THE GEOLOGY OF THE LIMESTONE OF ISLE LA MOTTE AND SOUTH HERO ISLAND, VERMONT

By

ROBERT B. ERWIN

VERMONT GEOLOGICAL SURVEY

CHARLES G. DOLL, *State Geologist*

Published by

VERMONT DEVELOPMENT COMMISSION

MONTPELIER, VERMONT

BULLETIN NO. 9 1957

OUTCROPPING AUTOCHTHONOUS STRATIGRAPHIC SEQUENCE

– GENERALIZED AND DIAGRAMATIC –

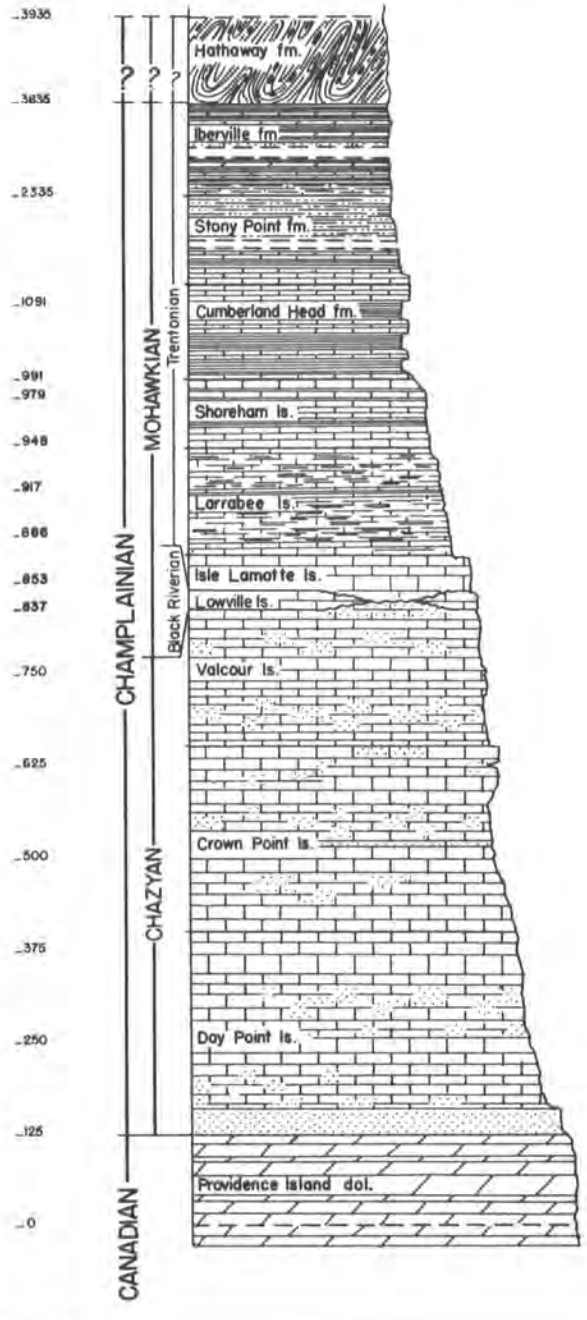


TABLE OF CONTENTS

Illustrations

THE GEOLOGY OF THE LIMESTONE OF ISLE LA MOTTE AND SOUTH HERO ISLAND, VERMONT

By
ROBERT B. ERWIN

ABSTRACT

Detailed study of the two islands reveals many similarities in structure, stratigraphy and paleontology. Both areas have been cut into fault blocks by "normal" and "thrust" faulting. Isle La Motte has been cut into two blocks, while South Hero Island has been cut into several. The amount and direction of dip of the larger faults is indeterminate, but most are considered normal in accordance with the faults of the Champlain Valley as a whole. Evidence is presented to establish the presence of hitherto unrecognized thrust faulting in the limestone. South Hero Island displays a western belt of simple folding separated by a thrust fault from an eastern belt of more complex folding, the origin of which is attributed to northwesterly moving thrusting forces. The same structural setup is noted in the overlying shaly beds, but faulting is generally indeterminate in the shale.

The greatest differences noted between the islands is in the stratigraphy of the Chazyan rocks. These differences are attributed mainly to differing reef and interreef environments. The Chazyan rocks of Isle La Motte constitute the reef facies and are considered in detail. The Trenton group of rocks is very similar in both areas, but the Cumberland Head beds show extensive lateral and vertical variation on both islands. There is some indication that the Lowville beds may be present on South Hero Island, but due to very local unconformity are not found outcropping.

The overall paleontologic aspect of the two islands is quite similar, but environmentally controlled differences in the distribution and abundance of fossils is shown by the Chazyan and Cumberland Head beds. Many of the forms considered to be index fossils may well be facies fossils and not reliable time horizon markers. It is the writer's opinion that most of the formations of the Champlain Valley are depositional phases of a fluctuating sea and, therefore, of varying age. Further work to the south must be undertaken to show this however.

INTRODUCTION

General Statement

The two areas covered in this report, South Hero Island and Isle La Motte, are located in the upper Champlain Valley of Vermont. The rocks of the areas are Lower and Middle Ordovician in age and are relatively flat lying. Black and gray limestone, dolomitic limestone and shale comprise the sequence. This strip of Ordovician sedimentary rocks is bounded on the east by the Cambrian quartzite and dolomite of the Champlain overthrust and on the west by the pre-Cambrian rocks of the Adirondack Massif.

Topographically the area of the Champlain Valley is low. Heights above lake level (mean elevation 95 feet) rarely exceed 200 feet, and nowhere are they known to exceed 280 feet (Perkins 1903–04, p. 104). The islands of the lake are elongated in a north-south direction and characteristically have numerous promontories and shallow water bays. Generally the surface of these islands slopes toward the west or northwest, and low swampy areas are common. The Champlain lowland is extensively covered by Pleistocene glacial deposits.

The present work was started in 1954 as a Master's thesis while attending Brown University. The subject matter of this report, *The Biostromes and Bioherms of the Lower Middle Ordovician of Isle La Motte, Vermont*, concerned itself only with the rocks of the southern half of Isle La Motte. The following summer, 1955, work on the northern half of Isle La Motte and South Hero Island (exclusive of the shale) was completed. All of the work on the shale (Stony Point and younger) contained herein was done by Professor David Hawley who generously allowed the writer to use his manuscript and map.

Acknowledgments

The writer wishes to extend his thanks to those who have aided in the writing of this paper. Professor Charles G. Doll, Vermont State Geologist, helped both in the field and in the preparation of the manuscript and provided financial aid from the Vermont Geological Survey. Thanks are due to Professor William Oliver of Brown University who directed the work on southern Isle La Motte. Professor Alonzo Quinn of Brown University made helpful suggestions and made possible aid, in the form of the Brown University Geological Fellowship, for summer field expenses. Thanks are due to Professor John W. Wells of Cornell University for

making several helpful suggestions. Professor David Hawley of Hamilton College made his work on the shale of the Champlain Valley available to the writer prior to publication and generously permitted the writer to include some of this work on the geologic maps.

ISLE LA MOTTE

Location and Topographic Setting

Isle La Motte lies near the center of the Rouses Point, New York-Vermont quadrangle, just inside of the Vermont state boundary. It is one of the larger islands of northern Lake Champlain and is located 6.5 miles south of the Canadian border, 5 miles east of Chazy, New York, and about 28 miles northwest of Burlington, Vermont. Access to the Island is gained by a bridge approximately one-half mile long, which connects it to the Alburg Peninsula.

Isle La Motte has a length of 5.75 miles and an average width of 1.5 miles. It is elongated in a slightly northeast-southwest direction and is separated into a northern and southern half by a low swampy area. The highest topographic relief is obtained near the extreme southern end of the island, the Head, where the rocks rise rather abruptly in a step-like fashion to about 170 feet above lake level. North of this point the surface of the southern half of the island slopes east and west from a low northeast-southwest trending ridge. North of the swamp the same general topography is found, but there is no ridge and the surface simply slopes toward the northwest.

Due to glacial cover nearly half of the island shows no outcrops at all. The rocks rise abruptly along most of the east and south shore, dip generally to the north or northwest, and disappear beneath the extensive glacial clay and gravel which cover much of the island.

Pleistocene Deposits

Nearly half of the bedrock geology of Isle La Motte is concealed by glacial cover which, especially on the west side of the island, is very thick. Some of the gravel pits dug in the Pleistocene deposits expose 30 feet or more of gravels and sands without exposing bedrock. The Pleistocene deposits yield an abundance of marine pelecypods, the shells occurring either in thin concentrated bands or disseminated throughout the well-sorted, sandy layers. The fauna is not a normal one, for the shells show inhibited growth and are very thin walled. Specimens may easily

be collected, but the decreased calcium carbonate content and thin shells render them extremely fragile. The stunted growth may be due to abnormally cold marine waters resulting from proximal vast ice masses and reduced temperatures during the Pleistocene Epoch. Dilution of the seas by large volumes of glacial meltwater may have reduced the salinity to such a point that the intake of $CaCO_3$ was insufficient to maintain normal shell growth, hence resulting in the thin walled character of the shells. Living examples of stunted and thin walled forms may be noted today in the Baltic Sea where the environment is much like that just postulated. Species present in abundance on Isle La Motte are *Macoma groenlandica*, *Saxicava rugosa*, *Mytilus edulis*, and *Yoldia arctica*. *Mya arenaria* is commonly found, but is much less abundant than the other forms.

Geologic Setting

The early workers (Brainerd and Seely, 1896, p. 312 and Perkins, 1903–04, p. 120) considered Isle La Motte to be separated geologically, as well as topographically, by the east-west trending swamp which traverses it. Only rocks Chazyan in age or older were thought to underlie the southern half of the island, and only rocks Black River in age or younger were thought to underlie the northern half. This relationship is true, as far as actual outcrops are concerned, but detailed mapping indicates that the areas just north and east of the swamp and just south and west of the swamp are underlain by concealed older and younger rocks respectively. The low swampy area is considered by the writer to be the surface expression of a high angle fault showing downward movement of the northern block. All of the rocks outcropping on the island are of Lower (Canadian) and Middle (Champlainian) Ordovician age. The northwestern part of the island, completely concealed by glacial deposits, is probably underlain by rocks of the Stony Point formation.

Stratigraphy

The organic structures of the Day Point and Crown Point formations are noted only briefly in the following discussion, as they are treated in detail in a subsequent section. In general, the structural geology and its stratigraphic significance is discussed along with the units which it most concerns. Included in the discussion of each unit is a listing of the characteristic fossils and their relative abundances.

Providence Island Dolomite

Along the shore at the extreme south end of the island, the dark blue and gray, commonly fetid, Providence Island dolomite is excellently displayed. The beds are generally massive, but shaly partings and thin bedded zones are not uncommon (Pl. 3, fig. 1). Upon weathering, the bituminous material is leached out, and the rocks take on various shades of light and dark gray, buff, cream, and white. Mud cracks and ripple marks seem to indicate a shallow water origin for the sediments. Unidentifiable fossil fragments were noted at the top and about 26 feet below the top of the Providence Island on the southwest and east shores respectively. Perkins (1903–04, p. 121) states that he and Seely found specimens of *Isochilina* at the top of this formation on the southwest side of the island. Some of the fragments collected by the writer may well represent this ostracod.

Along the south and southwestern shore a 74-foot section was measured. Only 3 feet 4 inches of this section is concealed and it is believed that this figure (74 feet) more closely approximates the true thickness of the formation on Isle La Motte than does the figure of 60 feet given by Brainerd and Seely (1896, p. 310).

The dip of the beds is generally low, averaging 2 or 3 degrees. The directions of dip indicate a very shallow synclinal structure plunging to the northwest.

Day Point Limestone

The Day Point limestone, conformably overlying the Providence Island dolomite, covers somewhat less than half of the southern part of the island. Lithologically the rocks of this highly fossiliferous unit are extremely variable, both laterally and vertically. Certain overall trends are readily apparent, however. Generally from top to bottom and from southwest to northeast the beds show a decrease in grain size and quartz sand content. The lithologic character of the beds, and especially the contained fossils permit a breakdown of the formation into four distinct units. These units are, in essence, those of Brainerd and Seely (1896, p. 310).

