominique formation presents a problem in that its relation to the Chazy of the Montreal area cannot so easily be ascertained. Firstly, the fossils are less well preserved due to the deformation along Logan's Line, and, secondly, the formation belongs to a different facies. Whereas at Montreal and vicinity the rocks are siltstone or sandstone, shaly limestone, and calcarenite units with a predominant brachiopod and pelmatozoan fauna, the St. Dominique is fine-grained, calcareous sandstone and argillaceous limestone with but minor pure calcarenite horizons, and carries a fauna consisting of fewer brachiopods and a good many more trilobites. The typical fossils of the Laval formation are very rare or entirely absent. Neither Rostricellula plena, nor R. raymondi, nor Mimella was recognized, and only a few specimens of Bolboporites could be found. Thus, a correlation based on zones of these fossils cannot be carried out directly with the Montreal area. Nevertheless, when compared with the Chazy group of Lake Champlain the fossils present seem to indicate that lower, middle, and upper Chazy are present (see Correlation Chart). This conclusion agrees with Kay (1958, p.85, Fig.10).

A fairly good correlation can be made with the local Pamela formation (Fig.21, p.78). This is due to its small thickness, its distinct orange-weathering, silty, dolomitic beds interlayered with dark shales, and its position just below the distinctive Lowville limestone.

Correlation with Standard Section and Other Localities

The Chazy of the Montreal area has traditionally been correlated with the upper Chazy standard of the Lake Champlain region. This has been on the basis of the occurrence of Rostricellula plena (Hall), which Raymond (1905) established as the index fossil for the Valcour formation.

As a result of the present investigation the concepts must

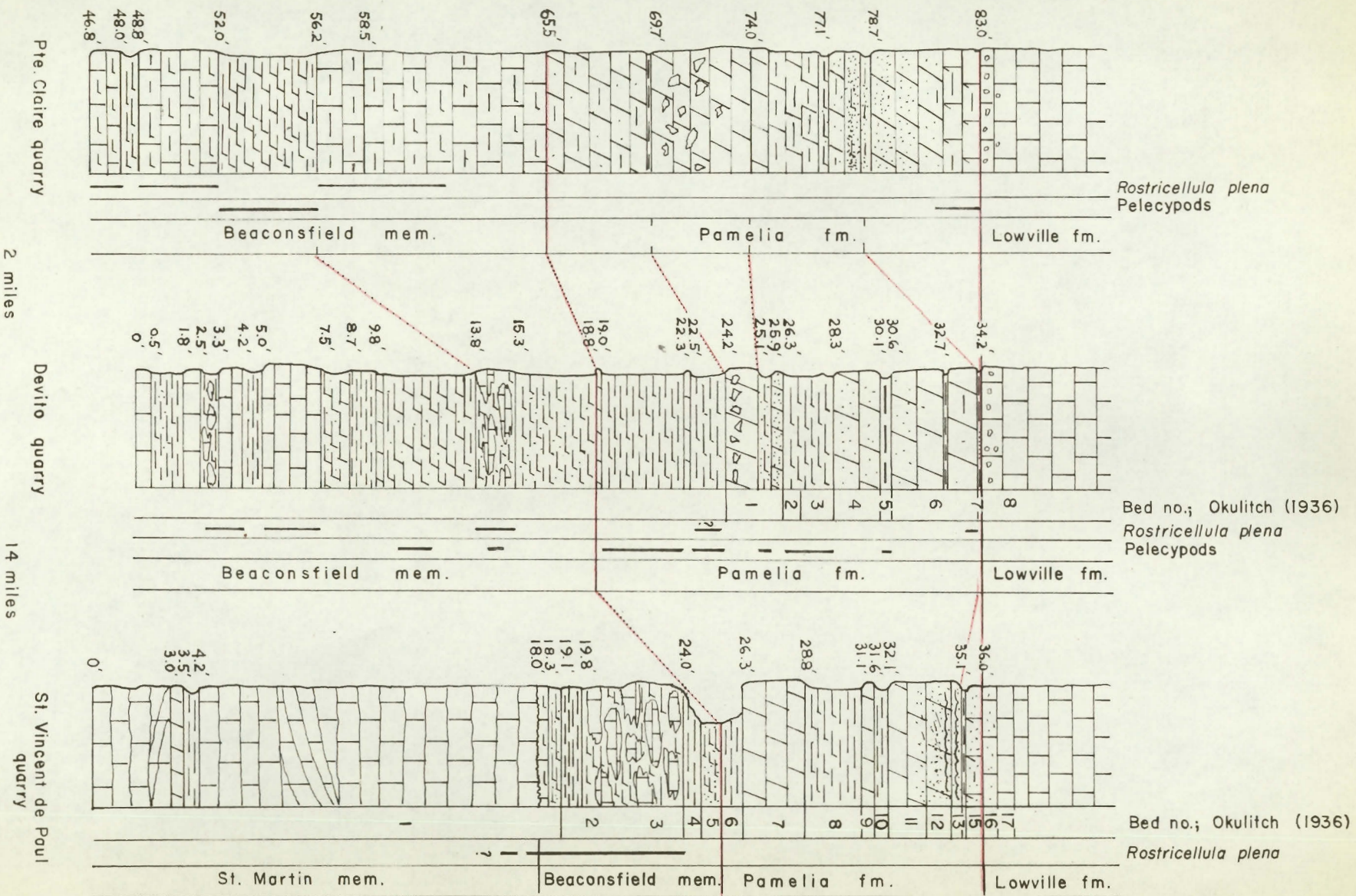


Fig. 21. Correlation of uppermost Chazy in the Montreal area.

now be revised, in the light of the following significant observations.

1) The occurrence of Rostricellula plena is confined to the uppermost part of the local Chazy succession. This is the only zone which should have been correlated with the Valcour, had its existence been known before.

2) Rostricellula raymondi Cooper (= Rostricellula orientalis of some authors) is a common brachiopod below the Rostricellula plena zone, and hence it is older, not younger as Raymond (1911, p.223) believed.

3) The section below the Rostricellula plena zone of the Laval formation is characterized by a number of fossils, of which the very common Bolboporites americanus Billings and Sphenotreta acutirostris (Hall) deserve special attention, because these two were found by Raymond (1906) only in the lower Chazy and in the lower parts of the middle Chazy (see Fig.22, p.80). Cooper (1956, p.29) listed Sphenotreta acutirostris under the Crown Point formation, but not under the Day Point. In any event, we are dealing with pre-upper Chazy fossils. As the pre-Rostricellula plena zone (Bolboporites zone) of the Laval is not further divided faunally, this zone is correlated with the Day Point - Crown Point, undivided.

4) At the top of the Bolboporites zone, and possibly at the base of the Rostricellula plena zone, there is a development of coral bioherms, whose species are identical with those found in the bioherms at the Crown Point - Valcour boundary region (Oxley and Kay, 1959, p.825). These species also occur at the Mingan Islands, but there they are apparently somewhat lower in the section, as the index for the middle Chazy, the gastropod Maclurites magnus LeSueur, occurs above them (Twenhofel, 1938).

5) The lower sandstone beds of the Day Point formation have lithologic equivalents in the Montreal area, and the index brachiopod Orthambonites? exfoliatus (Raymond) is also represented by similar shells, such as those found in the lower parts of the Bolboporites zone at the Lagacé Quarry (Locality 25).

6) Many of the species listed in the Correlation Chart occur

throughout the typical Chazy, but others are restricted to the Day Point - Crown Point, in support of the contention that pre-upper Chazy is represented in southern Quebec.

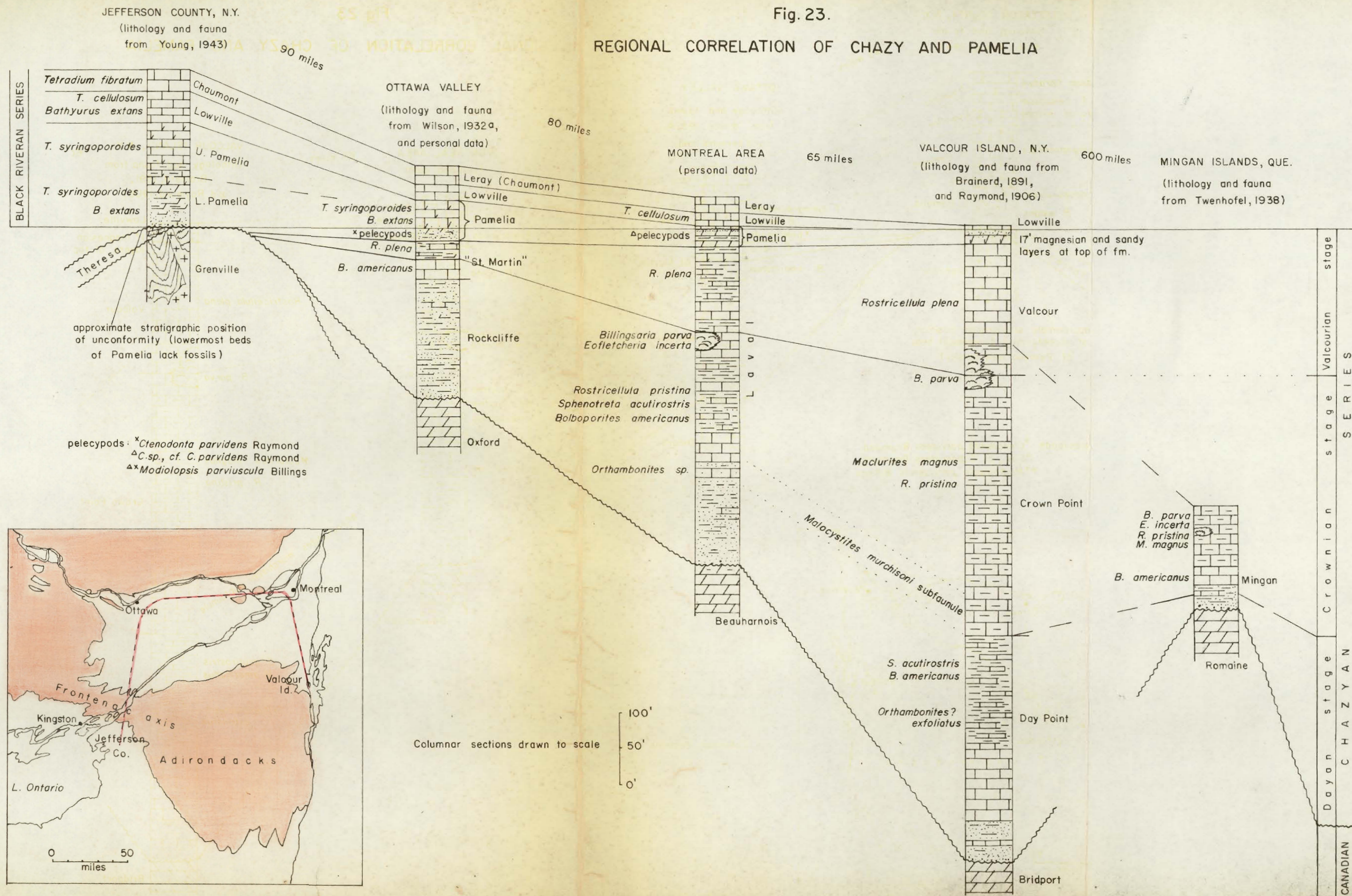
7) Maclurites magnus was not identified in the present collections. This gastropod, so common in the Crown Point and at Mingan, may be a provincial fossil. Its absence at Montreal and vicinity does not necessarily mean the absence of middle Chazy there, as the remainder of the fauna amply illustrates. Especially important is the subfaunule 2a of Raymond (1905, p.357; 1906, p.565), the Malocystites purchisoni zone at the base of the Crown Point. This zone, which has 12 characteristic species, is represented at Montreal and vicinity by 6 of these species in the middle part of the Bolboporites zone of the Laval formation, as exposed at Village Bélanger and at Cap St. Martin. These are: Raphistoma stamineum, Eoharpes sp., cf. E. antiquatus, Cheirocrinus forbesi, Palaeocystites tenuiradiatus, Canadocystis barrandi (= Malocystites emmonsii), and Malocystites purchisoni.

8) Compared to the typical Chazy, much of the Laval formation carries a restricted and slightly depauperate fauna. Many of the species found in the 3 formations of the standard section are lacking in southern Quebec. This is interpreted as being the result of different ecological conditions in the two areas during deposition. A similar dwarfing of the fauna was recognized in the Beekmantown of the St. Lawrence Lowland by Byrne (1958, p.141).

The preceding observations are incorporated into a regional correlation diagram (Fig.23, p.82). The greatest part of the Mingan formation is correlated with the Crown Point because of the abundance of Maclurites magnus throughout the section, and the presence of several brachiopods they have in common (see Cooper, 1956, p.14). Cooper found no brachiopods indicating a lower Chazy age, and only one, Hesperorthis ignicula, which might indicate upper Chazy rocks. However, in the Montreal area Hesperorthis sp., cf. H. ignicula was found in pre-Rostricellula plena horizons. The occurrence of Bolboporites americanus suggests that at least some of the lower part is equivalent to the Day Point or early Crown Point. The

Fig. 23.

REGIONAL CORRELATION OF CHAZY AND PAMELIA



presence of the two coral species may mean that beds equivalent to the Crown Point - Valcour boundary region are represented, and for this reason the correlation line (in Fig.23) is placed accordingly. Rostricellula plena or a related, multiplicate form has not been observed by Billings or Twenhofel.

The Aylmer formation in the Ottawa Valley is composed mainly of shales and sandstones, with ichnofossils that are also found in the lower sandstones in the Montreal area, but no good indexes are evident. The common Mimella imperator (Billings) is a relative of M. borealis (Billings) from the lower parts of the Laval formation. Calcarenite beds with Bolboporites americanus and shaly limestone beds with Rostricellula plena and the related R. wilsonae are correlatable with the upper parts of the Laval formation. No coral bioherms have been reported from the Chazy of the Ottawa Valley.

The correlation of the Pamela was already discussed in a previous section (pp.48-50).

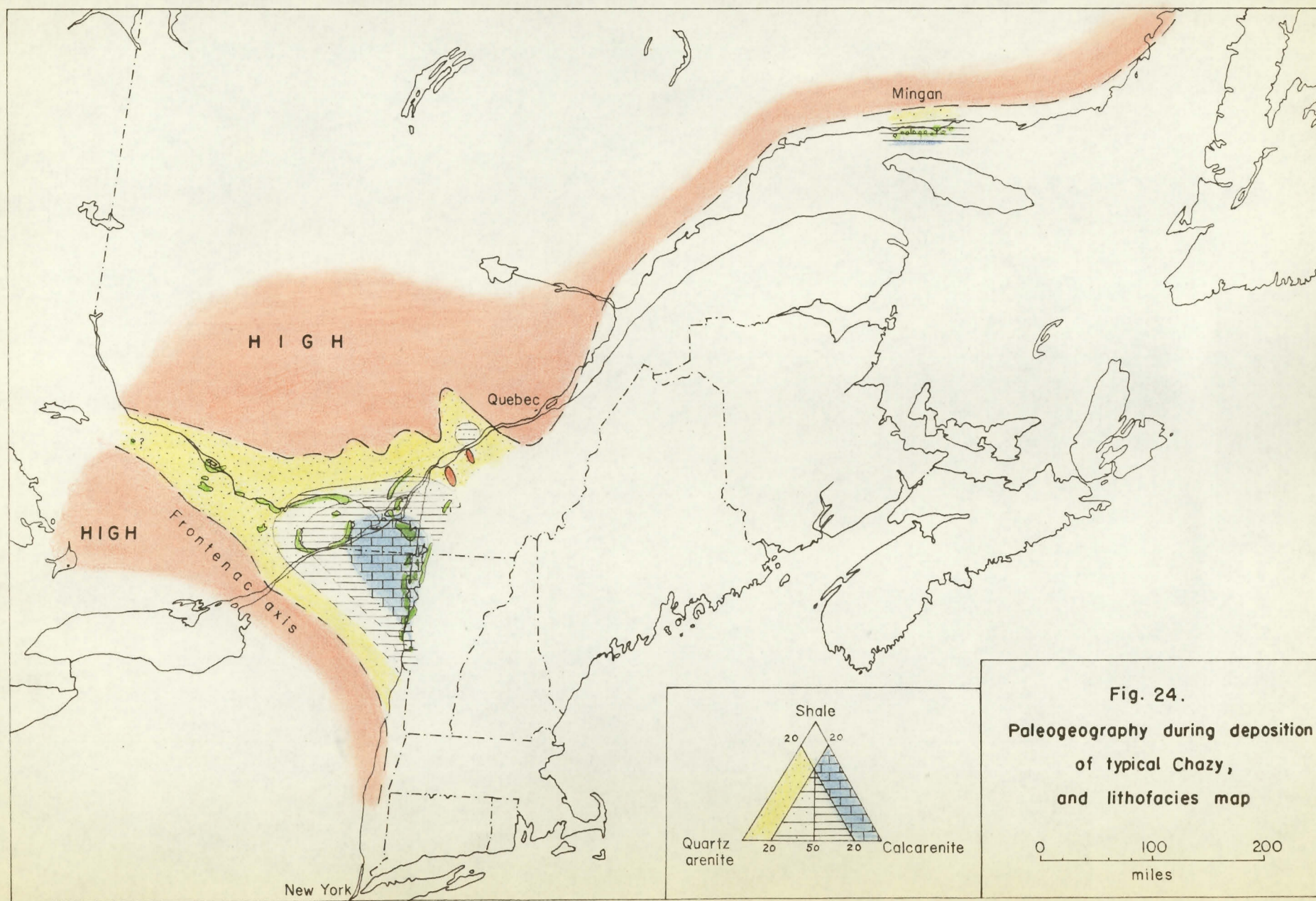
S E D I M E N T A T I O N

Today, Chazy rocks in southern Quebec are confined to a belt along the southern margin of the Laurentian massif, the Ottawa and St. Lawrence Valleys. The original distribution can only be surmised, for no conclusive records are available from west and northwest of the Precambrian escarpment. The rocks to the east of Logan's Line, presumably shales, are deformed, and in part metamorphosed, and cannot be traced directly into the St. Dominique or Laval formations.

Thickness and lithofacies distribution imply that the Chazy sea must have covered at least part of the Precambrian terrain to the west of the St. Lawrence Lowland. The large thickness of calcarenites on the west side of the Champlain Valley is an indication that the Chazy sea overlapped large areas of the Adirondacks region.

Outcrop areas (in green) and generalized lithofacies relationships are seen in Fig.24, p.85. The facies pattern consists of a core of marine limestones, surrounded by a zone of terrigenous sediments (the relationships in the Adirondacks cannot be substantiated). Great irregularities, perhaps due to faulting, occur in the thickness in the Three Rivers area, where the larger part of the section is composed of sandstone. Hills of Precambrian rocks stood above the sea floor, and the shoreline was probably very uneven during Chazy time. The pattern intimates that the sediments were deposited in an arm of the sea which occupied the Ottawa-St. Lawrence-Champlain Valleys and bordering areas. Another part of the sea covered the Mingan region. The shape of the Chazy coast line between these two main outcrop areas is conjectural. The position of this line is probably close to the present course of the St. Lawrence River, as there are many post-Chazy outliers resting directly on the Precambrian. If there were any Chazy sediments there at one time, they must have been all eroded again before Trenton-Utica-Richmond time.

The position of the southwestern coast line is also approximate. There appears to have been a 'high' in the Bancroft region west of the Frontenac axis, where corundum-bearing rocks supplied detritus for



some of the sandstone beds in the Laval. The Frontenac axis seems to have been a low barrier until Pamelia time when the sea was able to cross it. Possible Chazyan rocks have been found in the Brent Crater (Gilmour Lake) (Caley and Liberty, 1957, p.238; Innes, 1960, p.29), and for this reason the facies pattern is extended to include this area.

The Chazy sea advanced over Beekmantown and older rocks, and covered depressions which were not completely filled during Potsdam and Beekmantown deposition. On its floor the basal sediments were laid down, chiefly fine- to coarse-grained quartz sands and silty muds, material of which was derived from the weathering of preëxisting rocks. At some places in the basal few feet one can find a Lingulella coquina, witness to the earliest aquatic fauna of the Chazy.

Vagrant benthos flourished in shallow, near-shore waters, while in the shallow waters further off shore a varied pelmatozoan, brachiopod, ostracod, and trilobite fauna thrived. Upon death the skeletons were broken up by currents and waves. Strong currents, some of them perhaps tides, carried them off (in a predominantly southeasterly direction in the Montreal area) and piled them up in banks and shoals, generally in a cross-bedded fashion, forming a calcarenite coquina. Local slumping of unconsolidated material occurred due to overloading on unstable slopes. Where these burial grounds were close to shore considerable quartz sand and silt detritus mixed with the skeletal remains. After final burial the skeletons of the echinoderms crystallized and the fragments cemented. In many places where the waters were muddy and the animals not so abundant, or where strong currents were not available for skeleton transport, the lumpy-bedded shaly limestones were the main types to be deposited.

Bryozoan bioherms formed at various horizons, but in southern Quebec it was not until just before the beginning of late Chazy time that coral bioherms developed, in depressions on shoals of skeletal sands, where larvae could find a sheltered, warm and clear water environment for growth. These bioherms, at times, stood above water level, when channels were cut into them by erosion or solution, or both. They later became buried again when the rate of growth could not keep up with the rate of sedimentation around them, or for other reasons.

During the deposition of the upper Chazy the sea became somewhat restricted, and the number of species living in it became smaller, till in the later part of the upper Chazy only Rostricellula plena and Lingulella? sp. were abundant. In the Montreal region calcareous muds accumulated, followed by more shaly, silty, and dolomitic sediments. Ripple marks developed locally, and in the uppermost parts soft-shelled pelecypods abounded, foreshadowing the Pamelia environment.

During the deposition of the Pamelia in the Montreal area the sea became even more restricted, and animals disappeared almost completely. Calcareous oozes covered the floor of large lagoons, and evaporation was taking place in the restricted warm waters, increasing the salinity of the waters. The calcareous ooze was then perhaps dolomitized while still in contact with the highly saline waters. With a further receding of the waters ripple-marked silts and muds accumulated, and at times when the sea moved out altogether the muds developed dessication cracks. When water returned the mudflakes were spalled off the floor and swept away, and deposited with silt and sand to form intraformational conglomerate. Dolomitized calcareous ooze continued to be deposited till the end of local Pamelia time and into local Lowville time with but a very slight break which is marked by calcilutite and silt grains in the basal Lowville. However, this may be just another intraformational sandstone within the essentially continuous upper Pamelia - Lowville sequence. The uppermost Pamelia and the Lowville are lithologically very similar, except for the orange weathering color, which is imparted to the Pamelia by hydrous iron oxides derived from the weathering of disseminated authigenic pyrite.

It was during late Pamelia - Lowville time (Montreal section) that a new arm of the sea extended to this region, or that the sea was finally able to spill over the Frontenac axis and extend to the western side of the Adirondacks, joining up with the interior sea.

Thus, the typical Chazy group, which is only developed on the east side of the Frontenac axis, is the first unit of a nearly continuous record of deposition that continued till the end of the Ordovician in eastern North America.

S Y S T E M A T I C P A L E O N T O L O G Y

The fauna of the Chazy group of southern Quebec has much in common with that of the Champlain Valley, but fewer similarities exist with those of the more limited sections at the Mingan Islands and in the Ottawa Valley. Compared to the type area the number of species is smaller — about three-fifths are present — and the fauna is somewhat dwarfed. In the St. Lawrence Lowland there are more species of brachiopods and echinoderms than at Mingan, but not as many as at Lake Champlain, and the cephalopods and sponges are rare indeed. The Lichenaria [Lamottia] reefs of the upper Day Point were not found, but the Billingsaria and Eofletcheria bioherms in the upper half of the Chazy are present.

Only two main faunal divisions were recognized, the Rostricellula plena zone, which corresponds to the R. plena division of the type Chazy, and the Bolboporites americanus zone, which comprises correlatives of the lower and middle Chazy.

About 135 species have been completely or partially identified, compared to over 200 in the typical Chazy; 43 fully identified species are common to both areas. The Mingan formation has 74 species (Twenhofel, 1938, p.29), 9 of which are also found in the Laval formation.

A fossil list appears in the Correlation Chart on p.76 (Fig.20). It is complete except for ostracods and certain trilobites, which are listed in the text under their respective headings.

All available fossiliferous specimens were examined. The largest number comprises the collection made by T.H. Clark for the Quebec Department of Mines (now Department of Natural Resources), which are stored at present in the basement of the Redpath Museum. Smaller collections are those belonging to the Redpath Museum and those made by the writer. The specimens described and photographed were separated from the remainder and are deposited with the Depart-

ment of Geological Sciences, McGill University, for future reference.

Identifications were mainly made with the aid of the original publications, many of which are obscure journals. Professor Clark very kindly made available his private library of rare reprints for this purpose. Billings' type specimens, stored at the Geological Survey of Canada in Ottawa, were used for reference. Cooper's (1956) excellent publication was immensely useful in identifying the brachiopods. The rather poorly preserved cephalopods were submitted to Dr. R.H. Flower, New Mexico Institute of Mining and Technology, for identification.

The order of presentation of descriptions is that usually followed in the literature. A classification for each major taxon (class rank, or higher) is placed at the beginning of each section. This is done to permit the reader to gain at a glance a knowledge of the orders, families, and genera represented, as published in the most recent treatises on systematic paleontology. The classification scheme is then followed by separate descriptions of genera (where applicable) and species.

ALGAE

Three kinds of algae were found, and, according to the classification of Johnson (1961), their systematic position is as follows.

Phylum Rhodophycophyta Papenfuss, 1946

Class Rhodophyceae Ruprecht, 1901

Order Cryptonemiales Schmitz in Engler, 1892

Family Solenoporaceae Pia, 1927

Genus Solenopora Dybowski, 1877

Algae incertae sedis

?Genus Girvanella Nicholson and Etheridge, 1880
Unclassified form.

Genus Solenopora Dybowski,

Johnson (1960, p.15) gave the following description of the

genus: "Solenoporaceae in which the most apparent structures in vertical section are the vertical or slightly radiating cell threads. The cross partitions separating the cells in the threads are irregularly spaced, and commonly thinner and less conspicuous than the vertical walls of the threads. Little or no differentiation of tissue occurs. Growth form commonly rounded nodular masses."

Three species of this fossil are said to occur in the Chazy of the St. Lawrence Lowland: Parachaetetes (Solenopora) compacta Billings, Solenopora embrunensis Wilson, and S. paquettiana Ami. Only two species were found in the collections. They are small, solid masses of irregular globular shape, and may be easily mistaken for lutitic clumps.

Solenopora embrunensis Wilson.

Pl.2, fig.1

Solenopora? embrunensis Wilson, 1948, Geol. Surv. Can. Bull. no.11, p.15, Pl.6, figs.3,4.

MacGregor (1954) identified S. embrunensis and S. paquettiana in the local Chazy. He deposited one thin section of each of these with the Department of Geological Sciences at McGill University. A reëxamination of the two slides leads one to conclude that they are from different individuals of the same species. The distinguishing features of the two species are that in S. embrunensis the polygonal tubes are much finer than in S. paquettiana, there being about 12 to 15 in 1 mm., compared to 5 or 6 in 1 mm. in S. paquettiana. In the specimens from the Montreal area there are from 14 to 18 in 1 mm., and as long as tube size is of specific importance, then both of MacGregor's specimens should be designated S. embrunensis.

S. paquettiana was not listed by Johnson (1960, 1961) in his papers on Paleozoic Solenoporaceae.

Occurrence: Localities 12, 22, S. embrunensis is a long-ranging form which also occurs in the Black River and Trenton groups of the Ottawa Valley region.

Solenopora ouareauensis Fritz

Pl.2, fig.2

Solenopora compacta ouareauensis Fritz, 1941, Roy. Can. Inst. Trans.,
vol.23, pt.2, no.50, pp.157-160, 1 pl.

This species is characterized by its fine tubes, irregular cross section, and short septa. Its tubes are slightly smaller than those of Parachaetetes compacta and it lacks the regular tabulae. The specimens from the local Chazy have tubes that are spaced 12 to 15 in 1 mm. This fossil may be what has previously been identified as Solenopora compacta.

Occurrence: Localities 18, 23, 51. This is another long-ranging species, found in the Chazy of Montreal and in the Black River group at the Ouareau River, near Joliette.

Girvanella? sp.

Pl.12, fig.1

Girvanella sp. has been reported from the Chazy of the Montreal area (Clark, 1952, p.46). Although none of the specimens examined can definitely be assigned to this genus, those that might possibly belong to it are small globular bodies less than 1 cm. in diameter, composed of argillaceous limy material showing concentric banding, but lacking a well developed microstructure of sinuous tubes which is characteristic of this genus. Instead, small irregular dark spots and areas appear in thin sections. These globular bodies, which may be inorganic, were found in the upper parts of the Chazy at Localities 12, 51, and 52.

Unclassified form.

Pl.11, fig.4

In Oil Selections No.6 well, at 1810'-1815' and 1907'-1910.5', a dark greenish grey, slightly silty shale contains minute carbonaceous smears. These are 0.1 mm. or less wide, up to 5 mm. long, and fairly strongly curved. Some of the fragments are dichotomously branched; no surface structure is visible. They may be fragments of very delicate algal filaments.

PORIFERA

About a dozen species of sponges have been described from the Chazy in the Champlain Valley, and a few from the Mingan Islands. None has heretofore been observed in the Laval formation. One has been found in the St. Dominique formation. Using the classification published by the Geological Society of America in "Treatise on Invertebrate Paleontology, Part E", the two species found in the Quebec Chazy belong to the following groups:

- Phylum Porifera Grant, 1872
 - Class Desmospongia Sollas, 1875
 - Order Lithistida Schmidt, 1870
 - Family Aulocopiidae de Laubenfels in Moore, 1955
 - ?Genus Hudsonospongia Raymond and Okulitch, 1940
 - Family Eospongiidae de Laubenfels in Moore, 1955
 - Genus Eospongia Billings, 1861

Genus Hudsonospongia Raymond and Okulitch.

Hudsonospongia Raymond and Okulitch, 1940, Bull. Mus. Comp. Zool., Harvard College, vol.86, no.5, p.203.

Type species: Hudsonospongia cyclostoma Raym. and Okul., 1940.

Hudsonospongia? infundibulosa n.sp.

Pl.2, figs.3-6

Description: Solitary, globular to pear- or club-shaped sponges, tapering downward. Top surface convex, smooth, marked only by faint concentric undulations; shallow centrodorsal osculum. Specimens generally break into oblate or top-shaped bodies, the underside of which bears widely spaced narrow, straight or branching crenulations extending upward and outward. Radial partitions and canals not observed.

Polished sections in vertical plane exhibit a characteristic funnel-in-funnel structure, produced by alternating curved, conical laminae of differing mineralogical composition. Transverse sections show the cones as wrinkled concentric bands.

Thin sections show no structures except for conical laminations of argillaceous material, in a matrix of very fine-grained

quartz grains, dark flakes, and carbonate cement. No spicules preserved.

Measurements: The best specimen is incomplete at the base; it has a length of 85 mm., is 30 mm. wide near the bottom, and expands to 52 mm. just below the top. The top diameter of the other specimens ranges from 50 to 100 mm. The osculum is one quarter to one third as wide as the top diameter.

Occurrence: Common in shaly, calcareous quartz sandstone and siltstone of the Laval formation at Cap St. Martin (Localities 22, 23); also at Caughnawaga (Locality 40) and St. Martin (Locality 25).

Discussion: The new species here described is provisionally assigned to Hudsonospongia on the basis of general external shape and lack of regular radial partitions, such as are found in Zittellella. H.? infundibulosa resembles H. porosa Raymond and Okulitch, and H. fistulosa Raymond and Okulitch, in size and shape, but lacks the canals and has the funnel-in-funnel structure. The absence of canals and spicules, which is probably due to the method of preservation, makes it difficult to classify the fossil, but it is sufficiently distinct to warrant a new name at this time.

Name: The species was named for its funnel-in-funnel structure.

Eospongia sp., cf. E. roemeri Billings.

Eospongia roemeri Billings, 1862, Rept. Geol. Vermont, vol.2, p.956; 1865, Palaeozoic Fossils, vol.1, Geol. Surv. Can., p.19. Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.35, pl.5, figs. 4,5. Raymond and Okulitch, 1940, Harvard College Mus. Comp. Zool., Bull. vol.86, no.5, p.198, pl.1, fig.1.

Kay (1958, p.84) reported this fossil to be somewhat common in the reefy beds at St. Pie Hill (Locality 52), in association with Maclurites magnus. It has not been found anywhere else to the west. E. roemeri occurs at the Mingan Islands.

SCYPHOZOA

The Chazy conularids were treated most extensively by Sinclair (1940, 1942), and, with one important exception, no new information from the present investigation can be added to the material presented by him in 1942. Six species are now known in the Laval formation, and a seventh may possibly belong here. The genera can be classified as follows, using the classification followed in the "Treatise on Invertebrate Paleontology, Part F", published by the Geological Society of America.

Phylum Coelenterata

Class Scyphozoa Götte, 1887

Subclass Conulata Moore and Harrington, 1956

Order Conulariida Miller and Gurley, 1896

Suborder Conulariina Miller and Gurley, 1896

Family Conulariidae Walcott, 1886

Genus Metaconularia Foerste, 1928

Climacoconus Sinclair, 1942

Conularina Sinclair, 1942

Uncertain scyphozoan

Genus "Serpulites" Billings, 1859

Genus Metaconularia Foerste.

Metaconularia Foerste, 1928, Jour. Sci. Lab. Denison Univ., vol.23, no.1, p.107. Sinclair, 1940, Roy. Soc. Can. Trans. 3rd ser., vol.34, sec.4, p.101.

Type species: Conularia aspersa Lindström, 1884.

Metaconularia mascouchensis n.sp.