The total thickness of the Day Point limestone, according to the writer's data, is 233 feet, which does not differ greatly from the 223 feet postulated by Brainerd and Seely (1896, p. 310). With the original figures of Brainerd and Seely (1896, p. 310) given in parentheses, the

PLATE 3

Figure 1. Northwesterly dipping massive Providence Island dolomite showing shaly partings and thin-bedded zones, looking north. South shore of Isle La Motte.

Figure 2. Contact between the Providence Island dolomite and the basal Chazy sandstone of the *Lingula* zone. South shore of Isle La Motte.

divisions and thicknesses, in ascending order are: a basal sandstone, the *Lingula* zone, 18 feet (23 feet); the *Mimella* zone, 61 feet (55 feet), the *Plectorthis* zone, 86 feet (75 feet); and an upper Pelmatozoan zone, 68 feet (70 feet).

The *Lingula* Zone

This unit shows a maximum thickness of 18 feet along the west shore and has the same areal extent as the underlying Providence Island dolomite. The rocks consist mainly of impure quartz sandstone with hard and soft shaly partings. Near the middle of the unit there is a 2- to 4-foot cross-bedded sandstone layer. The contact between the lower Chazy and the Providence Island dolomite is lithologically sharp. (Pl. 3, fig. 2).

The average grain size of the sandstone is 0.5 mm, but in the cross-bedded layer the grains range up to 3.5 or 4.0 mm. The cross-beds (Pl. 4, fig. 1) have an easterly dip of about 21 degrees and seem to indicate a sedimentary source to the west.

Perkins (1903–04, p. 310) has interpreted the cross-beds as being due to a tilting of the ocean bottom, but it seems more likely that the beds represent small-scale submarine "delta" deposits.

The cross-beds are apparent along the shore for about 238 feet; then they disappear abruptly at a fault. Approximately 100 feet to the north the beds reappear for a few feet and then dip beneath the water. The overlying bed is a massive sandstone, which, in turn, is overlain by thin beds of shale, sandstone and sandy limestone, all highly fossiliferous.

On the west shore the lower 10 feet of this unit contains an abundance of *Lingula brainerdi* and fucoids; no other fossils were noted. The upper 8 feet, especially near the top, contain:

Phylloporina incepta	a*	*Basilicus marginalis*	a
Orthis acutiplicata	c	*Isotelus harresi*	a
Eurychilina latimarginata	a	trilobite fragments	a

*The following symbols are used:

a abundant	(l) locally
c common	(t) near the top
r rare	(b) near the base

Double letters indicate the superlative.

Along the east shore of the Head the beds appear to be thinner even though the top of the section is concealed. The lowest beds, 3.5 feet of

PLATE 4

Figure 1. Cross-bedded sandstone of the *Lingula* zone showing an easterly dip of about 21 degrees. Southwest shore of Isle La Motte.

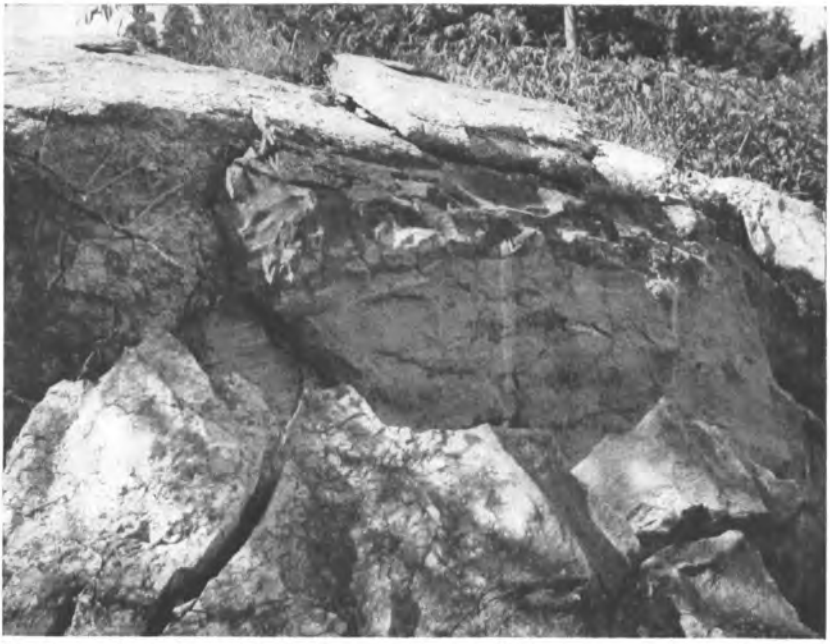


Figure 2. A small pocket of calcarenite in the oölitic limestone of the *Plectorthis* zone which contains fragments of coral. Large quarry 0.3 miles south of Holcomb Point. East shore of Isle La Motte.

sandstone, contain an abundance of *Lingula brainerdi;* the overlying 1.5 feet of black siltstone contain an abundance of *Lingula columba.* This black siltstone is considered to be an offshore finer grained facies of the cross-beds to the west.

If the beds of the *Lingula* zone, which appear in four traverses made on the Head, are considered progressively from west to east, a thinning of the beds in that direction is clearly shown. The traverses cover a total distance of 0.9 miles, and were made at 0.3 miles intervals.

The first traverse, along the west shore, displays the maximum thickness of the beds, 18 feet. The lower 8 to 10 feet of beds are massive sandstone with shaly partings. A cross-bedded sandstone layer, 2 to 4 feet in thickness, succeeds these beds upward. Overlying the cross-beds is a 6- to 8-foot massive sandstone layer with thin beds of shale, sandstone and sandy limestone near the top. Both the lower and upper contacts between the Providence Island dolomite and the *Mimella* zone, respectively, are exposed here.

The second traverse, 0.3 miles to the east, shows a possible 14-foot thickness for the *Lingula* zone. Only 6 feet of the *Lingula* beds are exposed here. These beds are in contact with the overlying *Mimella* beds. The underlying 45 feet are concealed. A correlation, based upon the thickness of the Providence Island, with the complete section obtained on the west shore, indicates the lower 8 feet of the *Lingula* beds are concealed. The cross-bedded layer, if it is present, must lie within the lower concealed 8 feet.

The third traverse, 0.6 miles east of the west shore, shows no beds of the *Lingula* zone exposed at the surface. A concealed section of 7 feet, underlain by the Providence Island and overlain by the *Mimella* zone, indicates a maximum thickness of 7 feet for the *Lingula* beds.

The fourth traverse, along the east shore, encounters only 5 feet of *Lingula* beds. The beds are in contact with the Providence Island below, but the section is concealed above. The lower 3.5 feet of beds are sandstone typical of the *Lingula* zone, the succeeding 1.5 feet of beds are black siltstone.

Over a distance of 0.9 miles, then, the beds show a thinning of approximately 13 feet. At 0.3 miles intervals, from west to east, the progressive thinning is 4, 7, and 2 feet respectively, if the Providence Island dolomite is assumed to be of uniform thickness. The slightly greater reduction in thicknesses between traverses two and three might possibly indicate a small-scale submarine subsidence, which may have

set up conditions favorable for the development of cross-beds. The increased grain size (3.5 to 4.0 mm.) to the west, may indicate a slight accompanying upwarp of the ocean bottom or of the land to the west. The siltstone is considered an offshore finer-grained facies of the easterly dipping cross-beds and the thinning of the beds to the east is attributed to conditions of lesser deposition.

The *Mimella* Zone

The *Mimella* zone is composed of a series of fossiliferous sandy limestones, 61 feet in maximum thickness, which overlie the sandstones and shales of the *Lingula* zone. The beds are extremely variable lithologically, being thin bedded and shaly in places and rather massive in others. Pockets of calcareous sandstone are not uncommon, nor are small areas of pure crystalline limestone. Generally the beds become less sandy from bottom to top and grade into the more massive and pure limestone of the *Plectorthis* zone. As a rule, the thin beds and shaly layers are restricted to the basal 15 or 20 feet of the unit.

Wherever the beds outcrop they are fossiliferous and are characterized by an abundance of the brachiopod, *Mimella vulgaris*. Lithologically there is generally no break between this zone and the overlying *Plectorthis* zone. In some places, such as on the west shore, there is a sharp contact between the two units. The beds, as a rule, contain fewer species and fewer fossils than the beds of the overlying *Plectorthis* zone. The fossils identified from this zone and their relative abundances are listed in Table 1.

Areally the rocks of the *Mimella* zone are restricted to the southern part of the Head. At Reynolds Point, the northernmost extent of the zone, the beds end abruptly at a fault which cuts directly across their strike. To the southwest, the beds are again faulted and reduced to a thickness of 8 feet along the shore.

TABLE 1

FAUNA OF THE DAY POINT LIMESTONE

Lingula Zone

Phylloporina incepta	a	*Eurychilina latimarginata*	a
Lingula brainerdi	a	*Basilicus marginalis*	a
L. columba	a	*Isotelus harresi*	a
Orthis acutiplicata	c	trilobite fragments	a
		Fucoids	(b)aa

Mimella Zone

Phylloporina incepta	a	*Clitambonites multicosta*	c
Stictopora sp.	c	*Zygospira (?) acutirostra*	c
Plectorthis exfoliata	r	*Leperditia nana*	c
Mimella vulgaris	aa	*Eurychilina latimarginata*	c
Orthis acutiplicata	c	*Remopleurides canadensis*	rr
Valcouria strophomenoides	r	trilobite fragments	c
Clitambonites porcia	c	pelmatozoan columnals	c

Plectorthis Zone

Stromatocerium sp.	(t)a	*Strophomena sp.*	c
Lichenaria heroensis	(l)aa	*Gyronema leptonotum*	rr
Phylloporina incepta	c	*Raphistoma sp.*	rr
Stictopora sp.	a	*Leperditia nana*	c
Bryozoa spp.	(l)aa	*Eurychilina latimarginata*	a
Plectorthis exfoliata	aa	*Remopleurides canadensis*	r
Mimella vulgaris	(b)c	*Isotelus canalis*	c
Valcouria strophomenoides	r	*Vogdesia bearsi*	c
Clitambonites porcia	c	*Bumastus globosus*	c
C. multicosta	a	trilobite fragments	(b)c
Camerella varians	a	pelmatozoan columnals:	
Zygospira (?) acutirostra	c	pentagonal	(b)a
Rafinesquina champlainensis	a	round	(t)a

Pelmatozoan Zone

Stromatocerium sp.	(l)aa	*"Orthoceras" lentum*	?
Lichenaria heroensis	(l)aa	*"O". sp.*	(l)c
Phylloporina incepta	c	*Vaginoceras oppletum*	(l)c
Stictopora sp.	a	*Leperditia nana*	a
bryozoa spp	a	*Eurychilina latimarginata*	a
Plectorthis exfoliata	a	*Remopleurides canadensis*	rr
Mimella vulgaris	(l)a	*Thaleops arctura*	rr
Valcouria strophomenoides	c	*Bumastus globosus*	c
Clitambonites multicosta	c	trilobite fragments	c
Camerella sp.	rr	*Blastoidocrinus carchariaedens*	aa
Rostricellula pristina	c	pelmatozoan columnals	aa
Zygospira (?) acutirostra	a		
Rafinesquina champlainensis	a		

The *Plectorthis* Zone

The beds of the *Plectorthis* zone are predominantly massive pure limestone which have a maximum thickness of 86 feet. To the west and southwest they are quite sandy and may even be called calcareous sandstone. To the east and northeast the rocks gradually change to massive pure limestone. In and near the large quarry just south of Holcomb Point the upper 40 feet of the zone are a massive, cross-bedded, pure, oölitic limestone. The full 40 feet of the oölitic beds is shown in the quarry and along the shore to the south. Intercalated beds of sandy and pure limestone and thin beds of shale occur at the base of the oölitic beds.

Coral (*Lichenaria heroensis*) appears in the *Plectorthis* zone about 8 feet above the base of the unit at the Head. Large isolated masses of bryozoa and coral, not mentioned by Raymond (1923–24) in his report on the coral structure of the overlying Pelmatozoan zone, are abundant for the succeeding 30 feet. The structures are considered biostromes, for the bedded nature of the closely packed coral is excellently displayed. The beds appear as low topographic ridges and hills because of their greater resistance to erosion.