Pl.2, figs.7-9

Description: Species based on a single flattened specimen, incomplete at both ends, from diamond drill core. Length preserved 31 mm. Apical angle about 15°. Periderm very thin, black, iridescent on inner surface. Four straight, sharp, longitudinal ridges shown, each marked by deeply impressed, narrow groove. Faces almost plane, traversed by horizontal wrinkles that are pronounced in immature region and become obsolescent in mature region. Equally well marked horizontal and vertical rows of pustules, 12 to 13 in the length of 1 mm., forming a series of minute squares. The rows slightly sinuous

where the shell is deformed. Some of the vertical rows of pustules start in the very immature region of the animal. Horizontal rows become distinct where vertical rows suddenly appear regularly, at what is about the 75 percent growth stage of the shell, 16 mm. below the abapical end.

Occurrence: Quonto-International No.1 Mascouche well (DeBlois, 1959, p.55), at 1094 feet depth, in greenish grey shale, 14 feet above the base of the 205 feet thick Chazy. Associated with ostracods, Sphenotreta, and minute inarticulate brachiopods.

Discussion: This species very much resembles Metaconularia parroquetensis (Twenhofel) (Twenhofel, 1938, p.65, pl.9, fig.3), from which it differs by the more pronounced regular vertical rows, in having the angles on the sides grooved, and in not having well defined, closely spaced transverse wrinkles in the mature region. Twenhofel's single specimen comes from the black shales 15 feet above the base of the Chazyan Mingan formation. The striking similarities between these two rare species, as far as morphology and stratigraphic position are concerned, is indeed remarkable, considering that each locality has provided only unique specimens.

The finding of a second species close to the base of the Chazy shows that some of the earliest conularids known in North America had a more widespread geographic distribution than was previously thought.

Name: The species is named after the locality at which it was found.

Genus Climacoconus Sinclair.

Small conularids with square to rectangular cross sections. Faces with large smooth transverse ridges that meet along prominent mid-line keel in opposed or alternating position.

Climacoconus rallus Sinclair.

Climacoconus rallus Sinclair, 1942, Ann. Carnegie Mus., vol.29, p.228, pl.2, figs. 11,12.

This species is distinguished from others by the sharpness

of the transverse ridges and the great width of the spaces between these ridges. The holotype comes from a quarry at Locality 12. No new specimens were found by the writer.

Genus Conularina Sinclair.

Conularida having faces with mid-line expressed as a low ridge, flanked by shallow depressions that form a low ridge internally. Transverse section triangular or quadrangular. Surface marked by fine transverse striae.

Conularina irrasa Sinclair.

Conularina irrasa Sinclair, 1942, Ann. Carnegie Mus., vol.29, p.223, pl.1, figs. 1-3.

The large size and the extremely irregular fine, smooth, distant thread-like striae on the first inner shell layer are distinctive of this species. Sinclair found this fossil at Locality 23. It was not recognized in the McGill University collections.

Conularina raymondi Sinclair.

Conularina raymondi Sinclair, 1942, Ann. Carnegie Mus., vol.29, p.223, pl.2, fig.3.

Sinclair distinguished this species by its circular cross section which is indented at the margins of the faces, and by the indistinct, arched, transverse wrinkles of which there are about 5 in one mm. It occurs at Locality 22, associated with Rostricellula raymondi, and also in the upper Chazy at Valcour Island.

Conularina triangulata (Raymond).

Conularia triangulata Raymond, 1905, Amer. Jour. Sci., vol.20, p.379. 1908, Ann. Carnegie Mus., vol.4, p.216, pl.54, fig.18.

Conularina triangulata Sinclair, 1942, Ann. Carnegie Mus., vol.29, p.220, pl.1, figs. 4-10.

The characteristic triangular cross section and the fine ornamentation on the faces (16-20 wrinkles in the length of 1 mm.) are sufficient to identify this species. It has been found at Localities 12 and 23 in calcarenite beds. Raymond's specimens came from the upper Chazy at Valcour Island.

Conularina undosa Sinclair.

Conularina undosa Sinclair, 1942, Ann. Carnegie Mus., vol.29, p.222, pl.2, figs. 1,2.

Sinclair collected a single specimen at Locality 23. No others have been found since. This species resembles C. triangulata, but is distinguished from it by the low, indistinct striae which traverse the faces in curves, convex apicad, and stop abruptly at the mesial depression. The cross section is quadrate. Found at Locality 23.

"Serpulites" splendens Billings.

Pl.2, fig.10; Pl.5, fig.5

Serpulites splendens Billings, 1859, Can. Natur. Geol., vol.4, p.470.

Specimens of this fossil are up to 20 cm. long, 1 cm. wide, gradually tapering, flattened black phosphatic bodies whose surface is sculptured by closely spaced transverse striae, about 35 in the length of 1 cm. These fossils have been regarded as annelids, following the practice of Billings. The presence of transverse striae, the spiral twisting of some specimens (see one of the cotypes no. 1081, a-e, Geol. Surv. Can. coll.), the phosphatic nature, and their shape in cross section are not characteristic of the true Serpulites, and cast doubt on this interpretation. The features resemble those of the conularids, although they lack the characteristic square cross section and the mesial ridges. However, since there are conularids with triangular cross section, one might speculate that "Serpulites" splendens Billings is a conularid with only two angles and elliptical cross section. One such cross section was observed in a fragment encrusted with a bryozoan colony (Pl.5, fig.5), but whether this specimen actually is "Serpulites" splendens could not be ascertained.

Occurrence: Localities 12, 40. Logan collected several specimens on the Island of Montreal and at Caughnawaga. The cotypes are on shaly limestone slabs rich in Rostricellula sp.

ANTHOZOA

The oldest known coralline bioherms are found in the Chazy group of northeastern North America. They were built up by several genera of tabulate corals which flourished in the shallow seas associated with the Appalachian geosyncline. In the Chazy of the Champlain Valley the following species have been recognized:

Billingsaria parva (Billings), in the Valcour formation;

Eofletcheria incerta (Billings), in the Valcour formation;

Foerstephyllum wissleri Welby, in the middle and upper Chazy;

Lichenaria heroënsis (Raymond), in the upper part of the lower Chazy;

Nyctopora vantuyli Bassler, in the upper Chazy.

Of these only the first two were observed in the St. Lawrence Lowland; they also occur at the Mingan Islands. A related coral fauna, comprised of Billingsaria parva and Eofletcheria laxa is found in the Lenoir limestone in Tennessee (Bassler, 1950). Eofletcheria and Lichenaria have been identified in the upper part of the Pogonip group of Nevada (Duncan, 1956, p.216).

The systematic position of the corals from the Quebec Chazy is as follows, using the classification adhered to in "Treatise on Invertebrate Paleontology, Part F", published by the Geological Society of America.

Phylum Coelenterata

Class Anthozoa Ehrenberg, 1834

Order Tabulata Milne-Edwards and Haime, 1850

Family Syringophyllidae Pořta, 1902

Genus Billingsaria Okulitch, 1936

Family Auloporidae Milne-Edwards and Haime, 1851

Genus Eofletcheria Bassler, 1950

Billingsaria parva (Billings).

Pl.3, figs.1,2

Columnaria parva Billings, 1859, Can. Natur. Geol., vol.4, p.428.

Stylarea parva Lambe, 1899, Contr. Can. Pal., vol.4, pt.1, p.91., pl.5, figs. 9,9a,9b, (fide Twenhofel, 1938, p.39).

Billingsaria parva Okulitch, 1936, Roy. Soc. Can. Trans., 3rd ser., sec.4, pp.62-63, pl.1, figs 3,4.

Stylarea parva Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.39, pl.7, fig.1.

Description: Corallum thin, flat or undulating encrusting mass, up to 3 cm. thick, and up to 20 cm. across; composed of several distinct layers of growth. Upper surface pitted. Corallites polygonal, often quadrate, 0.6 to 0.8 mm. wide, 2 to 6 mm. high. Tabulae horizontal, evenly spaced, 0.5 to 0.8 mm. apart. Numerous septa, usually 8 larger ones extending about halfway to the thin columella, and 8 secondary, very short septa in between. Walls common to adjacent corallites, 0.1 to 0.3 mm. thick, crossed by fine canals.

Occurrence: Common only in bioherms; rare as pebble-size fragments in reef flanks. Localities 4, 9, 12, 22, 23, 47, 49; reported by Kay (1958, p.93) at Locality 52. Also found at the Mingan Islands, in the Champlain Valley, and in the Lenoir limestone near Knoxville, Tennessee.

Eofletcheria incerta (Billings)

Pl.3, figs. 3-6

Columnaria incerta Billings, 1859, Can. Natur. Geol., vol.4, p.428, figs. 1,2.

Fletcheria incerta Lambe, 1899, Contr. Can. Pal., vol.4, pt. 1, p.48 (fide Okulitch, 1937, p.314).

Okulitch, 1937, Roy. Can. Inst. Trans., vol.21, pt.2, no. 46, pp.314-315, pl.1, figs. 1-4.

Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.40, pl.6, figs. 5-7.

Wilson, 1948, Geol. Surv. Can. Bull. no.11, p.42, pl.21, fig.3.

Eofletcheria incerta Bassler, 1950, Geol. Soc. Amer. Mem. no.44, p.266, pl.19, figs. 16-18.

Description: Corallum phaceloid, irregularly hemispherical, composed of numerous subparallel, independent cylindrical tubes, up to 30 cm. across and 5 to 8 cm. high. Corallites 0.75 to 1.5 mm. in diameter, circular in cross section, polygonal when crowded. Outer surface of tubes smooth or finely rugose. Tabulae numerous, irregularly spaced, slightly concave or convex upward. Septa absent over most of corallite length, but faintly indicated as 8 undulations on the periphery in the mature region. Increase by budding.

Occurrence: Confined to some of the bioherm structures, at Localities 9 and 12. Found at the Mingan Islands and in the Champlain Valley region. Occurs also in Black River - Trenton beds in

the Ottawa Valley (Wilson, 1948, p.43).

Discussion: In southern Quebec this species is more restricted than Billingsaria parva, but where it does occur, it is very abundant.

At Ste. Anne-des-Plaines (Locality 9) this fossil is the main contributor to the bioherm. It can be readily recognized in weathered parts of the rock by its short, spaghetti-like appearance. Many samples from this outcrop were available for study, and interesting new information concerning morphology was obtained. For a long time investigators were in doubt about the presence of septa. Billings (1859) and Twenhofel (1938) did not observe any. Lambe (1899) found very minute septa, apparently spiniform (see Okulitch, 1936, p.69) in outline. Okulitch (1937) and Bassler (1950) believed this coral to be aseptate, and Wilson (1948) stated that the presence of septa is doubtful. Hill and Stumm (1956) said there are no septa. The present study has revealed that septa are, indeed, to be found in certain corallites of a colony which otherwise is composed of empty circular tubes. Those corallites that do not exhibit septa are the incomplete lower fragments of the colony, the upper surfaces having been destroyed by weathering. Through fortunate circumstances there are a few individuals which have the topmost region preserved, and these possess 8 distinctly marked septa. The partitions thus seem to be confined to the late mature growth stage, and this may account for the failure to detect them in most thin sections. Actually, the photograph of a thin section published by Okulitch (1937, pl.18, fig.2) displays at least one corallite (close to the center) having an octagonal interior periphery, suggestive of rudimentary septa.

The genus Eofletcheria as proposed by Bassler (1950, p.266) is based on Eofletcheria incerta (Billings), as described by Okulitch (1937), who thought it to be aseptate. It is clear now that the fossil has a more complex morphology in the mature region than was previously believed. This additional information should be incorporated in any future reference to the generic characteristics of the Middle Ordovician coral Eofletcheria.

BRYOZOA

By far the most abundant bryozoans are the branching Trepostomata, among which a fair number of species and several genera are represented. This is the group to which 'Stenopora fibrosa' (see Billings, 1859b, pp.346, 427) belongs.

Among the encrusting Trepostomata also several species are found, 'Stenopora patula' Billings (1859b, p.427) being one of them. In the Correlation Chart (Fig.20, p.76) these two groups of bryozoans are separated and designated by their field terms according to their habit of growth, although it must be understood that a species may have either habit of growth.

With a few exceptions (Family Phylloporinidae), the generic and specific identifications are not attempted in this thesis. They are left for future study of the bryozoan group as a whole. Those that were identified have the following systematic position, following the classification adopted in "Treatise on Invertebrate Paleontology, Part G", published by the Geological Society of America:

- Phylum Bryozoa Ehrenberg, 1831
 - Subphylum Ectoprocta Nitsche, 1869
 - Class Gymnolaemata Allman, 1856
 - Order Trepostomata Ulrich, 1882
 - Suborder Integrata Ulrich and Bassler, 1904
 - Family Phylloporinidae Ulrich, 1890
 - Genus Phylloporina Ulrich, 1887
 - Carinophylloporina Bassler, 1952
 - Chasmatoporella Nekhoroshev, 1936
 - Subretepora d'Orbigny, 1849
 - Unidentified branching and encrusting Trepostomata
 - Order Cryptostomata Vine, 1883
 - Family Stictoporellidae Nickles and Bassler, 1900
 - Genus Stictopora Hall, 1847

In the papers and faunal lists compiled by Logan, Billings, Ami, and Raymond the following bryozoans are mentioned at various localities:

Joliette	Monticuliporidae
Cap St. Martin	<u>Callopora</u> or <u>Calloporella</u>
	<u>Dicranopora?</u> sp.
	<u>Stictopora glomerata?</u>

L'Abord-à-Plouffe	Branching Monticuliporidae <u>Intricaria</u> sp.
Montreal Island	<u>Monotrypella undulata</u> <u>Monticulipora?</u> sp. <u>Phylloporina aspera</u> <u>Stenopora fibrosa</u> <u>Stenopora patula</u> <u>Stromatocerium rugosum</u> [probably an encrusting trepostomate form]
Grande Ligne quarries	<u>Amplexopora?</u> sp. or branching Monticuliporidae <u>Dicranopora</u> sp. <u>Stictopora glomerata</u> <u>Stictopora</u> sp., cf. <u>S. glomerata</u>
St. Dominique	Branching Monticuliporidae <u>Ptilodictya fenestrata</u>

MacGregor (1954, p.76) assigned the bryozoans associated with Chazy bioherms at Localities 9, 12, and 22 to:

Heterotrypa sp., cf. H. prolifica
Mesotrypa infida
Pachydictya foliata
Stigmatella sp., cf. S. personata
Stigmatella vulgaris

Phylloporina aspera (Hall)

Pl.4, figs. 6-7

Gorgonia? aspera Hall, 1847, Pal. New York, vol.1, p.16, pl.4, figs.3a,b.

Subretepora aspera Miller, 1889, N. Amer. Geol. Pal., p.326.

Phylloporina aspera Ulrich, 1890, Ill. Geol. Surv., vol.8, p.332,
pl.52, figs. 4-4c.

Chasmatopora aspera Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11,
p.42.

Description: Somewhat variable meshwork of anastomosing branches. Vertical bars parallel to subparallel, slightly wider than the elliptical fenestrules, bearing 2 to 4 rows of minute granular zooecia. Length of fenestrules 0.6 to 0.8 mm., width 0.2 to 0.3 mm. Back of zoarium with 2 or 3 longitudinal striae.

Occurrence: This is a common species in calcarenites, but is less common in argillaceous beds. It also occurs in the lower part of the Chazy at Chazy, according to Hall. However, Raymond (1905, 1906)

made no mention of it; instead he found Phylloporina incepta to be very common all through the Chazy of the Champlain Valley.

Phylloporina sp.

Pl.4, fig.2

Several fragments of a species apparently different from Phylloporina aspera were found at Localities 23, 35, and 44. The specimens have the regular arrangement of the branches, but the fenestrules are smaller and less elongated, and the zooecia are more irregularly spaced and much fainter. This fossil may be Phylloporina incepta (Hall).

Carinophylloporina sp.

Pl.4, fig.1

This bryozoan is represented by a fragment of a zoarium of the same shape as Phylloporina aspera, but instead of having the granular zooecia, the branches are covered with 2 or 3 rows of subrounded apertures, separated by a sharp, irregular keel. These are characteristics of the genus Carinophylloporina Bassler 1952. Such a form has not previously been known in the Quebec Chazy, and it is most likely a new species.

Occurrence: In the shaly, calcareous siltstone beds at the bottom of the Billet Quarry at Village Bélanger (Locality 23).

Chasmatoporella sp.

Pl.4, figs. 3-4

Description: Meshwork of irregularly branching and anastomosing zoaria, with 2 or 3 longitudinal striae. Fenestrules rounded, highly irregular, about twice as wide as zoaria, and very long. Width of zoaria 0.4 to 0.5 mm., wider where branching takes place.

Occurrence: Found in coarse-grained calcarenite at Localities 1, 3, 4, 8, 42.

Remarks: This genus is new to the Chazy, and a new species can be described when more material is available. The fossil has

zoaria very similar to those of Phylloporina aspera, but the fenestrules are irregular.

Subretepora sp.

Pl. 4, fig.5

Description: Network of reticulate, acutely branching stems. Fenestrules angular, very long and narrow. No ornamentation on zoaria visible due to poor preservation. Width of branches and fenestrules 0.2 to 0.5 mm., average length of fenestrules 2 to 3 mm.

Occurrence: Common in fine-grained, dolomitic sandstone at Locality 7. Also found in loose blocks at Locality 4.

Discussion: This bryozoan should be compared with Subretepora (Intricaria?) reticulata of the Trenton, described by Hall (1847, p.77, pl.26, figs. 8 a-c). The growth pattern is similar, but in Hall's species the fenestrules are much shorter, and wider. A similar fossil has not heretofore been recorded in the Chazy of the St. Lawrence Lowland. One is dealing here with a new species, whose complete description must be postponed until better specimens are found.

Stictopora spp.

Pl.5, figs. 1-4

Under this genus are included all the branched, bifoliate cryptostomatous Bryozoa of the Laval formation. The reasons for such a grouping procedure, as with the Trepostomata, are the complexity of classification, which depends on the detailed examination of thin sections or acetate peels, and also the lack of adequate previous study. The term 'Stictopora', as used here, is intended as a field term to distinguish the Cryptostomata from the Trepostomata.

The bifoliate bryozoans break easily along the mesothecal plane, exposing flat surfaces which show a multitude of parallel crescentic wrinkles that are convex in the direction of growth. In addition, minute closely spaced, distally diverging longitudinal

striae can often be seen. These features, almost always observable, are absent in the Trepostomata.

The specimens collected resemble the Trenton species Stictopora elegantula, illustrated and described by Hall (1847, p.75, pl.26, figs. 4 a-g). Hall also described two bifoliate bryozoans from the Chazy: Stictopora fenestrata and S. glomerata, to which the specimens bear resemblance.

In a recent restudy of the types of several bifoliate bryozoans Phillips (1960) discussed among others the genera Stictopora and Graptodictya, and showed that Stictopora and Rhinidictya are synonyms. She retained the generic name Stictopora for Hall's Chazyan species, but assigned Hall's Trentonian Stictopora to Graptodictya.

As used here, Stictopora probably includes the following genera listed on pp. 101-102:

Dicranopora
Dicranopora?
Intricaria
Ptilodictya
Stictopora

The specimens examined are quite varied. Usually only short fragments are visible, but sometimes, as shown in the figures on Plate 5, fine dichotomously branching examples are encountered. The widths of the branches are between 2 and 5 mm.

Occurrence: Fossils of this group are widespread in the Chazy, and are most commonly collected as fragments in the calcarenites of the upper parts of the Laval formation. Some good specimens have been obtained from the calcilutite associated with the bioherm development at Locality 49.

BRACHIOPODA

In a voluminous monograph G.A. Cooper (1956) recently described, reclassified, and profusely illustrated Chazy and related brachiopods. His outstanding reference work served as the basis for identifying the shells of this group from southern Quebec.

Thirty-five species are known from the Chazy of the Champlain Valley, and 15 from the Mingan formation at the Mingan Islands. In the Laval formation 24 species were recognized, 2 of which are new, and 8 of which do not occur at Lake Champlain, as far as is known.

The present status of the Chazy brachiopods in the St. Lawrence Lowland, following an abbreviated form of Cooper's (1956) classification, is as follows:

Subclass Gastrocaulia

Order Atremata Beecher, 1891

Family Obolidae King, 1846

?Genus Lingulella Salter, 1866

?Genus Palaeoglossa Cockerell, 1911

Family Siphonotretidae Kutorga, 1848

Genus Schizambon Walcott, 1884

Subclass Pygocaulia

Suborder Orthoidea Schuchert and Cooper, 1932

Family Orthidae Woodward, 1852

Genus Orthambonites Pander, 1830

Family Hesperorthidae Cooper, 1956

Genus Hesperorthis Schuchert and Cooper, 1931

Glyptorthis Foerste, 1914

Ptychopleurella Schuchert and Cooper, 1931

Family Dinorthidae Schuchert and Cooper, 1931

Genus Valcourea Raymond, 1911

Multicostella Schuchert and Cooper, 1931

Family Plectorthidae Schuchert and Cooper, 1931

Genus Mimella Cooper, 1930

Suborder Clitambonitoidea Opik, 1934

Family Clitambonitidae Winchell and Schuchert, 1893

?Genus Atelelasma Cooper, 1956

Family Triplesiidae Quenstedt, 1931

Genus Onychoplectia Cooper, 1956

Suborder Syntrophioidea Ulrich and Cooper, 1936

Family Camerellidae Hall and Clarke, 1894

Genus Camerella Billings, 1859

Suborder Pentameroidea Schuchert and Cooper, 1931

Family Rhynchotrematidae Cooper, 1956

Genus Rostricellula Ulrich and Cooper, 1942

Family Oligorhynchiidae Cooper, 1956
 Genus Sphenotreta Cooper, 1956
 ?Genus Dorytreta Cooper, 1956
 Suborder Strophomenoidea Maillieux, 1932
 Family Leptaenidae Cooper, 1956
 Genus Dactylogonia Ulrich and Cooper, 1956
 Family Strophomenidae King, 1846
 *Genus Platymena Cooper, 1956
 ?Genus Glyptomena Cooper, 1956
 ?Genus Macrocoelia Cooper, 1956

* Said to occur at St. Dominique (Locality 51) (Kay, 1958, p.84).

Lingulella? sp.

Pl.6, fig.1

All unrecognizable inarticulate brachiopods are here assigned to Lingulella? rather than to Lingula as has been the previous practice (Cooper, 1956, p.132). The fragmentary remains are found in a variety of lithologies, two of which are distinct.

The first group comprises the basal quartz sandstones in which there is a coquinal assemblage of obolid fragments. One can compare this to Lingulella brainerdi (Raymond), which occurs in a similar geological setting confined to the lowermost sandstone of the Chazy group on Lake Champlain, and to L.? huronensis minganensis (Twenhofel and Whiting), which is found in the basal beds at the Mingan Islands. The obolids in this group thus have paleoecological significance.

The second group of inarticulate brachiopods is abundant in the shaly upper layers of the Laval formation (Beaconsfield member), where they are accompanied by Rostricellula plena. In these horizons some nearly complete shells are preserved, and these can be assigned to Palaeoglossa? belli (Billings). This has been done where possible, but all other fragments are referred to Lingulella? sp.

The remainder of the inarticulate brachiopod fragments are sporadically distributed through the calcarenites and shaly limestones which make up the greater part of the succession.

In Oil Selections No.6 well, at 1907'-1910' there occur

microscopic, Leptobolus-like, inarticulate brachiopods in dark greenish grey shale, together with fine, branching, carbonaceous smears that may be algae.

Palaeoglossa? belli (Billings).

Lingula belli Billings, 1859, Can. Natur. Geol., vol.4, p.431, figs.7,8.
1863, Geology of Canada, p.124, figs. 47a,b.

Obolus belli Walcott, 1912, U.S. Geol. Surv. Mon. no.51, pt.1, p.386;
pt.2, pl.38, figs. 3a,b. (fide Cooper, 1956, p.221).

Palaeoglossa? belli Cooper, 1956, Smithsonian Misc. Coll., vol.127,
p.221, pl. 7,F, figs. 25-29.

Obolids belonging to this species are scattered over most of the area and through most of the section. However, there are some shale layers in the Beaconsfield member where they are very abundant as fragments and nearly complete valves, in association with Rostricellula plena, such as at Pont Viau (Locality 26). Where no complete or nearly complete valves are present, the fragments are referred to Lingulella? sp.

Raymond (1911, p.216) observed that a rare form, similar, but smaller in size, occurs only in the upper Chazy at Valcour Island. Cooper (p.221) did not include Raymond's specimens in this species, and mentioned that Palaeoglossa? belli occurs at the base of the Chazy group at Valcour Island.

Schizambon duplicimuratum Hudson.

Pl.6, fig.2

Schizambon duplicimuratus Hudson, 1905, N.Y. St. Mus., Bull. no.80,
p.284, pl.5, figs. 6,7.

Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.228, pl.34,
figs. 23-25.

Schizambon duplicimuratus Twenhofel and Whiting, 1938, Geol. Soc.
Amer. Spec. Pap. no. 11, p.45, pl.7, fig.16.

Schizambon duplicimuratum Cooper, 1956, Smithsonian Misc. Coll.,
vol.127, p.266, pl. 13,D, fig.6; pl. 15,B, figs. 5,6.

This fossil is very rare. One specimen was obtained at each of Localities 21, 40, and 49. In the Champlain Valley it is present in the Crown Point formation, and at the Mingan Islands it has been found in the basal beds of the Mingan formation.

Genus Orthambonites Pander.

Orthambonites Pander, 1830, Beitr. Geogn. Russ. Reiches, p.80.
Cooper, 1956, Smithson. Misc. Coll., vol.127, p.294.

As used by Cooper, this genus is for biconvex orthids having a costate ornamentation, orthoid cardinalia, and the pedicle musculature of the Orthidae.

Orthambonites palaformis n.sp.

Pl.6, figs. 4-6

Description: Shell biconvex, about medium size for the genus, wider than long. Hinge line slightly smaller than midwidth. Anterior margin strongly rounded. Cardinal extremities slightly obtuse. Surface marked by 52 rounded costae, closely spaced.

Pedicle valve crushed, slightly concave in anterior region, but appears to have been gently convex in lateral profile. Greatest convexity in umbonal region. Anterior profile swollen in umbonal region, slightly concave on sides. Interarea obtusely triangular, short, very gently incurved, marked by transverse striations. Delthyrium open.

Brachial valve moderately convex, greatest curvature in posterior region, slightly concave in posterolateral areas. Anterior profile evenly and broadly convex, very small flat area on umbo. Interarea short, strongly curved. Cardinal process rounded, protruding through notothyral cavity beyond interarea.

Length of holotype 17.6 mm., brachial length 16.8 mm., width 19.2 mm., thickness 7.6 mm.

Occurrence: In rusty weathering shaly limestone on Ile Bizard (Locality 35), where only a single specimen was found.

Remarks: This species is similar to O. multicostellatus Cooper, which has about 36 costae and occurs in the Edinburg formation in Virginia. No other species of Orthambonites has as many costae as the one here newly described.

Name: The specific name was chosen for the resemblance to a shovel; the term multicostellatus would have been better, if it were not already occupied for Cooper's species.

Orthambonites sp.

Pl.6, fig.3

Several valves of a species of Orthambonites were collected in the lowermost 11 feet of the Lagacé Quarry at St. Martin (Locality 25), in the silty and shaly beds interbedded with calcarenite. The specimen figured here is a nearly flat brachial valve with semicircular outline and greatest width at the hinge. It is 8.0 mm. wide, 6.0 mm. long, and has 28 straight, direct costae. Other specimens were found at Locality 18, and in Oil Selections No.6 well at 1938'-1968'.

The valves resemble Orthambonites? exfoliatus (Raymond), which is an index for the lower Chazy in the type area. Orthambonites has not previously been detected in southern Quebec, and its occurrence there throws new light on the paleogeography of the lower half of the Chazy.

Hesperorthis sp., cf. H. ignicula (Raymond).

Pl.6, fig.7

Orthis disparalis Billings, 1859, Can. Natur. Geol., vol.4, p.440, figs. 20a,b.

Orthis ignicula Raymond, 1905, Amer. Jour. Sci., ser.4, vol.20, p.369. 1911, Ann. Carnegie Mus., vol.7, no.2, p.236, figs. 10,11.

Hesperorthis ignicula Twenhofel and Whiting, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.46, pl.7, figs. 3-5.
Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.352, pl.51,F, figs. 27-34.

A large number of small Hesperorthis specimens were found in coarse-grained calcarenite at Localities 3 and 4, in association with Eurychilina, Bucania sulcatina, bryozoans, and very small rhynchonellids. A few more specimens were seen at Localities 40, 45, and 51. Almost all are exfoliated, about 5 mm. long and 5 or 6 mm. wide. In external form and arrangement of the costae they resemble H. ignicula from the upper Chazy of Valcour Island.

Glyptorthis transversa Cooper.

Glyptorthis transversa Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.376, pl. 50,F, figs. 24-28.

Cooper fully described and pictured this species. The holotype

comes from Village Bélanger (Locality 23). The species was also found in calcarenite at Caughnawaga (Locality 40). "Hebertella bellarugosa" in Clark's list (1952, p.46) is probably a Glyptorthis, and may belong here.

Ptychopleurella porcia (Billings).

Orthis porcia Billings, 1859, Can. Natur. Geol., vol.4, p.439, figs. 16-18. 1863, Geology of Canada, p.130, fig.58.

Clitambonites porcia Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.248, pl.36, figs. 15,16.

Ptychopleurella porcia Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.389, pl. 42,B, figs. 10,11.

Billings found and described a single pedicle valve from "Two miles north of city of Montreal." This specimen was reexamined and figured, first by Raymond, and then by Cooper, so that the holotype is now well known. Cooper (1956, p.29) listed the species as occurring in the Crown Point formation, although he did not mention this fact on p.389 where the fossil is discussed. The most diligent search in the present collections failed to produce any additional specimens, and the writer thinks that it is indeed a very rare species.

The slab in which the holotype is embedded (Geol. Surv. Can. coll., no. 1044), also contains Malocystites murchisoni, Mimella sp., and encrusting bryozoans.

Valcourea sp., cf. V. intracarinata Ulrich and Cooper.

Pl.6, figs. 42-43

Valcourea? intracarinata Ulrich and Cooper, 1938, Geol. Soc. Amer. Spec. Pap. no.13, p.125, pl. 21,C, figs. 9-12.

Valcourea intracarinata Cooper, 1956, Smithsonian Misc. Coll., vol. 127, p.408, pl. 73,A, figs. 1-4.

Usher (1947) found a very interesting specimen of an exotic Valcourea in the argillaceous limestone on St. Pie Hill (Locality 52), which has a striking resemblance to V. intracarinata from the upper part of the Pogonip group in Ikes Canyon, Toquima Range, Nevada. This unique specimen is here described.

Description: Brachial valve; shell of medium size for the genus, wider than long, hinge forming widest part. Anterior margin evenly convex, posterolateral margins nearly straight; surface costellate, costellae about 4 or 5 in 1 mm. at the front. Well defined narrow ridge on inside. Cardinal process trilobed. Length of valve 7.5 mm., width 13.8 mm.

Remarks: The median ridge is not quite as high and not as pronounced as in the species from Nevada. Otherwise, there are no recognizable differences. Valcourea strophomenoides of similar length is much narrower, and subquadrate in outline. The occurrence of this exotic form in the St. Dominique limestone suggests a link of the Chazy sea with the sea in which the upper Pogonip was deposited.

Valcourea strophomenoides (Raymond).

Pl.6, figs. 44,45

Plaesiomys strophomenoides Raymond, 1905, Amer. Jour. Sci., ser.4, vol.20, no.2, p.370.

Valcourea strophomenoides Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.240, pl.35, figs. 15,17,19 (not figs. 16,18); pl.36, fig. 1; text fig. 12.

Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.411, pl.74,B, figs. 15-25.

This species is not very common. It has been recognized with certainty only at localities 12, 18, 26, and 52. In the Champlain Valley it is usually found in the Crown Point formation.

Multicostella platys (Billings).

Pl.6, fig.40

Orthis platys Billings, 1859, Can. Natur. Geol., vol.4, p.438, fig.15. 1863, Geology of Canada, p.129, fig.54.

Dinorthis platys Schuchert, 1897, U.S. Geol. Surv. Bull. no.87, p.216 (fide Cooper, 1956, p.421).

Plaesiomys platys Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.238, pl.35, figs. 13,14.

Multicostella platys Schuchert and Cooper, 1932, Peabody Mus. Nat. Hist., Mem. vol.4, pt.1, p.98.

Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.421, pl. 68,A, figs. 1-4.

Specimens of this fossil are not very abundant except at certain localities, in the upper shaly limestone layers. They are not as common as Billings' account might lead one to believe. As with other brachiopods, this one is also invariably exfoliated.

Occurrence: Localities 15, 30, 35, 49, 52. In the Champlain Valley it is common in the middle Chazy, and ranges into the upper Chazy at Valcour Island (Raymond, 1906, p.528).

Multicostella? sp.

Pl.6, fig.46

In the St. Dominique limestone at St. Pie Hill (Locality 52) there occur moderately small, exfoliated shells of a species which may belong to Multicostella. The valves are more deeply sulcate anteriorly, and more transverse than M.platys, and may belong to a new species.

Mimella borealis (Billings).

Pl.6, figs. 9-13

Orthis borealis Billings, 1859, Can. Natur. Geol., vol.4, p.436, figs. 14 a-c. 1863, Geology of Canada, p.129, fig.56.

Hebertella borealis Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.241, figs. 13,14.

Mimella borealis Cooper, 1956, Smithsonian Misc. Coll., vol.127, pl. 85,E, figs. 38,39.

One of the most abundant species throughout the calcarenites and shaly limestones of the Bolboporites zone is Mimella borealis. This is a fairly large, primitive Mimella with direct costae, and is a form that has not been recognized outside the St. Lawrence Lowland.

Description: Shell somewhat variable, subpentagonal to transversely oval; greatest width at about midlength, hinge width considerably smaller; slightly wider than long. Anterior margin straight or slightly convex or concave. Anterolateral extremities well rounded; posterolateral margins meeting hinge line at about 110°. Flat space or low broad depression in the anterior region of both valves. Lateral profile moderately convex, brachial valve slightly deeper. Cardinal area of pedicle valve high and incurved. Delthyrium

narrow. Surface covered by 30 to 45 coarse, direct costae.