To the north, in the oölitic beds, rounded coral fragments in yellowish sandy calcarenite pockets or thin beds again appear about 15 feet below the top of the zone (Pl. 4, fig. 2). The rounded and fragmental nature of the coral, as well as the cross-bedded nature of the oölitic beds is suggestive of rather strong current action at the time of deposition.

All outcrops of this zone are characterized by an abundance of the brachiopod *Plectorthis exfoliata* (*Orthis costalis* of older reports); however, numerous other brachiopods are abundantly represented. With the exception of the coral and its associated branching type bryozoa which seem to occur only in rocks that are notably sandy, the listed fossils show no preferred rock type. The fossils identified from these beds and their relative abundances are given in Table 1.

The contact between the *Plectorthis* zone and the overlying Pelmatozoan zone is generally a faunal one, since the units are both typically massive pure limestones.

Cutting across Reynolds Point and continuing across the southwestern corner of Cloak Island is a northwest-southeast trending fault downthrown to the northeast (Perkins, 1903–04, p. 128; Quinn, 1933, p. 128). The stratigraphic throw of the fault has not been previously

indicated. Just south of the fault, the rocks are shaly and sandy limestone containing a typical *Plectorthis* fauna. This lithology combined with the common occurrence of *Mimella vulgaris*, indicates a stratigraphic position at or near the base of the *Plectorthis* zone. The fossils collected from south of the fault line and their relative abundances are:

Phylloporina incepta	c	*Zygospira(?) acutirostra*	r
Stictopora sp.	a	*Leperditia nana*	c
Plectorthis exfoliata	a	*Eurychilina latimarginata*	c
Mimella vulgaris	c (b)	*Isotelus platymarginalis*	c
Clitambonites porcia	c		

The rocks to the north of the fault are gray, pure limestone which contrast greatly with the sandy and shaly rocks a few feet to the south on the opposite side of the fault line. These rocks are much less fossiliferous and show a completely different fauna. The fossils collected from north of the fault line and their relative abundances are:

Mimella vulgaris	r	*Raphistoma striatum*	rr
Multicostella platys	a	*Loxoceras monofiliformis*	rr
Valcouria strophomenoides	rr	*Leperditia nana*	c

The genera *Loxoceras*, *Multicostella*, and *Raphistoma* point to a Crown Point age, but the number of identifiable fossils is too small to indicate this definitely. Perhaps more indicative of a Crown Point age is the complete absence of a Day Point fauna and the strikingly small number of fossils, a condition often noted in the Crown Point rocks to the north. On Cloak Island, rocks containing numerous specimens of *Maclurites magnus* are found north of the fault line (Perkins, 1903–04, p. 135). Westward from Reynolds Point along the strike of the fault, glacial cover obscures the relationships and prevents any further stratigraphic deductions, but outcrops adjacent to the inferred fault line indicate the same relative movement on a smaller scale. The movement, then, increases progressively southeastward along the strike and the fault is assumed to be a normal one. The fault plane appears to be almost vertical, but may dip slightly to the northeast. Assuming that the beds to the north of the fault line occur at the base of the Crown Point limestone, the stratigraphic throw, in the vicinity of Reynolds Point, is at least 150 feet. Access to Cloak Island was not possible during the course of the field work, but the presence of *M. magnus* (Perkins 1903–04, p. 135) indicates that the throw there is perhaps 10 feet greater.

The Pelmatozoan Zone

The uppermost zone of the Day Point formation is a pure, massive, gray, crystalline limestone, which is locally sandy. The rocks display a maximum thickness of 68 feet and have the greatest areal extent of any of the Day Point subdivisions. In spite of their wide areal extent, the rocks are poorly exposed since, in general, the dip of the beds is low (1 or 2 degrees) and commonly coincides with the slope of the land surface. For this reason, rocks of the same or nearly the same age outcrop over wide areas (especially on the Head) and collecting from these outcrops is extremely difficult. Many good outcrops occur adjacent to the biostromal deposits (coral beds), but these are not characteristic of the zone as a whole.

The term used by Brainerd and Seely (1896, p. 310) for the Pelmatozoan zone was Crinoidal limestone, since the beds characteristically abound in stems and columnals. The only identifiable echinoderm remains, however, are the exfoliated deltoid plates of the blastoid *Blastoidocrinus carchariaedens*. This fossil, at the time of the original work, was wrongly identified as a bryozoan "*Streptolasma expansum*" (a coral!). The stems and columnals were evidently assumed to be those of crinoids. Under the circumstances the writer feels that the term Pelmatozoan is more appropriate than the term "Crinoidal."

The coral beds originally described by Raymond (1923–24) as "the oldest coral reef" occur 15 feet above the base of this unit west and southwest of Holcomb Point. Calculations based on average dip, indicate that the stratigraphic extent of the beds is approximately 15 feet. To the west, a smaller patch of coral occurs at about the same stratigraphic horizon. Southwest of these coral patches two smaller patches occur; one at the contact of the *Plectorthis* and Pelmatozoan zones and the other just above the base of the Pelmatozoan zone.

The rocks of the Pelmatozoan zone are generally characterized by an abundance of pelmatozoan stems and columnals and the exfoliated deltoid plates of the *Blastoidocrinus carchariaedens*. The fossils identified from this zone and their relative abundances are listed in Table 1.

One area, along the shore due north of Holcomb Point, seems to merit special attention. Here a fault outcrops, which, according to Perkins (1903–04, p. 126), shows that "30 feet of rock" (presumably Crown Point) "has gone out." Along the shore, just north of the fault, collections were made from a dark, oölitic, somewhat sandy limestone which seemed

to be typical of the Crown Point. Upon inspection, however, the beds revealed a typical Day Point fauna:

bryozoa spp.	c	*Raphistoma sp.*	c
Plectorthis exfoliata	r	*Leperditia nana*	aa
Clitambonites multicosta	r	*Eurychilina latimarginata*	aa
Rostricellula pristina	c	*Bumastus globosus*	a
Zygospira(?) acutirostra	c	columnals	a

The oölitic appearance of the rocks was found to be due to an extreme abundance of the two ostracod genera, *Leperditia* and *Eurychilina*. The fauna, while typical of the Day Point limestone, is not indicative of any particular zone. Perkin's calculation of a 30 foot displacement is, then, open to question.

Along the shore at Fleury Bay the rocks are very sandy and contain the only occurrence of nautiloids noted in the Day Point limestone.

Where the southern shoreline of Fleury Bay swings westward, opposed dip readings indicate that faulting has occurred. The rocks characteristic of the Pelmatozoan zone are not actually seen to be faulted, but west of the fault only rocks of the Plectorthis zone are present. Perkins (1903–04, p. 310) suggested the presence of a fault at this place, but his work was of too general a nature to prove it. Fossil evidence is not available to allow calculation of the throw of this fault, but the generally unbrecciated nature of the rocks in the immediate vicinity tends to indicate that it is not great.

Crown Point Limestone

The beds of the Crown Point limestone conformably overlie those of the Day Point formation, and outcrop with a general northeast-southwest trend except toward the southwest where the strike of the beds is deflected sharply to the northwest. The rocks are poorly exposed and do not lend themselves readily to subdivision. The subdivisions made by the writer are valid, lithologically and faunally, but relationships and thicknesses of the units are not definite. The thickness of the formation given by Brainerd and Seely as 150 feet (1896, p. 310) seems to be substantially correct in the vicinity of Goodsell's quarry (the quarry located 0.4 miles north of Holcomb Point), the one place where it could be checked. The upper contact is not exposed except in this area. The beds generally have a northerly or northwesterly dip of 4 to 7 degrees, but in the vicinity of Jordan Point dips as high as 10 to 18 degrees were noted.

The Day Point—Crown Point contact is readily apparent in the field. Brachiopods, so prevalent in the Day Point, decrease both in total numbers and in numbers of species, while the number of gastropods and nautiloids increases sharply. Lithologically, the Crown Point is much darker in color and is generally less sandy and more massive.

The "Basal Beds"

At the base of the Crown Point are 10 feet of gray or blue massive limestone which in places are oölitic or sandy. The oölitic beds, however, are not as widespread as implied by Brainerd and Seely (1896, p. 310). These beds are designated the "Basal beds." This member occasionally contains *Maclurites magnus*, never in great numbers, and appears to be present wherever the lowermost Crown Point is exposed. The fossils which have been identified from these beds and their relative abundances are given in Table 2.

The *Maclurites* Beds

In contrast to the "Basal beds," the succeeding 25 to 40 feet of gray to dark gray, vertically jointed limestone abound in the fossil remains of the gastropods, *Maclurites magnus* and *Raphistoma striatum*, (Pl. 5, fig. 1). These beds are exceptionally well exposed all along the northwest side of the road leading to the Goodsell quarries where it branches from the main north-south road of the island. These beds are further characterized by the general absence of nautiloids so abundant in the upper portions of the formation.

Along the shore, at Jordan Point, a fault outcrops which has brought the Cumberland Head shale up against the limestone containing *Maclurites magnus*. The fault is referred to by previous workers who have mapped the area (Brainerd and Seely 1896, Perkins 1903–04, Quinn 1933, Bain 1934). All of the workers except Bain agree that it is a high angle normal fault with an easterly dip. Bain considers the fault to be a westerly dipping underthrust. The writer is inclined to agree with the majority viewpoint. According to Quinn (personal communication) the throw of the fault is at least 300 feet. A previously unmapped fault located at Holcomb Point is considered to be part of this same fault and is so indicated on the geologic map.

Outcrops containing *Maclurites magnus*, unquestionably Crown Point in age, were mapped by Brainerd and Seely (1896, p. 311) at Holcomb

PLATE 5

Figure 1. Weathered surface of an outcrop in the *Maclurites* beds showing the extreme abundance of that fossil in the rocks. Along the road 0.25 miles southwest of the Goodsell Quarry, Isle La Motte.

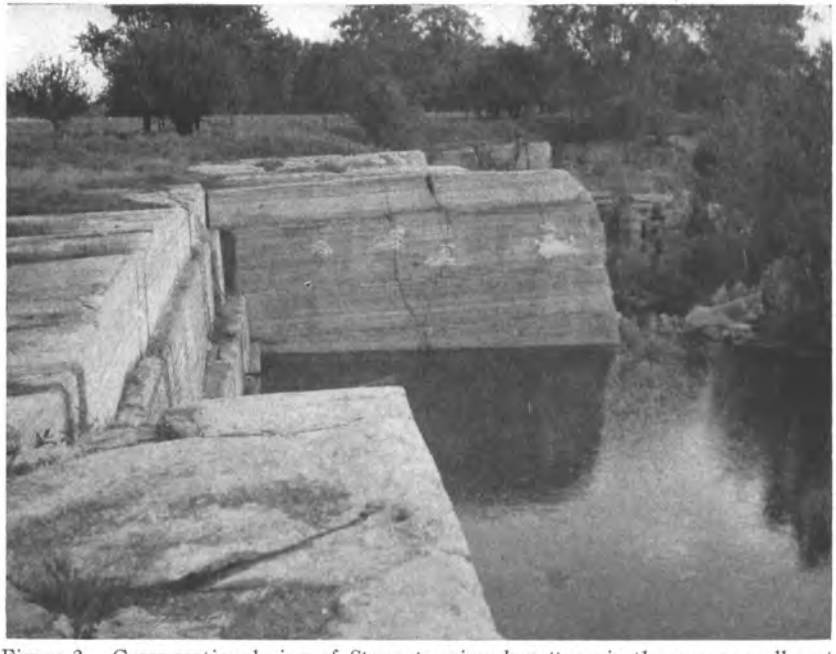


Figure 2. Cross-sectional view of *Stromatocerium lamottense* in the quarry wall east of Fisk Point. The mass to the west is about 4 feet from top to bottom. Looking south, Isle La Motte.

Point and noted by Perkins (1903–04, p. 127). Perkins gives no explanation for the presence of the beds here, but Brainerd and Seely's map shows the beds conformably in place by virtue of a series of complex zig-zag folds. Brecciated zones, opposed and increased dip readings, and the anomalous strike of the rocks indicate without doubt that faulting has occurred here. The juxtaposed rocks of the *Plectorthis* zone and Crown Point beds indicate that the eastern block has moved down relative to the western block, a stratigraphic distance of at least 78 feet.

The fossils which have been identified from the *Maclurites* beds and their relative abundances are given in Table 2.

The Fisk-Goodsell Beds

Overlying the *Maclurites* beds in most places are rocks termed by Bain (1934, p. 129) the Fisk-Goodsell horizon. These rocks range in thickness from 0–40 feet. The beds are unusually massive dark, blue-black limestones which characteristically contain nautiloids and large isolated masses of *Stromatocerium lamottense* (Pl. 5 fig. 2). Upon weathering, the rocks become light or dark gray due to leaching of the bituminous material (Bain, 1934, p. 128). Rock quarried from the Fisk-Goodsell beds has a dark gray or black lustre upon polishing and is sold commercially as "French Gray" or "Radio Black" marble.

In the V-shaped area made by the main north-south road and the road leading to the Goodsell quarry, a large bioherm outcrops at the Fisk-Goodsell horizon. As the Fisk-Goodsell beds approach the bioherm, they seem to thin out and to be replaced by the underlying *Maclurites* beds. Hence the Fisk-Goodsell beds do not form a continuous unit on Isle La Motte. Northeast of the Goodsell quarry the beds appear to be offset by a fault, for along the strike rocks containing nautiloids in fair abundance appear juxtaposed to rocks containing *Maclurites magnus* in abundance. The Fisk-Goodsell beds then seem to trend northward, but are not exposed again.

The fossils which were identified from these beds and their relative abundances are given in Table 2.

The "Upper Limestone" Beds

The "Upper Limestone" beds range in thickness from 40 to 80 feet, and are characterized by *Raphistoma striatum*, nautiloids and *Zittelella varians*. The latter is found in all horizons but is especially abundant at the base of this unit.

Lithologically the beds are variable, ranging from massive pure limestone to sandy (quartz) limestone and calcarenite. Generally the beds are more massive near the top of the unit. The beds adjacent to the bioherm are predominantly calcarenites, while those away from the bioherm contain sand grains predominantly of quartz.

At Fisk Point, the "Upper Limestone" beds directly overlie the Fisk-Goodsell beds and contain the following fossils:

Zittelella varians	a	*Maclurites sp.* (small)	a
Raphistoma striatum	a	nautiloids	c

These outcrops at Fisk Point are low, flat, and smoothed by glaciation, making collecting difficult. The uppermost beds at Fisk Point show a peculiar cuboidal type of weathering. Their exposed thickness is 3 feet, and they are unfossiliferous.

The contact with the overlying Valcour limestone is recognizable only at one place, north of the Goodsell quarry. Elsewhere the contact is covered or is not determinable. The beds, as a whole, are much less fossiliferous than those thus far discussed in the Crown Point formation.

The fossils which were identified from these beds and their relative abundances are given in Table 2.

Valcour Limestone

The upper Chazyan on Isle La Motte, the Valcour limestone, outcrop over a limited area in the vicinity of Jordan Point. According to Brainerd and Seely (1896, p. 310) 270 feet of beds are present. Of this 270 feet, 150 feet are exposed and a calculated 150 feet are concealed beneath glacial deposits and the low swamp northwest of the outcrop area. The rocks of the Valcour are poorly exposed, and no attempt at subdivision has been made. Only a very small portion of the area designated Valcour limestone on the geologic maps is actually substantiated by outcrops. This small area lies south and southeast of the dotted glacial-cover line in the vicinity of Jordan Point. The remainder of the area designated Valcour limestone has been placed on the map according to the assumed thickness of the rocks and the average dip of the nearest underlying beds.

A light bluish-gray limestone, sandy in places, occurs at the base of this formation. A stromatoporoid-like form is abundant in these beds, but thin-sections reveal no structure. This is undoubtedly the form referred to by Seely (1903–04, p. 150) as *Cryptozoon* (?) *perkinsi*. The basal beds are succeeded upward by a number of interbedded iron-gray and sandy limestones. *Stromatocerium moniliferum*, as well as numerous

TABLE 2

FAUNA OF THE CROWN POINT LIMESTONE

"Basal Beds"

Stromatocerium sp.	c	*Raphistoma sp.*	c
bryozoa spp.	c	*Maclurites magnus*	r
Plectorthis exfoliata	r	*Conularia triangulata*	rr
Mimella vulgaris	?	*Leperditia nana*	aa
Multicostella platys	c	*L. limulata*	c
Clitambonites multicosta	r	*Eurychilina latimarginata*	aa
Rostricellula pristina	c	*Bumastus globosus*	c
Zygospira (?) acutirostra	c	trilobite fragments	c
Raphistoma striatum	r	pelmatozoan columnals	a

Maclurites Beds

Stromatocerium sp.	c	*Maclurites magnus*	aa
Plectorthis exfoliata	r	*M. sp.*	c
Mimella vulgaris	r	*Leperditia nana*	c
Multicostella platys	r	*L. limulata*	a
Clitambonites multicosta	c	*Eurychilina latimarginata*	c
Rafinesquina incrassata	c	trilobite fragments	r
Raphistoma striatum	a	pelmatozoan columnals	r
R. sp.	c		

Fisk-Goodsell Beds

Stromatocerium lamottense	aa	*"Orthoceras" vagum*	aa
S. eatoni	cc	*Cameroceras tenuiseptum*	c
bryozoa spp.	a	*Spyroceras clintoni*	c
Mimella vulgaris	r	*Ooceras perkinsi*	c
Rostricellula pristina	c	*Ormoceras tenuifilum*	c
Zygospira (?) acutirostra	a	*Leperditia nana*	c
Rafinesquina incrassata	aa	*L. limulata*	c
Raphistoma striatum	cc	*Eurychilina latimarginata*	c
Maclurites magnus	a	trilobite fragments	c
M. sp.	r	pelmatozoan columnals	c

"Upper Limestone" Beds

Stromatocerium sp.	r	*Maclurites sp.* (small)	a
Zittelella varians	aa	*"Orthoceras" vagum*	c
bryozoa spp.	a	*Cameroceras tenuiseptum*	c
Plectorthis exfoliata	r	*Spyroceras clintoni*	c
Mimella vulgaris	r	*Endoceras champlainense*	r
Rostricellula pristina	c	*Leperditia nana*	c
Zygospira (?) acutirostra	c	*Eurychilina latimarginata*	c
Raphistoma striatum	c	trilobite fragments	r
Maclurites magnus	c	pelmatozoan columnals	r

nautiloids and trilobites, are abundantly represented in these beds. The outcrops are flat and the rocks very brittle, making identifiable specimens almost impossible to collect. Overlying these beds is a dark impure limestone (represented by only one small outcrop) which contains an abundance of *Rostricellula plena*. These *R. plena* beds seem to represent the uppermost exposed Valcour rocks on Isle La Motte. The fauna of the Valcour limestone as a whole is given in Table 3.

The upper contact of the Valcour limestone is completely concealed; the lower, however, presents a problem, for it is often difficult to distinguish between the Valcour and Crown Point beds. According to Perkins (1903–04, p. 123):

> "In some places we found great difficulty in separating the Upper Chazy from the Middle and in some instances we failed to find a dividing line."

The writer was able to distinguish the contact at only one place, a point due north of the Goodsell quarry. From this point the contact is inferred to continue northeastward to the shore immediately south of Jordan Point. The rocks on Jordan Point to the north of this inferred contact are definitely Valcour limestone, but those immediately to the south may be referred to either formation. The writer has tentatively designated these beds as the "Upper limestones" of the Crown Point formation. The beds underlying the tentatively-designated "Upper limestones" immediately to the south, are assigned with some question as to their actual age to the Fisk-Goodsell beds. These beds appear in the small bay south of Jordan Point, and the underlying beds immediately to the south at this locality are known to be of the *Maclurites* horizon. Should subsequent work show that these tentative Crown Point designations are in error, an unconformity or fault between the Crown Point and Valcour beds would have to be postulated.

The Lowville and Isle La Motte Limestones

On the east side of the island, just north of Jordan Bay, massive, black, gray-weathering rocks outcrop in the Hill quarry and along the shore for a short distance to the north and south. Kay (1937, p. 254) has designated the lower beds Lowville and the upper beds Isle La Motte.

TABLE 3

FAUNA OF THE VALCOUR LIMESTONE

Cryptozoon(?) perkinsi	a	nautiloids spp.	a
Stromatocerium moniliferum	a	*Leperditia nana*	cc
Solenopora compacta	c	*Eurychilina latimarginata*	c
Zittelella varians	r to c	*Pliomerops canadensis*	a
Plectorthis exfoliata	r	*Homotelus obtusus*	(l)aa
Rostricellula plena	aa	trilobite fragments	(l)aa
Rafinesquina incrassata	c	pelmatozoan columnals	c

According to Kay (1937, p. 265), the Lowville represents the Middle Black River in the Champlain Valley and the Isle La Motte is representative of the lowest Trenton or is Rockland in age. The intervening Chaumont limestone present to the south at Crown Point, New York, (Kay 1937, p. 254), is missing here, but there appears to be no unconformity between the two units. A measured section, started along the shore south of the quarry, showed 6.5 feet of *Phytopsis*-bearing Lowville limestone overlain by 13.25 feet of Isle La Motte limestone.

The Isle La Motte beds contain *Lambeophyllum profundum* and *Favistella halli* near the base; the top contains abundant remains of *Maclurites logani*. The fossils identified from the Isle La Motte beds and their relative abundances are

Maclurites logani	(t)a	*Hesperorthis tricenaria*	(b)rr
Favistella halli	(b)c	*Triplesia cuspidata*	rr
Lambeophyllum profundum	(b)c	*Rafinesquina alternata*	c
Stromatocerium rugosum	(l)c	*Actinoceras sp.*	rr

The upper Isle La Motte limestone continues along the shore north of the quarry and ends abruptly at a small fault on the south side of Cranska Point. An easterly dipping, flat, glaciated outcrop at the shore north of the quarry contains *Maclurites logani*, *Stromatocerium rugosum* and an unidentified nautiloid. The fault at Cranska Point has juxtaposed the upper Isle La Motte and lower Larrabee limestones. The throw of this fault probably does not exceed 10 or 15 feet. The Larrabee limestone continues around the point for a few feet but at the water's edge is partially overlain by the massive Isle La Motte beds (Pl. 6 fig. 1). A small easterly-dipping thrust fault has brought the older Isle La Motte beds over the Larrabee limestone. This small overthrust mass of rock constitutes the northernmost extent of the Isle La Motte beds on the island.

PLATE 6

Figure 1. Small, drag-folded, overthrust mass of Isle La Motte limestone (massive beds). The Larrabee limestone (thin bedded) lies in the upper left. Looking north, Cranska Point, Isle La Motte.

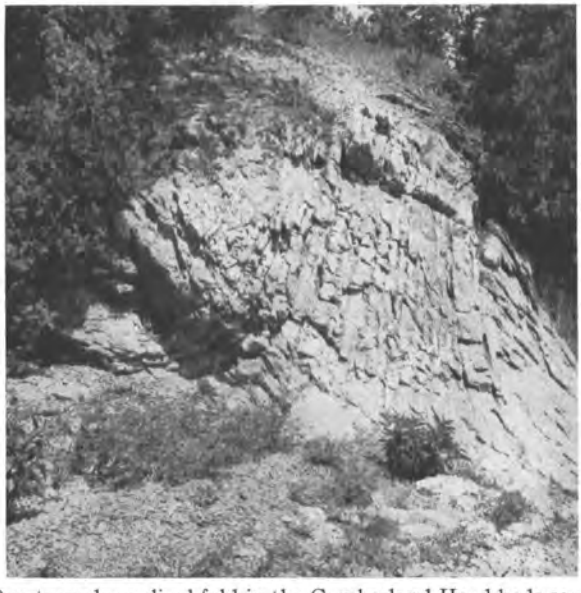


Figure 2. Overturned synclinal fold in the Cumberland Head beds south of Cooper Point. The beds to the east are faulted and on end. Looking north, east shore of Isle La Motte.

South of the quarry the massive Lowville beds outcrop for only a short distance along the shore. The southernmost outcrop at the shore strikes S40°W, but the beds do not appear again beyond this point. The existence of the Isle La Motte and Lowville formations in the area west of Jordan Bay and south of the swamp is not substantiated by outcrops.