Occurrence: At many localities, as shown in Fig.20, p.76.

Discussion: Raymond stated that M. vulgaris is closely allied to M. borealis, but that it is wider (1911, p.242). The similarities are easily appreciated when specimens of the two species are observed side by side. It may well be that M. borealis is a local variety of M. vulgaris. Raymond, following Billings, also considered it very probable that the large M. imperator, which is so common in the Chazy in the Hawkesbury area, is only a local variation of M. borealis, as the two differ in but minor details: M. borealis usually has a shallow sinus in the pedicle valve, which is lacking in M. imperator.

There thus appears to be a gradational sequence of forms, from M. vulgaris, abundant in the middle Chazy of the Lake Champlain area, to the somewhat larger M. borealis of the Montreal area, to the giant M. imperator of the Ottawa Valley, with M. vulgaris also present near Montreal due to intermingling of the faunas.

The great number of specimens of coarsely costellate Mimella borealis suggests the presence of middle Chazy rocks in the Montreal area. The species is most commonly seen together with Rostricellula raymondi, Sphenotreta acutirostris, branching Trepostomata, and cystids.

Mimella transversa Cooper.

Pl.6, fig.17

Mimella transversa Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.484, pl. 85,D, figs. 33-37.

This recently erected species occurs in the upper Chazy at Valcour Island. It was also found in the St. Lawrence Lowland, in the calcarenite beds at Localities 12 and 30, in the upper parts of the Laval formation. It is the only Mimella of the local Chazy with numerous fine costellae, possessing about 8 in 5 mm. at the anterior margin. This fossil resembles M. nucleoidea Cooper, but is not so thick, or so convex.

Mimella vulgaris (Raymond).

Pl.6, figs. 14-16

Hebertella vulgaris Raymond, 1906, Ann. Carnegie Mus., vol.3, p.501.
1911, ibid., vol.7, no.2, p.242, text fig.16, pl.36, fig.3.

Mimella vulgaris Cooper, 1956, Smithsonian Misc. Coll., vol.127,
p.488, pl. 85,A, figs. 1-12; pl. 92,E, figs. 29-33.

Mimella vulgaris is a common species, both in Quebec and in New York. Raymond found it to range through most of the Chazy section, but this must now be revised in view of the action taken by Cooper. Cooper separated Raymond's species into two and erected a new one, M. nucleoidea. Mimella vulgaris Cooper occurs in the Crown Point formation and in many localities in the vicinity of Montreal (see Correlation Chart, p.76).

"Hebertella acuminata" (Billings).

Orthis acuminata Billings, 1859, Can. Natur. Geol., vol.4, p.44, fig.19.
1863, Geology of Canada, p.130, fig.59.
Raymond, 1911, Ann. Carnegie Mus., vol.7,no.2, p.246, fig.22.

A single valve was described by Billings under Orthis acuminata. The most outstanding character of this fossil is supposed to be the spiriferoid outline produced by the acuminate cardinal extremities. Raymond reexamined the holotype and concluded that this specimen is an imperfect brachial valve of some species of Mimella, perhaps M. vulgaris. He suggested that the name be dropped. No new specimens have ever been found. The writer also examined the holotype (Geol. Surv. Can. coll., no.1045) and concurs with Raymond.

Orthoidea spp. indet.

A large number of detached, exfoliated, or otherwise poorly preserved, often immature valves cannot be identified with certainty as to genus, and these are grouped together under the above heading. They most likely belong to the genera Mimella, Hesperorthis, and Orthambonites.

Atelelasma? parvum (Wilson).

Pl.6, fig.8

Clitambonites? parva Wilson, 1932, Trans. Roy. Soc. Can., ser.3, vol. 26., sec.4, p.383, pl.2, figs. 8-10.

Wilson referred this brachiopod to Clitambonites with a query because the delthyria of each of her specimens were obscured by matrix, and compared the species to Ptychopleurella porcia (Billings), which Cooper regards as a hesperorthid, not a clitambonitid. A.? parvum has a prominent beak and a delthyrium which apparently occupies one-half of the flat cardinal area, and specimens from Montreal have the same characteristics. The comparison with Ptychopleurella is much less convincing than one with the clitambonitid Atelelasma Cooper. Ptychopleurella has hesperorthid outline, the pedicle valve is provided with a median costa which may be elevated or depressed, and the delthyrium is narrow. The shape, the uniform costae, and the wide delthyrium of Wilson's species all agree much better with Atelelasma. However, as no interiors have been obtained, the genus is not certain.

Occurrence: Small exfoliated individuals occur together with Rostricellula raymondi, Sphenotreta acutirostris, Mimella, Bolboporites americanus, and bryozoans, in the coarse-grained calcarenite beds at Localities 9, 37, 40, 52, and in the Mallet well 165' above the base of the Laval formation. Wilson collected the species in a shaft on Barnhart Island, New York, near Cornwall, Ontario, in association with Rostricellula orientalis (probably = R. raymondi). A similar and much larger species, A.? multicostum (Hudson), is abundant in the middle Chazy of the Champlain Valley.

Onychoplecia sp., cf. O. gracilis (Raymond).

Pl.6, fig.31

Triplecia gracilis Raymond, 1902, Bull. Amer. Paleont., vol.3, p.303, pl.18, fig.1.

Camerella longirostris Raymond (non Billings), 1911, Ann. Carnegie Mus., vol.7, no.2, p.249, pl.36, figs. 29,30.

Onychoplecia gracilis Cooper, 1956, Smithsonian Misc. Coll., vol.127, pl. 100,C, figs. 11-14.

The genus has not heretofore been reported from the study area. O. longirostris (Billings) was described from the lower part of the Chazy at the Mingan Islands (Billings, 1859; Twenhofel and Whiting, in Twenhofel, 1938), and the Crown Point formation in New York

(Raymond, 1911). Cooper revised the classification of this species and assigned the specimens from the Lake Champlain area to O. gracilis. It is distinguished from O. longirostris by its longer, narrower, and deeper pedicle sulcus.

All the specimens from the Laurentides map-area have a pronounced sulcus, narrow and deep, but not very long. The shells are 5 mm. long, or less, and show faint concentric striae. The greatest convexity is in the posterior third. The posterolateral margins are slightly concave, and in a specimen from Locality 40 the dental plates are visible. Thus, the specimens resemble the New York species more than that from the Mingan Islands, although there is not too great a difference between the two species.

Occurrence: Localities 1, 9, 23, 40, 46.

Remarks: At Valcour Island Onychoplectra ranges from about 10 feet above the base to the top of the Chazy, and consequently it has no practical value in correlation.

Camerella varians Billings.

Camerella varians Billings, 1859, Can. Natur. Geol., vol.4, p.445, fig.24. 1863, Geology of Canada, p.127, fig.52.
Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, pp.250-253, pl.36, figs. 25,26.

Rhynchocamera varians Twenhofel and Whiting, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.53, pl.7, figs. 19-21.

Camerella varians Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.583, pl. 110,B, figs. 6,7; pl. 110,D, figs. 12-15; pl. 110,E, figs. 16-21; pl. 118,F, figs. 50-54.

C. varians was first described from the Mingan Islands, and later it was reported at Chazy Village (Billings, 1865, p.220). Raymond observed that the fossil is also quite variable in the Lake Champlain region, and commented on the appropriateness of the specific name. Cooper redescribed Raymond's specimens from the Crown Point formation near Chazy, and referred them to a new species, C. ventricosa. The difference between these two species is very slight. Only a few specimens of a Camerella were found, and these are moderately convex and have a sulcus with a short tongue; according to Cooper's classification they belong to C. varians as originally described by Billings.

Occurrence: Locality 52. In the type region of the Chazy group Camerella occurs in the middle Chazy (Raymond, 1906, p.528) and the upper part of the lower Chazy (Oxley and Kay, 1959, p.829). Its presence at the Quebec locality is ~~is~~ indicative of lower or middle Chazy an age of the containing rocks.

Rostricellula plena (Hall).

Pl.6, figs. 32-35

Atrypa plena Hall, 1847, Pal. New York, vol.1, p.21, pl. 4bis, figs.7a-c.

Rhynchonella plena Billings, 1859, Can. Natur. Geol., vol.4, p.444, figs. 22a-c. 1863, Geology of Canada, p.125, figs. 50a-c.

Camarotoechia plena Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.221, pl.33, figs. 7-18.
Wilson, 1932, Roy. Soc. Can. Trans., ser.3, vol.26, sec. 4, p.384.

Rostricellula plena Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.645, pl. 129,I, figs. 39-53; pl. 132,D, figs. 19,20; pl. 137,E, figs. 34-36.

For extensive synonymy see Bassler, 1915, U.S. Nat. Mus. Bull. 92, p.178.

R. plena is the index fossil for the upper Chazyan Valcour formation in the type region, and is said to be the most abundant, and the most variable of the fossils of the Chazy (Raymond, 1911, pp.221-222), and one of the earliest, largest, and most robust species of this genus (Cooper, 1956, p.645. Its morphology and ontogeny are well known through the detailed studies of previous authors, and need not be considered here.

It has generally been cited as being very abundant in the Montreal area. On this basis many authors have considered the Montreal Chazy to be of late Chazyan age. The present study vindicates this conception, as it was found that R. plena is not so widely distributed, but that it is very abundant in certain localities, and that it is confined to the uppermost parts of the Laval formation.

The specimens examined are quite variable, ranging in size from small specimens, about 6 mm. long, to giants, about 20 mm. long. The number of costae in the sulcus is not constant, some individuals having 5, others 7 or more. Immature shells are very thin, yet their specific characteristics are already distinguishable: many plications

of equal size, low wide sulcus, and subtriangular outline. In some mature valves the sulcus is deep and pauciplicate, in which case they may be easily confused with R. wilsonae. Indeed, in the St. Vincent de Paul Quarry (Locality 20) there seem to be a whole range of intermediate forms, with both end members present. This free mixing is not well developed in approximately equivalent beds in the Devito Quarry (Locality 39), or in the Pointe Claire Quarry (Locality 38).

Another important result of the present study is the discovery of specimens that appear to be R. plena (Pl.6, fig.35) in the upper layers of the Pamelia formation in the Devito Quarry, which Okulitch (1934, 1936) and Clark (1952) considered to be of Black Riveran age. These fossils are preserved as casts and molds in dense, orange-weathering dolomite. No internal structures are visible, and no details of the delthyrial region can be distinguished. Nevertheless, the external shape, the 6 or 7 even costae in the low, broad sulcus, and the size range of the individuals are exactly the same as in the R. plena specimens which form a coquinoïd in argillaceous limestone beds 20 to 30 feet below the top of the Pamelia.

Similar casts and molds, and also silicified specimens, were observed in the Pamelia of the Ouareau River section. These were identified as 'Camarotoechia plena or Rhynchotrema increbescens' by Parks (1931, p.21), and as 'Rhynchotrema increbescens' by Okulitch (1939, p.84). These brachiopods are admittedly far from being well preserved, but Rhynchotrema increbescens Hall 1860 usually has 3 costae in the sulcus, 4 on the fold, and imbricate ornamentation. These characteristics are not visible in the specimens from the Montreal Pamelia, and the Pamelia of the Ouareau River.

Occurrence: Mainly in argillaceous limestones of the Beaconsfield member, the upper part of the Laval formation. Also in the Ottawa Valley Chazy, and in the Valcour formation on Lake Champlain; locally, in the Pamelia of the Montreal area. The species has been reported in the Row Park formation of the Stones River group in Pennsylvania, but this identification is doubtful (Cooper, 1956, p.645).

Rostricellula pristina (Raymond).

Pl.6, figs. 27-30

Camarotoechia pristina Raymond, 1905, Amer. Jour. Sci., ser.4, vol. 20, p.368. 1911, Ann. Carnegie Mus., vol.7, no.2, p.225, pl.34, figs. 1-10.

(?) Rostricellula pristina Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.646, pl. 132,B, figs. 6-10.

At Localities 16, 18, and 40 one can find specimens of a small Rostricellula with the characteristics of R. triangulata Cooper, and of R. pristina (Raymond) in particular. The median costa of the sulcus and the central costae on the fold are weaker than the adjoining ones; the fold and sulcus are very indistinct. These specimens may, however, be the young of R. raymondi which is present at the same localities in various sizes and shapes.

The last listing in the above synonymy is questionable because Cooper's pictured hypotype is quite unlike the original specimens photographed by Raymond, in that the shell is much larger and much more transverse, suggesting affinities with R. raymondi or R. wilsonae.

Rostricellula raymondi Cooper.

Pl.6, figs. 23-26

Camarotoechia orientalis Raymond (partim), 1911, Ann. Carnegie Mus., vol.7, no.2, p.223, pl.35, figs. 19-22, 24-31 (not 32,33).

Rostricellula raymondi Cooper, 1956, Smithsonian Misc. Coll., vol.127, p.647, pl. 130,E, figs. 25-34; pl. 130,F, fig.35; pl. 132,C, figs. 11-18.

This is the fossil which was referred to Camarotoechia orientalis Raymond, until Cooper showed that the specimens from southern Quebec and New York are actually distinct from the related R. orientalis (Billings) from the Mingan Islands.

Raymond mentioned that near Montreal R. plena does not occur where R. raymondi is abundant, and that R. plena is very abundant on Valcour Island, where R. raymondi is lacking. Wilson (1932, p.384) observed that in a shaft on Barnhart Island, New York, near Cornwall, Ontario, Camarotoechia orientalis (probably = R. raymondi) occurs most commonly in the lower part of that section, together with Mimella,

followed by R. plena in the stratigraphically highest horizons. The same can be said for the Montreal region: R. raymondi occurs in association with Mimella borealis and M. vulgaris below the Rostricellula plena zone. At Aylmer, Quebec, R. orientalis (probably = R. raymondi) and R. plena occur together (Wilson, 1932, p.384).

Raymond's suggestion that R. raymondi developed from R. plena by the checking of the costae at an early growth stage, while the fold and sulcus continued to maturity, has already been questioned by Wilson. Rather than a decrease, there was an increase in the number of plications during the evolution of these species. An intermediate stage is probably represented by R. wilsonae. This would mean that R. orientalis from the Mingan Islands is the most primitive of the genus, and that the genus originated in the east or northeast and spread southwestward, unless one interprets the differences as local, contemporaneous variations.

Rostricellula wilsonae Cooper.

Pl.6, figs. 36-39

Rostricellula wilsonae Cooper, 1956, Smithsonian Misc. Coll., vol. 127, p.655, pl. 135,F, figs. 36-48.

Specimens of this species are common in the region around Ottawa. They have a less triangular outline and a deeper sulcus than R. plena. The species also resembles R. raymondi, and intermediates between all three species are present. It appears then that the classification is somewhat artificial, especially if the three species are considered as representing different stages in a fairly short evolutionary sequence.

The species was found in the uppermost parts of the Laval formation in the St. Vincent de Paul Quarry (Locality 20), together with R. raymondi below 18.0', and with R. plena above 18.0'. In this locality some of the individuals are very large, measuring 20 mm. in length.

Rostricellula spp.

Fossils under this heading include all those shells in which

	<i>R. orientalis</i>	<i>R. raymondi</i>	<i>R. major</i>	<i>R. plena</i>	<i>R. wilsonae</i>	<i>R. pristina</i>	<i>R. triangulata</i>
pedicle view							
brachial view							
side view							
posterior view							
anterior view							
Occurrence	MINGAN ISLANDS	MONTREAL	L. CHAMPLAIN	L. CHAMPLAIN, MONTREAL	OTTAWA VALLEY, MONTREAL	L. CHAMPLAIN, MONTREAL	MINGAN ISLANDS
Horizon	Mingan fm.	Laval fm.	Valcour fm.	Valcour fm., Pamelia fm., Laval fm.	Aylmer fm. Laval fm.	Crown Point fm., Day Point fm., Laval fm.	Mingan fm.

Species of *Rostricellula* in the Chazy of eastern North America.

Fig. 25

the specific characters are not identifiable due to bad preservation. They are most likely R. raymondi and R. plena, but include also several specimens from Localities 44 and 45, which have slight concentric corrugations on their surfaces. The latter are tightly imbedded in dark grey coarse-grained calcarenite, and exhibit no good identification features.

In Fig. 25 on p. 122 the main characteristics and the distribution of Rostricellula in the Chazy of eastern North America are summarized.

Sphenotreta acutirostris (Hall).

Pl.6, figs. 18-20

Atrypa acutirostra Hall, 1847, Pal. New York, vol.1, p.21, pl. 4bis, fig.6.

Rhynchonella acutirostris Hall, 1859, 12th Ann. Rept. Cab. Nat. Hist., p.65.

Zygospira (?) acutirostris Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.227, pl.34, figs. 15-22.

Sphenotreta acutirostris Cooper, 1956, Smithsonian Misc. Coll., vol. 127, p.664, pl. 124,F,figs. 32-38; pl. 143,H, figs. 37-40.

The most prolific brachiopod in the Laval formation is without doubt Sphenotreta acutirostris. This little brachiopod was identified in most of the outcrops, ranging from the upper parts of the lower Laval sandy and shaly beds into the lower part of the Rostricellula plena zone. Due to its small size it may be easily overlooked, but with a hand lens one can almost always count a fair number of individuals in any one hand specimen. It most frequently is found in the cystidogenic calcarenite beds in association with ostracods, bryozoans, Mimella, Rostricellula raymondi, and Bolboporites americanus. A few specimens have been found together with R. plena, but none in the upper parts of the R. plena zone.

This species has its widest variations in shape in the calcarenites of the Laurentides map-area, where there is an assemblage of diversified small rhynchonellids, probably comprising several species. One of these may belong to another genus, Dorytreta. One of the varieties of S. acutirostris is very long (Pl.6, fig.20);

another has comparatively coarse costae. In the rest of the study area this species is fairly constant in size and shape.

At Valcour Island this fossil is confined to the lower Chazy (Raymond, 1906, p.528); elsewhere in the Champlain Valley it is common in the lower and middle Chazy (Raymond, 1911, p.228). Cooper (1956, p.664) mentioned its occurrence only in the Crown Point formation.

It has been identified as far west as Hawkesbury, Ontario, but has not been found at the Mingan Islands. The presence of S. acutirostris in the rocks of southern Quebec is taken as an indication of a lower or middle Chazy age of the containing rocks.

Genus Dorytreta Cooper.

Dorytreta Cooper, 1956, Smithsonian Misc. Coll, vol.127, p.666.

The genus Dorytreta is similar to Sphenotreta externally but with the sulcus reverting to a fold anteriorly. "Foramen elongate oval and with margin thickened; deltidial plates small, triangular.

Pedicle interior with short divergent dental plates. Brachial interior with small triangular socket plates divided by a wide space; crura short, bent abruptly toward the pedicle valve."

Type species: Dorytreta bella Cooper, 1956.

Dorytreta? arduamarginata n.sp.

Pl.6, figs. 21-22

Description: Shell small, subtriangular to ovate in outline, strongly biconvex, widest part anterior to the middle, thickest at middle. Apical angle 60-70°. Posterior lateral margins gently rounded. Surface marked by 13 or 14 angular costae, 2 in the brachial sulcus.

Pedicle valve strongly and evenly convex. Anterior profile subtrapezoidal, lateral profile semicircular. Fold poorly defined, originating at middle and bearing 1 costa, and ending anteriorly in a shallow sulcus. Median costa flanked on each side by 6 anteriorly diverging curved costae. Fairly steep lateral slopes. Beak moderately incurved.

Brachial valve strongly convex in lateral profile, greatest

depth at middle. Anterior profile convex with median region concave. Sulcus originating on umbo and passing into a moderately pronounced fold at the middle, bearing 2 costae. Flanks swollen, lateral slopes steep.

Length of one pedicle valve 3.8 mm., width 3.1 mm. Length of a brachial valve 3.1 mm., width 2.9 mm. Complete specimen not seen.

Occurrence: Shells of this little brachiopod were collected at Localities 1, 3, 7, and 23, in coarse-grained calcarenite.

Discussion: The genus Dorytreta has not been reported elsewhere in the Chazy of eastern North America, but has been observed in the Lenoir formation of Tennessee, and in the upper part of the McLish formation in Oklahoma (Cooper, 1956, pp.666-668).

Name: The species from southern Quebec is named for its steep lateral slopes.

Dactylogonia incrassata (Hall).

Pl.6, figs. 47,47a

Leptaena incrassata Hall, 1847, Pal. New York, vol.1,p.19, pl. 4bis, figs. 2a-d.

Raymond, 1911, Ann. Carnegie Mus., vol.7, no.2, p.230, pl.34, figs. 32-37.

Dactylogonia incrassata Cooper, 1956, Smithsonian Misc. Coll., vol. 127, p.828, pl. 219,I, figs. 16-23; pl. 219,J, figs. 24-27; pl.220,B, figs. 6-8; pl. 226,C, figs. 5-9.

A single specimen of this species was found in the calcarenite horizon at Locality 50, in association with Eoharpes sp., cf. E. antiquatus, Raphistoma stamineum, and Stictopora sp. It is finely costellate, and there are only faint indications of stronger costellae. The fine concentric growth lines pass into concentric wrinkles on the ears of the shell.

Glyptomena? spp.

The designation 'Glyptomena? spp.' is here used as a loose term for the Chazy brachiopods of Quebec belonging to the family Strophomenidae, and may embrace the genera Glyptomena, Macrocoelia, and possibly Platymena, which were erected by Cooper (1956) on

material that had been previously referred to Rafinesquina. Species of the first two genera have been found in the Lake Champlain region, and Platymena is said to occur in the St. Dominique area (Kay, 1958, p.84).

Fossils of this group are not easily studied, as they are often deformed, and almost always exfoliated. The shells are thin, and it is practically impossible to remove them from the rock for examination of the pedicle region and the interiors. Their surface features, however, are well shown in some specimens.

The shells are subrectangular to spade-shaped in outline and have flat or concavo-convex profiles. Their surfaces are finely costellate, with larger costellae setting off groups of numerous finer costellae. Exfoliated valves show a dense mat of pseudopunctae.

Strophomenids are widespread geographically and stratigraphically, ranging from near the bottom of the Laval formation to the top. They are most often seen in calcarenite beds, and in shaly limestone with lumpy bedding. None were encountered in the dark greenish grey shale horizons. Several species are represented, as seen by the considerable variation in shape and ornamentation. One group resembles exteriorly Raymond's Glyptomena? (Strophomena) prisca. Another distinct species, which occurs at Localities 3 and 4, has pronounced reversal of curvature of the valves. Macrocoelia champlainensis (Raymond) has previously been reported from the Quebec Chazy (Clark, 1952, p.46), but none of the specimens collected could be definitely identified with this species. Rafinesquina alternata appears in the lists compiled by Raymond (1906, pp.554-557) from published sources; Cooper believes (1956, p.16) that this fossil was incorrectly identified. Wilson (1932, p.382) described Glyptomena? (Rafinesquina) laurentina from the Chazy near Cornwall, Ontario; it is another species that may be represented in the Laval formation.

MONOPLACOPHORA

Only two species of these single-shell mollusks have been found in the Laval formation, compared with six from the Champlain Valley. The two from Quebec have the following systematic position, using the classification followed in "Treatise on Invertebrate Paleontology, Part I", published by the Geological Society of America:

Phylum Mollusca

Class Monoplacophora Wenz in Knight, 1952

Order Tryblidioidea Lemche, 1957

Family Palaeacmaeidae Grabau and Shimer, 1909

Genus Scenella Billings, 1872

Order Archinacelloidea Knight and Yochelson, 1958

Family Archinacellidae Knight, 1956

Genus Archinacella Ulrich and Scofield, 1897

Archinacella propria Raymond.

Pl.7, figs. 1,2

Metoptoma montrealensis Raymond (non Billings), 1902, Bull. Amer. Pal., no.14, p.34.

Archinacella? propria Raymond, 1906, Ann. Carnegie Mus., vol.3, p.575.
1908, Ann. Carnegie Mus., vol.4, nos. 3 and 4, p.172, pl. 46, figs. 7-8.

The present specimens are somewhat smaller than those described by Raymond.

Description: Shell patelliform, nearly circular in outline, about 10 mm. across; rounded cone rising to an acute apex 3 mm. high and located between center and anterior margin. Beak small, anterior slope almost vertical for 1 mm., then curving forward to anterior margin. Posterior slope regularly convex. No surface markings seen. Shell about 0.2 mm. thick.

Occurrence: In calcarenite at Van Horne and Stuart Avenues in Outremont (Locality 33), and in calcarenite 1 mile N.N.E. of Grande Ligne (Locality 48); also at Locality 12. Said to be fairly common at Crown Point; Valcour Island; and Chazy, New York.

Scenella montrealensis (Billings).

Pl.7, fig.3

Metoptoma montrealensis Billings, 1865, Pal. Foss. Can., vol.1, p. 394, fig.371.

Scenella montrealensis Ulrich and Scofield, 1897, Paleontology of Minnesota, vol.3, pt.2, p.838 (fide Raymond, 1908, p.173). Raymond, 1908, Ann. Carnegie Mus., vol.4, p.173, pl.46, figs. 9-10; pl.55, fig.1.

One poor specimen was found in the collections. It is a smooth interior mold without any distinct markings, but the shape agrees with the first part of Billings' description: "Acutely conical; apex a little in advance of the centre; base obtusely elliptical, the antero-posterior diameter a little the longest. On a side view the outline is gently convex from the apex to the posterior, and concave to the anterior margin. Surface, when perfect, with fine vertical striae running from the apex to the margin, and with both fine engirdling striae and obscure undulations of growth parallel to the base. In most specimens the fine striae are not perceptible."

Occurrence: Billings found the species at "Montreal". One specimen was collected at Locality 33. The fossil also occurs at Chazy Village, and on Isle La Motte, Vermont (Raymond, 1908).

Discussion: According to Knight and Yochelson (1960, p. I 77), ?Scenella Billings 1872 is a Cambrian genus which occurs in North America and northeastern Asia. Either the shells in the Chazy do not belong to this genus, or the genus ranges into much younger rocks. None of the other genera described by Knight and Yochelson fit the description of Scenella montrealensis, so that this fossil is here kept under Scenella.

GASTROPODA

The fossils in this group are somewhat common in the local Chazy, but are generally found to be rather poorly preserved. They are of small to medium size and comprise only a small number of species, compared to the large variety of forms in the Champlain Valley. For extensive descriptions, illustrations, and lists of species of the typical Chazy gastropods the reader should consult the paper by Raymond (1908). The genera found in the Laval formation have the following systematic position, based on an abbreviated form of the classification in "Treatise on Invertebrate Paleontology, Part I", published by the Geological Society of America:

Phylum Mollusca

Class Gastropoda Cuvier 1797

Order Archaeogastropoda Thiele, 1925

Suborder Bellerophontina Ulrich and Scofield, 1897

Family Bellerophontidae M'Coy, 1851

Genus Bucania Hall, 1847

Suborder Macluritina Cox and Knight, 1960

Family Macluritidae Fischer, 1885

Genus Maclurites LeSueur, 1818

Family Helicotomidae Wenz, 1938

?Genus Helicotoma Salter, 1859

Suborder Pleurotomariina Cox and Knight, 1960

Family Raphistomatidae Koken, 1896

Genus Raphistoma Hall, 1847

Family Lophospiridae Wenz, 1938

Genus Loxoplocus (Lophospira) Whitfield, 1886Genus inquirendum ?Cyclora Hall, 1845Bucania sulcatina (Emmons).

Pl.7, fig.4

Bellerophon sulcatus Emmons, 1842, Geol. New York, Rept. of the Second District, p.312.

Bucania sulcatina Hall, 1847, Pal. New York, vol.1, p.32, pl.6, figs. 10, 10a; pl.33, fig. 4d.

Bucania rotundata Hall, 1847, Pal. New York, vol.1, p.33, pl.6, figs. 11a-c.

Bucania champlainensis Whitfield, 1897, Amer. Mus. Nat. Hist., Bull. vol.9, pl.4, figs. 14-16 (fide Raymond, 1908, p.194).

Bucania sulcatina Raymond, 1908, Ann. Carnegie Mus., vol.4, nos. 3 and 4, p.191, pl.49, figs. 15-17; pl.50, figs.3,4; pl.55, figs. 13,14.

This species is common only in the Laurentides map-area, where the shells are found in calcarenite. They are much smaller than most of the specimens from the Champlain Valley.

Description: Shell small, planispiral, slightly involute. Whorls broad, with angular sides. Surface ornamented with wavy revolving striae that pass backward and sideward, about 7 or 8 in 1 mm., traversed by transverse growth lines with irregular spacing. Along the middle of the shell is a narrow (0.2 mm.) carina. The growth lines cross this narrow band, diverging anteriorly and then curving backward as they approach the sides of the whorl. Apertures not preserved. Most of the shells are less than 8.0 mm. long (measured in plane of symmetry) and less than 7 mm. wide.

Occurrence: Observed at Localities 2,3, 6, and 23. Kay (1958, p.84) encountered it at St. Pie Hill (Locality 52). It is abundant in the Champlain Valley.

Remarks: Raymond (1908, p.196) mentioned that this species is especially common at two horizons in the typical Chazy. One is in the lower part of the Chazy, where it is associated with Scalites angulatus, and the other is just below the Rostricellula plena zone, where it is accompanied by other fossils, especially Pliomerops canadensis. The common association of B. sulcatina and P. canadensis is now also recognized in the Chazy of the St. Alexis-de-Montcalm region, and, with the occurrence of Rostricellula plena in the vicinity, serves to indicate the approximate stratigraphic position of that Chazy sequence.

Maclurites magnus LeSueur.

Maclurite magna LeSueur, 1818, Philadelphia Acad. Nat. Sci., Jour. vol.1, p.312, pl.13, figs. 1-3.

Maclurea magna Hall, 1847, Pal. New York, vol.1, p.26, pl.5, figs. 1a-d; pl. 5bis, figs. 1a-c.

Maclurites magnus Raymond, 1908, Ann. Carnegie Mus., vol.4, pp.199-201, pl.50, figs. 1-2; pls. 51,52.
Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.59, pl.10, figs. 1-2.

The writer did not recognize any specimens in the collections which could be identified with this species, although Raymond (1908,

p.199) said it occurred at Montreal. The only large gastropods seen are those from the upper parts of the Laval formation, and they are spire-bearing and orthostrophic dextral. However, one very large specimen of what may be M. magnus can be seen in one of the building stones of the Peoples Church, at 2097 Union Street in Montreal. This fossil was pointed out to the writer by Dr. Clark, who suggests that the stone was derived from one of the Chazy quarries in the Montreal region.

M. magnus is the index fossil for the middle Chazy, and its absence (or extreme rarity) in the Montreal area could mean first that no middle Chazy is present, and second that middle Chazy is present, but that the species is a provincial or a facies fossil. The argument in favour of the latter interpretation was already given on p.81.

The species occurs at the Mingan Islands, and is said to be present on the northeast slope of St. Pie Hill (Locality 52) (Kay, 1958, p.84).

Helicotoma? sp.

Pl.7, fig.7

In the limestones at Localities 16 and 20 one can find fairly large gastropods which appear to be a species of Helicotoma. The shell is dextral, obtusely conical, with pleural angle of 150°-160°. There are three whorls with very acutely angular shoulders and deep sutures. The ramps are nearly horizontal or sloping gently downward. Some specimens are up to 5 cm. across. Better material is needed to identify these gastropods.

Raphistoma immaturum (Billings).

Pleurotomaria immatura Billings, 1859, Can. Natur. Geol., vol.4, p.454.
Raphistoma immaturum Raymond, 1908, Ann. Carnegie Mus., vol.4, pp. 182-183, text fig.2.

This species was not identified in the collections. It is the only species in the Chazy, belonging to Raphistoma, which has step-like coils. The last whorl is concave. The surface markings

appear to be the same as those of R. stamineum, yet the lower part is not so conical as in R. striatum and R. stamineum.

Occurrence: Billings collected the type specimens "two miles north of Montreal". This locality is probably in the upper Chazy at Villeray (Locality 32). Raymond found good specimens in the lower Chazy at Plattsburg, New York, together with Scalites angulatus and Bucania sulcatina, and also at Chazy Village.

Raphistoma stamineum Hall.

Pl.7, figs. 8-10

Raphistoma staminea Hall, 1847, Pal. New York, vol.1, p.29, pl.6, figs. 4,5,5a.

Pleurotomaria calyx Billings, 1859, Can. Natur. Geol., vol.4, p.455, figs. 30-32. 1863, Geology of Canada, p.132, fig.62.

Pleurotomaria pauper Billings, 1859, Can. Natur. Geol., vol.4, p.457.

Raphistoma stamineum Raymond, 1908, Ann. Carnegie Mus., vol.4, p.180, pl.47, figs. 11-13; pl.48, figs. 1-5; pl.55, figs. 5-8; text fig.1.

Raymond studied this fossil in detail and concluded that it is very variable in size, shape, and ornamentation. This led him to place under R. stamineum about half a dozen species that were previously described by Hall, Emmons, and Billings. These are listed in his synonymy. Raymond thought R. stamineum Hall to be distinct from R. striatum (Emmons), but Shimer and Shrock (1944, p.449, pl.181, figs. 21-23) did not differentiate between the two species.

Description: The shells of the specimens from southern Quebec are of medium size, 10 to 25 mm. across, with several dextral, gradually enlarging whorls.

Top surface with gentle slope, meets lower part of last whorl at a fairly sharp angle (45°-70°); marked by collabral cords which make a double curvature in passing downward and outward. The growth lines touch adjoining ones in a very characteristic manner, so as to produce a pseudo-suture that runs parallel to the true suture, about two-fifths of the distance from the inner to the outer suture of a whorl. The sinuous lines become obscure at the outer rim of the coils; in some individuals they culminate in a notch, forming an angular

selenizone. Bottom surface smooth, showing sinuous collabral lines that extend downward and forward for some distance, then inflect and turn backward to the columella on the bottom. Umbilicus not seen.

Occurrence: Shells most common in the Grande Ligne region, in calcarenite (Localities 48 and 50), and in shaly, dolomitic beds at Villeraie (Locality 32). Also at Localities 1, 5, 16, 23, 25, 33, 40, 52, and in the middle and upper Chazy in the Champlain Valley.