The Glens Falls Formation

The Glens Falls formation (Ruedeman 1912, p. 28) has a thickness of about 115 feet on Isle La Motte. The formation is divided into a lower member, the Larrabee limestone of Hull age (Kay 1937, p. 262) and an upper member, the Shoreham limestone of lower Sherman Fall age (Kay 1937, p. 264).

The base of the Larrabee limestone as exposed in the Hill quarry shows 12.25 feet of thin-bedded, hard, dark blue-black limestone with one-quarter inch calcarenite and shaly partings. Elsewhere on the island, wherever the Larrabee beds are exposed, they are less massive, thin-bedded, shaly limestone. The Larrabee beds have a total thickness of about 70 feet on Isle La Motte.

The Larrabee beds are best displayed on the island in, and immediately to the west and northwest of the Hill quarry. The outcrop area is somewhat restricted, but where the rocks appear at the surface they are well exposed. In the pasture 0.4 miles west of the Hill quarry and 0.2 miles south of the road leading east from the village, the Larrabee appears as low, flat ridges dipping moderately (3 to 11 degrees) to the north. Immediately south of the road, about 0.1 miles west of the Hill quarry, the dip swings sharply around to the west and northwest. This sharp swing in the strike of the beds is reflected in all of the overlying rocks to the northwest. Very good exposures of the upper Larrabee beds may be seen a little southwest of Cranska Point where the topography rises to the west. The rocks here are less massive and considerably more shaly than the rocks at the base of the unit exposed in the Hill quarry.

The fossils identified from the Larrabee beds and their relative abundances are

Sowerbyella sericea	cc	*Rafinesquina alternata*	r
Hesperorthis tricenaria	r	*Bathyurus ingalli*	r
Parastrophina hemiplicata	c	*Encrinurus cybeleformis*	(b)c
Doleroides attawanus	r	*Hemiarges paulianus*	(b)c
Strophomena filitexta	c	*Phragmolites compressus*	c

The contact between the Larrabee and overlying Shoreham beds is

gradational; the faunal distinction, however, is rather abrupt. There appears to be an interval of from 5 to 10 feet throughout which the typical thin-bedded, shaly Larrabee limestone grades into the dark, heavy-bedded limestone with calcareous shale partings of the typical Shoreham. Faunally, the occurrence of *Prasopora orientalis* and *Cryptolithus tesselatus* in abundance at the base, and indeed almost everywhere that the Shoreham rocks are exposed, sets off the two units very distinctly. The Shoreham limestone has a thickness of approximately 45 feet on Isle La Motte.

The most southerly outcrop of the Shoreham, 0.5 miles west of the Hill quarry and 0.2 miles south of the road leading east out of the village, displays the base of the member excellently. At this locality the northerly dipping basal beds may be followed northeastward to the road where the dip swings abruptly around to the west; the beds may then be traced northward until, just west of Reed Point, the rocks become covered. The upper Shoreham beds are best displayed about 0.2 miles east of Isle La Motte Village. Here the thick-bedded limestone with shaly partings typical of the Shoreham may be seen in contrast to the transitional shaly beds at the base of the unit.

The only outcrop of the Shoreham member north of Reed Point is in a small thrust mass on the northeast corner of the island on Cooper Point. The Shoreham and overlying Cumberland Head beds are separated from the shore by the Stony Point shale which has been faulted into its present position, almost continuously, between Cranska and Cooper points.

At Cooper Point approximately 25 feet of the Shoreham member is exposed. The thrust plane does not outcrop, but probably dips at a rather high angle a little to the north of east. The rocks are dark, gray-black, thin-bedded limestone interbedded with calcareous shale. Upon weathering, the rocks become light gray in color and, in places, weather into ellipsoidal nodules 4 to 6 inches in length and 2 to 4 inches in width. The dip of the beds is variable, but an average figure would be 30 degrees N50°W. The stratigraphic throw of the fault probably does not exceed 50 feet. Bedding plane faulting with slickensides and small-scale normal faulting are prevalent throughout the rocks. Just to the south of Cooper Point the beds have been thrown into a tight synclinal fold overturned to the west (Pl. 6 fig. 2). The rocks were evidently very fossiliferous, but few fossils are now identifiable. An abundance of *Prasopora orientalis* and an occasional identifiable fragment of *Cryptolithus tesselatus* may be

found. Pelmatozoan fragments are common, and unidentifiable fossil fragments occur in abundance.

An overall consideration of the Shoreham member shows a progressive change from bottom to top lithologically and to some extent faunally. The shaly limestone at the base grades upward into heavy-bedded limestone with calcareous shaly partings, and near the top the rocks tend to become interbedded dense limestone and calcareous shale.

Prasopora orientalis and *Cryptolithus tesselatus*, although common throughout the Shoreham, are most abundant near the base of the member. *Isotelus gigas* and *Flexicalymene senaria*, occasionally found throughout the Shoreham, are most numerous near the top and very common in the overlying Cumberland Head formation. The fossils identified from the Shoreham and their relative abundances are:

Prasopora orientalis	(b)cc,aa	*S. conradi*	c
bryozoa sp.	c	*Reuschella edsoni*	c
Lingula sp.	r to c	*Cryptolithus tesselatus*	(b)cc, aa
Zygospira recurvirostris	r	*Flexicalymene senaria*	(t)r,c
Sowerbyella sericea	cc	*Isotelus gigas*	r
Strophomena filitexta	c		

The Cumberland Head Formation

The Cumberland Head formation (Cushing 1905, p. 375) of lower Denmarkian age (Kay 1937, p. 274) is the most widely outcropping and best exposed unit of the Trenton group of rocks on Isle La Motte. Lithologically the Cumberland Head is composed of interbedded dark calcareous shale and dark homogeneous limestone. The beds tend to increase in shale content upward, but the interbedded nature is retained throughout the exposed rocks on the island. The exposed thickness is 150 feet; the complete thickness, although the top of the unit is covered, is probably not much in excess of this figure.

The Cumberland Head formation is considered by Kay (1937, p. 275):

> " . . . to overlap gradationally northward; thus, the top of the limestone should be younger at the north end of the lake than to the south."

Indeed, it is the writer's opinion that most of the formations of the Champlain Valley are depositional phases of a fluctuating sea and, therefore, of varying age. Many of the "index" fossils such as *Maclurites*, *Cryptolithus* and *Prasopora* may well be facies fossils and, therefore, not reliable time horizon markers.

Over most of the area underlain by the Cumberland Head formation, the topography is flat and the rocks appear as low sinuous ridges. A typical outcrop area, northeast of Isle La Motte Village and west of Reed Point, is shown in Plate 7, figure 1. The direction of dip of the beds is generally within the northwest quadrant at an angle of 4 to 15 degrees. Just south of the above-cited area, between more steeply dipping beds, is a topographically low area in which the beds are essentially flat lying. This east-west strip of flat lying rocks is about 1500 feet long and about 200 feet wide. While there is no field evidence to substantiate this view, it is believed that these horizontal beds are bounded by small-scale, normal faults.

The rocks are generally very fossiliferous, but several completely barren layers were noted. Near the base of the Cumberland Head, 0.3 miles northeast of the village, the following fossils were collected from a dark, gray-weathering limestone layer:

Prasopora orientalis	c	*Flexicalymene senaria*	c
Sowerbyella sericea	a	*Isotelus gigas*	r to c
Rostricellula sp.	c	Pelmatozoan fragments	cc
Loxobucania punctifrons	(l)a		

Southeast of the above area, at a locality in the village known locally as Monkey Hill, the following forms were identified from a thin-bedded, blue black limestone:

Zygospira recurvirostris	c	*Flexicalymene senaria*	cc
Resserella rogata	cc	Pelmatozoan columnals	a
Hesperorthis tricenaria	c		

A small very fossiliferous outcrop of dark blue limestone in the center of the village, at the Isle La Motte Garage, yielded the following forms:

Prasopora orientalis	c	*Hesperorthis tricenaria*	c
Zygospira recurvirostris	c	*Rhynchotrema increbescens*	c
Resserella rogata	a		

Just north of the village, both east and west of the main road, the following forms were noted:

Prasopora orientalis	r to c	*R. alternata*	cc
Lingula sp.	r	*R. sp.*	c
Zygospira recurvirostris	c	*Flexicalymene senaria*	a
Sowerbyella sericea	c	*Isotelus gigas*	cc
Resserella rogata	a	pelmatozoan columnals	cc
Rafinesquina trentonesis	a		

Figure 1. Typical outcrops of the Cumberland Head beds north of Isle La Motte Village and west of Reed Point. The beds are wrapping around and dipping northwest. Looking northwest, Isle La Motte.

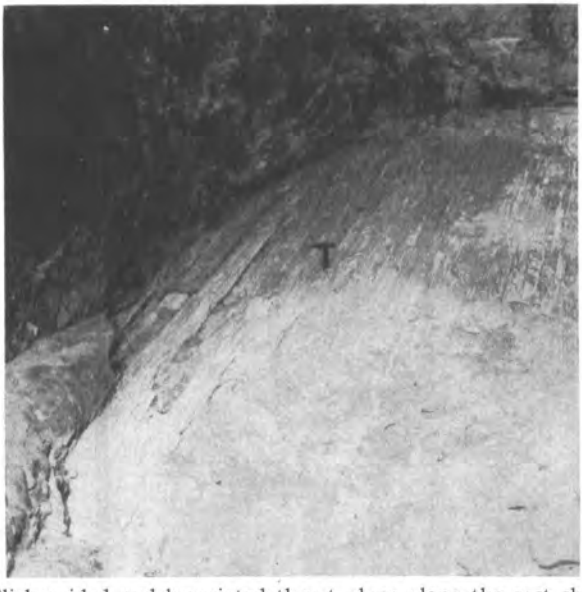


Figure 2. Slickensided and brecciated thrust plane along the east shore north of Cranska Point. The hammer rests on the Larrabee beds, the overlying rocks are Stony Point. Looking west, Isle La Motte.

Along the northernmost road leading to the east shore, a very interesting area of Cumberland Head rocks appears at the surface. The outcrops are located just north of the road about midway between the east shore and the main road of the island. The rocks are composed of interbedded shale and brittle, dark blue limestone. Stratigraphically, these beds lie about 140 feet above the base of the Cumberland Head formation. Only a few fossils were noted, all of them fragmentary. *Flexicalymene senaria, Diplograptus amplexicaulis, Prasopora* (?) and *Triarthrus* constitute the identifiable forms; an abundance of gastropod fragments was noted also. The presence of *D. amplexicaulis* and *Triarthrus* would seem to indicate that the beds are well up in the Cumberland Head formation, probably very near the base of the Stony Point formation (Ruedemann 1921, p. 111). The interbedded shale is much less resistant to erosion than the limestone and, in general, does not appear at the surface. The trace of the resistant limestone layers, however, outline shallow anticlinal and synclinal structures (Plate 8). The syncline measures 50 feet across and plunges southwest at an angle of about 4 degrees. The anticline, 45 feet across, plunges to the southwest at an angle of 6 degrees. The distance between limestone layers, appearing at the surface in the photograph, gives a good rough approximation of the proportion of limestone to weaker interbedded shale.

An interesting sedimentary feature, undoubtedly some sort of "scour and fill" structure, occurs in the outcrops nearest the road. These same structures have been noted a little lower in the Cumberland Head beds at two places on South Hero Island. The "scours" are filled with a matrix of finely broken fossil fragments and calcareous sand grains. In plan view the "scours" show up as long, narrow, darker weathering, straight-sided areas which have a coarser texture than the enclosing rock. The structures range in length from 4 to 6 inches and in width from 0.75 to 1.25 inches. The ends of the "scours" show several degrees of convexity outward, but always end abruptly. Transverse and longitudinal sections range in depth from 0.25 to 0.50 inches and appear as flattened semicircles and semiellipses respectively. The structures seem to show no preferred orientation with regard to direction of elongation. Branching seems never to occur, but cross-cutting, without regard to direction, is common. The apparent lack of orientation and random cross-cutting nature of the structures at the same horizon, would seem to preclude their origin from any of the normal scour and fill phenomena. Only a cursory field and laboratory examination of the structures was made by

PLATE 8

An air view looking west of minor folding in the upper Cumberland Head beds northeast of Isle La Motte Village. The sharper western structure is an anticline. Isle La Motte.

the writer; more detailed work would undoubtedly give some rewarding results.

The Stony Point Formation

The Stony Point formation (Ruedeman 1921, p. 112) of upper Sherman Fall, upper Denmarkian age (Kay 1937, p. 275) does not outcrop any place *in situ* on Isle La Motte. A few years ago a drainage ditch along the west road of the island uncovered a shale outcrop (Doll, personal communication); this shale, now covered, was probably of Stony Point age. According to Hawley (1952, p. 6), the Stony Point formation is:

> "Predominantly calcareous shale in the lower part, with a gradational change upward to predominantly quartz-silty argillaceous limestone."

The thickness of the Stony Point formation in the northern Champlain Valley given by Hawley (1952, p. 6) is 1000–1500 feet.

With the few exceptions previously noted in the discussion of the underlying limestones, all of the rocks appearing at the east shore between Cranska and Cooper Points are calcareous shale of Stony Point age. The rocks along the shore show signs of great disturbance, have well developed cleavage, and show the characteristic Stony Point light and dark banding. Fossils are usually rare, but *Triarthrus beckii* is locally found in fair abundance.

In a few places, excellent slickensided surfaces (Pl. 7, fig. 2), brecciated zones and calcite veining were seen. Just above the slickensided surface figured above, relatively large quartz crystals (up to 3 inches in length) were obtained from the calcite veins.

The mode of emplacement of the shale along the shore here has been variously designated normal and reverse faulting by the previous workers in the area. Perkins (1903–04, p. 134) and Bain (1934, p. 124) suggest or maintain thrusting; Brainerd and Seely (1896, map, p. 311), Hudson (1931, p. 1) and Quinn (1933, map, p. 121) indicate emplacement by normal faulting. The writer believes that although both types of faulting are in evidence, the main displacement was due to normal faulting. Reverse faulting must be kept in mind, however, for the very sinuous nature of the fault trace is extremely suggestive of low angle thrusting.

Typical fossils from the Stony Point formation listed by Kay (1937, p. 275) are

Cryptolithus tesselatus
Triarthrus beckii
Climacograptus spiniferus
Glossograptus quadrimucronatus
G. cornutus

Figure 1. Looking east toward Raymond's biostrome (the north-south trending ridge in the middle background) showing the low relief and gentle slope to the north. Isle La Motte.

Figure 2. Small channel deposit near the southwest side of Raymond's biostrome containing rounded coralla in a matrix of calcareous sand. Isle La Motte.

The Day Point-Crown Point Organic Structures

The position and extent of the Lower and Middle Chazyan organic structures has been noted only briefly in connection with the stratigraphy of the units in which they occur. The structures and their stratigraphic importance are herein treated in detail.

The Day Point Coral Beds

Raymond's Biostrome:

The coral deposits of the Day Point limestone, described by Raymond (1923–24) as "The Oldest Coral Reef," are found due north of Wait Bay about 15 feet above the base of the Pelmatozoan zone. The north-south trending outcrop is slightly arcuate, 1880 feet in length and 600 feet in maximum width.

Topographically, the deposits form a low ridge with a maximum relief of 6 to 8 feet (Pl. 9, fig. 1). The ridge is highest on its eastern and southern extremities and slopes gently to the west and north. To the north the coral-bearing rocks disappear beneath the surface. To the south and east, however, the coral bearing rocks end abruptly while the ground surface continues to drop down in small steps of 1 to 3 feet.

The coral deposits are cut by two prominent sets of joints, one set parallel and the other transverse to the elongation of the structure. Solution has enlarged these joints in places, to a width of 2 feet, and a maximum depth of 6–8 feet. The joints provide the only vertical sections through the structure. The maximum observable thickness of the coral zone is 6 feet.

The surface of the structure is generally well exposed, but in places is covered by turf or masked by lichens. One central area, approximately 200 feet by 90 feet, is completely exposed and shows very well the areal relationships of the various parts of the structure. The rocks are generally gray to white; in some places they have a brownish hue.

In places the coralla are closely packed, producing patches of rock composed almost entirely of coral. These areas are generally concentrated toward the east side of the outcrop and south of the center. A portion of one such area is shown on Plate 10, figures 1 and 2. Within these patches there are smaller areas, up to 7 or 8 feet in diameter, composed entirely of coral in which there are no spaces whatsoever between the individual coralla. Here, the rocks usually have weathered almost white and are very striking. More commonly, however, the corals are less closely

PLATE 10

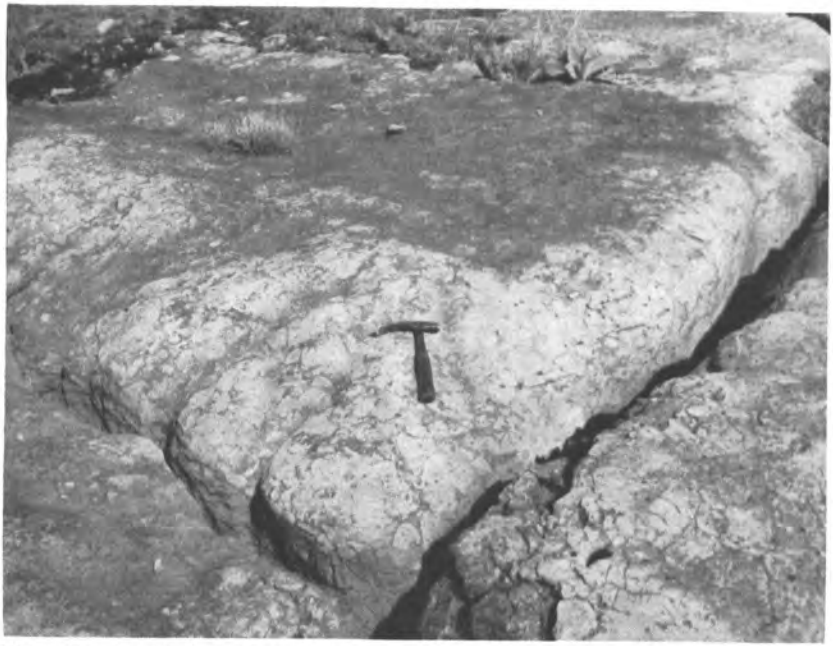


Figure 1. A typical massive coral bed well displayed in the prominent, vertical joints near the center of Raymond's biostrome southwest of Holcomb Point. Isle La Motte.

Figure 2. A close-up view of Plate 10, figure 1.

packed. The interstices between coralla are invariably filled with brownish calcareous sand (calcarenite). The masses or patches of coralline rock vary greatly in size and shape. The dimensions and the general shape of a few of the patches are given below:

46 feet x 13 feet	elongated
21 feet x 4.5 feet	oval
20 feet x 4.5 feet	highly irregular shape
13 feet x 5 feet	elongated
7.5 feet in diameter	round
1 foot in diameter	round

The elongated patches generally show an east-west orientation of their long axes. The smaller masses, which are not elongated, are crudely aligned in an east-west direction also.

Limestone composed of *Stromatocerium*, bryozoa, and brachiopods or calcareous sands containing an abundance of pelmatozoan debris, bryozoa, isolated coral fragments and brachiopods, surround the massive coral patches. These calcareous sands, considered channel deposits by Raymond, appear coarsely crystalline because of the great abundance of pelmatozoan columnals. The size and shape of these calcarenite deposits are a direct function of the orientation and concentration of the coral and *Stromatocerium* patches. The deposits, then, have a rough east-west trend and may vary in width along this trend from 6 inches to 15 feet, the larger patches being most concentrated along the east side of the outcrop. Along the west side where the patches are less concentrated the interpatch areas may be as large as 40 or 50 feet in diameter.

The masses of *Stromatocerium* and bryozoa are generally widest and most commonly present along the eastern sides of the coral patches. The contact between these and the coral masses (seen in section only at three places) is nearly vertical. The masses of *Stromatocerium* and bryozoa may completely or partially surround one or more of the coral patches. In many cases the *Stromatocerium* masses are missing from around the coral patches, and in other cases do not appear on the east side, but do on the west. Thicknesses on the east side range from 0 to 20 feet, and although not usually present on the west side, may be as thick as 10 or 15 feet where they do occur.

Small meandering channels containing rounded coralla in a matrix of calcareous sand are noted mainly along the western side of the structure (Pl. 9, fig. 2). The maximum observed depth of the channels is 4 inches. These channels do not appear to be present to the east. The calcarenite

deposits between coral patches, considered channels by Raymond, are cut into in many places by these smaller channels.

Vertical relationships are obscure due to the lack of sections through the structure. The joints, widened by solution, allow some observation of the rocks for a maximum thickness of 6 feet. At one place, a 5-foot thickness of coral rock with no apparent inorganic partings is underlain by a massive non-coralline bed. At other places and at lesser depths, coral beds were definitely seen to be interbedded with inorganic beds. Rather than grading laterally, the coral layers seem to have an intertonguing relationship with the adjacent rocks. This is especially well shown in the smaller coral beds of the *Plectorthis* zone to the south. The individual layers of coral range in thickness from 0.5 feet to 5 feet. The average thickness, however, is 2 to 3 feet.

The maximum thickness of the structure as a whole, based upon the dip of adjacent beds, is approximately 15 feet.

Faunally, the rocks of the structure are distinct from those of the Pelmatozoan zone considered as a whole. The extreme abundance of *Lichenaria heroensis*, *Stromatocerium*, bryozoa and the brachiopods, *Plectorthis exfoliata*, *Mimella vulgaris*, and *Zygospira* (?) *acutirostra* undoubtedly indicates a special environment. No fossils were identified from these rocks that are not found elsewhere in the Pelmatozoan zone. Further, all of the fossils identified for the zone as a whole are present in the coral beds. *Lichenaria heroensis* is not restricted to the coral beds, for isolated fragments of the coral are found in various horizons in both the *Plectorthis* and Pelmatozoan zones. Such occurrences, noted in connection with the stratigraphy of the zones, are considered by the writer to indicate the proximity of coral beds.

Smaller Pelmatozoan Zone Coral Beds

Immediately to the west and southwest of Raymond's biostrome, three smaller occurrences of coral are found. These are of the same general nature as Raymond's biostrome but on a smaller scale.

The most northerly outcrop is an area about 319 feet long and 170 feet wide. Three small patches of coral, approximately 20 feet in diameter, are found associated with *Stromatocerium* and bryozoa. Three hundred yards to the southwest, at the base of the Pelmatozoan zone, is a single patch of coral approximately 35 feet in diameter. The third structure just to the southwest is larger, about 100 feet long, but is poorly exposed. The exposed width is about 30 feet.

The relationships in vertical section are almost completely obscured in all three of the outcrop areas; however, individual beds do not appear to have thicknesses in excess of 1 or 1.5 feet. The most southerly outcrop has the largest total thickness, approximately 5.5 to 6 feet. The thicknesses of the two northern beds do not seem to be greater than 3 or 4 feet.

Plectorthis Zone Coral Beds

At the Head, 8 feet above the base of the *Plectorthis* zone, previously undescribed coral beds are found (see geologic map). The beds range through 30 feet stratigraphically and do not represent a single related system. Three separate horizons of coral beds seem to be indicated, but correlation is uncertain. The corals appear in flat outcrops or small mounds. The two largest coral patches measure 40 by 30 feet and 35 by 25 feet, the thickness of coral rock being 3 feet and 2.5 feet respectively. The mounds are generally of limited extent, never being more than 10 or 15 feet across. The thicknesses of these beds are 2 or 3 feet. A typical mound is shown on Plate 11, figure 1. Many smaller, flat outcrops are noted also. In many places they are extensively covered by turf and lichens. Many of the layers of coral appear interbedded with rocks of inorganic origin. On plate 11, figure 2, the illustrated bed is about 1 foot thick and may be observed laterally for about 20 feet.

The areas shown on the Head as coral biostromes (see geologic map) are the entire areas within which the deposits occur and do not represent continuous outcrops.

The most easterly outcrop of coral on the Head (see geologic map) appears as an elongated ridge about 970 feet in length with a relief of from 3 to 7 feet. The ridge rises rather abruptly to the south. Coral beds from 0.5 to 1.5 feet in thickness appear in the southern face of this ridge. The beds are especially interesting, for they show quite well the lateral and vertical relationships of the coral layers. It is apparent that influxes of sediment from time to time covered and killed off the coral. In places, growth began anew immediately above the inorganic layers. Laterally, the beds show an intertonguing relationship with the adjacent sedimentary layers.