Raphistoma stamineum crevieri (Billings).

Pleurotomaria Crevieri Billings, 1859, Can. Natur. Geol., vol.4, p. 456, figs. 33-35.

Raphistoma stamineum Raymond (partim), 1908, Ann. Carnegie Mus., vol. 4, p.180.

A species under the name Pleurotomaria crevieri was described and illustrated by Billings, from material collected near St. Dominique. In his comprehensive review of Chazy gastropods Raymond assigned many of the species described before him to R. stamineum Hall, including P. crevieri. Several specimens of Billings' species collected in the St. Dominique area exhibit constant characteristics, and for this reason this fossil is retained here as a variety of R. stamineum. The original description is as follows (Cotypes, Geol. Surv. Can. coll., nos. 1059 a,b):

"Shell small; whorls four; spire nearly flat; base sub-hemispherical; no umbilicus.

On the upper surface the first two whorls form a low, rounded elevation in the centre, rising a little above the outer margin; the others are gently concave, and a little depressed below the margin of those preceding. The base is sub-hemispherical or depressed conical, the length a little more than half the width of the spire. The surface is marked with fine striae of unequal size, curved as in all other species of this group. The outer margin is acutely rounded, not bevelled as it is in specimens of P. calyx, of the same size. Width of spire, five or six lines [10.6 or 12.7 mm.]."

To this may be added that the fossil has distinctly elliptical or ovoid spiral shape, as seen in top view. Perhaps this is a deformational feature.

Occurrence: Only encountered in argillaceous limestone in the St. Dominique area (Localities 51 and 52).

Raphistoma? sp.

Pl.7, fig.11

Several fragments of a rare gastropod were found in calcarenite at Localities 23 and 33. The shells are about 10 mm. across and have a shape very similar to Raphistoma stamineum, but instead of being covered with collabral striae, they are sculptured with strongly defined sinuous ridges and very faint transverse corrugations. The outer top and bottom surfaces meet at an angle of approximately 70°.

Loxoplocus (Lophospira) sp.

Pl.7, figs. 5,6

Two fairly large individuals of a Lophospira were collected. They are preserved as an internal filling and as a vertical section in a slab. This is the first record of the occurrence of the genus in the Laval formation. It is common in the Champlain Valley and has also been found at the Mingan Islands and in the Rockcliffe formation at Aylmer, Quebec. Of all the species reviewed by Raymond (1908) Lophospira billingsi has the closest resemblance to the specimens from the Montreal area.

Occurrence: Found in the gastropod layer in the St. Vincent de Paul Quarry (Locality 20), in the 4.2'-18.0' interval (see p.74).

Cyclora? sp.

Pl.7, fig.12

Hall (1845, p.294) described a very minute, naticiform gastropod from the Upper Ordovician of the Cincinnati region, using the name Cyclora. Similar fossils were seen at Localities 20, 38, and 39, in the shaly, dolomitic limestone beds of the Beaconsfield member, associated with Rostricellula plena. They are less than 0.8 mm. in greatest dimension, and have one and one-half rapidly expanding, rounded, dextrally coiled whorls. The bodies are composed of a black substance, without surface markings, and probably are steinkerns.

CEPHALOPODA

The cephalopods are represented by a small number of poorly preserved orthocones. This is in noticeable contrast to the large number and great variety of forms of cephalopods known in the typical Chazy rocks.

Billings (1859b, p.462) mentioned Orthoceras multicameratum Conrad and O. subarcuatum Hall as occurring on the Island of Montreal. To these he added (1865, p.173) a new species, O. velox, from Ile Bizard.

Raymond (1906, p.554) listed O. bilineatum Hall and Endoceras velox (Billings) as having been identified in the Grande Ligne quarries (Localities 48, 49, 50) by previous investigators; Orthoceras sp. is listed with other fossils from Joliette (Locality 1).

The cephalopod genera from the present collections have the following systematic position, following the classification of Flower and Kummel (1950):

Phylum Mollusca

Class Cephalopoda Leach, 1817

Subclass Nautiloidea Zittel, 1884

Order Endoceratida Flower and Kummel, 1950

Family Endoceratidae Hyatt, 1883

Genus Vaginoceras Hyatt, 1883

Order Actinoceratida Flower and Kummel, 1950

Family Ormoceratidae Saemann, 1852

Genus Ormoceras Stokes, 1838

Order Michelinoceratida Flower and Kummel, 1950

Family Michelinoceratidae Flower, 1945

Genus Michelinoceras Foerste, 1932

Family Stereoplasmodoceratidae Kobayashi, 1934

Genus Stereospyroceras Flower, 1955

Order Oncoceratida Flower and Kummel, 1950

Family Valcouroceratidae Flower, 1946

Genus Valcouroceras Flower, 1943

cf. Vaginoceras oppletum Ruedemann.

Vaginoceras oppletum Ruedemann, 1906, N.Y. St. Mus., Bull. no.90, p.413, pl.4, figs. 2,3; pl.5, figs. 1-4; pl.6, fig.1; pl.9, figs. 1-3; fig.4.

This fossil is known from one fragment of a fairly large individual from the orange weathering shaly beds at Locality 36.

Ormoceras sp.

A single specimen, probably a new species, was collected in the orange weathering shaly beds of the Laval formation at Locality 35. It is not complete enough to justify a specific description.

Michelinoceras sp.

Two tiny specimens were obtained. One is a short fragment with 5 camerae that was collected from the dark Pamelaia shale in the Devito Quarry (Locality 39, interval 19.0'-22.3'). Another specimen, which may be a Michelinoceras, is a tiny smooth orthocone living chamber that was collected in calcarenite at Locality 50.

Stereospyroceras sp., cf. S. clintoni (Hall).

Orthoceras subarcuatum Hall, 1847, Pal. New York, vol.1, p.34, pl.7, fig.3 (fide Ruedemann, 1906, p.445).

Billings, 1859, Can. Natur. Geol., vol.4, p.462 (fide Ruedemann, 1906, p.445).

Orthoceras clintoni Miller, 1877, Amer. Paleoz. Foss. (1st ed.) p.244.

Spyroceras clintoni Ruedemann, 1906, N.Y. St. Mus. Bull. no.90, p.445, pl.11, fig.4; pl.16, figs. 4-7; text fig.18.

Two medium-sized specimens were found in widely separated places (Localities 12 and 50), each in oölitic calcarenite. Billings reported similar fossils from Montreal Island. Stereospyroceras clintoni occurs all through the Chazy in the Champlain Valley (Bassler, 1915, p.1181).

Valcouroceras sp.

One poor fragment of an undescribed species of Valcouroceras, approaching Minganoceras in proportions, was found in oölitic calcarenite at Locality 50, associated with Stereospyroceras sp., cf. S. clintoni and Raphistoma stamineum.

Unidentified orthocones.

There are several crushed fragments of a fairly large orthocone with marginal siphuncle. They are the only cephalopods

which are somewhat common, but occur solely at Locality 35 in orange weathering shaly beds, where Billings reported Orthoceras velox. The fragments resemble this species somewhat, and they may possibly be the same, though the material does not allow one to be certain about this.

Crushed, unidentifiable orthocones, which according to Flower (written communication, 1961) could be small endoceroids, Murrayoceras, or michelinoceratids, were collected in approximately equivalent horizons in the lower part of the Bolboporites zone, at Localities 26 and 42. The specimens have a large marginal siphuncle and resemble the specimens from Ile Bizard (Locality 35) mentioned in the last paragraph, but are smaller.

PELECYPODA

Pelecypods are not very abundant in the local Chazy succession, and, where they do occur, they are almost invariably badly preserved. Hence there are often great difficulties in determining these fossils, even on the generic level. No good internal structures have been encountered in any of the present specimens, and the identifications are based on comparisons of exteriors, and shell shape and size with Raymond's (1916) illustrations and descriptions.

The pelecypods have their commonest occurrence in the topmost dolomitic shales of the Laval formation, and the shales of the Pamelaia, where their flattened valves form thin black films on the bedding surfaces, or where they accumulated as rounded black fragments of coarse sand grain size (Pl.7, fig.18). Billings (1859b, p.446) said he recognized 17 species in the Chazy of eastern Canada, but that the material was too fragmentary to permit description. Of these 17 species only Modiolopsis parviuscula and Clionychia montrealensis were said to occur in the Montreal region.

The best paper to date on Chazy pelecypods is that by Raymond (1916), in which the first full set of illustrations was put

forth. In all, 18 species are described from the Chazy of the Champlain Valley, and another 5 from the Chazy and Pamelaia of the Ottawa Valley.

No species of pelecypods have been reported from the Chazy of the St. Lawrence Lowland since 1859. Some new information has become available in the present study. The genera represented can be classified as follows;

- Phylum Mollusca
 - Class Pelecypoda Goldfuss
 - Order Taxodonta
 - Genus Ctenodonta Salter, 1851
 - Order Schizodonta
 - Genus Clionychia Ulrich, 1892
 - Order Dysodonta
 - Genus Modiolopsis Hall, 1847

Ctenodonta sp., cf. C. parvidens Raymond.

Pl.7, fig.15

- Ctenodonta parvidens Raymond, 1905, Amer. Jour. Sci., ser.4, vol.20, p.73; no figs.
 Whiteaves, 1908, Ottawa Nat., vol.22, p.113, pl.3, fig.16.
 Raymond, 1916, Ann. Carnegie Mus., vol.10, nos. 3 and 4, pp.340-341, pl.29, figs. 7,8.
 Wilson, 1956, Geol. Surv. Can., Bull. no.28, p.27, pl.2, fig.18.

According to Raymond (1916), C. parvidens is one of the commonest species in the Pamelaia formation near Ottawa. Very similar pelecypods are numerous in the Devito Quarry as compressed dark films in the 5-foot unit of black dolomitic shales, immediately underlying the orange-weathering carbonate bed which Okulitch (1934, 1936) referred to the Pamelaia formation. Although their morphological features are somewhat obscure due to the flattening they may well be the same as Raymond's species.

Description: Shell very thin, oval in outline; anterior and posterior margins evenly rounded. Regular slopes from umbo forward, downward, and backward. Umbo located at about half the distance between middle and anterior extremity. Faint rounded ridge extending from umbo to central part of the posterior margin. Surface ornamented by concentric growth lines. No teeth seen. Length of figured specimen 14.5 mm., height 7.0 mm.

Occurrence: In the uppermost part of the Chazy in the Pointe Claire - Beaconsfield area (Localities 38 and 39).

Clionychia montrealensis (Billings).

Pl.7, figs. 13,13a

Vanuxemia Montrealensis Billings, 1859, Can. Natur. Geol., vol.4, p. 447, figs. 25,26. 1863, Geology of Canada, p.131, figs.61a-b.

Clionychia montrealensis Whiteaves, 1908, Ottawa Natur., vol.22, p.107. Raymond, 1916, Ann. Carnegie Mus., vol.10, nos. 3 and 4, p.334, pl.29, figs. 18-24.

Billings has already stated that this species is not common. One specimen in the Redpath Museum collection (no. 10,050) was examined and photographed, and it is briefly described here.

Description: Right valve, medium size, oval in outline, black. Evenly rounded posterior margin; rounded umbo pointed forwards. Beak obscure. Slightly curved anterior and straight dorsal margins make an angle of about 70°. Valve strongly convex, thickest part and greatest convexity near middle. Posterior end drawn out into a short wing. Surface marked by concentric striae. Length 13 mm., height 9.2 mm.

Occurrence: C. montrealensis is reported from Montreal Island and L'Orignal, Ontario. It is more common in the middle and upper Chazy at Valcour Island and Chazy, New York.

Clionychia? sp.

Pl.7, fig.14

One poor specimen of an undescribed pelecypod was found on Ile Bizard. Fragments of both valves are preserved, and show some resemblance to those of C. montrealensis. The specimen differs in having a very long posterior wing. The dorsal and posterior margins are approximately at right angles. The beak is angular and pointed. Surface sculpturing on the lower side of the left valve is in the form of minute corrugations. The shell is 15 mm. long, 11 mm. high, and 7 mm. thick.

Occurrence: Found in the orange weathering shaly beds at Locality 35.

Remarks: This is the only pelecypod collected in a horizon where Bolboporites americanus, Rostricellula raymondi, and Sphenotreta acutirostris are also present, and hence it is the stratigraphically lowest representative of this class in the local Chazy. A Clionychia has also been found in the lower Chazy in the Champlain Valley (Oxley and Kay, 1959, p.825).

Modiolopsis fabaformis Raymond.

Pl.7, fig.17

Modiolopsis fabaformis Raymond, 1905, Amer. Jour. Sci., ser.4, vol. 20, p.374. 1916, Ann. Carnegie Mus., vol.10, nos. 3 and 4, p.338, pl.30, figs. 12,13.

(non) Modiolopsis fabaeformis Whiteaves, 1908, Ottawa Natur., vol.22, p.110, pl.3, figs. 7-8 (fide Raymond, 1916, p.338). Wilson, 1956, Geol. Surv. Can., Bull.28, p.67.

Description of specimen from Outremont: Small, thick, elongated shell, 10.5 mm. long. Highest part posteriorly, 5.5 mm. Strong rounded ridge extending from umbo to lower posterior angle. A marked broad, rounded indentation runs to the middle of the lower margin in front of the ridge. Deepest part of valve anteriorly, 1.1 mm., one third the distance between anterior and posterior extremities. Posterior margin evenly rounded. Surface marked by numerous concentric striae.

Occurrence: Occurs in calcarenite at Van Horne and Stuart Avenues, Outremont (Locality 33), upper part of Laval formation. Also found in the upper Chazy at Valcour Island, New York.

Remarks: This pelecypod is common in the upper 100 feet of the Chazy at Valcour Island, along with Rostricellula plena (Raymond, 1916, p.338). In the Montreal area it also occurs together with this brachiopod.

Modiolopsis parviuscula Billings.

Pl.7, fig.16

Modiolopsis parviuscula Billings, 1859, Can. Natur. Geol., vol.4, p.446.

Whiteaves, 1908, Ottawa Natur., vol.22, p.106, pl.3, figs.1,?2. Raymond, 1916, Ann. Carnegie Mus., vol.10, nos. 3 and 4, p.339, pl.30, figs. 14, ? 15, 16.

Billings described the fossil as follows: "This species closely resembles M. modiolaris (Conrad); but is always less than half the size of that species." Raymond reexamined and figured the holotype, and made a more nearly complete description of it. Many of the flattened pelecypods in the upper Laval and Pamela beds at Pointe Claire belong to this species, and one of the better preserved specimens is pictured and described here.

Description: Left valve, 19.6 mm. long, 10.0 mm. high in highest, posterior part. Anterior margin semicircular, ventral margin straight, posterior margin oblique with lower angle sharply rounded; posterior dorsal angle rounded, obtuse. Dorsal margin straight. Umbo 6 mm. behind front. Indistinct broad ridge stretches from umbo to lower posterior angle. Surface ornamented by numerous concentric growth lines.

Occurrence: Found in uppermost Chazy in the Devito Quarry (Locality 39) in dark, dolomitic shales. Billings' holotype came from the upper Chazy at Cornwall, Ontario, where it was found accompanied by Rostricellula plena. The same species is said to occur in the lower Pamela formation at Aylmer, Quebec (Raymond, 1916, p.339).

Remarks: M. parviuscula is stratigraphically confined to the Chazyan part of the Pamela formation and the uppermost part of the Beaconsfield member, in the Ottawa - St. Lawrence Lowlands, and has not been reported from the Champlain Valley. The same applies to Ctenodonta parvidens and C. sp., cf. C. parvidens. These fossils constitute a definite faunal zone and represent a shallow water facies, and a restricted, marine environment.

TRILOBITA

The trilobites are a very widespread and diversified group in the Chazy calcarenites of the St. Lawrence Lowland. Nevertheless, fragments that can be classified as to genus are not common, and as to species, even less so.

Billings carried out the first work on the group, but it was not until 50 years later that the Chazy trilobites received their most detailed study by Raymond. Over a period of several decades he published comprehensive papers dealing with the paleontology as well as with the stratigraphic and geographic distributions of these trilobites.

The present status of the Chazy trilobites in southern Quebec, using an abbreviated form of the classification proposed in the "Treatise on Invertebrate Paleontology, Part O", published by the Geological Society of America, is as follows:

Phylum Arthropoda

Class Trilobita Walch, 1771

Order Ptychopariida Swinnerton, 1915

Suborder Ptychopariina Richter, 1933

Family Glaphuridae Hupé, 1953

?Genus Glaphurus Raymond, 1905

Genus Glaphurina Ulrich, 1930

Family Remopleurididae Hawle and Corda, 1847

Genus Remopleurides Portlock, 1843

Suborder Asaphina Salter, 1864

Family Asaphidae Burmeister, 1843

Genus Basilicus Salter, 1849

Isotelus DeKay, 1824

Homotelus Raymond, 1925

Vogdesia Raymond, 1910

Suborder Illaenina Jaanusson, 1959

Family Styginidae Vogdes, 1890

?Genus Bronteopsis Nicholson and Etheridge, 1879

Family Illaenidae Hawle and Corda, 1847

Genus Bumastus Murchison, 1839

Thaleops Conrad, 1843

Suborder Harpina Whittington, 1959

Family Harpidae Hawle and Corda, 1847

Genus Eoharpes Raymond, 1905

Suborder Trinucleina Swinnerton, 1915

Family Raphiophoridae Angelin, 1854

Genus Lonchodomas Angelin, 1854

- Order Phacopida Salter, 1864
 - Suborder Cheirurina, Harrington and Leanza, 1957
 - Family Cheiruridae Salter, 1864
 - Genus Ceraurinella Cooper, 1953
 - Kawina Barton, 1915
 - Pseudosphaerexochus Schmidt, 1881
 - Nieszkowskia Schmidt, 1881
 - Sphaerexochus Beyrich, 1845
 - Family Pliomeridae Raymond, 1913
 - Genus Pliomerops Raymond, 1905
 - Suborder Phacopina Struve, 1959
 - Family Pterygometopidae Reed, 1905
 - ?Genus Pterygometopus Schmidt, 1881
 - Genus Calliops Delo, 1935
- Order Lichida Moore, 1959
 - Family Lichidae Hawle and Corda, 1847
 - Genus Amphilichas Raymond, 1905

Glaphurus? sp.

Pl.8, fig.1

One fragment of a cephalon was found that may belong to the genus Glaphurus.

Description: Cranidium small, 3.3 mm. wide, 2.0 mm. long. Glabella almost hemispherical, separated from fixed cheeks by deep axial furrow which extends around front, making a little more than a semicircle. Occipital ring 0.3 mm. wide; occipital furrow not sinuous. No glabellar furrows visible. Fixed cheeks very convex, extending in front of glabella to form a short preglabellar field. Anterior border narrow, concave. Anterior margin sharply rounded. Right cheek showing narrow palpebral furrow and lobe. Fossulae distinct. Surface of cranidium covered by minute granular tubercles.

Occurrence: Locality 9, in calcarenite, associated with Sphenotreta acutirostris, Basilicus marginalis, and ostracods.

Glaphurina lamottensis Ulrich.

Pl.8, fig.2

Glaphurina lamottensis Ulrich, 1930, U.S. Nat. Mus. (Washington), Proc. vol.76, p.45, pl.8, figs. 14-16.

A single cranidium was collected in the bioherm at Locality 49. The specimen differs from the type only in that the anterior border

of the cranidium still remains attached. The holotype comes from the basal upper Chazy at Isle La Motte, Vermont.

The genus is represented at the Mingan Islands by G. decipiens (Raymond, 1925, p.130); in the lower Lenoir limestone at Bluff City, Tennessee, by G. falcifera; and in the "Holston" calcarenite north of Salem, Virginia, by G. brevicula (Ulrich, 1930, p.46).

Basilicus marginalis (Hall).

Pl.8, fig.3

Asaphus marginalis Hall, 1847, Pal. New York, vol.1, p.24, pl. 4bis, fig.15.
Emmons, 1855, American Geology, vol.1, pt.2, p.235, pl.3, fig.16.
Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.339, pl.10, figs. 17-20; pl.11.

Basilicus marginalis Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.220, pl.32, figs. 17-20; pl.33. 1910, Ann. Carnegie Mus., vol.7, no.1, p.62, pl.17, fig.6; pl.19, figs. 1,2.

This species is known from southern Quebec by several minute pygidia, usually less than 2 mm. long and less than 4 mm. wide, whereas in the Champlain Valley Raymond recorded specimens nearly 8 cm. long. The pygidia are very convex, with a wide concave border, and have 7 or 8 well defined ribs. The axial lobe is extremely convex and ends at the border. The specimens were collected in calcarenite at Localities 3, 7, 9, 49, 51, and 52. Other occurrences are on Valcour Island, and below the Maclurites magnus zone at Chazy, New York.

Isotelus sp., cf. I. harrisi Raymond.

Pl.8, figs. 4,5

Isotelus harrisi Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.343, pl.12, figs. 3-7. 1910, Vermont Geol. Surv., 7th Rept., p.221, pl.34, figs. 3,5-7; pl.37, fig.1. 1910, Ann. Carnegie Mus., vol.7, no.1, p.65, pl.17, fig.1.

Several quite small cranidia were found in calcarenite in the Laurentides map-area. In outline they resemble the figures given by Raymond. Somewhat larger individuals can be seen in the St. Dominique area. The fossil occurs at Localities 6, 7, 9, 40, and 52.

I. harrisi ranges all through the Chazy in the Champlain Valley, and is thus of no use in the present correlation problem.

Isotelus platymarginatus Raymond.

Pl.8, fig.6

Isotelus platymarginatus Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.225, pl.34, fig.4; pl.37, figs. 2-5; pl.39, fig.3.
1910, Ann. Carnegie Mus., vol.7, no.1, p.66, pl.17, figs. 2-5; pl.19, fig.3.

This fossil is abundant in the argillaceous limestone beds at St. Pie Hill. One of the pygidial fragments examined showed some important characteristics; these are described and discussed below.

Description: Pygidium subtriangular, width 11 mm., length 8.5 mm.; surface smooth. Axial lobe faintly indicated by tapering elevation. On right side wide concave border marked by minute concentric striae. Left pleural lobe with additional layers, covering concave border as smooth, regularly convex exoskeleton.

Occurrence: Locality 52; Isle La Motte; Valcour Island.

Discussion: The illustrated specimen shows that this fossil can have different appearances depending on the state of preservation of the exoskeleton. When the complete pygidial skeleton is observed the appearance is very similar to that of Homotelus obtusus, but where the upper posterior shell is removed the characteristic wide concave border becomes visible and the fossil assumes a very different shape. The pygidia of the two species were here distinguished by their over-all shape: I. platymarginatus is slightly longer in proportion to its width than the other, and the terminal margin is more angular.

Isotelus spp.

Under this heading have been grouped all fragments of smooth trilobites that have the characteristic features of the Asaphidae but lack features of generic importance. They occur in a wide range of sizes. One fragment of a pygidium from Locality 16 shows that the animal must have been about 9 cm. wide.

The members of the Asaphidae are most often found in coarse-grained calcarenites. They are generally smaller than the related species in the Champlain Valley.

Homotelus obtusus (Hall).

Pl.8, fig.7

Asaphus? obtusus Hall, 1847, Pal. New York, vol.1, p.24, pl. 4bis, fig.14.Isotelus obtusum Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.344, pl.12, figs. 1,2.Onchometopus obtusus Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.222, pl.34, figs. 1,2; pl.38, figs. 2-4. 1910, Ann. Carnegie Mus., vol.7, no.1, p.64, pl.18, figs. 2-4.Homotelus obtusus Raymond, 1925, Harvard Coll. Mus. Comp. Zool., Bull. vol.67, no.1, p.90, pl.4, figs. 7,8.

This is a very common species in the St. Dominique area, but is rare in the rest of the region under study. The remains most often found are smooth flattish pygidia, the largest of which measures 27 mm. in length and 31 mm. in width. The fossil was collected at Localities 12, 51, and 52.

Raymond found the species to be most common in the upper Chazy, at Valcour Island, Crown Point, Plattsburg, and Isle La Motte. Hall originally mentioned that it occurs only at Chazy in compact limestone near the base of the Chazy group.

Vogdesia bearsi Raymond.

Pl.8, figs. 8,9

Isotelus? bearsi Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.345, pl.10, figs. 21-25.Vogdesia bearsi Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.225, pl.32, figs. 21-25; pl.39, figs. 10-12. 1910, Ann. Carnegie Mus., vol.7, no.1, p.70, pl.19, figs. 10-12.

This small asaphid trilobite is known in the St. Lawrence Lowland by a good many small pygidia.

Description: Pygidia almost semicircular, with faintly indicated, wide, tapering axial lobe and concave border. Surface smooth, traces of interpleural furrows in some pygidia. Frontal region of each pleural field bearing one distinct furrow. Articulating facets fairly large. Most of the specimens less than 5 mm. long.

Occurrence: Localities 12, 25, 48, 49, 52; always in calcarenite. Raymond (1910, p.226) stated that the species is found

"only in the trilobite layers in Sloop Bay, Valcour Island, New York, in the middle of the Chazy." Oxley and Kay (1959, p.825) found it in the lower Chazy.

Remarks: The new occurrences in the St. Lawrence Lowland are further indications of a more widespread early or middle Chazyan sea.

Bumastus sp., cf. B. aplatus Raymond.

Pl.8, fig.10

Bumastus aplatus Raymond, 1925, Harvard Coll. Mus. Comp. Zool., Bull. vol.67, no.1, p.119, pl.8, figs. 3,4.

A cranidium resembling Bumastus aplatus was found. Its visible features agree well with the characteristics of Raymond's species.

Description: Cranidium semicircular, smooth; dorsal region evenly convex, curvature increasing abruptly in anterior region. Well defined shallow and narrow dorsal furrows, converging from posterior margin behind the eyes, then straightening out and curving outward to meet the sides at about three fifths the distance to the front. Eyes close to the posterior margin. Length of cranidium 10 mm., width preserved 13 mm.

Occurrence: A very rare fossil at Locality 16, in argillaceous fine-grained limestone. B. aplatus is very common in the upper part of the lower Chazy on Isle La Motte, according to Raymond, who also found it in the lower Lenoir, 1 mile east of Bluff City, Tennessee.

Bumastus globosus (Billings).

Pl.8, fig.11

Illaenus globosus Billings, 1859, Can. Natur. Geol., vol.4, p.367, figs. 1-3. 1863, Geology of Canada, p.133, figs. 64a-c. Raymond, 1905, Ann. Carnegie Mus., vol.3, p.350, pl.13, fig.7 (non fig.6).

Bumastus globosus Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.228, pl.35, fig.7 (non fig.6). 1925, Harvard Coll. Mus. Comp. Zool., Bull. vol.67, p.117. Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.67, pl.11, figs. 14,15.

Large and small specimens of this fossil are widespread.

They usually occur only as detached cranidia or pygidia. The pygidia vary somewhat in shape, ranging from elongated to the transverse types. Great numbers of small specimens occur in the upper calcarenite layers of the local Chazy. Large individuals are present at the Mingan Islands, and Raymond (1925, p.118) found the fossil to be most abundant at the base of the upper Chazy of the Champlain Valley.

Thaleops conifrons (Billings).

Pl.8, fig.12

Illaenus conifrons Billings, 1859, Can. Natur. Geol., vol.4, p.378, fig.11.

Illaenus arctura Billings, 1859, Can. Natur. Geol., vol.4, p.379.

Illaenus vindex Billings, 1865, Pal. Foss. Can., vol.1, p.179, figs. 16 a,b.

Thaleops conifrons Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, pp.73-75, pl.11, figs. 9,10.

The three species of Billings were combined into one by Twenhofel because he did not confirm the identification of Thaleops arctura (Hall) in the Mingan Islands sequence, and because he considered I. conifrons to be an exfoliated sample, or internal filling, of I. vindex. The writer has examined Billings' types of I. conifrons and I. vindex in the collections of the Geological Survey of Canada and concurs with Twenhofel. Hence T. conifrons is used according to the rules of priority.

A single specimen in the present collections was found by Usher (1947). It is a non-exfoliated specimen and would, according to Billings, be assigned to T. vindex.

Occurrence: Locality 52, and at the Mingan Islands.

A related species, T. arctura (Hall, 1847, p.23) is common in the Champlain Valley.

Eoharpes sp., cf. E. antiquatus (Billings).

Harpes antiquatus Billings, 1859, Can. Natur. Geol., vol.4, p.469, fig.38. 1863, Geology of Canada, p.133, fig.67.

Harpina antiquatus Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.330, pl.10, fig.1.

Eoharpes antiquatus Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.214, pl.32, fig.1.

This species is not very abundant in the study area, and when observed, only the horseshoe-shaped cephalic border can be recognized. The specimens range in size from small to very small. The few examples collected at Localities 3, 15, 23, and 35 are all about 5 mm. long, whereas the ones from the Lacolle area and St. Pie Hill (Localities 49, 50, and 52) are all larger, about 15 mm. long. The samples may belong to a species different from E. antiquatus, but the material at hand is not so well preserved to permit separating them except as to size.

Billings originally described E. antiquatus from the Chazy at Mingan, and mentioned that the fragments of another Eoharpes had been found in the Chazy at Montreal. He did not elaborate. E. antiquatus is common in the lower Chazy, and less frequent in the middle Chazy, at Valcour Island, Valcour, and Chazy, New York (Raymond 1905, 1910). The only other species of this genus recorded in the Chazy is the much larger E. ottawaensis (Billings, 1865, p.183, fig.166), which was first found in the Trenton at Ottawa. This species is abundant in the lower Chazy near Valcour.

Lonchodomas halli (Billings).

Pl.8, fig.13

Ampyx Halli Billings, 1861, Geol. Surv. Can. adv. sheets. 1861, Geol. Surv. Vermont, vol. 2, p.959, fig.365. 1865, Pal. Foss. Can., vol.1, p.24, figs. 25 a-c.

Ampyx halli Vogdes, 1893, Amer. Geologist, vol.11, p.106, fig.5.

Lonchodomas halli Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.332, pl.10, figs. 3-7. 1910, Vermont Geol. Surv., 7th Rept., p.216, pl.32, figs. 3-7.

These fossils are known as small, elongate, triangular cranidia with diamond-shaped glabella and long glabellar spine, from the Chazy at Locality 52 where they occur in abundance. Raymond (1910) stated that this species is limited to the lower and middle Chazy in the area between St. Dominique and Valcour, with occurrences in between, at Highgate Springs and Isle La Motte, Vermont. This species, and the peculiar dark olive grey, argillaceous limestone in which it occurs, are not found in the Montreal area.

Kawina vulcanus (Billings).

Pl.8, fig.21

Cheirurus Vulcanus Billings, 1865, Pal. Foss. Can., vol.1, p.284, figs. 271 a-c.

Cheirurus prolificus Billings, 1865, Pal. Foss. Can., vol.1, p.285, fig.273; p.325, figs. 311,312.

Pseudosphaerexochus vulcanus Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.367, pl.14, fig.16; p.368, fig.10. 1910, Vermont Geol. Surv., 7th Rept., p.241, pl.36, fig.16.

Kawina vulcanus Barton, 1916, Washington Univ. Studies, vol.3, pt.1, no.1, p.117, fig.9. (fide Raymond, 1925, p.143). Raymond, 1925, Harvard Coll. Mus. Comp. Zool., Bull. vol.67, no.1, p.143.

This is an uncommon fossil in the St. Lawrence Lowland, and only a few cranidia have been found, at Locality 23. It is said to occur at Cow Head, Newfoundland; Stanbridge, Quebec; Mingan Islands; and in the upper Chazy at Valcour Island.

K. vulcanus has a wider geographic distribution than most of the Chazy fossils, and for this reason it is useful in long range correlations.

Nieszkowskia satyrus (Billings).

Cheirurus Satyrus Billings, 1865, Pal. Foss. Can., vol.1, p.324, fig.309.

Pseudosphaerexochus (Nieszkowskia) satyrus Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.371, pl.14, fig.21.

Nieszkowskia satyrus Raymond, 1910, Vermont Geol. Surv., 7th Rept., p.244, pl.36, fig.21.

With the exception of Raymond's single specimen, no others have been found since Billings' time, and nothing can be added here. Billings found the fossil at "Montreal", and Raymond collected it on Sloop Island on the east side of Valcour Island. A related species, N. glaucus, was described by Billings from Stanbridge, Quebec.

Sphaerexochus parvus Billings.

Pl.8, figs. 14-16

Trilobite, genus indet., Billings, 1859, Can. Natur. Geol., vol.4, p.468, fig.36.

Sphaerexochus parvus Billings, 1865, Pal. Foss. Can., vol.1, p.180, fig.161 a,b.

Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, p.372, pl.14, fig.22. 1910, Vermont Geol. Surv., 7th Rept., p.246, pl.36, fig.22.
 Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.76, pl.10, fig.12.

S. parvus is known only by its glabella despite its common occurrence all through the Chazy in the Champlain Valley. It is much less frequent in the Montreal region. Billings reported it at the Mingan Islands, but Twenhofel did not find any specimens there. It seems that this trilobite is more typical of the Lake Champlain Region. In southern Quebec it was found at Localities 9, 13, 23.

Pliomerops canadensis (Billings).

Pl.8, fig.17

Amphion canadensis Billings, 1859, Can. Natur. Geol., vol.4, p.381, fig.12. 1863, Geology of Canada, p.133, fig.69.
 1865, Pal. Foss. Can., vol.1, p.288, fig.278.
 Raymond, 1905, Ann. Carnegie Mus., vol.3, no.2, pp.363-365, pl.14, figs. 10-13.

Pliomerops canadensis Raymond, 1905, Amer. Jour. Sci., vol.19, p.377. 1910, Vermont Geol. Surv., 7th Rept., p.238, pl.34, figs. 10-13; pl.38, fig.14. 1910, Ann. Carnegie Mus., vol.7, no.1, p.75, pl.18, fig.14.
 Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.70, pl.11, fig.18.

No new morphological data can be added to Raymond's descriptions. Fragments of cranidia and pygidia of this species are common locally, especially in the Laurentides map-area.