Only one bed was noted in the upper part of the *Plectorthis* zone above the three coral horizons at the Head. The bed outcrops about 440 yards west of Wait Bay and is poorly exposed. The outcrop shows the corals to be in growth position and interbedded with inorganic sediments. The beds of coral are approximately 6 to 8 inches in thickness. The overall

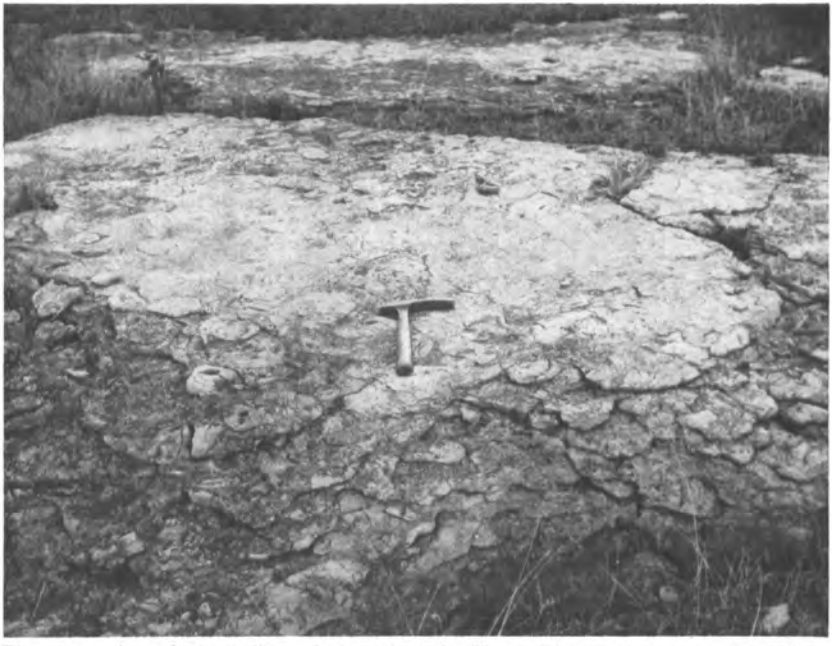


Figure 1. A typical small coral mound at the Head. The coral bed represented by this outcrop is about 3 feet thick. Isle La Motte.

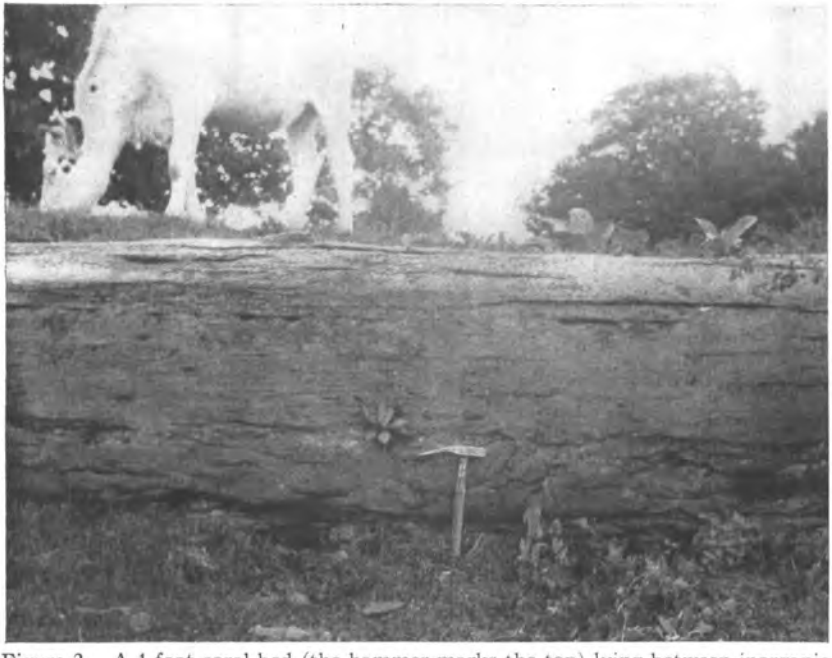


Figure 2. A 1-foot coral bed (the hammer marks the top) lying between inorganic layers at the Head. "Marie" (upper left) was a constant field companion. Isle La Motte.

thickness of the structure is not known. *Stromatocerium* is not associated with the coral here, but occurs in an outcrop about 40 feet to the east of the coral beds.

The rocks adjacent to the coral masses are faunally distinct from the rocks of the *Plectorthis* zone as a whole, but no fossils were identified which are not found elsewhere in the zone. The brachiopods, *Plectorthis exfoliata*, *Mimella vulgaris*, *Zygospira* (?) *acutirostra*, bryozoa and pelmatozoan remains are extremely abundant and indicate a special environment. The three species of brachiopods are found in extreme abundance in all of the rocks immediately above, below, and adjacent to the coral beds. The bryozoa are particularly abundant and were used during the course of the field work as indicators of the proximity of coral beds. The bryozoa do not seem to bear as close a relationship to the corals as noted in the Pelmatozoan zone to the north. In some cases masses of coral and bryozoa occur in contact, but more commonly they are separated from each other by 2 to 4 feet, the intervening rock, in many cases, having been eroded away. Pelmatozoan stems and columnals and brachiopods are usually intimately associated, especially in the beds just peripheral to the coral and bryozoan masses. Perhaps the most striking difference between these coral beds and the beds of the Pelmatozoan zone is the absence of *Stromatocerium* which is found only near the top of the *Plectorthis* zone.

Lichenaria heroensis

The coral so abundantly represented in these coral beds was considered a new genus by Raymond (1923–24, p. 76) and was described by him as *Lamottia heroensis*. According to Raymond, the genus is characterized by lateral rather than calcinal gemmation, and lacks both septa and mural pores.

Okulitch (1936, p. 65) redescribed the genus, indicating that mural pores were present. He recognized the genus *Lamottia* as valid, and proposed a new family for it, the Lichenaridae, characterized by the absence of all endothecal structures except tabulae. This family he assigned to the Tabulata.

In 1950 Bassler (p. 260) redescribed the species and stated that the mural pores reported by Okulitch (1936) were merely calcite crystals piercing the walls of the corallites. Bassler referred the form to the genus *Lichenaria*, the generic name used in this report. *Lichenaria*, according to Bassler, is a tetracoral belonging to the family Favistellidae.

Shrock and Twenhofel (1953, p. 165), in reference to the coral deposits of Isle La Motte, again refer to the genus as *Lamottia*, a "favositoid" belonging to the Tabulata.

Numerous thin sections were made by the writer of specimens collected at all of the coral localities on Isle La Motte. The sections indicate that only one species, *Lichenaria heroensis*, is present; but preservation is too poor to establish the presence or absence of mural pores. No pores are apparent, however, and the form is therefore an exact synonym for the genus *Lichenaria*. Although the genus apparently has no mural pores, the writer is more inclined to place the form with the Tabulata than with the Tetracoralla.

The coralla of *Lichenaria heroensis* noted on Isle La Motte range in size from 3 inches to over a foot in diameter. One oval specimen measured 2 feet in length and 1 foot in width. The average diameter of the coralla in both the *Plectorthis* and the Pelmatozoan zones is from 0.5 feet to about 1 foot. The potential of the form as a rock-builder is shown in all of the coral beds on Isle La Motte.

It was noticed in the course of the field work that where the coralla are closely packed the rock has a great tendency to weather to white or light gray, while coralla not in growth position weather to a very dark gray or brown. The reason for this different coloring is not readily apparent.

Conclusions

An analysis of the coral deposits of Isle La Motte indicates that they are biostromal in nature. Raymond's biostrome seems to be an organic complex designed to obtain a maximum of food and oxygen from the environment.

There is no evidence that the structure ever withstood the force of breakers, or that it ever projected above the general level of sedimentation. Disarticulated brachiopod valves, fragmental pelmatozoan and bryozoan remains, as well as isolated coralla, do, however, indicate the presence of rather strong currents.

A study of the stratigraphy of the Day Point formation shows a decrease in quartz sand content from west to east and from bottom to top. These sediments may well have been deposited by a westward encroaching shallow sea.

The elongation and alignment of coral patches in an east-west direction may well represent a response to longshore currents moving north.

Evidence of water movement from the south to the north is generally the fact that the greater concentration of coral seems to be on the south side of the structure. The general occurrence and thickest growth of *Stromatocerium* and bryozoa along the eastern (seaward) sides of the coral patches may be an indication of periodic, or slight but continuous, influxes of sediment from the western (landward) side. Periodic slight upwarps to the west may have produced relatively excessive rates of sedimentation which overwhelmed the coral growth from time to time. These upwarps, or periodic influxes, may well be recorded by the interbedded coral and inorganic beds. The intertonguing relationships of the coral with the adjacent beds indicate accordant levels of sedimentation at the time of deposition. The calcarenites between coral patches are not assumed to be channel deposits, as postulated by Raymond, for they do not thicken toward their centers or show evidence of cross-bedding. Small meandering channels along the westward (landward) side of the structure do show that channeling did occur to a limited extent. The channels are not found along the eastern side of the biostrome and may be further evidence that currents from a western (landward) direction were operative.

The mere presence of rock-building coral suggests relatively warm, clear waters. Organic growth must have taken place below wave base but within reach of terrigenous muds which periodically stopped coral growth. Conditions analogous to this are found in the epineritic zones of present-day seas.

The smaller coral beds of the Pelmatozoan zone seem to be biostromes representing the same general conditions.

The biostromes of the *Plectorthis* zone, however, seem to present a somewhat different situation. The two inorganic beds, which are thought to separate the three coral horizons at the Head, may be due to periods of excessive sedimentation. The consistent orientation of rounded coral fragments in the rocks to the west of any given coral patch, regardless of horizon, appears to be due to the action of currents moving from the west (landward) to the east. If the horizons are due to excessive deposition, the time interval between horizons would not have to be great, and the currents could have moved consistently from west to east during the time represented by the biostromes.

Warm water and epineritic zone conditions are again indicated. The intertonguing relationships of the coral with adjacent beds, so well shown at the Head, indicate accordant levels of sedimentation at the time of deposition.

The faunas above and below the coral biostromes indicate no great changes in the temperature or depth of water in the *Plectorthis* zone.

The introduction of coral into the area, now represented by the rocks of Isle La Motte, may have been due to the migration of the corals in the wake of an encroaching sea. An earlier appearance may have been prohibited by unfavorable conditions, such as turbid or slightly colder waters. It is possible, also, that the westward migration rate of the corals was slower than that of the sea. The stratigraphy of the lower Day Point limestone, however, suggests that the presence of turbid waters and generally unfavorable conditions for coral growth were the reasons.

The disappearance of the corals does not appear to be due to turbid waters or excessive rates of deposition, for the rocks of the upper Day Point limestone are not sandy or silty. A possible cause is a drop in temperature. This temperature change may have reduced the rate of metabolism of the corals to such a degree that they could not keep pace with the rate of deposition.

The Crown Point Bioherm Deposits

Raymond (1923–24, p. 74) made the following statement concerning the stromatoporoid deposits on Isle La Motte:

> "The Goodsell quarries on Isle La Motte exhibit extremely well the reefs of *Stromatocerium* so characteristic of the Middle and lower part of the Upper Chazy. In them, one finds excellent examples of fragments of *Stromatocerium* which have been torn from the parent mass and battered about until they have become rounded boulders."

The Goodsell quarries were not accessible during the 1954 field season due to flooding, but similar masses in the Fisk quarry to the south are shown in Plate 6, figure 2. The "parent mass" referred to by Raymond above, is presumably the bioherm of the present paper.

Description of the Bioherm

The bioherm is located in the V-shaped area made by the main north-south road in the center of the island and the northeast trending road leading to the Goodsell quarries. The ellipsoidal outcrop area, which has a northeast-southwest trend, is about 2295 feet in length and 1120 feet in maximum width.

The deposits form a low ridge which rises rather abruptly along its southeast side and slopes gently to the northwest. Both to the north and

south, the rocks of the bioherm seem to plunge beneath the surface. To the northwest, the beds of the "upper limestones" appear to dip away from the structure, but to the southeast the direction of the dip of the *Maclurites* beds immediately adjacent to the bioherm is not apparent.