Billings (1859, p.382) mentioned its occurrence at the Mingan Islands and near Montreal, in both regions associated with "a group of Cystideae, allied to the European Echinosphaerites" (he probably meant Malocystites or Canadocystis), and also with Bolboporites. Raymond (1910) reported it from Valcour, Valcour Island, Chazy, Cooperville, and Isle La Motte. In the St. Lawrence Lowland it occurs in calcarenite beds at localities 3, 7, 34, and 48. The stratigraphic range at Valcour Island was given by Raymond (1906, p.528) as from the middle Day Point formation to the middle of the Valcour formation.

Pterygometopus? sp.

Pl.8, fig.20

One cephalic fragment of a species belonging to the family Cheiruridae was studied.

Description: Fragment showing glabella and parts of the fixed cheeks. Anterior profile subtriangular. Glabella subtrapezoidal, fairly long, slightly expanded towards front, with 3 pairs of furrows. Frontal lobe rounded, short, with steep anterior slope. Most convex part of glabella between frontal furrows. Second and third pair of lobes small and rounded. Lateral preoccipital lobes subrounded and small; median preoccipital lobe very distinct. Fixed cheeks have considerable convexity, springing from deep axial furrows. Surface smooth. Length of cranidium 7.5 mm.

Occurrence: Pont Viau (Locality 26); in dolomitic and shaly limestone of the Beaconsfield member. The slab from which the specimen came also had Multicostella platys and echinoderm remains.

Calliops annulatus (Raymond).

Pl.8, figs. 18,19

Pterygometopus annulatus Raymond, 1905, Ann. Carnegie Mus., vol.3, p.376, pl.14, figs. 24,25. 1910, Vermont Geol. Surv., 7th Rept., p.247, pl.36, figs. 24,25.

Calliops annulatus Delo, 1940, Geol. Soc. Amer. Spec. Pap. no.29, p.92.

C. annulatus is an abundant trilobite all through the Chazy at Valcour Island, but is rare in the St. Lawrence Lowland, where only a few pygidia and a cranidium have been located. It apparently does not occur in the Mingan Islands region. The pygidium figured here has one or two fewer pleural ribs than Raymond's specimens. Collections were made at Localities 6, 9, 16, and 23.

Other trilobite remains.

In addition to the species already discussed, the following have been reported as occurring at Locality 51 (Kay, 1958, p.84):

Bronteopsis? sp.

Bumastus sp.

Calliops sp.

Ceraurinnella sp., cf. C. pompilius (Billings)

Illaenus sp.

Isotelus sp.

*Platymetopus sp., cf. P. minganensis (Billings)

Pseudosphaerexochus sp.

Remopleurides sp.

* *Platymetopus* Angelin, 1854 is now *Amphilichas* Raymond, 1905 (see p.143).

There are a great many indeterminable fragments scattered through the Laval formation. Two of the more nearly complete ones are illustrated on Plate 8 (figs.22,23).

OSTRACODA

Ostracods are very abundant in the Chazy, and unusually well preserved. Yet despite this, their usefulness in correlation is hampered because almost all the species have smooth shells, and many have similar outlines. It takes considerable effort, experience, and good judgment to differentiate between individuals of different genera. Fortunately, Carter (1957) has recently completed a study of the Ordovician ostracods in the St. Lawrence Lowland, and Swain (1957) has studied the Chazyan ostracods of the eastern United States. As Carter has dealt with the group in great detail only a few comments are made here. The following 11 species were observed by Carter in the Chazy of southern Quebec:

Family Leperditidae Jones, 1856

*Eoleperditia nana (Jones)

Briartina modesta Ulrich and Swain

Family Leperditellidae Ulrich, 1894

Leperditella? obscura (Jones)

L. ornata Weller

Schmidtella affinis Ulrich

S. labiata Carter (in manuscript). 1957

Family Primitiidae Ulrich and Bassler, 1923

**Primitia logani* (Jones)

Conchoprimitia sp., cf. C. tolli (Bonnema)

Eurychilina crassimarginata Carter (in manuscript),
1957)

Apatochilina dimorpha Carter (in manuscript), 1957.

Family Bairdiidae Sars, 1887
Bythocypris? granti Ulrich

(* Found in the Chazy of the Ottawa Valley)

To this list may be added Eurychilina latimarginata Raymond (1905, p.38; 1911, p.255, fig.26). Kay (1958, p.84) published the following list for Locality 51.

Aparchites sp.
Bythocypris sp.
Dilobella? sp.
Eridoconcha sp.
Euprimitia sp.
Eurychilina sp.
Schmidtella sp.

In the present study all the smooth ostracods described by Carter have been grouped together in the Correlation Chart (Fig.20, p.76), and only the genus Eurychilina is put separately due to the greater facility with which it is identified.

Neither Swain nor Carter made reference to Eurychilina latimarginata which Raymond (1911) found to be common all through the typical Chazy. The characteristics of this species are very similar to E. crassimarginata, and the two fossils may possibly be the same species. No distinction is made here, and the two are included under Eurychilina spp. in the Correlation Chart.

The ostracods were found to be most common in the coarse-grained pelmatozogenic calcarenite horizons of the Laval formation. They are almost always seen together with Sphenotreta acutirostris, Mimella, Rostricellula raymondi, trepostomatous bryozoans, and echinoderm fragments. They do occur in dark greenish grey shale beds, but only sporadically so.

CYSTOIDEA

Fragments of cystids are so abundant in the Chazy of the St. Lawrence Lowland as to make up thick beds of what is best referred to as cystoidogenic calcarenite. Rarely does one find nearly complete columns or calyces. For satisfactory identification characteristics one must rely on weathered samples, as the calcarenite presents a uniform, coarse-grained, crystalline appearance on fresh fractures. As a result the complete features of some genera and species are not known, and their taxonomic position is uncertain. The following is a classification of the cystids and blastoids of the Laval formation, based on the one proposed by Regnéll (1945).

Phylum Echinoderma

Subphylum Pelmatozoa Leuckart, 1848

Class Cystoidea von Buch, 1846, emend. Jaekel, 1918

Subclass Hydrophoridae Zittel, 1903

Order Rhombifera Zittel, 1879, emend. Bather, 1899

Family Cheirocrinidae Jaekel, 1899, emend. Bather,

Genus Cheirocrinus Eichwald, 1856 1913.

Family uncertain

Genus Palaeocrinus Billings, 1859

Palaeocystites Billings, 1858

Bolboporites Pander, 1830

Subclass Blastoidea Say, 1825

Order Parablostoida Hudson, 1907

Genus Blastoidocrinus Billings, 1859

Cheirocrinus forbesi (Billings).

Pl.9, fig.2

Glyptocystites forbesi Billings, 1857, Geol. Surv. Can. Rept. Prog. 1853-1856, pp.283-284. 1858, Can. Org. Rem., dec.3, p.59, pl.4, figs. 3a-h.

Chirocrinus forbesi Jaekel, 1899, Stammes. Pelmat., vol.1, p.221

The original description is based on a fragment of the basal part of the calyx and on several detached plates and columns. Through fortunate circumstances the writer found a slab in which 3 fairly complete, though strongly crushed specimens are imbedded. These provide new material for description. One of these (specimen 2) shows what Billings called the anterior position, and the other two the reverse side. There are no fixed food grooves, and consequently,

the fossil is not a Glyptocystites but a Cheirocrinus.

Description: Specimen_1. Column curved, broken off at bottom, 38 mm. long, 24 columnals preserved. Diameter of bottom columnal 4 mm., topmost columnal flattened, 13 mm. across. Columnals bearing ring of elongated pustules, about 5 in the length of 2 mm., with longer diameter in vertical position.

Calyx flattened and sunk into matrix; length 40 mm., width 25 mm.; composed of 4 series of thick, polygonal, ornamented plates. Basal plates, 2 visible, pentagonal, directly attached to top columnal. Surface marked by sharp ridges, at an acute angle to one another and producing a V-shaped figure whose apex is at the middle of the lower side of the plates. Faint indication of a second V-shaped ridge inside the first one. Inter-ridge area shows fine regular, netlike surface structure that is related to underlying pores.

Second series of plates, two and one half visible, hexagonal; plates bear a series of angular ridges so arranged that there are several V's diverging from center area; each main ridge has one or more parallel subsidiary ridges. Inter-ridge area shows fine, regular, netlike surface structure.

Third series shown by one complete hexagonal plate and the halves of two others. This series has 5 main ridges and no subsidiary ones. Inter-ridge area covered by dense fine mesh pattern, related to the evenly spaced pores exposed along the ridges. These pores parallel, 7 in 2 mm., at acute angles to the ridges and perpendicular to the sutures. The V-shaped ridges and parallel pores of two contiguous plates outlining a characteristic pore rhomb.

The fourth and last (topmost) series represented by 2 complete plates, similar to those of third series, but somewhat larger. Mouth and anus not visible.

A series of fine cirri near one side of specimen, extending in curves for at least 25 mm. Cirri uniserial, 0.6 to 0.7 mm. in diameter.

Specimen_2. Column curved, with 4 columnals and impressions of 24 more, rapidly tapering downward. Width of topmost columnal 10 mm.

Calyx 43 mm. long. Basal series represented by a plate different from those of specimen 1, but similar to Billings' plate of anterior side (his fig. 3f). Hexagonal, surface sculptured with vertical central ridge, flanked by additional V-shaped ridge pattern on either side.

The plates of the second series quite similar to those of specimen 1, except for one or two extra ridges in the lower half of the plates. No differences between specimens 1 and 2 recognized for the third and fourth series.

Specimen 3. Column straight, 38 mm. long, tapering rapidly. 24 columnals preserved. Calyx 30 mm. long. Specimen very similar to specimen 1.

Occurrence: Recognized at Localities 22, 23, 42, but probably present at many other localities. Wilson (1932, p.378) found a fragment, probably of this species, in the Aylmer formation at Barnhart Island, New York, near Cornwall, Ontario. Raymond (1905, p.357) collected specimens at Valcour Island near the base of the middle Chazy.

Remarks: The finding of the three specimens now makes it possible to visualize the relationship between the different thecal plates, and to prove that the large columnals with the ring of oblong pustules belong to the same species as the detached plates. However, the pustules are not diamond-shaped as pictured by Billings (his figs. 3g, 3h), but are rounded on all sides.

There is a definite decrease in number of coarse plate ridges from the base to the top of the calyx, coupled with an increase in plate size and inter-ridge area. The external shapes of the column and the calyx, and the regular arrangement of the plates resemble those of the Cambrian genus Macrocystella of the class Eocrinoidea, which lacks the thecal pores.

Palaeocrinus striatus Billings.

Palaeocrinus striatus Billings, 1859, Can. Org. Rem., dec.4, p.25, pl.1, figs. 5a,b.
Hudson, 1911, N.Y.St. Mus. Bull. 149, pp.216-242, pls. 5-7, text figs. 4-12, 14,19.
Moore and Laudon, 1943, Geol. Soc. Amer. Spec. Pap.no.46, p.131, pl.2, fig.10.

This species is based on a single complete calyx (Geol. Surv. Can. coll., holotype no. 1015) which has a regular arrangement of plates and possesses pore rhombs. Its plates resemble in great detail the detached plates of what has been referred to as Palaeocystites tenuiradiatus (Hall). Billings distinguished between them by the striae (pores), which are a little finer and of nearly uniform size in Palaeocrinus striatus. It is possible that the difference in the size of the striae is due to weathering. Billings placed the fossil in the crinoids, and in all subsequent papers by other authors this practice has been perpetuated. The presence of pore rhombs, however, is a typical cystidean feature, and for this reason P. striatus is here put in the cystids.

Billings mentioned that the species is somewhat common at Caughnawaga (Locality 40) and on Montreal Island, but no complete cups were found in the present collections, only detached plates that may belong to this species. All these loose plates are referred to Palaeocystites tenuiradiatus, and are further discussed under that heading.

Hudson, who made a detailed study of the morphology of this fossil, suggested tentatively (1911, p.246) that the single plate of the holotype of Palaeocrinus chapmani (Billings) is but a plate of P. striatus. No additional information concerning this matter was obtained.

Palaeocystites dawsoni Billings.

Pl.9, fig.7

Palaeocystites Dawsoni Billings, 1858, Can. Org. Rem., dec.3, p.70.

Palaeocystites dawsoni Hudson, 1911, N.Y. St. Mus. Bull. 149, pp.247-253, figs. 21-34.

The morphology of this species is well described and pictured in the paper by Hudson, and nothing further can be added here. The species was found at Localities 12, 23, 33, and 35.

Palaeocystites tenuiradiatus (Hall).

Pl.9, figs. 3-6; Pl.10, fig.12

Actinocrinus tenuiradiatus Hall, 1847, Pal. New York, vol.1, p.18, pl.4, figs. 8,9.

Palaeocystites tenuiradiatus Billings, 1858, Can. Org. Rem., dec.3, p.69, figs. 1-3.

Billings described this species as being 2 inches (5 cm.) or more in length and pyriform in shape, the upper part of the body being the largest. But almost always one finds only single, detached plates, like the ones which were the basis for Hall's original description. A slab from Hall's collection, which was kindly loaned by the New York State Museum, has plates which are the same as the ones found in the Montreal area.

Billings' description of the genus Palaeocystites does not specifically state whether the plate arrangement is regular or irregular.

Description of plates: Plates with polygonal outline, pentagonal to hexagonal, with smooth low pyramid on outside. When weathered, characteristic pores exposed, forming a series of parallel canals running from lines connecting the center and angles of one plate straight across suture to corresponding positions on a contiguous plate, and making a pore rhomb. The pores are narrow and deep, about 2 in the length of 1 mm.; their number depends on the size of the plate. At the suture each pair of furrows connects with the interior by means of an oval canal. Weathered inner surface slightly concave, smooth, showing notched, comb-like periphery produced by the oval canals (Pl.10, fig.12).

Occurrence: Widespread in the cystoidogenic calcarenite horizons and shaly beds of the Laval formation. Common all through the Chazy of the Champlain Valley. A related species, P. pulcher Billings, is known by a few plates from the Mingan Islands.

Discussion: Two more characteristics may be added to the data given by Billings and Hall. Firstly, there is one specimen (Pl.9, fig.6) that apparently belongs to this species; it shows the

juxtaposition of 5 plates of equal dimensions, which meet in a common region, at a hole 2 mm. across. The furrows are plainly visible at the outer margin, but become obscure towards the hole, perhaps due to weathering. The specimen is interpreted as representing the basal series of plates of a calyx, which had the column attached at the central hole.

Secondly, a slab (Pl.9, figs. 3,4) collected by T.H. Clark 1 mile south of St. François de Sales (Locality 12) contains a plate which has a notch occupying part of the area of the plate. This notch is 2.7 mm. wide at the open end and narrows to a rounded terminus close to the middle of the plate; it is surrounded by a 1.2 mm. wide ridge. This structure conceivably served as the attachment surface of one of the food grooves.

It would seem from Billings' descriptions that he intended to assign to Palaeocystites only species with irregular plate arrangement. He considered P. tenuiradiatus (Hall) to be such a species, although Hall's original specimens are much too fragmentary to permit such a conclusion. It is possible that this species is a more regular or specialized form resembling or identical with Palaeocrinus striatus Billings, as already mentioned on p. 158. If this is the case, the bodies of Bolboporites americanus, which are so often found together with it and which are interpreted as specialized spines or appendages, would be more reasonably explained. One would expect to find such structures on a specialized body, rather than on a generalized form with irregular disposition of the plates.

Genus Bolboporites Pander.

Bolboporites Pander, 1830, Beiträge zur Geognosie des russischen Reiches, pp. 106-107.

Eichwald, 1840, Jour. Méd. Hist. Nat. Acad. Méd. St.-Pétersbourg, p.215.

Quenstedt, 1881, Petrefaktenkunde Deutschlands, p.58.

Wanner, 1920, Kon. Akad. Wet. Amsterdam, Proc. Sec. Sci, vol.22, pt.2, pp.705-711.

Yakovlev, 1921, Ann. soc. paléont. Russie, vol.3, pp.1-10.

Eltysheva, 1955, Voprosy Paleontologii, vol.2, pp.136-147.

The name Bolboporites is applied to small bodies of calcite, in the form of a smooth, flat to globular base, surmounted by a celluliferous projection that may be conical to hemispheric in shape. A small double-winged depression is located on the base either at the center or towards one side. The size of the fossils ranges from a few millimeters to about 15 mm. in length, and a little less in width. In thin sections one can observe an eccentric axial structure which terminates at the base in a little opening situated between the two wings of the basal depression, and pinches out apicad before reaching the apex of the cone. A three-dimensional lattice-like microstructure is discernible in some specimens, and the compartments of this meshwork have an edge length of approximately 20 microns. As far as is known at present, the genus has heretofore been found only in the Ordovician of northern Europe and eastern North America.

Genotype: Bolboporites mitralis Pander 1830.

Bolboporites americanus Billings.

Pl.10, figs. 1-11

Chaetetes sp. Hall, 1847, Pal. New York, vol.1, p.18, pl.4, figs.7a-d.

Bolboporites americanus Billings, 1859, Can. Natur. Geol., vol.4, pp.429-430, figs. 3-6. 1863, Geology of Canada, p.124, figs. 44a-d.

Chapman, 1863, Can. Jour. Sci. Arts, n.s., vol.8, no.45, p.195, fig. 165b. In book form in 1864, 1871, 1883.

Miller, 1889, N. Amer. Geol. Pal., p.174, fig.140.

Ruedemann, 1901, N.Y. St. Mus. Bull. 49, p.11, pl.1, fig.1.

(This may be a different species)

Twenhofel, 1938, Geol. Soc. Amer. Spec. Pap. no.11, p.42.

[non] Bolboporites americanus? Butts, 1940, Virginia Geol. Surv. Bull. no.52, pt.1, p.199. 1941, idem, pt.2, pl.95, fig.34.

No holotype seems to have been designated. The cotypes are in the collections of the Geological Survey of Canada (nos. 1013 a-e), and were collected on the Island of Montreal.

Morphology: Billings' original description is as follows:

"These curious little fossils consist of a smooth solid hemispherical base surmounted by a conical projection which is celluliferous, the cells being about the size and shape of those of the common Stenopora fibrosa. In the centre of the base there is a small pit which appears to have been

the point of attachment. The solid part, under the hammer, usually breaks up into rhomboidal fragments, but some specimens when fractured exhibit a prismatic structure, the prisms radiating from the centre and being about the size of the tubes in the celluliferous conical extremity. It is remarkable that the cells slope downwards instead of upwards as in all other zoophytes, and it is possible that the apex of the cone is the base: the greater size and solidity of the hemispheric extremity, however, would seem to favour the opposite conclusion.

The specimens are from three to eight lines in length, and about the same in greatest diameter. The cone is usually of the same height as the hemisphere, but sometimes it is either shorter or longer."

Much additional information has been gained during the present study of material from outcrops and quarries in the Montreal region. The morphological features of the specimens examined are shown in Fig. 26, p.163.

The fossil is composed of a smooth base with a basal depression and opening, and a cell-bearing cone. In certain of the larger and better preserved (well weathered) specimens there is a groove along the bottom of the cone, which appears as if it has been a place of attachment for some soft part (coating?) of the body (Pl.10, fig.11). A number of individuals from shale beds do not show the cells (Pl.10, fig.10). Instead the surface is smooth, and it is sometimes difficult to distinguish between base and cone; their appearance is that of a short spine.

The small pit that Billings mentioned is actually, in good samples, a double-winged depression surrounded by a narrow raised rim, the structure having an outline similar to the number 8. It is about 1.2 mm. by 2.0 mm. across, and 0.4 to 0.7 mm. in depth. A small opening is located in the middle, but is normally obscured by weathering or detritus. The position of this basal depression is commonly close to the center in prolate forms, but in larger specimens, and in those with a high value for the ratio of base diameter to total length, it is displaced upward and sideways, as much as halfway to the cone. The orientation in this eccentric position is such that the long diameter of the 8 is bisected by a vertical plane of bilateral symmetry.

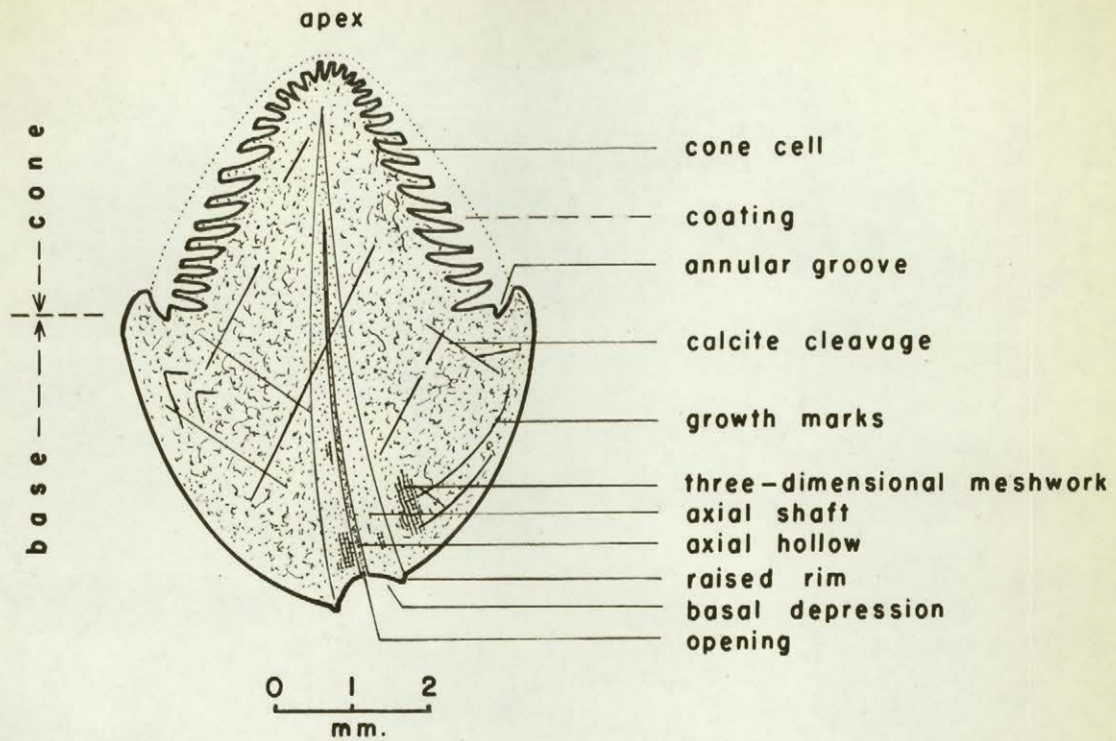
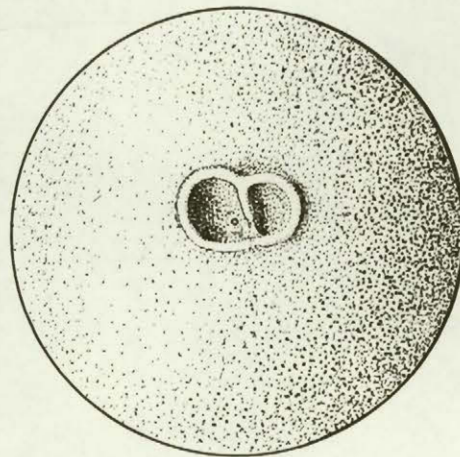
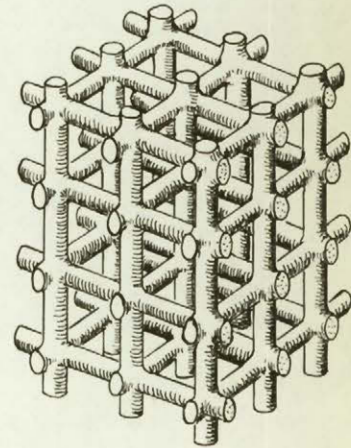


Diagram of longitudinal section in plane of symmetry.



Bottom view.



Three-dimensional meshwork.
(interpretation)

Morphological features observed in *Bolboporites americanus* Billings.

Figure 26.

The cone cells slope downwards over most of the cone surface, except at the apex and, rarely, at the bottom of the cone. They are circular to elliptical or slightly angular in cross section, and range in diameter from 0.2 to 0.4 mm., being smallest at the apex. They may be shallow pits or may taper to a point about 0.8 mm. deep into the cone. For any particular specimen there are from 80 to over 200 cells and their arrangement is irregular, or regular over part of the cone surface (Pl.10, figs. 1,7,9). Thin walls separate cells from adjoining ones.

A few fragments of the basal part of the fossils show the prismatic structure (Pl.10, fig.6) to which Billings referred. On close examination this structure is found to be due to closely spaced intersecting calcite cleavage faces, the orientation of each of the crystals being slightly different from that of its neighbour.

Fractured specimens exhibit a pointed greyish axial region originating at the basal depression and pinching out just inside the apical portion. It is curved when the depression is eccentrically located. In thin section this structure is seen to be composed of an axial hollow (filled with silt detritus), and an axial shaft made up of flesh-colored calcite that is distinctly less cloudy than that of the rest of the body. In several slides there are faint dark lines subparallel to the bottom of the cone or the basal surface, which may be growth marks.

The smallest structure recognizable in thin section is a three-dimensional meshwork filled with an opaque substance. Dimensions of the edges of the resulting compartments are approximately 17 microns at the base, and smaller towards the apex. The material in the collections is not sufficiently well preserved to show whether their form is cubic, rhombohedral, or something else. This micro-structure was observed only close to, and in the axial region, and greatly resembles that found in spines of modern echinoids, such as Heterocentrotus.

The optical orientation of the calcite in specimens having good single-crystal structure differs from one individual to the next. The c-axis is at a variable angle to the axis of the fossil. There

are 2 well developed cleavage faces on fractured individuals, one being more inclined to the fossil axis than the other. A third cleavage direction is not pronounced.

In several localities, where it occurs in coarsely crystalline calcarenite, B. americanus has a pink color due to the presence of some manganese in the calcite crystal lattice.

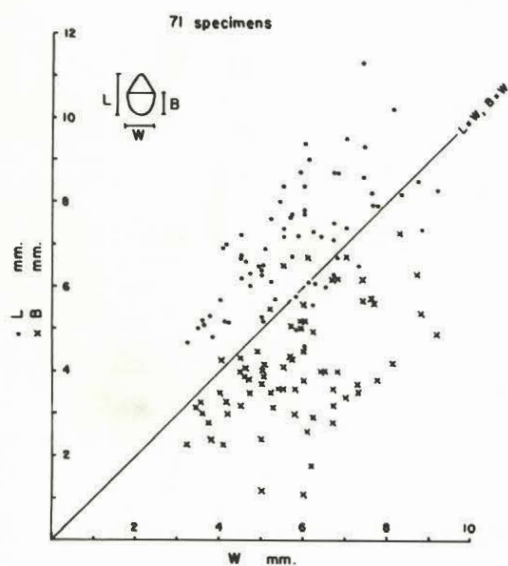
The total length (L) of the specimens measured lies between 4.5 and 11.5 mm., and the base length (B) ranges between 1.0 and 7.3 mm. The smallest width (base diameter, W) is 3.2 mm., and the greatest 9.2 mm. Most of the bodies have a circular cross section, but about one fifth of them are slightly elliptical. The maximum and minimum diameters of the latter were averaged for plotting purposes. Results of the caliper measurements on 71 samples from the Montreal region are plotted on the scatter diagram (Fig. 27). It is evident that most of the bodies are longer than wide, and also that the base is generally wider than it is long.

Variations in shape are considerable, and can best be seen by consulting Fig. 29 (p.166), which was developed expressly for the presentation of data on Bolboporites americanus. The numerical data obtained by caliper measurements of the three variables L, B, and W were transformed into a three-ratio-plot. The W/L ratio is plotted against B/W. Superimposed on this are the related B/L curves. On the resulting graph the three ratios (i.e., shape) can be read off directly, and the frequency of any particular shape is indicated by the closeness and number of the dots. To facilitate the visualization, a pictograph drawn on the same scale is added. The vectors in the diagram indicate the variation of a quantity with respect to total length as one goes from one shape to an adjoining one. As can be seen, the shapes vary continuously over a wide range between three arbitrarily designated end members: conical, globular, and prolate.

Not much could be gained by proposing an elaborate classification of the forms based on arbitrary limits. Strictly, the three-ratio-plot is inadequate in expressing the degree of curvature of the

Figure 27.

Scatter plot of total length/width (+)
and base length/width (x)



Other occurrences:

MINGAN ISLANDS, Que.
RYSSEBORGH HILL, N.Y.

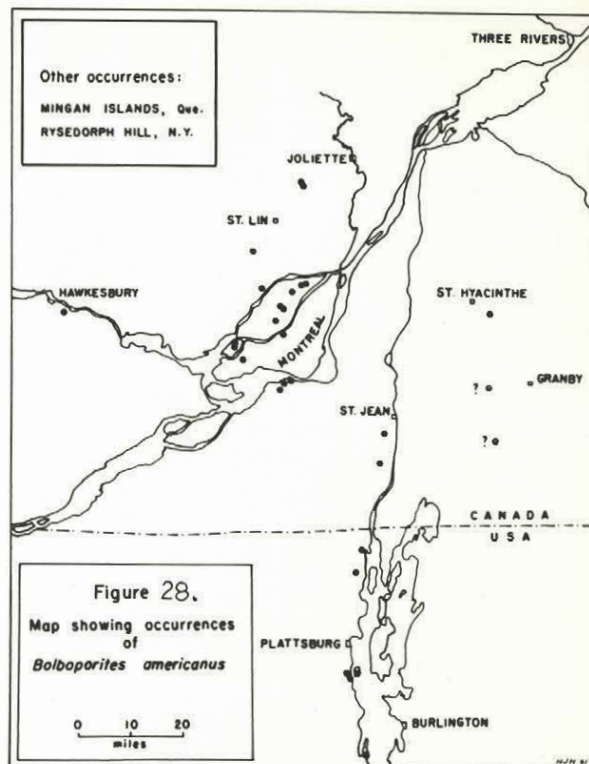
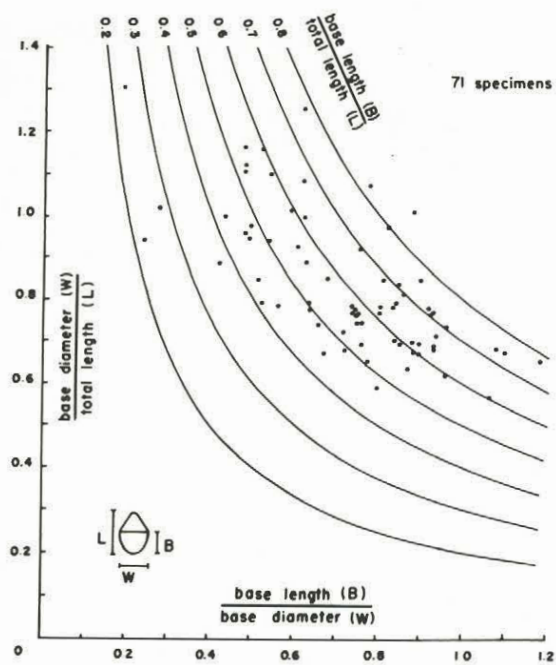


Figure 28.

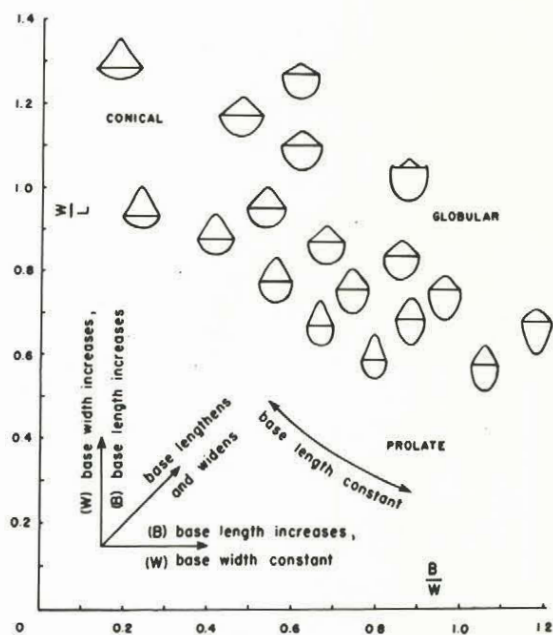
Map showing occurrences
of
Bolboporites americanus

Figure 29.

Shape analysis of *Bolboporites americanus* from southern Quebec.



Scatter diagram showing shape variations by
three-ratio-plot.



Pictograph showing shape variations.

surface. However, it does give an idea of the relative proportions of base and cone. On Fig.29 most of the European forms would fall in the top left corner of the field, because the base length is generally short.

The continuous variation of shape within a certain range is of significance and bears on the problem of the character of this fossil. A study was made by plotting the measurements and derived ratios according to occurrence in lithology, and according to their geographic and stratigraphic positions, but no significant trends were obvious. This may be due to the small number of satisfactory samples. A good example of lack of association is demonstrated by the specimens from Caughnawaga, which showed the widest variations, from conical to globular to prolate.

Occurrence: The geographical distribution is given in Fig.28 (p.166). B. americanus is a common fossil in the Laval formation below the Rostricellula plena zone. It occurs in shaly beds as well as in the coarse-grained calcarenites. The species covers a considerable stratigraphic interval, but the exact amount cannot be determined because there is no complete surface section in this region. A minimum of 110 feet is indicated in the Lagacé Quarry (Locality 25). No specimens were found in the Beaconsfield member, 65.5 feet of which are exposed in the Pointe Claire Quarry (Locality 38), nor were any specimens found in the uppermost part of the Laval formation at other localities.

The species occurs on the Trans-Canada Highway in a quarry and road cut 5 miles southeast of the cloverleaf at Hawkesbury, Ontario, where the rock is coarsely crystalline calcarenite. The quarries at St. Dominique (Locality 51) provided only a few fragments, but enough for identification. The two localities 12 and 22 miles to the south of the latter, and west of Granby have been reported to contain the species (Ami, 1896, pp. 118, 134). This is probably a misidentification, for Chazy rocks are not recognized there.

Logan (1863, p.134) reported Bolboporites americanus in cross-bedded calcarenite at the Mingan Islands, in a section at

Clearwater Point on the mainland, 27 miles east of the village of Mingan. Twenhofel (1938, p.42) found only a single specimen on Perroquet Island, in an interval 21-46 feet above the base of the Mingan formation.

Bolboporites americanus also occurs in the type region of the Chazy group. According to Oxley and Kay (1959, p.820), it is confined to the 200-feet thick Fleury member of the lower Chazy Day Point formation. Raymond (1906, p.528) found the species to extend 75 feet into the middle Chazy at Valcour Island.

Ruedemann (1901, p.8, 11) made a collection of Bolboporites in certain of the blocks in the breccia at Rysedorph Hill, east of Albany, N.Y. However, his specimens (N.Y. St. Mus. coll., type no. 4877) do not show the base, and , consequently, the species is not certain. The internal structure illustrated by him is more interpretation than fact.

Bolboporites americanus? (U.S.N.M. no.97750) is said to occur in the Chambersburg limestone (Edinburg formation - lower Middle Ordovician) at Strasburg in northern Virginia (Butts, 1940, 1941). Five specimens from that locality and another specimen from a locality 1.5 miles south of Hansonville in southwestern Virginia, from the Benbolt limestone (Middle Ordovician) were kindly loaned by the United States National Museum. Only one of the samples (U.S.N.M no.139457) from the Strasburg area resembles the forms of the typical Chazy in that it has a comparatively large base. Yet it is larger and has oval cone cells that are arranged in vertical rows. Its measurements are: L = 11.0 mm., B = 3.7 mm., W = 9.4 mm.

The other five specimens from Virginia resemble each other, and look more like small specimens of the European species. Instead of a globular base they have a smooth oval base with an axis of curvature that is perpendicular to the plane of bilateral symmetry, and the double-winged depression is located close to the periphery of the basal surface.

The lower part of the Chambersburg limestone and the Benbolt limestone were considered by Kay (1956, p.95) to be Bolarian in age

(post-Chazy, pre-Trenton), and by Cooper, (1956, Chart 1) of Porterfield age (post-Chazy, pre-Black River). This was revised by Kay (1958, p.94), who put the lower part of the 'Porterfield' stage of the Bolarian series equivalent to the upper Chazyan, and the upper part equivalent to the Black Riveran. This correlation problem is still not solved, but evidently the fossils from Virginia belong to a stratigraphic horizon somewhat younger than the typical Chazy.

The genus has so far not been recognized in western North America.

Character of the fossils: *Bolboporites americanus* has been variously regarded as a coral, bryozoan, echinoderm, or as an unclassified fossil. The most favoured interpretation has been that it belongs to the echinoderms, because of its close association with echinoderm remains and its crystallized form.

Among paleontologists who studied the European species several other interpretations were advanced. Milne-Edwards and Haime (1851, p.246) found a resemblance to the dactylopores and considered them to belong to the foraminifera, whereas Pander, who also saw this resemblance, classed the dactylopores, and hence *Bolboporites*, as corals. Von Wöhrmann (in Jaekel, 1899) thought *Bolboporites* to be parts of thecal plates of *Cheirocrinus*.

A detailed study of the three-dimensional microstructure led Yakovlev (1921) to believe that the fossils are related to the Hydrozoa or Stromatoporoidea. He also commented (p.9) that it must be characterized as being unattached and as having the apex pointing downward.

A year before that, Wanner (1920) suggested that *Bolboporites* bodies represent spines of some echinoid. Following Lindström (1883, p.7), the spine theory was taken up again by Eltysheva (1955), who thought that they were spines of an asteroid, similar to the conical protrusions on the Recent *Oreaster*. Echinoids and asteroids are not known to occur in the Chazy, so that these two interpretations find as yet no support, as far as *Bolboporites americanus* is concerned. On the other hand, cystids are very abundant, and to some extent crinoids, and if the forms represent spines, they more likely would

belong to a class of the Pelmatozoa.

Regnéll (1955, 1956, p.81, and written communication, 1960) is of the opinion that there is a connection between Bolboporites and the hydrophorid genus Cheirocrinus.

The puzzle is unlikely to be solved completely until specimens are found which indicate the nature of the bodies attached to the basal depression or to the cone cells. In this respect the present investigation was unsuccessful. Nevertheless, it was noted that in the Montreal region bodies of Bolboporites americanus usually, though not always, occur together with plates of Palaeocystites tenuiradiatus (Hall), with Cheirocrinus forbesi (Billings) present in a few places too. Raymond (1906, p.528) found no consistent association on Valcour Island, but Ruedemann collected Bolboporites and Palaeocystites together at Rysedorph Hill near Albany, N.Y. Hall (1847, pl.4, figs. 8,9) figured the association without apparently realizing the significance of it.

The character of the material from southern Quebec leads one to conclude that Bolboporites is part of a cystid rather than a single organism or a colony. One of the problems now is to establish whether the bodies are external (such as specialized appendages), part of the theca, or internal structures. The specimens provided nothing to indicate that the body is part of a thecal plate.

Arguments for the spine theory are mainly based on the presence of the basal depression which is explained as an articulating device, and on the superficial resemblance to some modern echinoderm spines. Difficulties are encountered in trying to explain the double-sided concavity, as this does not occur in modern echinoderms. The depression can perhaps be considered as having functioned as a hinge joint by restricting the mobility to one plane and permitting up-and-down movements of the appendages. One could explain the orientation of the depression with respect to the bilateral symmetry plane, in specimens with eccentric basal depression, by considering the bodies to have come from different parts of the animal. The ones with eccentric hinge joints would probably be situated towards the

bottom and would be large; the ones towards the top would be smaller and prolate in shape. This speculation is in agreement with the variety of shapes present in any one locality. The bodies would be detached soon after death, and this may account for the lack of attached specimens. The thecal plates of Palaeocystites tenuiradiatus and Cheirocrinus found in the Montreal area have about the size required to accomodate such spines. However, no hinge joint tubercle was observed in any of three fairly complete specimens of Cheirocrinus forbesi (Billings). Plates of Palaeocystites tenuiradiatus have a flat cone shape. They might have supported a spine, though the plates are too much weathered to permit one to be certain that the apex of the cone is actually double-sided. With this hypothesis the function of the cone cells on a spine still remains unexplained.

Another possible interpretation should be considered briefly, namely, that of an internal organ, as was suggested by Ami (1896, p.121). Whereas Billings originally compared the size and shape of the cone cells to the zooecia of a bryozoan, it is perhaps more significant to make a comparison between the cells and the thecal pores of Palaeocystites tenuiradiatus (Pl.10, fig.12). A similarity is readily seen. The number of pores in any one animal must be large, but as no complete calyces are available the actual number could not be determined. The number of cone cells in Bolboporites is also large (80 to 200 or more). If the structure occupied an internal position it could perhaps have served in the respiratory process in some way. One of the difficulties here is to interpret the double-winged depression, especially when it is eccentrically situated. This interpretation of internal position should be easily proved or disproved when complete specimens of the cystid are available for sectioning.

In conclusion, it may be said that from a consideration of the present evidence it seems more likely that the bodies referred to Bolboporites from the Laval formation represent external organs such as specialized spines or appendages of cystids, possibly of Palaeocystites tenuiradiatus (Hall). Both fossils are excellent indexes for the Chazy in southern Quebec and New York.

BLASTOIDEABlastoidocrinus carchariaedens Billings.

Pl.9, fig.1

Blastoidocrinus carchariaedens Billings, 1859, Can. Org. Rem., dec.4, p.18, pl.1, figs. 1a-n.

Miller, 1889, N. Amer. Geol. Pal., p.229, fig.257.

Hudson, 1907, N.Y. St. Mus. Bull. 107, pp.97-120, pls. 1-7, text figs. 1-3.

Blastoidocrinus carcharidens Hudson (nom. van.), 1911, N.Y. St. Mus. Bull. 149, pp.203-211, pls. 1-4, text fig.1.

This fossil received a most thorough study by Billings, and especially by Hudson. Their descriptions are complete, and besides occurrences, nothing in the present study can add to their work. The fossil was found at Localities 5, 12, 23, 33, 34, 40, 46, 47, and 49. No specimens are known from the Mingan Islands. In the Champlain Valley it occurs in the Day Point and Valcour formations (Bassler and Moodey, 1943, p.27).

PARACRINOIDEA

The paracrinoids are represented in the Laval formation by two species, belonging to two genera, and can be classified as follows:

Phylum Echinoderma

Subphylum Pelmatozoa Leuckart, 1848,

Class Paracrinoidea Regnéll, 1945

Genus Canadocystis Jaekel, 1900Malocystites Billings, 1858Canadocystis barrandi (Billings).

Pl.9, fig.9

Malocystites Barrandi Billings, 1858, Can. Org. Rem., dec.3, p.67, pl.7, figs. 2a-c.Canadocystis barrandi Jaekel, 1900, Zeitschr. Deutsch. Geol. Gesell., vol.52, p.675, text fig.11.Malocystites emmonsi Hudson, 1903, N.Y. St. Mus. Bull. 80, p.270.Sigmacystis emmonsi Hudson, 1911, N.Y. St. Mus. Bull. 149, p.253, figs. 35,36.Canadocystis emmonsi Foerste, 1916, Ottawa Nat., vol.30, p.76.

This species closely resembles Malocystites purchisoni in its general shape, sigmoid ambulacral area, irregular shape of the plates, position of the anus, and thin column. It is different from it by not having fixed ambulacra extending over most of the calyx, and by having fewer and thinner plates. C. barrandi is more fragile than M. purchisoni, and usually the specimens are much deformed.

A new genus, Sigmacystis, was erected by Hudson (1911) on specimens which he had named (1903) Malocystites emmonsi. His description of this fossil and its very good illustration (1911, fig. 35, p. 254) differ in no particulars from Billings' description and illustrations of Malocystites barrandi, except that the photographed specimen is perhaps better preserved. On the basis of these two descriptions and a comparison with Billings' holotype (Geol. Surv. Can. coll., no. 1011b), the writer concludes that the two species are the same, and that Canadocystis barrandi has priority and must be retained; C. emmonsi is a junior synonym and should be discarded.

Description: Calyx globular, attached to a very thin stem. Plates thin, not very convex, irregularly polygonal, about 30 in number; covered with small pustules, 15 to 20 in 1 mm. square; no thecal pores. Oral part of food grooves short, following a two half-circle sigmoid curve which is raised several millimeters above the theca near the top. Arms uniserial, not fixed, of unknown length, attached to the sigmoid groove on the convex side at close intervals, up to 8 on each side of the mouth. Oral opening at midlength of sigmoid, deep, elliptical, about 0.8 mm. by 1.2 mm. in cross section. Anus nearly circular, 2.5 mm. in diameter, slightly pentamerous, suggesting the presence in life of a lid of 5 plates; located at the top of the cup, 1 or 2 mm. away from elevated sigmoid area, and in line with the greater diameter of the mouth and the short straight section of the sigmoid food groove. Length of calyx 1 to 3 cm., diameter 1 to 2 cm.

Occurrence: In the Montreal area the fossil is abundant only in shaly, calcareous fine-grained quartz sandstone at Localities 23 and 30. Canadocystis emmonsi (Hudson) is found in the middle and upper Chazy on Lake Champlain (Raymond, 1906, various faunal lists).

Malocystites murchisoni Billings.

Pl.9, fig.8

Malocystites Murchisoni Billings, 1858, Can. Org. Rem., dec.3, p.66, pl.7, figs. 1a-i. 1874, Amer. Jour. Sci., vol.40, 2nd ser., p.128, fig.85.

Billings' description and illustrations are quite sufficient to identify the species, but as some new data have become available from a study of over 300 specimens, it was thought best to incorporate these into a new description.

Description: Body spherical to slightly drop shaped. Plates irregularly polygonal, flat to strongly convex, indefinite in number, 40 to 50; each with dense mat of closely and randomly spaced pustules, 3 to 5 in the length of 1 mm.; no pores, sutures depressed. Basal series 3, second series variously 5 to 7, indefinite number above. Ambulacra fixed, usually 8 or 10, in 2 fascicles of 4 or 5 each, connected by sigmoid curve, at the center of which the mouth is located. Arms compound, uniserial, with biserial platelets along axial region, very long, extending almost to the bottom of the calyx and passing over the middle of each plate in its path; 0.7 to 1.0 mm. wide. Mouth oval or elliptical, about 1.0 mm. by 0.7 mm.; near top, slightly removed to one side and with the longer diameter pointing in general direction of anus. Anus nearly circular, situated 5 to 10 mm. away from mouth, covered by 5 triangular plates. Interior generally completely filled with crystalline calcite. Column very thin, nearly 2 mm. in diameter in specimen 15 mm. wide.

Measurements: The specimens have a large size distribution, ranging from 4 to 30 mm. in diameter. Billings reported observing fragments of specimens that must have been 2 inches (50 mm.) across. Such were not found in the collections studied. The results of caliper measurements of 359 individuals are incorporated in Fig. 30, p.175. The horizontal diameter was used, because all the specimens are more or less globular, so that this dimension can be considered representative of size. A slightly skewed distribution is evident. The arithmetic mean diameter of all samples measured is 14.0 mm., and is somewhat less than the average given by Billings (1 inch or 25 mm.).

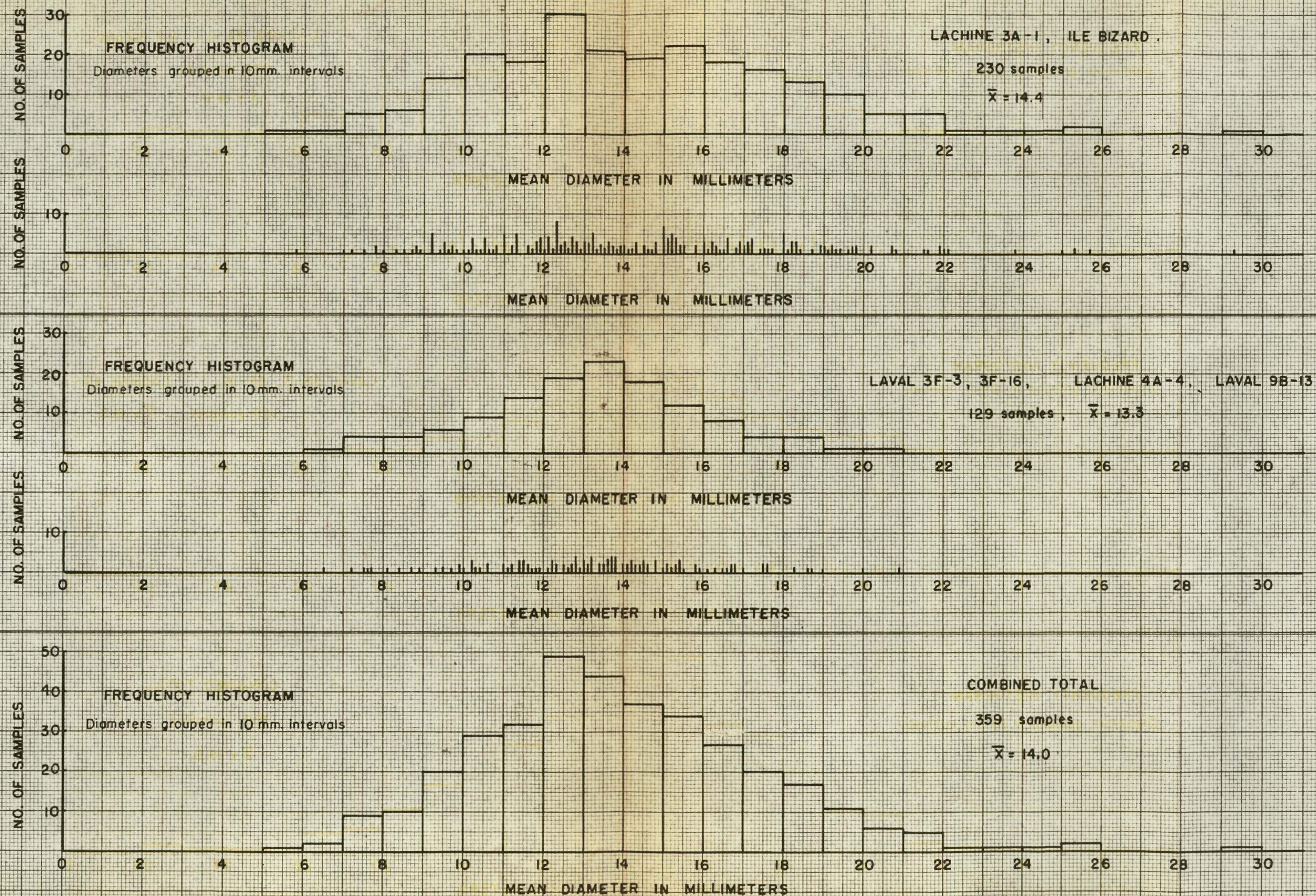


Fig. 30. Size frequencies of *Malocystites murchisoni* Billings.

Occurrence: Abundant in many localities in the vicinity of Montreal. On Lake Champlain it occurs at the base of the middle Chazy and ranges into the upper Chazy. It is found at L'Orignal, Ontario (Raymond, 1906, p.568), but has not been found at the Mingan Islands.

Discussion: This species is a very good index fossil for the Chazy of the Champlain - St. Lawrence Lowlands, and it is easily identified in the field by its nearly spherical shape and by the disposition of its 8 or 10 recumbent food grooves in 2 fascicles.

One outstanding feature of this species is the almost complete preservation of the calyx of such large numbers of individuals, whereas almost all other pelmatozoan remains are disaggregated. One of the reasons for this preservation is that the sutures on the theca are very tightly closed and the lack of thecal pores or other openings. In fact, only 3 small apertures would allow debris to enter the coelum: mouth, anus, and a small hole where the calyx was attached to the thin column. When the animals died probably only the mouth was open. The bodies broke off their stem and were buried before the sutures loosened and mud could enter. The crystalline interior of a large number of specimens proves that the theca was quite well sealed upon burial. After the soft interior organic material decayed the calyx crystallized and behaved in a fashion much like a geode in the making: calcite was deposited inside, starting from the interior of the thecal plates and growing towards the center. The result is a beautiful set of clear radial crystals, visible in some specimens, or of white radial crystals, seen in many other specimens.

CRINOIDEA

Although very rare as complete specimens, crystallized crinoid remains are abundant in the upper part of the Laval formation. Billings (1859b, p.430) said he recognized 14 species, but considered only 5 of them worthy of description (1859a). Two of these,

Blastoidocrinus carchariaedens and Palaeocrinus striatus, are not crinoids, so that really only 3 species are described. Eight species are known in the Lake Champlain region (Bassler and Moodey, 1943, p.22), all of them in the upper Chazy Valcour formation.

No new crinoids have been described from southern Quebec since 1859, and no further information is available from the present study. The Laval crinoids are classified as follows.

Phylum Echinoderma

Subphylum Pelmatozoa Leuckart, 1848

Class Crinoidea Miller, 1821

Order Inadunata Wachsmuth and Springer, 1897

Family Hybocrinidae Zittel

Genus Hybocrinus Billings, 1857

Order Camerata Wachsmuth and Springer, 1897

Family Rhodocrinitidae Bassler

Genus Deocrinus Hudson, 1907

Unclassified genus Pachyocrinus Billings, 1859

Hybocrinus pristinus Billings.

Pl.9, fig.12

Hybocrinus pristinus Billings, 1859, Can. Org. Rem., dec.4, p.23, pl.1, fig. 2a; text figs. 4,5, p.25.

Occurrence: According to Billings, "Detached plates are rather common in the Chazy limestone at Caughnawaga, and at various localities on the Islands of Montreal, Jesus and Bizard; also in the front part of the Township of Hawkesbury. Perfect specimens are rare."

Deocrinus asperatus (Billings).

Pl.9, figs. 10-11

Rhodocrinus asperatus Billings, 1859, Can. Org. Rem., dec.4, p.27, pl.1, figs. 4 a-e.

Deocrinus asperatus Hudson, 1907, N.Y. St. Mus. Bull. 107, p.122, pl.8, figs. a,b; text fig.5.

A unique specimen of this species was described by Billings from the Chazy limestone "in a quarry about two miles north of the City of Montreal", probably at Locality 32. The morphology is well known, though no additional specimens have been found. The holotype is shown on Pl.9, figs. 10-11.

Pachyocrinus crassibasalis Billings.

Pachyocrinus crassibasalis Billings, 1859, Can. Org. Rem., dec.4,
p.22, pl.1, figs. 3a-b.

Hudson, 1907, N.Y. St. Mus. Bull. 107, p.120, text fig.4.

This species is based on the incomplete lower part of a calyx collected "two miles north of Montreal", probably at Locality 32. Billings described it as having 5 small pentagonal plates where the column was attached. However, a reëxamination of the holotype (Geol. Surv. Can. coll., no.1018) showed that only 4 plates are present, as was already demonstrated by Hudson.

This specimen lacks sufficient diagnostic features which would permit recognition, and Moore and Laudon (1943, p.104) have suggested that the species might well be discarded. No additional specimens were located in the present collections.

TRACKS, BURROWS, and INCERTAE SEDIS

Cruziana? lavalensis n.sp.

Pl.11, fig.2

Description: Markings on bedding plane in greenish grey shale, occupying a more or less oval area, and consisting of a series of parallel striae spaced 1 mm. apart and grouped into several parallel or subparallel bundles of 6 to 7 striae each. These bundles curved and slightly convex in cross section, each one separated from the adjoining one by a furrow. Bundles traceable for 67 mm.; structure appears diagonally segmented where the longitudinal curvature has inflection points which are more or less evenly spaced, about 10 mm. apart. Slab shows two sets of diverging bundles originating in a common region, each bundle concave towards the mid-region.

Occurrence: This unique specimen is on a slab of very fragile greenish grey shale, interbedded with laminae of siltstone, and was collected loose from the lower 58 feet in the Lagacé Quarry (Locality 25).

Remarks: The bundles are interpreted as marks made by some arthropod, probably a fairly large trilobite which moved along the sea floor. The striae are due to the brushing effect of elaborate appendages, and the direction of movement in the figured specimen was from lower left to upper right, as seen in a worm's eye view. Tracks of similar nature have been described in the literature under the name Cruziana.

Genus Palaeophycus Hall.

Palaeophycus Hall, 1847, Pal. New York, vol.1, p.7.

Hall diagnosed this genus as follows: "Stems terete, simple or branched, cylindrical or subcylindrical; surface nearly smooth, without transverse ridges, apparently hollow." Palaeophycus has not heretofore been recognized in the Laval formation.

Palaeophycus ancoraforme n.sp.

Pl.12, figs. 2-5

Description: Long, more or less straight, round stems, flat on two sides; uniformly thick over considerable length. Most stems with one to three longitudinal striae on each flattened surface (Pl.12, fig.4). The stems form irregular meshes on the bedding surfaces, criss-crossing in a random fashion, arranged with their flattened sides in a vertical position, and not parallel to the bedding, as would result from the normal course of compaction. Local flexures in the rods common where one overlies another, with no, or very little thinning at the crossing points. The stems 3 to 5 mm. wide, up to 12 mm. high, and very long; one fragment traced with uniform thickness for 29 cm.

A forked terminal structure (Pl.12, fig.5), resembling an anchor, on some thick stems. The branches on one of the better preserved specimens somewhat curved and not very long. The two largest branches traceable for only 2 cm., beyond that they grade into bulbous swellings. Two smaller branches a short distance away from the main bifurcation; all at acute angles to one another. The bodies composed of very fine-grained sandstone and set in a flaky greenish

grey illite shale matrix that weathers out easily.

Occurrence: Confined to the lower Laval quartz-sandy beds. Found in quarries at Localities 22, 23, 29, 40, 44. Similar long, rodlike bodies, but of smaller size, occur in the lower part of the St. Dominique sandstone at Localities 51 and 52. However, as no anchor-like structures were observed, the bodies in the St. Dominique area may not be Palaeophycus ancoraforme. In the Mallet well this fossil occurs below 190 feet depth.

Discussion: P. ancoraforme closely resembles in habit and form the Beekmantown species P. beauharnoisense Billings 1865, from which it differs in having a more compressed cross section, and by the presence of the terminal anchor-like structure. It also resembles P. simplex Hall 1847 of the Trenton, but has several longitudinal striae instead of just one. The fragments are usually longer than those of P. simplex, the rods are more compressed laterally, and there is a terminal branching structure.

The structures assigned to Palaeophycus have been interpreted as algae and as burrows (Johnson, 1961; Wilson, 1948; Dawson, 1890, p.611, fig.15). The similarity to certain modern seaweeds has been used as an argument in favour of the former. Yet certain difficulties are met in trying to account for the lack of compaction or flattening which should result from sedimentation of mud onto a fragile structure such as an alga. It is better to explain these fossils as filled-in burrows of some animal, such as a mollusk, worm, or arthropod. The apparent lateral compression and the striae could be related to the vertical cross section of the burrowing animal moving in the plane of the bedding. Palaeophycus ancoraforme is confined to the intimately interlayered shale-sandstone beds, which must have been fine burrowing grounds in their unconsolidated state. The anchor-like structure is perhaps not so readily understood; it is thought to be a specialized burrow. Similar structures produced by trilobites have been found in the Silurian of central Africa (Seilacher, 1959, p.393).

This ichnofossil resembles others which are known under the genera Licrophycus Billings and Teichichnus Seilacher, from the Lower Palaeozoic.

Genus Petalonia n.gen.

Small, rounded, curved, rodlike bodies, with plane of coiling parallel to bedding, and upturned ends, often resembling a miniature horseshoe; composed of fine sand or silt-sized particles, without internal structure. Filled-in dwelling burrows.

The genus resembles Arenicolites but has the plane of curvature parallel to bedding; it differs from the spiraliform genus Spiroscolex for the same reason. The name is derived from the Greek word for horseshoe.

Type species: Petalonia soleaformis n.sp.

Petalonia soleaformis n.sp.

Pl.11, fig.5

Description: Small, unbranched, cylindrical bodies, bent into horseshoe-shaped aggregates; variations in shape from laterally compressed forms to those with incomplete horseshoe shape. The ends of many of the bodies bent upwards, so that they resemble an inverted horseshoe. Surface generally smooth, but in some of the larger specimens faint annulations visible. Interior of the bodies composed of a structureless aggregate of fine-grained clastics, different from the enclosing shale matrix.

Occurrence: In the Montreal area this fossil was observed only in the lower part of the Laval formation in the Lagacé Quarry (Locality 25), in the 18.8'-36.5' interval. The species is very abundant in certain Chazy sandstone-shale layers near the Trans-Canada Highway cloverleaf at Hawkesbury, Ontario, and the slab containing the photographed specimens was derived from there.

Discussion: These fossils invariably occur in intimately interbedded, very fine-grained, siliceous sandstone and fissile greenish grey shale, and are confined to the shale beds or laminae. This suggests that the animals which produced these structures, probably worms, lived in quiet, muddy waters. There are two main interpretations for the structures: 1) they are coprolites, and 2) they are burrows that became filled with detritus.

The evidence indicates the bodies, with upturned extremities and annulations, silt-sized composition, and occurrence in shale laminae, originated below the water-sediment interface. The better conclusion of the two is that they are burrows which became filled after the animals died or moved away. If they were subsurface coprolites (worm castings) the size of the material which passed through the gastric tracts should resemble that of the green shale. It does not.

The interesting feature of this filled-in burrow is its tight curvature in the horizontal (bedding) plane. One possible explanation for this can be offered, and that is that the animals, for some reason, had difficulties in burying themselves in sandy and silty layers, but none in the muddy ones; as the shale interbeds are very thin the animals, when they struck the coarse-grained layers, had to burrow themselves laterally. As in other U-shaped dwelling burrows, the animals brought posterior and anterior ends of their bodies into proximity, but in this species by horizontal coiling and upturning of the ends. This feature is incorporated in the specific name.

Phymatoderma? sp.

Pl.11, fig.7

Under the name Phymatoderma have been described roofed tunnels or burrows, such as those from the Silurian in Ontario, pictured by Dawson (1890, p.602, fig.6). The fossils from the Laval formation are cylindrical bodies with faint annular grooves, somewhat flattened, and about 6 to 8 mm. in diameter. They are much larger than Petalonia soleaformis, and there is no horizontal coiling. In some of the long, straight specimens there is a sharp inflection at one extremity. These structures may belong to some other ichnogenus, dozens of which have been named, and some of which are synonyms.

Occurrence: Found in the lower Laval quartz-sandy beds in the Lagacé Quarry (Locality 25) and in the Bédard Quarry (Locality 40).

Rusophycus grenvillense Billings.

Pl.8, figs. 24-27

Rusophycus Grenvillensis Billings, 1862, adv. sheets, Geol. Surv. Can. 1865, Pal. Foss. Can., vol.1, p.101.

Rusophycus grenvillensis Dawson, 1864, Can. Natur. Geol., n.s. vol.1, pp.363, 458.

Rusichnites grenvillensis Dawson, 1890, Quart. Jour. Geol. Soc. London, vol.46, p.597, fig.1.

Original description: "This species is found in the form of irregular oblong-ovate or depressed hemispherical masses, one end usually divided into two parts by a furrow of more or less depth. the whole mass is generally crossed by numerous undulating wrinkles, which have a direction transverse to that of the furrow. The more common dimensions are from 3 to 4 inches in length, and from $2\frac{1}{2}$ to $3\frac{1}{2}$ in width, but occasionally specimens occur much larger and also smaller. One of these is $9\frac{1}{2}$ inches by $5\frac{1}{2}$, and in addition to the principal groove exhibits two or three obscure furrows on each side."

Occurrence: Poorly developed specimens were found in the lower part of the Lagacé Quarry (Locality 25). The species is very abundant in greenish shale and sandstone in the Ottawa Valley, at L'Orignal, Hawkesbury, and Grenville.

Discussion: This peculiar fossil is almost identical with the form which Hall (1952) called Rusophycus bilobatus, and which is found in the Clinton group in New York. Hall and Billings interpreted it as a kind of seaweed.

Dawson (1864) concluded that the markings are actually burrows and tracks of marine animals, probably of trilobites, and substituted (1873, p.18) a new generic name, Rusichnites, for the old one, to do away with the idea that the structures are plants. However, according to nomenclatorial rules, Rusophycus is the valid name.

The interpretation that the structures are filled-in tracks or burrows is more plausible than any other, when one considers the following. In polished sections there is no particular structure visible. Instead, the bodies are seen to be composed entirely of fine to very coarse sand grains. The bodies occur in greenish grey shale, and the original mud was, no doubt, an easy burrowing ground. The shape of the structure is one of bilateral symmetry, so striking in fact, that the fossils are known under the collective name Bilobites

(see Sinclair, 1951). The steep flanks do not converge towards either end in most specimens, but run parallel to the median furrow, which itself has a curvature parallel to that of the lobes. In well preserved samples (Pl.8, fig.26) one can see distinct concentric wrinkles on the sides, while the convex area between the flanks and on either side of the median furrow the surface is sculptured with closely spaced, curved transverse ridges.

Both lateral and transverse ridges could be due to the stroking of the burrowing appendages of some animal which dug itself into a preying, resting, or hiding place. The last of the three does not seem so likely because the animals must have been large, compared to the rest of the animals in the Chazy sea.

Rusophycus is an excellent facies fossil, for it is particularly well developed in shallow water, limestone-free, interbedded shale-sandstone sequences. Since these lithologies are often devoid of actual fossil fragments its value as a guide fossil must be appreciated.

The most recent treatment on the stratigraphic value of ichnofossils, and especially of bilobites, is by Seilacher (1960). On the basis of shape, and disposition of the numerous transverse ridges he distinguished between several Rusophycus-like structures, namely those produced by polychaetids, phyllopods, gastropods, and trilobites. Only the last two of these are abundant in southern Quebec, and hence could qualify, but which one of the two it is cannot be said with certainty, for both large gastropods and large trilobites are known.

Scolithus sp.

Pl.11, fig.1

A multitude of vertical tubes at the top of the calcarenite unit (at 18.0') in the St. Vincent de Paul Quarry (Locality 20) may be referred to this genus. They are cylindrical, about 7 mm. long and 1 mm. across, truncated on top by an unconformity, and overlain by shaly, dolomitic material with valves of Rostricellula.

This occurrence is unique in that the quarry wall is heavily weathered, exposing the tubes. They were not seen in corresponding beds in the Devito Quarry, or in the Pointe Claire Quarry.

Unidentified trails.

Pl.11, fig.6

In places the bedding surfaces are covered with long, sinuous bands of constant width and without distinguishing marks; they are 2 to 3 mm. wide and 10 to 20 cm. long, and are most likely trails. Such markings were encountered at Localities 16, 25, and 52.

Another kind of trail (Pl.11, fig.6) consists of two converging lines of small pits with adjoining mounds. The distance between successive pits is about 3 mm. The character of the originator is obscure; it is probably some kind of arthropod. This fossil was found in the Lagacé Quarry (Locality 25) in the 87'-96' interval. A similar structure, with parallel rows of pits and mounds, has been described under the name Ichthyoidichnites acadiensis from the Devonian of Nova Scotia (Ami, 1901, p.330).

SUMMARY AND CONCLUSION

The early Middle Ordovician Chazy group forms part of a 9,000 feet thick, mostly marine, sedimentary sequence in southern Quebec. It includes the lower Laval quartz arenites and shales, the middle Laval shaly limestones and cross-bedded calcarenites, and an upper part of shaly limestones, dolomitic shales and shaly dolomites, the Beaconsfield member, which grades into the Pamela formation in the Montreal area.

The areal distribution and thickness of the Laval formation is irregular, and lateral facies changes of beds within it are common. On a faunal basis the formation can be divided into an upper Rostricellula plena assemblage zone, correlatable with the upper Chazy of the standard section, and a lower Bolboporites americanus assemblage zone with lower and middle Chazy faunal aspects. The Bolboporites americanus zone has at its base quartz-sandy and shale beds which carry an autochthonous benthonic fauna of ichnofossils, while in the upper parts shaly limestone and calcarenites occur, with a varied allochthonous brachiopod-bryozoan-trilobite-ostracod-echinoderm fauna.

Calcarenite developments (St. Martin member) of the Laval formation are characteristically cross-bedded and indicate chief current directions from the northwest. They contain, in the uppermost parts of the Bolboporites zone, widely scattered coral bioherms. The species found in these structures are identical with those found in the Crown Point - Valcour boundary region in the Champlain Valley.

In the Montreal area a gradational contact exists between the upper part of the Laval formation and the Rostricellula-bearing Pamela, and between the upper part of the Pamela and the Lowville. The Chazy-Black River contact is placed at an unconformity within the Pamela, rather than at the base of it. The part below the unconformity is correlated with the lower phase of the Ottawa Valley Pamela.

The problematic Bolboporites americanus Billings is interpreted as representing specialized external appendages, such as spines, of cystids.

P O S T S C R I P T

In this thesis several important results were presented. Other, as yet unsolved problems have arisen during the course of study. Among the original contributions to geological knowledge are the following.

- 1) The recognition of two major faunal assemblage zones in the Laval formation: a lower Bolboporites americanus zone and an upper Rostricellula plena zone.
- 2) The recognition of faunas of lower and middle Chazyan affinities in the Montreal area.
- 3) The discovery of the upper Chazyan index fossil, Rostricellula plena, within the orange-weathering Pamelia in the Montreal area.
- 4) The recognition of a gradual transition from Laval to Pamelia deposition in the Montreal area, based on lithology and fauna.
- 5) The recognition of an unconformity within the Pamelia, which marks the boundary between the Chazy and Black River groups.
- 6) As a result of the above, the elucidation of the nature of the Chazy-Black River boundary on a regional scale, and related correlations.
- 7) The discovery and description of several new fossil species and one new genus.
- 8) The redescription of several already described species, due to the finding of better specimens.
- 9) The detailed study, classification, and hypothesis concerning the enigmatic Bolboporites americanus Billings.
- 10) The determination of the geographic and stratigraphic distribution of the various fossils found in the Chazy of the St. Lawrence Lowland.

Several matters bearing on the Chazy, which were not accomplished, are recommended for further investigation. These include the following.

- 1) A detailed study of cores and other well records to determine the exact subsurface extent of the Chazy.
- 2) An investigation into the abnormal thicknesses in the Three Rivers area to determine if all the sandstone logged as Chazy really

belongs to the Chazy.

- 3) Further fossil collecting and their study is necessary for a better understanding of the fauna, especially with regard to the rather rare cephalopods, the poorly preserved crinoids, the diverse bryozoans, and the poorly preserved strophomenoid brachiopods.
- 4) A study of the nature of the boundary between the Beekmantown and the Chazy, should the contacts become exposed by quarrying or otherwise.
- 5) The relation of the Beldens formation to the Beauharnois dolomite and the Chazy.

APPENDIX 1

Calcite-Dolomite Ratio Determinations

The relative amounts of dolomite with respect to total carbonate (calcite + dolomite) in various samples were estimated by a method similar to those developed by Tennant and Berger (1957), Webber (1957), and Gulbrandsen (1960b). It essentially consists of measuring and comparing on an automatic recording chart the amplitudes of the highest X-ray diffraction peaks of calcite and dolomite. These peaks are quite conveniently located close together, and are also relatively free from interference from peaks of other minerals. The following procedure was followed.

Representative fresh specimens collected in the field were passed separately through a jaw crusher which was adjusted so that a mixture of powder and small (< 5 mm.) fragments accumulated in the receptacle. Next, if the sample was large, the mixture was put through a Jones splitter to obtain a smaller representative fraction of the sample. This was then sieved and the minus 200-mesh (U.S. Standard) fraction collected and stored in a labelled plastic vial. The powder was later ground for 7 minutes with a Wig-L-Bug dental amalgamator, in a small covered steel container with 2 steel balls. The further size reduction is necessary for more precise work, according to Webber (1957), who investigated the reproducibility of results of calcite-dolomite ratios with various grain sizes. The powder obtained from the final grinding was then mounted into the hole of the glass slide sample holder by back packing (method of McCreery, 1949) it onto filter paper. This procedure counters some of the possible errors by minimizing preferred orientation of the carbonate grains.

The slide was then carefully inserted into the X-ray diffractometer for analysis. Nickel-filtered copper ($K\alpha$) radiation was used and resetting of controls was kept to a minimum. The sample was scanned at a rate of 2.0° per minute between 2θ values of 25° and 35° to include the two carbonate peaks (around 29.40° for the 104 reflection of calcite, and around 30.97° for the 112 reflection of dolomite). This scan also includes the peaks for the detrital minerals quartz (26.7°) and feldspars ($27.5^\circ - 28.0^\circ$). The next step was to make a "slow" scan (0.2° per minute) from $2\theta = 29.25^\circ$ to 31.25° , with the

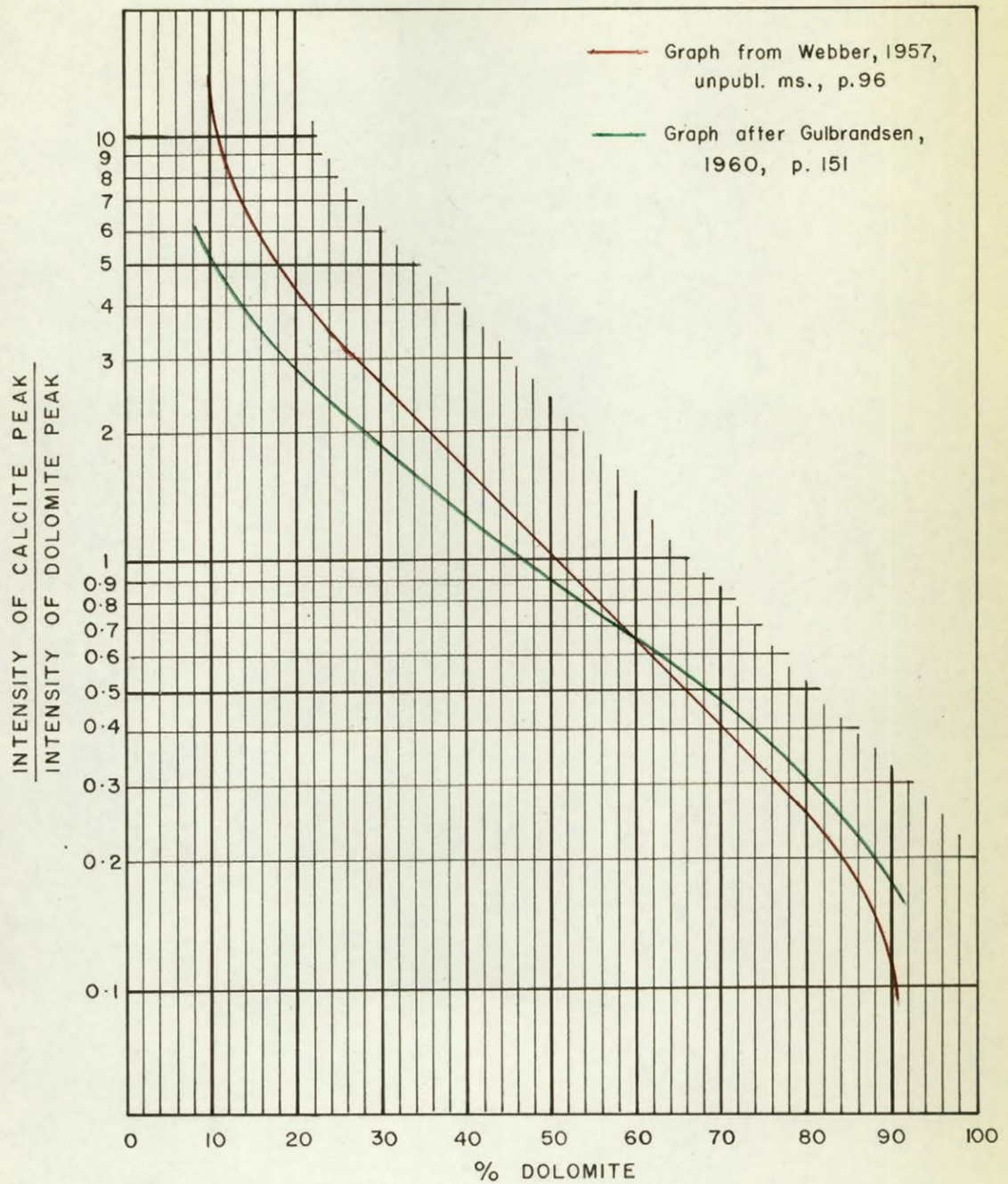


Fig. 31

DETERMINATION OF DOLOMITE
PERCENTAGE OF TOTAL DOLOMITE
& CALCITE IN CARBONATE ROCKS.

APPENDIX 2

LIST OF FOSSIL SPECIMENS SUBMITTED TO THE
DEPARTMENT OF GEOLOGICAL SCIENCES, MCGILL UNIVERSITY

Box	Name of fossil	Locality	Locality no.	Illustration pl. fig.	
1	Girvanella? sp.	LAVAL 9B-13	12	12	1
2	Solenopora ouareauensis Fritz	8D-3	23	2	2
3	Alga, unclassified form	Oil Selections No.6 Well		11	3,4
4	Hudsonospongia? infundibulosa n.sp.	LACHINE 8C-2	40	2	3,4
5	"	LAVAL 7D-9	22	2	5,6
6	" (thin sect.)	"	22		
7	"	"	22		
8	" (polished)	"	22		
9	Metaconularia mascouchensis n.sp.	Quonto-Intl. No.1 Mascouche		2	7-9
10	"Serpulites"splendens Billings	LAVAL 9B-7	12	2	10
11	Eofletcheria incerta (Billings)	10C-1	12	3	3
12	"	LAURENTIDES 5F-1	9	3	4
13	Billingsaria parva (Billings)	LACOLLE 5B-1	49		
14	Carinophylloporina sp.	LAVAL 8E-15	23	4	1
15	Phylloporina sp.	"	23	4	2
	Phylloporina aspera (Hall)	LACHINE 8C-2	40		
16	Chasmatoporella sp.	LAURENTIDES 9B-4	3	4	3,4
17	Subretepora sp.	8B-2	7	4	5
18	Unidentified bryozoan	9B-12	3	4	6
19	Stictopora spp.	LACOLLE 4C-1, 5B-1	49,50	5	1-4
20	Encrusting Trepotomata on?"Serpulites"	LAVAL 9B-11	12	5	5
21	Collection of unidentified bryozoa				
22	Lingulella? sp.	LAVAL 8E-15	23	6	1
23	Schizambon duplicimuratum Hudson	LACHINE 8C-2	40	6	2
24	Orthambonites sp.	LAVAL 7E-3	25	6	3
25	Hesperorthis sp., cf. H. ignicula (Raymond)	LACHINE 8C-2	40	6	7
26	Atelelasma? parvum (Wilson)	"	40	6	8
27	Mimella borealis (Billings)	LAVAL 8C-14	18	6	13
28	Orthoidea spp.; Glyptomena? sp.	LAURENTIDES 9B-4	3		
29	Mimella transversa Cooper	LAVAL 10C-1, 9B-13	12	6	17

30	Multicostella platys (Billings)	LAVAL 8F-6	30	6	40
31	Box of orthids and rhynchonellids				
	Orthambonites palaformis n.sp.	LACHINE 3A-1	35	6	4-6
	Mimella borealis (Billings)	LAURENTIDES 9B-1	5	6	9-12
	Mimella vulgaris (Raymond)	LAVAL 7D-4 to 11	22	6	14-16
	Rostricellula raymondi Cooper	9D-1	20	6	24-26
	"	9B-7	12		
	Rostricellula wilsonae Cooper	9D-1	20	6	36-39
	Rostricellula plena (Hall)	9D-1	20	6	32-34
	Rostricellula pristina (Raymond)	8C-14	18	6	27-30
	Leptobolus-like brachiopod	Cartierville			
	Sphenotreta acutirostris (Hall)	LAURENTIDES 8B-2	7	6	18-20
	Glyptomena? sp.	LAVAL 9D-1	20		
32	Dorytreta? arduamarginata n.sp.	LAURENTIDES 9B-4, 12	3	6	21-22
33	Rostricellula raymondi Cooper	LAVAL 8C-2	16	6	23
34	Rostricellula plena (Hall) (Pamelia fm.)	LACHINE 5B-2	39	6	35
35	Onychoplectra sp., cf. O. gracilis (Raymond)	LAURENTIDES 5F-1	9	6	31
36	Valcourea sp., cf. V. intracarinata Ulr.&Coop.	ST. HYACINTHE 3F-3	52	6	42-43
37	Valcourea strophomenoides (Raymond)	LAVAL 9B-12	12	6	45
38	Multicostella? sp.	ST. HYACINTHE 3F-3	52	6	46
39	Dactylogonia incrassata (Hall)	LACOLLE 4C-1	50	6	47-47a
40	Archinacella propria Raymond	LAVAL 10F-6	33	7	1
41	Bucania sulcatina (Emmons)	LAURENTIDES 9B-5	6	7	4
42	Loxoplocus (Lophospira) sp.	LAVAL 9D-1	20	7	5, 6
43	Helicotoma? sp.	8C-2	16	7	7
44	Raphistoma stamineum Hall	LACOLLE 4C-1	50	7	8-10
	Cyclora? sp.	LACHINE 5B-2	39	7	12
	Raphistoma stamineum crevieri (Billings)	ST. HYACINTHE 3E-1	51		
45	Raphistoma? sp.	LAVAL 10F-6	33	7	11
46	Gastropod Pamelia fm.	LACHINE 4B-1	38		
47	Pelecypods		35, 39	7	14-16
48	Modiolopsis fabaformis Raymond	LAVAL 10F-6	33	7	17
49	Michelinoceras sp.	LACHINE 5B-2	39		
50	Ormoceras sp.; endoceroid;	3A-1	35		
51	Stereospyroceras sp., cf. S. clintoni (Hall)	LACOLLE 4C-1	50		
52	"	LAVAL 9B-12	12		
53	cf. Vaginoceras oppletum Ruedemann	LACHINE 4A-4	36		
54	Valcouroceras sp.	LACOLLE 4C-1	50		
55	Unidentified endoceroids				
56	Unidentified endoceroids				

57	Glaphurus? sp.	LAURENTIDES 5F-1	9	8	1
58	Glaphurina lamottensis Ulrich	LACOLLE 5B-1	49	8	2
	Bumastus globosus (Billings)	LAVAL 10F-6	33	8	11
	Sphaerexochus parvus Billings (Hall)	9C-6	13		
59	Vogdesia bearsi Raymond; Basilicus marginalis	LACOLLE 4B-1	49	8	3,8,9
60	Isotelus sp., cf. I. harrisi Raymond	LAURENTIDES 8B-2	7	8	4,5
61	Isotelus platymarginatus Raymond	ST.HYACINTHE 3F-3	52	8	6
62	Homotelus obtusus (Hall)	ST.HYACINTHE 3F-3	52	8	7
63	Bumastus sp., cf. B. aplatus Raymond	LAVAL 8C-2	16	8	10
64	Thaleops conifrons (Billings)	ST.HYACINTHE 3F-3	52	8	12
65	Lonchodomas halli (Billings)	ST.HYACINTHE 3F-3	52	8	13
66	Sphaerexochus parvus Billings	LAVAL 8D-7	23	8	14
67	Pliomerops canadensis (Billings)	LAURENTIDES 9B-12	3	8	17
68	Calliops annulatus (Raymond)			8	18,19
69	Pterygometopus? sp.	LAVAL 8E-5	26	8	20
	Valcourea strophomenoides (Raymond)	"	26	6	44
70	Kawina vulcanus (Billings)	LAVAL 8D-7	23	8	21
71	Trilobite hypostoma	LAURENTIDES 9B-4	3	8	23
72	Ostracods				
73	Blastoidocrinus carchariaedens Billings	LACOLLE 6A-1	47	9	1
74	Cheirocrinus forbesi (Billings)	LAVAL 8E-15	23	9	2
75	Palaeocystites tenuiradiatus (Hall)	LAVAL 10C-1	12	9	3,4,6
76	Palaeocystites dawsoni Billings	LACHINE 3A-1	35	9	7
77	Malocystites murchisoni Billings	LAVAL 9B-13	12	9	8
78	Canadocystis barrandi (Billings)	8E-15	23	9	9
79	Unidentified echinoderm fragments	Local Chazy			
80	Bolboporites americanus Billings			10	
81	Palaeophycys ancoraforme n.sp.	LAVAL 7E-8	25	12	3
82	Cruziana? lavalensis n.sp.	"	25	11	2
83,84	Petalonia soleaformis n.gen. n.sp.	Hawkesbury, Ontario		11	3
85	Phymatoderma? sp.	LAVAL 7E-8	25	11	7
86	Scolithus sp.	LAVAL 9D-1	20		
87,88	Palaeophycys ancoraforme n.sp.	LAVAL 7E-8	25	12	4,5
89	Palaeophycys ancoraforme?	ST.HYACINTHE 3E-1	51		
90	"	3F-3	52		
91	Unidentified trails	LAVAL 7E-8	25	11	6
92	Unidentified trails and P. ancoraforme	LACHINE 8C-2	40		
93,94	Rusophycus grenvillense Billings	near Grenville, Quebec		8	24-27

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P L A T E S

Note 1: Unless otherwise stated, all scales alongside photographs are in millimeters.

Note 2: The number of the page on which the fossils are described in the text is given at the end of the explanation of each photograph.

PLATE 1

Lithologies of Laval formation.
Photographs of core samples.
(depth in feet below surface)

1. Uppermost calcarenite of Laval formation in Oil Selections No.6 well, at 1622'.
2. Shaly limestone of Beaconsfield member in Oil Selections No.6 well, at 1727'. Shale constitutes roughly half of the rock. Detached valves of Rostricellula plena (Hall) common.
3. Massive, coarse-grained calcarenite (St. Martin member) with stylolites. Oil Selections No.6 well, at 1873'.
4. Lumpy-bedded shaly limestone; shale makes up about 10 percent of rock. Oil Selections No.6 well, at 1934'.
5. Bryozoan shaly dolomite. Branching trepostomatous bryozoans constitute about 40 percent of the bed. Oil Selections No.6 well, at 1937'.
6. Lumpy-bedded shaly limestone. About half of the rock is limestone. Round white specks at center are bryozoans. Mallet well, at 107'.
7. Lumpy-bedded shaly limestone, in which shale is even more abundant than in fig. 6. Mallet well, at 188'.
8. Interbedded greenish grey, micaceous shale seams and fine- to medium-grained calcareous quartz sandstone. Mallet well, at 148'.
9. Interbedded dark brownish grey, dolomitic shale and fine-grained calcarenite. Oil Selections No.6 well, at 2007'. This unit is below the lowest beds which can definitely be assigned to the Laval formation. As the lower contact in this well is not clearly defined, this rock may not belong to the Chazy.
10. Specimen from mottled shaly and brecciated dolomite and limestone bed at 2036', in Oil Selections No.6 well. This unit is taken as the base of the Chazy, although no fossils are available to let one be sure of the age.



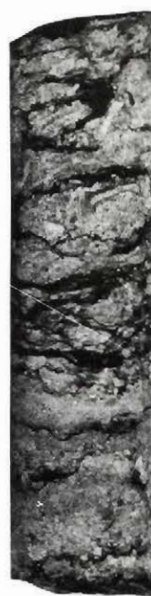
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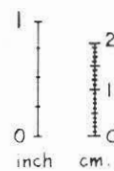
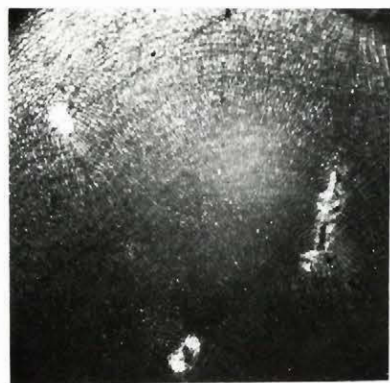


PLATE 2

1. Solenopora embrunensis Wilson. Thin section of a specimen from the Meunier Quarry (Locality 12). Specimen in collection of MacGregor (1954), deposited with Dept. of Geol. Sciences, McGill Univ. p.90.
2. Solenopora ouareauensis Fritz. Thin section of specimen from Que. Dept. Mines collection, box 14 in Redpath Museum basement. Locality 23. p.91.
- 3-4. Hudsonospongia? infundibulosa n.sp. Top view (fig.3) and bottom of a specimen from the Bédard Quarry at Caughnawaga (Locality 40), 49'-52' interval. p.92.
- 5-6. Hudsonospongia? infundibulosa n.sp. Polished surfaces of two specimens from the Cap St. Martin Quarry, 15.0'-24.0' interval (Locality 22).
Fig.5, transverse section through top.
Fig.6, vertical medial section of a short fragment. p.92.
- 7-8. Metaconularia mascouchensis n.sp. Two fragments of the same specimen. Quonto-International No.1 Mascouche well, at 1094' depth, 15 feet above the base of the 205 feet thick Chazy. p.94.
9. Metaconularia mascouchensis n.sp. Close-up of central region of fragment shown in fig.8. p.94.
10. "Serpulites" splendens Billings. Fragment of a long flattened specimen from calcarenite at Locality 12. p.97.



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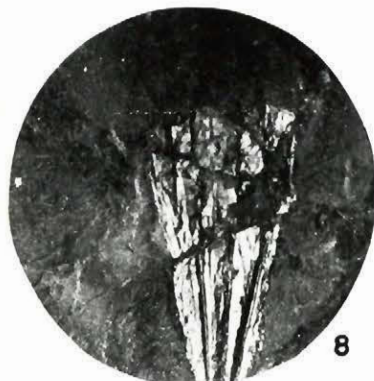
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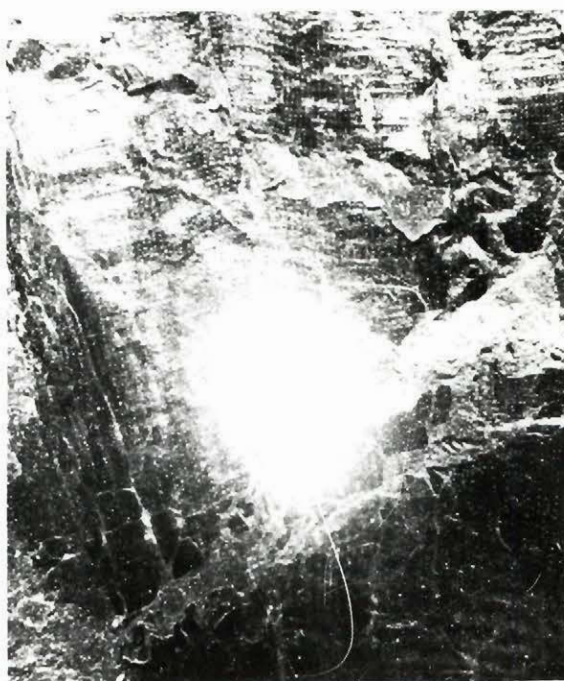
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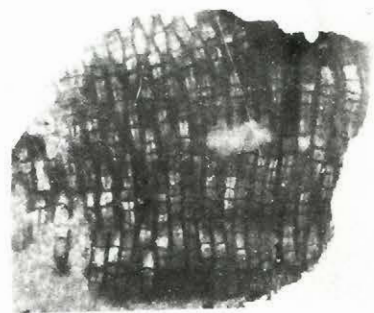
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PLATE 3

1. Billingsaria parva (Billings). Top view of a corallum.
Locality 9. p.98.
2. Billingsaria parva (Billings). Longitudinal thin section of
fragment of a tall corallum. MacGregor (1954) collection,
Dept. Geol. Sciences, McGill University. p.98.
3. Eofletcheria incerta (Billings). Side view of a corallum from
bioherm at the Meunier Quarry (Locality 12). p.99.
4. Eofletcheria incerta (Billings). Top view of a colony showing
rudimentary septa in some corallites, e.g., at bottom left.
Locality 9. p.99.
- 5-6. Eofletcheria incerta (Billings). Top view of a corallum,
natural size, and enlarged.
MacGregor (1954) collection, Dept. Geol. Sciences, McGill
University. Locality 12. p.99.



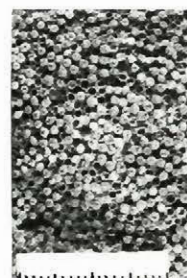
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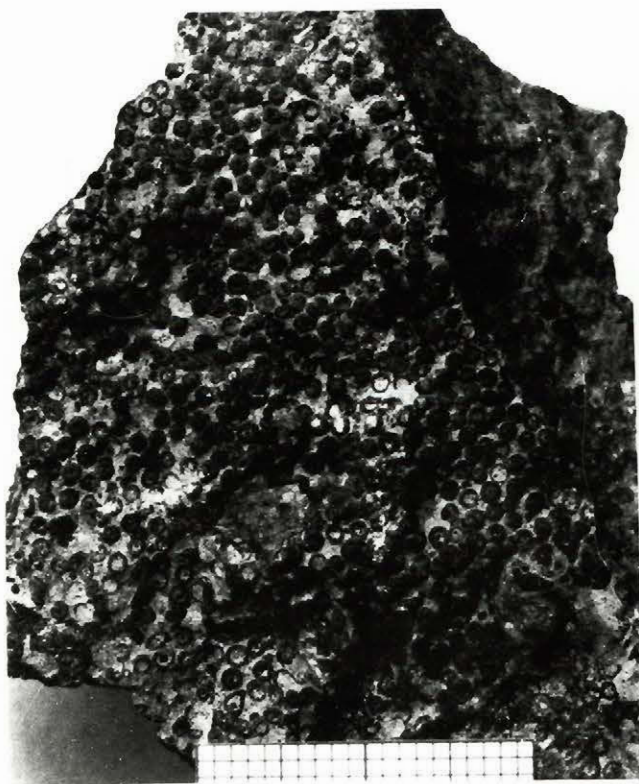
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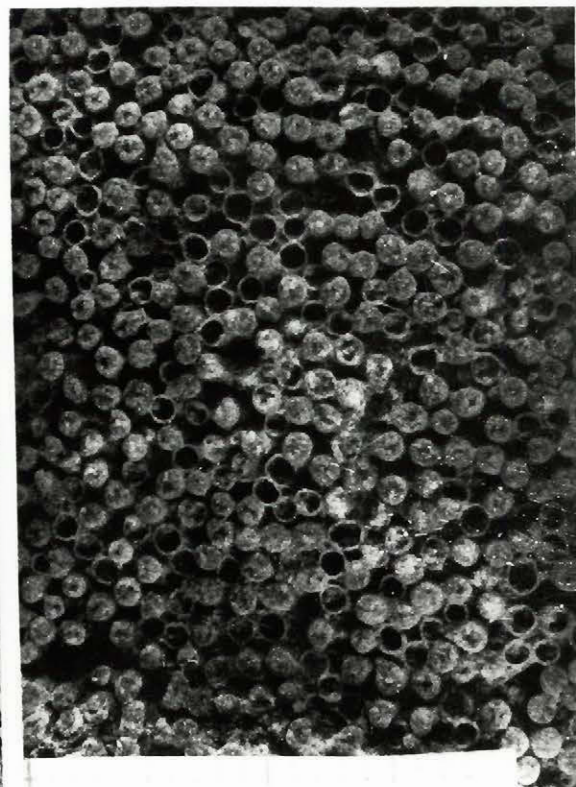
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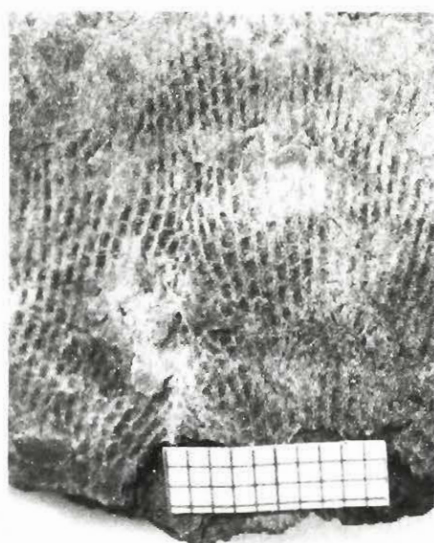
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PLATE 4

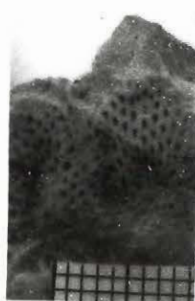
1. Carinophylloporina sp. Specimen from base of Billet Quarry,
Village Bélanger (Locality 23). p.103.
2. Phylloporina sp. Specimen from base of Billet Quarry, Village
Bélanger (Locality 23). p.103.
- 3-4. Chasmatoporella sp. Specimen from calcarenite beds near
St. Alexis-de-Montcalm (Locality 3). p.103.
5. Subretepora sp. Specimen from Que. Dept. Mines collection.
Locality 7. p.104.
- 6-7. Phylloporina aspera (Hall). Specimen from "Montreal" in Redpath
Museum collection (# 2.353). p.102.
8. Unidentified bryozoan; species with large fenestrule.
Que. Dept. Mines collection. Found loose at Locality 3.



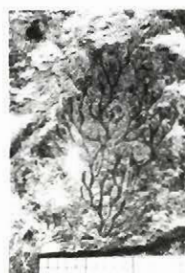
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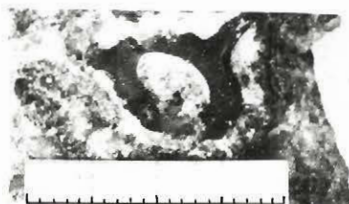
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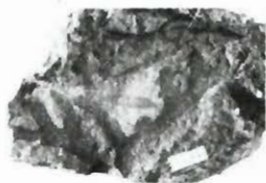
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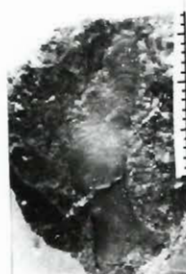
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PLATE 5

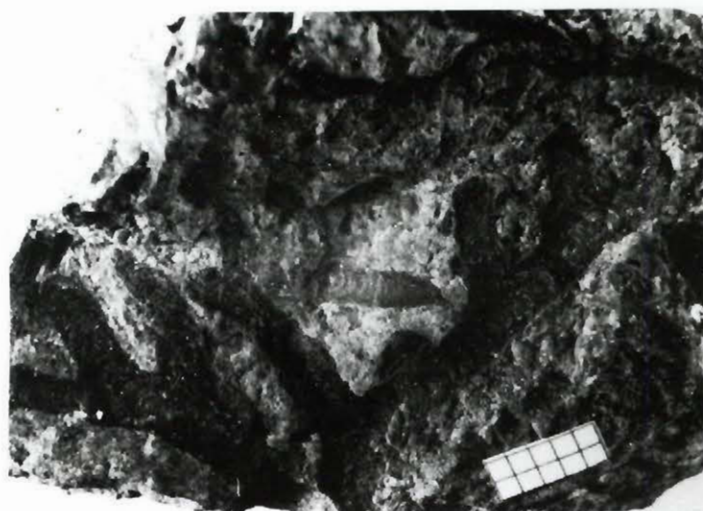
- 1-2. Stictopora sp. Specimen in argillaceous limestone; from bioherm at Locality 49. p.104.
- 3-4. Stictopora sp. Specimen in calcarenite. Locality 50. p.104.
5. Encrusting trepostomatous bryozoan colony on what may be "Serpulites" splendens (Billings). Locality 12. p.97.



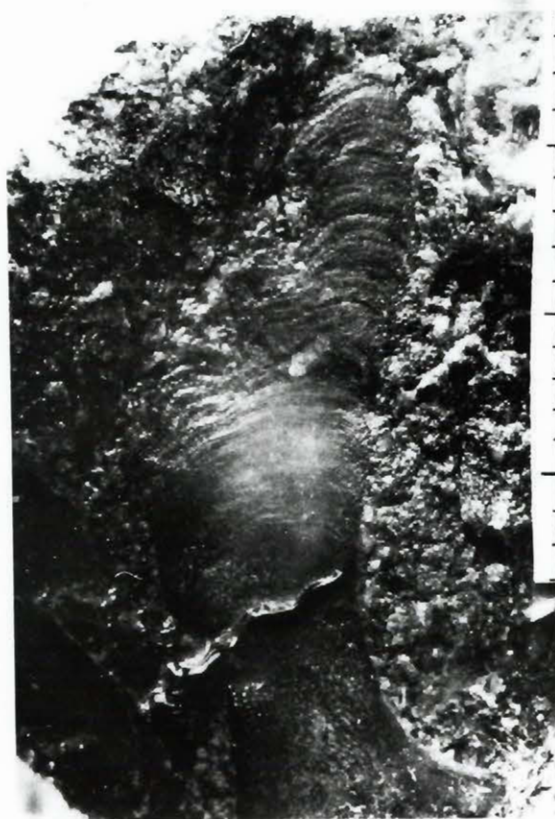
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PLATE 6

1. Lingulella? sp. fragment from base of Billet Quarry (Locality 23). p.107.
2. Schizambon duplicimuratum Hudson. Brachial valve. Locality 40. p.108.
3. Orthambonites sp. Brachial valve. Lagacé Quarry, 0'-11' interval (Locality 25). p.110.
- 4-6. Orthambonites palaformis n.sp. Brachial, pedicle, and posterior views. Ile Bizard (Locality 35). p.109.
7. Hesperorthis sp., cf. H. ignicula (Raymond). Pedicle valve. Locality 40. p.115.
8. Atelelasma? parvum (Wilson). Pedicle valve. Locality 40. p.115.
- 9-12. Mimella borealis (Billings). Brachial, pedicle, side, and posterior views of a very good specimen. Locality 5. p.113.
13. Mimella borealis (Billings). Pedicle valve. Locality 18. p.113.
- 14-16. Mimella vulgaris (Raymond). Brachial, pedicle, and posterior views of a specimen from Locality 22. p.115.
17. Mimella transversa Cooper. Specimen from Locality 12. p.114.
- 18-20. Sphenotreta acutirostris (Hall). Locality 7. p.123.
- 21-22. Dorytreta? arduamarginata n.sp. Brachial and pedicle views. Locality 3. p.124.
23. Rostricellula raymondi Cooper. Interior mold. Locality 16. p.120.
- 24-26. Rostricellula raymondi Cooper. Brachial, pedicle, and side views. Locality 20. p.120.
- 27-30. Rostricellula pristina (Raymond). Brachial, pedicle, side, and anterior views. Locality 18. p.120.
31. Onychoplecia sp., cf. O. gracilis (Raymond). Pedicle valve. Locality 9. p. 116.
- 32-34. Rostricellula plena (Hall). Brachial, pedicle, and side views. Locality 20. p.118.
35. Rostricellula plena (Hall). Cast from Pamela formation, Devito Quarry, 32.7'-34.1' interval. Locality 39. p.119.
- 36-39. Rostricellula wilsonae Cooper. Brachial, pedicle, side, and posterior views. Large specimen. Locality 20. p.121.
40. Multicostella platys (Billings). Locality 30. p.112.
- 41-41a. Multicostella platys (Billings). Specimen from "Montreal". Redpath Museum collection (# 2.349). p.112.
- 42-43. Valcourea sp., cf. V. intracarinata Ulr. and Coop. Brachial valve; mold of interior, and interior view. Locality 52. p.111.
- 44-45. Valcourea strophomenoides (Raymond). Small valve from Locality 26 and interior of pedicle valve from Locality 12. p.112.
46. Multicostella? sp. Locality 52. p.113.
- 47-47a. Dactylogonia incrassata (Hall). Locality 50. p.125.

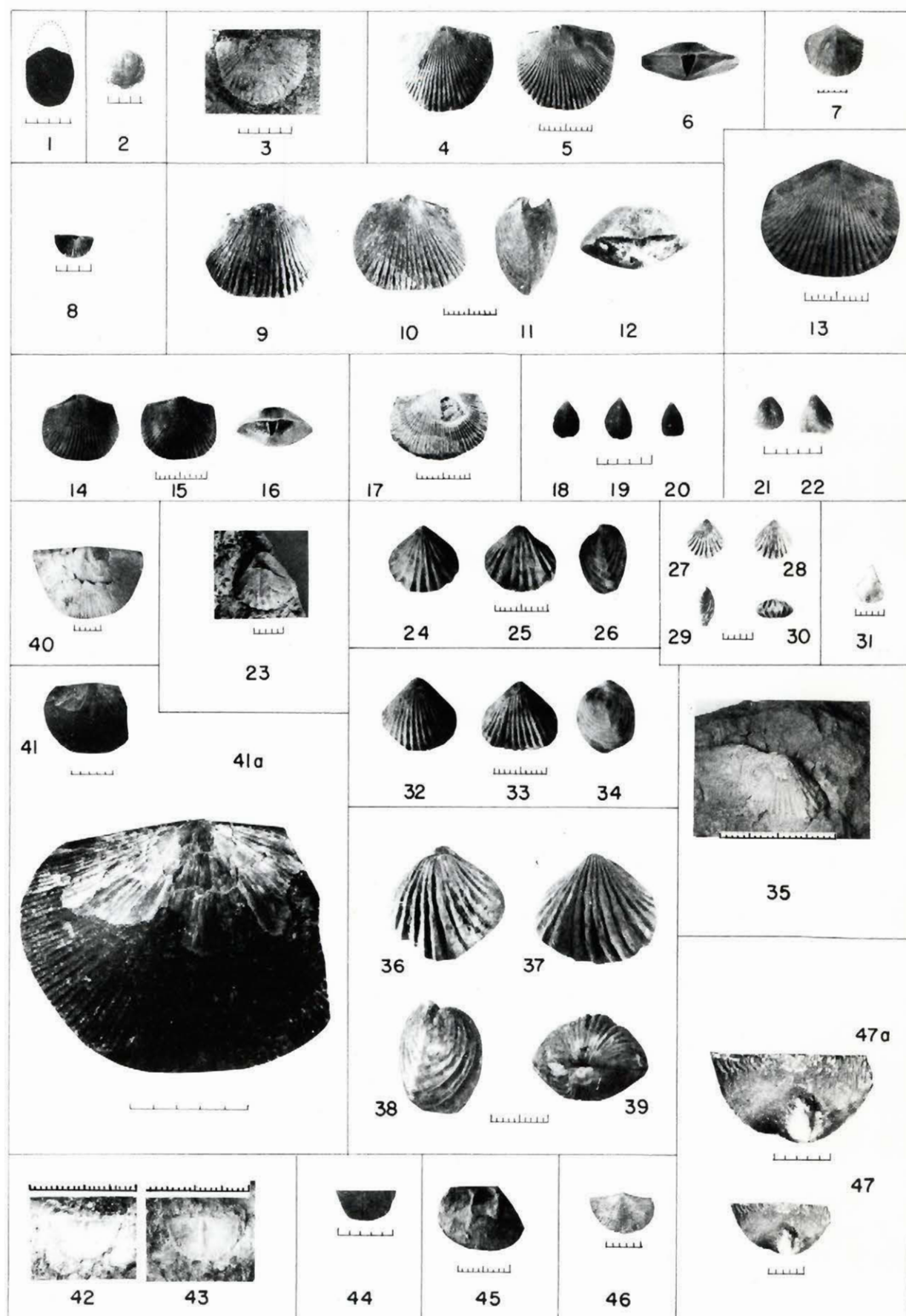


PLATE 7

- 1-2. Archinacella propria Raymond. Side and top views of an incomplete shell from Locality 33. p.127.
3. Scenella montrealensis (Billings). Reproduction of fig.371, p.394, in Billings (1865). Material from "Montreal". p. 128.
4. Bucania sulcatina (Emmons). Locality 6. p.129.
- 5-6. Loxoplocus (Lophospira) sp. Side and top views. Locality 20. p.134.
7. Helicotoma? sp. Vertical section. Locality 16. p.131.
- 8-10. Raphistoma stamineum Hall. Side, top, and enlarged top views. Locality 50. p.132.
11. Raphistoma? sp. Side view of shell from Locality 33. p.134.
12. Cyclora? sp. Top view of minute shell. Locality 39. p.134.
- 13-13a. Clionychia montrealensis (Billings). Right valve. Redpath Museum collection (# 10,050). p.139.
14. Clionychia? sp. Specimen from Locality 35. p.139.
15. Ctenodonta sp., cf. C. parvidens Raymond. Locality 39. p.138.
16. Modiolopsis parviuscula Billings. Locality 39. p.140.
17. Modiolopsis fabaformis Raymond. Locality 33. p.140.
18. Pelecypod fragments. Locality 39. p.71.

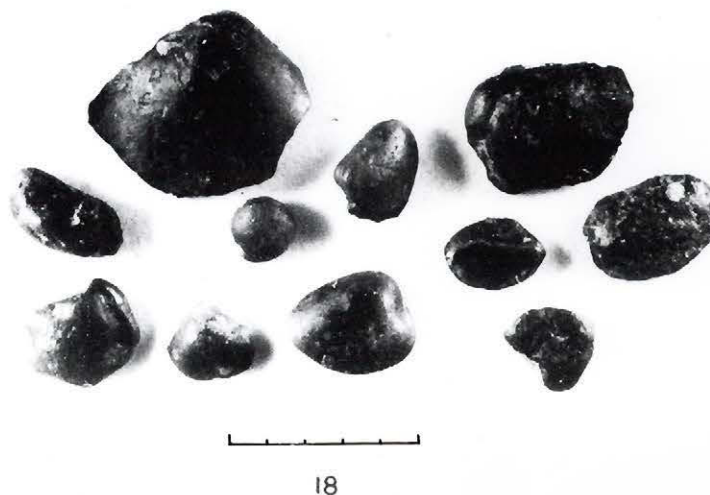
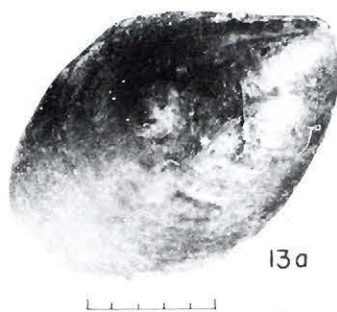
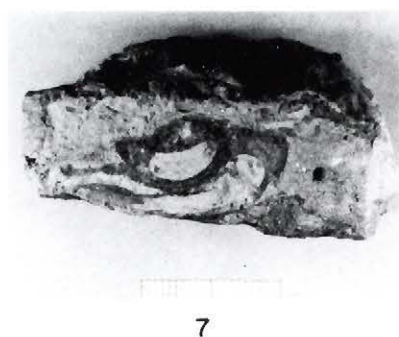


PLATE 8

1. Glaphurus? sp. Cephalic fragment from Locality 9. p.143.
2. Glaphurina lamottensis Ulrich . Cranidium. Locality 49. p.143.
3. Basilicus marginalis (Hall). Very small pygidium. Locality 49. p.144.
- 4-5. Isotelus sp., cf. I. harrisi Raymond. Cranidium. Locality 7. p.144.
6. Isotelus platymarginatus Raymond. Pygidium. Locality 52. p.145.
7. Homotelus obtusus (Hall). Pygidium. Locality 52. p.146.
- 8-9. Vogdesia bearsi Raymond. Two pygidia. Locality 49. p.146.
10. Bumastus sp., cf. B. aplatus Raymond. Cranidium. Locality 16. p.147.
11. Bumastus globosus (Billings). Cranidium (top) and pygidium from Locality 33. p.147.
12. Thaleops conifrons (Billings). Cephalic fragment. Locality 52. p.148.
13. Lonchodomas halli (Billings). Fragment of cranidium, showing only proximal part of long glabellar spine. Locality 52. p.149.
14. Sphaerexochus parvus Billings. Oblique view of cranidium. Locality 23. p.150.
- 15-16. Sphaerexochus parvus Billings. Top view of cranidium from "Montreal". Redpath Museum collection (# 2.344). p.150.
17. Pliomerops canadensis (Billings). Pygidium. Locality 3. p.151.
18. Calliops annulatus (Raymond). Cranidium. Locality 6. p.152.
19. Calliops annulatus (Raymond). Pygidium. Locality 16. p.152.
20. Pterygometopus? sp. Cephalic fragment. Locality 26. p.152.
21. Kawina vulcanus (Billings). Cranidium. Locality 23. p.150.
22. Unidentified trilobite. Cephalic fragment. Quonto-International No.1 Mascouche well, at 929' depth. p.153.
23. Unidentified trilobite. Nearly complete hypostoma. Locality 3. p.153.
- 24-27. Rusophycus grenvillense Billings. Bottom, end, side, and transverse section views. Specimens from the Ottawa Valley Chazy, in the creek west of Greece Point, 5 miles east of Grenville, Quebec. p.182.

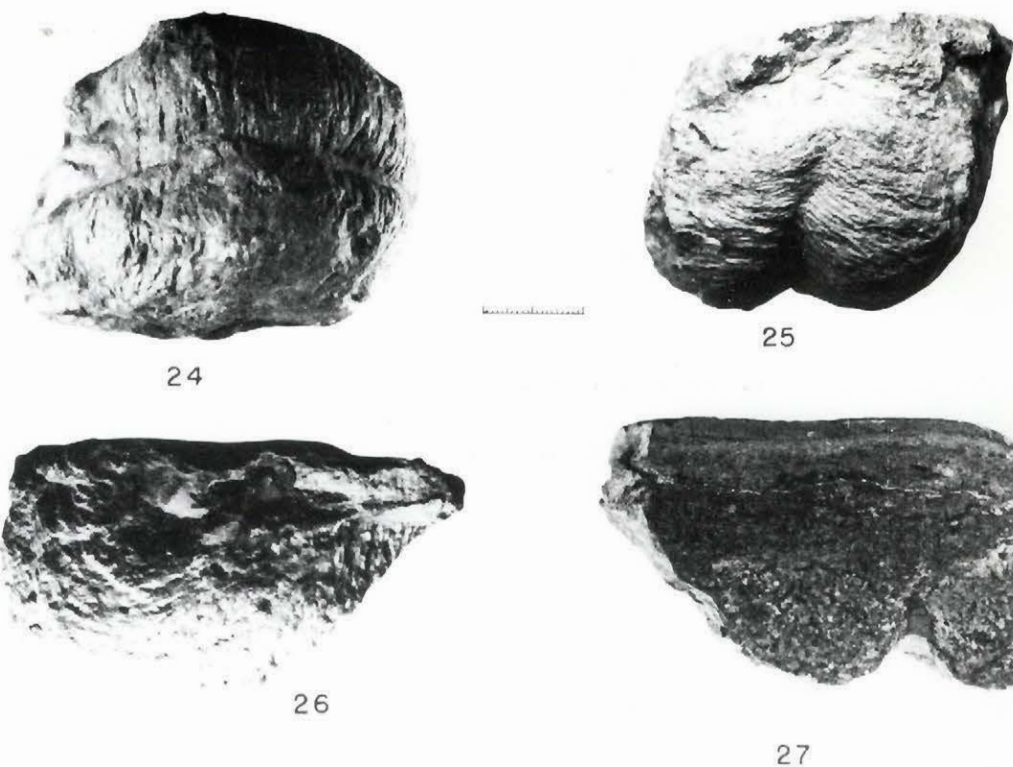
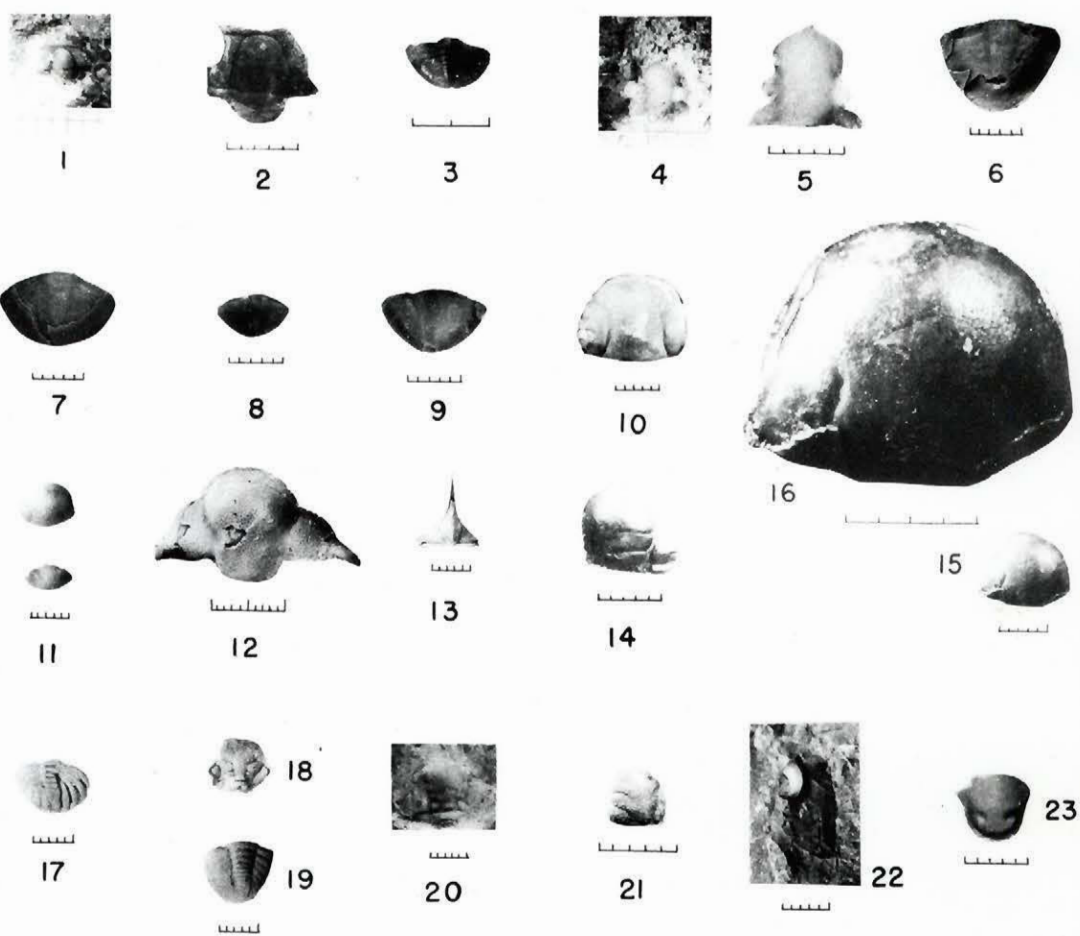
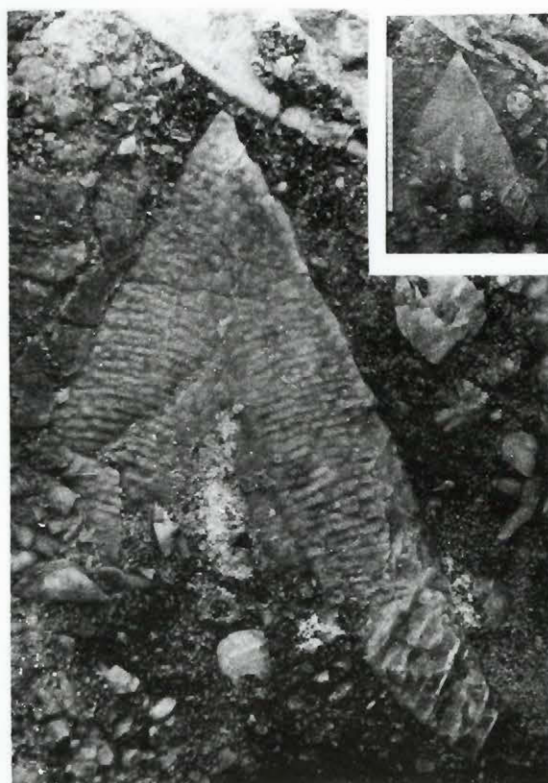


PLATE 9

1. Blastoidocrinus carchariaedens Billings. Natural size and enlargement of view of deltoid plate. Locality 47. p.172.
2. Cheirocrinus forbesi (Billings). Slab with three specimens. Locality 23. p.155.
- 3-4. Palaeocystites tenuiradiatus (Hall). Large plate with notch. The long column to the left of the plate may belong to one of the paracrinoids. Locality 12. p.159.
5. Palaeocystites tenuiradiatus (Hall). Large plate, and part of column that may possibly belong to this species. "Montreal". Study Collection, Dept. Geol. Sciences, McGill University. p.159.
6. Palaeocystites tenuiradiatus (Hall). Proximal part of calyx. Locality 12. p.159.
7. Palaeocystites dawsoni Billings. Several plates from Locality 35. p.158.
8. Malocystites murchisoni Billings. Oral view. Locality 12. p.174.
9. Canadocystis barrandi (Billings). Side view, showing the elevated sigmoid food groove (incomplete). Locality 23. p.172.
- 10-11. Deocrinus asperatus (Billings). Side and bottom views of holotype. Geol. Surv. Can. Coll. (# 1019a). Chazy, Island of Montreal. p.177.
12. Hybocrinus pristinus Billings. Side view of holotype. Geol. Surv. Can. Coll. (# 1017). Chazy, near Mile End, Montreal. p.177.



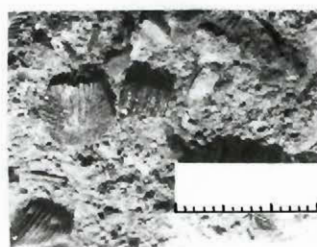
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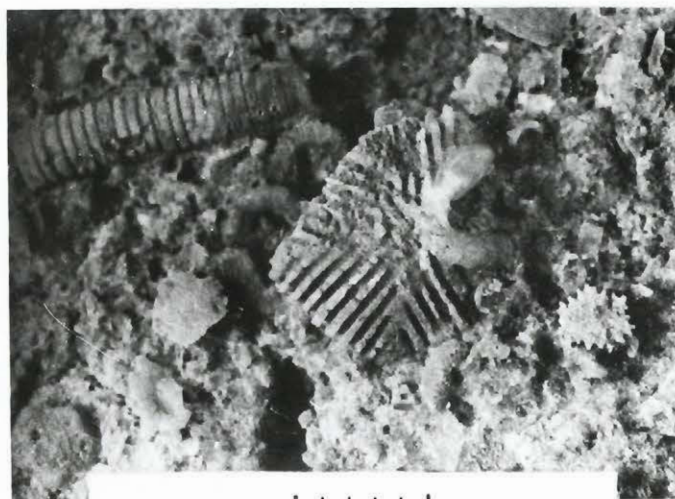
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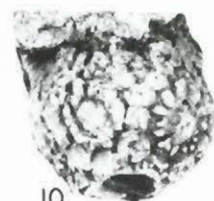
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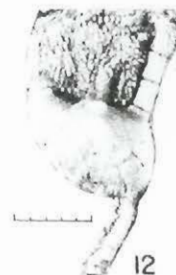
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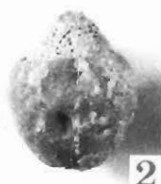
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PLATE 10

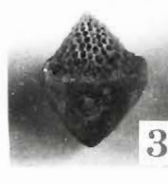
- 1-11. Bolboporites americanus Billings. pp.161-171.
1. Side view of a large prolate specimen showing calcite cleavage on base, narrow annular groove, and disposition of the cone cells. L'Abord-à-Plouffe, Ile Jésus. Redpath Mus. coll. (# 2.364).
 2. Side view of a specimen with annular groove, long base. Specimen from Locality 12.
 3. Side view of a rare specimen with conical base. Locality 12.
 4. Side view of specimen having measurements similar to those of the specimen shown in fig.3, but with rounded extremities. Locality 12.
 5. Specimen with very large base and deep annular groove. Locality 40. Redpath Mus. coll. (# 2.355).
 6. Top view of a basal fragment with radial structure of calcite crystal faces. Locality 40. Redpath Mus. coll. (# 2.355).
 7. Side view of a specimen with regularly arranged cone cells. L'Abord-à-Plouffe, Ile Jésus. Redpath Mus. coll. (# 2.365).
 8. Globular specimen with long base and shale-filled cone cells. Locality 23.
 9. Side view of a specimen lacking annular groove. Locality 40. Redpath Mus. coll. (# 2.355).
 10. Oblique view of a specimen without cone cells. Locality 12.
 11. Top view of a large specimen with annular groove. L'Abord-à-Plouffe, Ile Jésus. Redpath Mus. coll. (# 2.365).
 12. Palaeocystites tenuiradiatus (Hall). Weathered slab with scattered thecal plates showing parallel pores. The arrows point to plates showing smooth inner surfaces and notched sutures. Slab from the Montreal area. Study Collection, Dept. Geol. Sciences, McGill University.



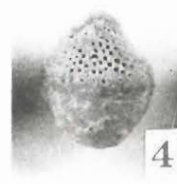
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5mm



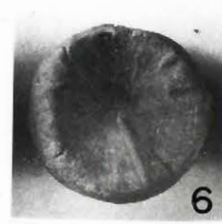
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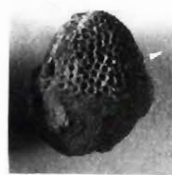
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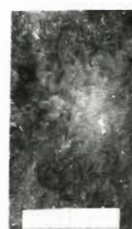
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PLATE 11

1. Scolithus sp. Section of vertical tubes, as exposed in the St. Vincent de Paul Quarry (Locality 20). p.184.
2. Cruziana? lavalensis n.sp. Markings on greenish grey shale slab from lower 58' of the Lagacé Quarry (Locality 25). p.178.
- 3-4. Algae, unclassified form. Carbonaceous smears on shale. Oil Selections No.6 well, at 1909' depth. p.91.
5. Petalonia soleaformis n.gen. et sp. Small horseshoe-like burrow fillings in green shale. Slab from outcrop of sandstone-shale beds near Trans-Canada Highway cloverleaf at Hawkesbury, Ontario. p.181.
6. Unidentified trails. Markings on micaceous sandstone. From 87'-96' interval in the Lagacé Quarry (Locality 25). p.185.
7. Phymatoderma? sp. Sand-fill cast of burrow. From 39.5'-58' interval in the Lagacé Quarry (Locality 25). p.182.



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Interstratified

PLATE 12

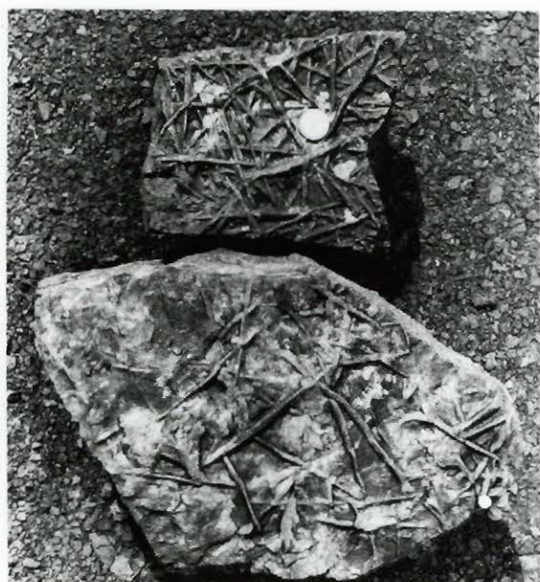
1. Girvanella? sp. Slab showing cross section of several specimens. The structures may be inorganic. Locality 12. p.91.
2. Palaeophycus ancoraforme n.sp. Two slabs from sandstone-shale beds, 11.0'-18.8' interval in the Lagacé Quarry (Locality 25). 25-cent coin on top specimen gives scale. p.179.
3. Palaeophycus ancoraforme n.sp. Close-up of top specimen of fig.2.
4. Palaeophycus ancoraforme n.sp. Individual stems, showing longitudinal striations. Lagacé Quarry, 11.0'-18.8' interval. p.179.
5. Palaeophycus ancoraforme n.sp. Specimen with branching, anchor-like terminal structure. Lagacé Quarry, 11.0'-18.8' interval. p.179.



1



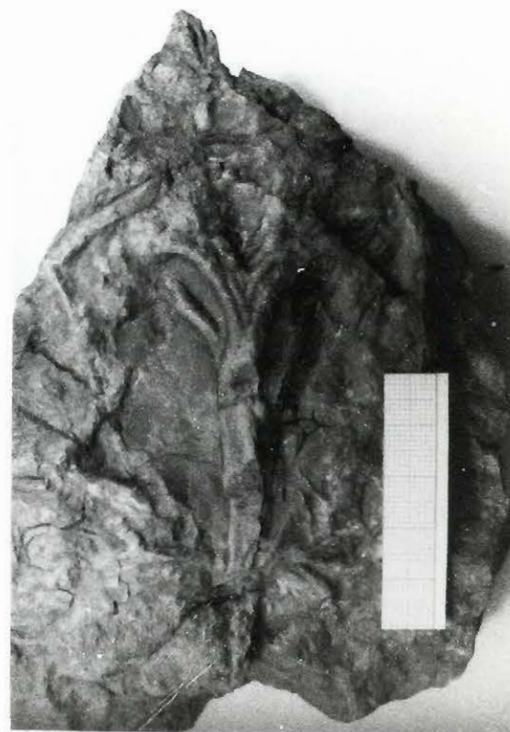
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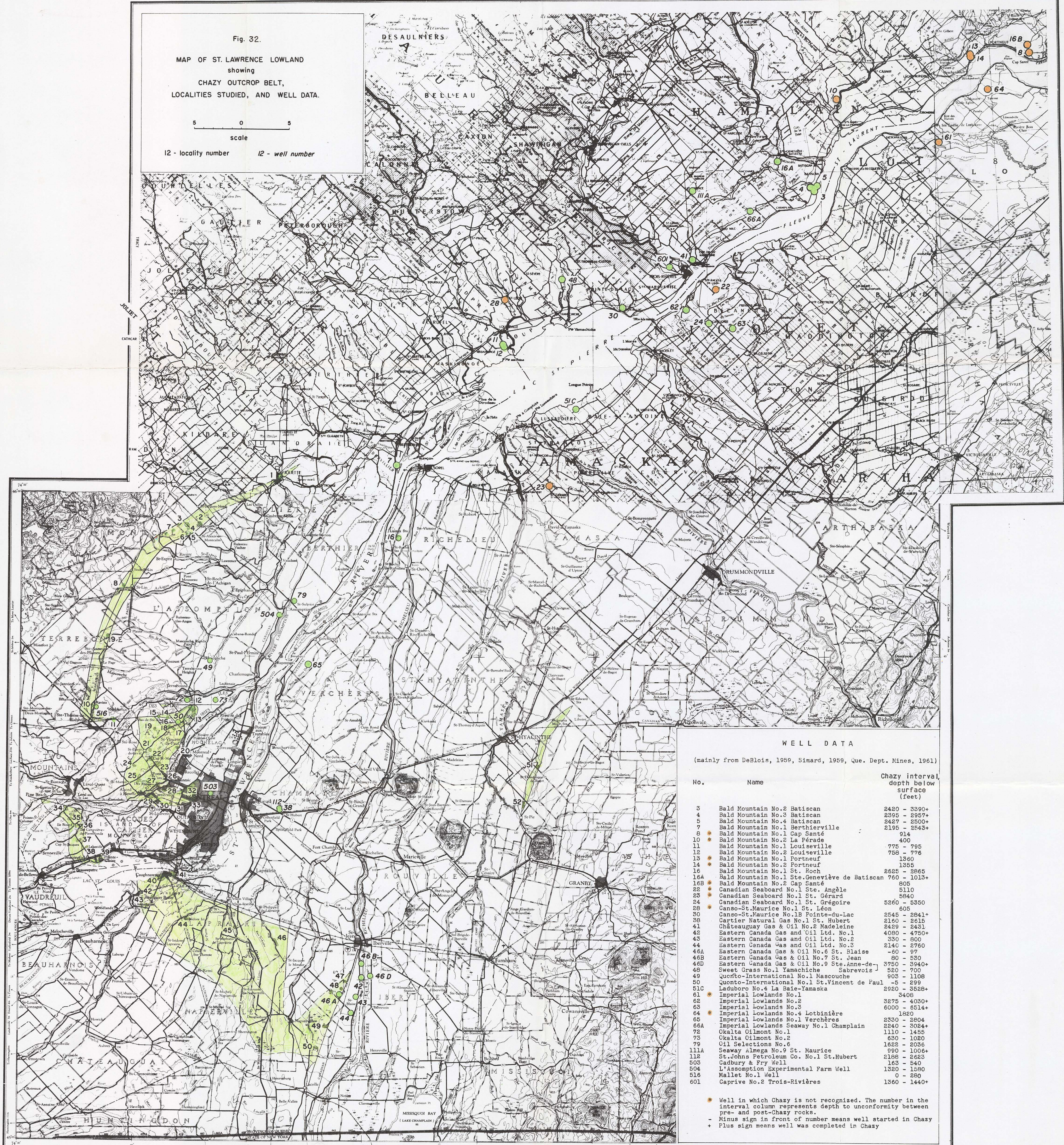
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Fig. 32.

MAP OF ST. LAWRENCE LOWLAND
showing
CHAZY OUTCROP BELT,
LOCALITIES STUDIED, AND WELL DATA.

5 0 5
scale

12 - locality number 12 - well number



WELL DATA

(mainly from DeBlois, 1959, Simard, 1959, Que. Dept. Mines, 1961)

No.	Name	Chazy interval, depth below surface (feet)
3	Bald Mountain No.2 Batiscan	2420 - 3390+
4	Bald Mountain No.3 Batiscan	2395 - 2957+
5	Bald Mountain No.4 Batiscan	2427 - 2500+
7	Bald Mountain No.1 Berthierville	2195 - 2543+
8	Bald Mountain No.1 Cap Santé	91
10	Bald Mountain No.2 La Pêrade	400
11	Bald Mountain No.1 Louiseville	775 - 795
12	Bald Mountain No.2 Louiseville	758 - 776
13	Bald Mountain No.1 Portneuf	1360
14	Bald Mountain No.2 Portneuf	1355
16	Bald Mountain No.1 St. Roch	2625 - 2865
16A	Bald Mountain No.1 Ste. Geneviève de Batiscan	760 - 1013+
16B	Bald Mountain No.2 Cap Santé	805
22	Canadian Seaboard No.1 Ste. Angèle	5110
23	Canadian Seaboard No.1 St. Gérard	5940
24	Canadian Seaboard No.1 St. Grégoire	5260 - 5350
28	Canso-St. Maurice No.1 St. Léon	605
30	Canso-St. Maurice No.1B Pointe-du-Lac	2545 - 2841+
38	Cartier Natural Gas No.1 St. Hubert	2160 - 2615
41	Châteauguay Gas & Oil No.2 Madeleine	2429 - 2431
42	Eastern Canada Gas and Oil Ltd. No.1	4080 - 4750+
43	Eastern Canada Gas and Oil Ltd. No.2	330 - 800
44	Eastern Canada Gas and Oil Ltd. No.3	2140 - 2760
46A	Eastern Canada Gas & Oil No.6 St. Blaise	-80 - 97
46B	Eastern Canada Gas & Oil No.7 St. Jean	90 - 530
46D	Eastern Canada Gas & Oil No.9 Ste. Anne-de-	3750 - 3940+
48	Sweet Grass No.1 Yamachiche	520 - 700
49	Quinto-International No.1 Mascouche	903 - 1108
50	Quinto-International No.1 St. Vincent de Paul	-5 - 299
51C	Ladue No.4 La Grosse-Yamaska	2920 - 3528+
61	Imperial Lowlands No.1	3406
62	Imperial Lowlands No.2	3275 - 4030+
63	Imperial Lowlands No.3	6000 - 6514+
64	Imperial Lowlands No.4 Lotbinière	1820
65	Imperial Lowlands No.1 Verchères	2330 - 2804
66A	Imperial Lowlands Seaway No.1 Champlain	2240 - 2024+
72	Okalta Oilmont No.1	1110 - 1455
73	Okalta Oilmont No.2	630 - 1020
79	Oil Selections No.6	1622 - 2036
111A	Seaway Almega No.9 St. Maurice	990 - 1006+
112	St. Johns Petroleum Co. No.1 St. Hubert	2186 - 2263
503	Cadbury & Fry Well	163 - 540
504	L'Assomption Experimental Farm Well	1320 - 1580
516	Mallet No.1 Well	0 - 280
601	Captive No.2 Trois-Rivières	1360 - 1440+

* Well in which Chazy is not recognized. The number in the interval column represents depth to unconformity between pre- and post-Chazy rocks.
- Minus sign in front of number means well started in Chazy
+ Plus sign means well was completed in Chazy