The bioherm is cut by joints, the most prominent of which run parallel to the elongation. Solution has enlarged these joints, in places, to a width of 10 inches and a maximum depth of 2–3 feet. These joints provide the only sections through the structure.

Channel-like deposits, varying in width from 2 inches to 8 feet and containing nautiloids in a matrix of calcareous sand, are widely distributed over the surface of the structure. They appear to have no particular orientation, but wander in and out between the masses of *Stromatocerium*. Due to the lack of vertical sections the depth of these channels is not known. Two typical channels containing nautiloids are shown in Plate 12, figures 1 and 2.

The surface of the bioherm is generally flat, and the stromatoporoids and channel deposits which make up the structure are well displayed in plan view. Small resistant mounds of both *Stromatocerium lamottense* and *S. eatoni*, on the present surface of the bioherm, are numerous. The structure displays no apparent bedding.

The masses of *S. lamottense* and *eatoni* seem to bear no particular orientation to one another. *S. lamottense* is by far the more common and is undoubtedly the main builder of the two. The two species are easily distinguished in the field.

Stromatocerium lamottense occurs as large masses (5 to 6 feet in diameter), which show minute wavy crenulated ridges upon weathering. Vertical sections of the species up to 6 feet thick may be seen in both the Goodsell and Fisk quarries. The sections appear to indicate that the forms are in their growth position. Almost all of the masses are oriented with their laminae convex upward (Pl. 5, fig. 2) and are specifically referred to by Shrock (1948, p. 298) as good top and bottom indicators. *S. eatoni* appears in plan view as 2- to 3-foot areas made up of closely packed 2- to 3-inch concentric rings. In vertical section, however, the form appears as encrustations, about 2 inches in thickness, which may be piled up to form masses 3 or 4 feet thick.

The fauna of the structure is made up predominantly of *Stromatocerium*, nautiloids, gastropods (*Raphistoma* and *Maclurites*), and a few brachiopods. *Stromatocerium* is by far the most abundant. Generally, the fauna of the bioherm is the same as that of the Fisk-Goodsell beds

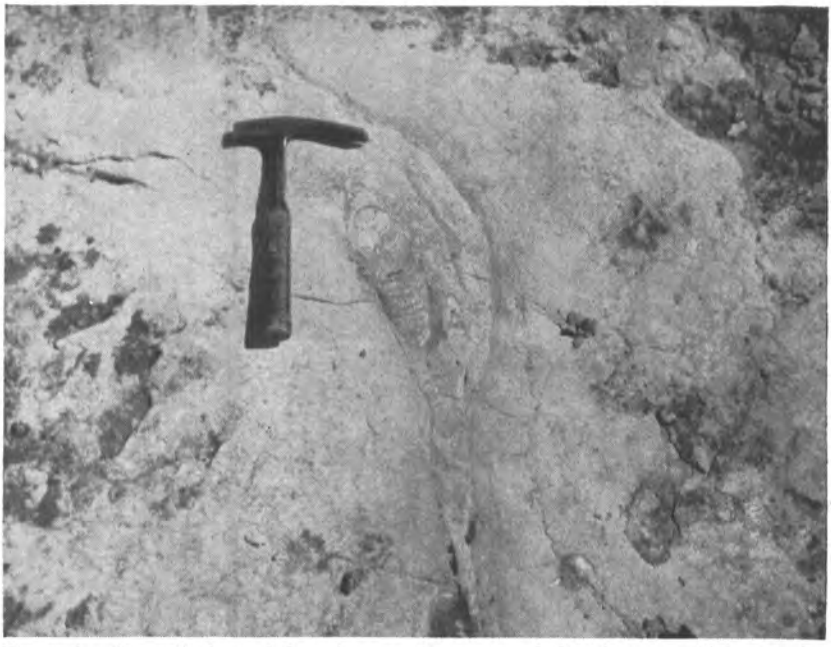


Figure 1. A small channel deposit near the center of the bioherm which contains nautiloids in a matrix of calcareous sand. About 0.5 miles southwest of the Goodsell quarry. Isle La Motte.

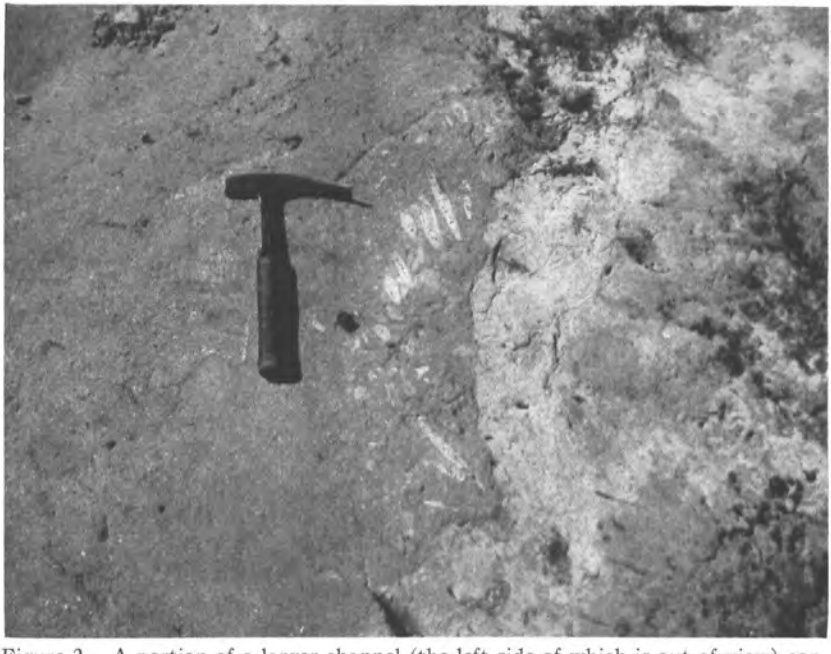


Figure 2. A portion of a larger channel (the left side of which is out of view) containing nautiloids in a matrix of calcareous sand. About 30 yards west of Plate 12, figure 1. Isle La Motte.

which are considered to be contemporaneous. The main difference in the fauna of the two units is in the numbers of fossils, the biohermal deposits having by far the greater abundance. The beds which flank the bioherm, the *Maclurites* and "Upper Limestone" beds, appear to be much more fossiliferous proximal to the structure than elsewhere. The present thickness of the structure does not appear to exceed 35 or 40 feet.

Stratigraphic Relationships

The structure is underlain by the Maclurites beds and overlain by the "Upper Limestones." The Fisk-Goodsell beds, which generally separate these two units, are missing in the vicinity of the bioherm.

Near the base of the *Maclurites* beds, southeast of the bioherm, the dip is consistently 3 degrees northwest. The upper *Maclurites* beds, immediately adjacent to the bioherm, appear as irregular hackly masses with poorly defined bedding. The irregular, hackly nature of the rocks is undoubtedly related to the proximity of the beds to the bioherm. The trend of these outcrops, and presumably the strike of the bedding, is northeast-southwest.

West of the Goodsell quarries and just east of the northern end of the bioherm the *Maclurites* beds dip 4 degrees in a direction east of north, as though thickening away from a positive structure at the time of deposition. The contact between the *Maclurites* beds and the overlying beds, apparently the "Upper Limestones," is concealed. The concealed rocks constitute a thickness of about 4 feet. The concealed interval may possibly represent the Fisk-Goodsell beds.

At the southwest end of the bioherm, the *Maclurites* beds are in contact with the "Upper Limestones." This contact is a faunal one. Although the exact dip and strike could not be determined here, the beds appear to be dipping almost due west at a low angle, perhaps 4 degrees.

Wherever the *Maclurites* beds outcrop adjacent to the bioherm, they range in thickness from 25 to 40 feet. They are apparently thinnest (25 feet) just southeast of (beneath) the bioherm and thicken rapidly to a maximum of 40 feet at the northeast end of the bioherm.

The "Upper Limestones" along the west, northwest, and north sides of the bioherm appear to dip away from the structure in each of those directions. By tracing the fauna of the rocks, the direction of strike of the beds may be approximated. The difficulty in obtaining specific dip readings here is due to the nature of the outcrop surfaces (Pl. 13, fig. 1). Wherever the "Upper Limestones" outcrop proximal to the bioherm,

Figure 1. A typical view of the northwest side of the bioherm showing the present land surface sloping to the northwest. About 0.5 miles southwest of the Goodsell quarry. Isle La Motte.

Figure 2. Massive and thin-bedded Isle La Motte limestone 0.95 miles north of the south shore in Block C. Looking north, South Hero Island.

the beds may vary in thickness from 40 to 80 feet. The thickness of the beds along the west and northwest side of the bioherm (see geologic map) cannot be given with any accuracy. The thickness of the zone at the north end, however, is approximately 80 feet. If measurements were possible, the "Upper Limestone" beds which overlie the bioherm along its northwest side would undoubtedly show signs of thinning.

The rocks of both the *Maclurites* and "Upper Limestone" beds are either light gray or blue and in the vicinity of the bioherm contain large amounts of calcareous sand. Away from the bioherm the beds contain much less sand, and the grains are predominantly quartz.

The Fisk-Goodsell beds apparently pinch out and disappear near the bioherm. They are definitely missing immediately to the southwest of the bioherm and are apparently missing to the northeast. The rocks which comprise these beds are massive, dark blue-black limestones containing large amounts of bitumen. The beds range in thickness from 0 to 40 feet and are thickest away from the bioherm.

Conclusions

A study of the stratigraphy of the beds surrounding the bioherm seems to indicate that the flanking beds dip away from the structure in all directions. Erosion has masked this relationship to the southeast, but the beds may be assumed to dip away from the structure here also. The flanking beds appear to obtain their maximum thickness near the northeast and southwest ends of the bioherm. The beds overlying and underlying the bioherm immediately to the northwest and southeast, respectively, appear to be at their minimum thicknesses. The evidence, then, is very strong that the structure was a topographic high, projecting above the general level of sedimentation at the time of deposition.

The Fisk-Goodsell beds, which seem to pinch out and disappear upon approach to the structure, are made up of massive, dark blue-black limestone. These beds may well represent deeper water accumulations flanking the structure at the time of deposition. The high bitumen content of the beds (Bain, 1934, p. 128) is undoubtedly due to stagnant bottom conditions in the deeper surrounding waters. These beds are considered by the writer to be contemporaneous with the bioherm, for they contain essentially the same fauna and occupy the same stratigraphic position.

The mere presence of sessile forms such as *Stromatocerium*, dependent on currents, and channels filled with "reef derived" calcareous sands,

show that moving water was present at the time of deposition. The water movements are, however, not considered to have been great. The almost complete and unbroken specimens of nautiloids and the apparent absence of cross-bedding in the channels attest to this.

The criterion, upon which Raymond (1923–24, p. 174) seemingly based his assumption that the structure lay within the wave or breaker zone, was the existence of fragmental *Stromatocerium* "torn from the parent mass" in the Fisk-Goodsell beds. These masses seem to be in growth position.

The apparent lack of areal orientation of the *Stromatocerium* colonies gives no indication as to the prevailing current direction. This absence of orientation may indicate that the currents were variable and had no prevalent direction of movement or that the bioherm is too small to show the differences.

The shoreline was undoubtedly to the west as shown by the stratigraphy of the Crown Point limestone. The depth of water is not clearly indicated, but it was probably not great. The environment was presumably that of the epineritic zone.

Summary

The stratigraphy of the Chazyan rocks on Isle La Motte, Vermont, shows a progressive encroachment of the seas to the south and west. The passage of the shoreline to the west was followed by warm clear, circulating waters, and rock-building "favositoid" corals (*Lichenaria heroensis*) entered the area. The corals appeared soon after conditions became favorable for their development and growth.

The coral deposits are biostromal in nature and first appear in a massive pure limestone (the *Plectorthis* zone), 70 feet above the basal quartz sandstone of the Chazyan stage. The *Plectorthis* zone biostromes occur roughly in three horizons separated by two inorganic beds which may represent periods of excessive deposition. Individual coral beds range from 0.5 to 3 feet in thickness. The three horizons range through 30 feet stratigraphically. The intertonguing relationships of the biostromes with the adjacent sediments indicates that the corals did not build above the surrounding level of deposition. Concentrations of fragmental coral to the west of any given biostrome, regardless of horizon, probably indicate eastward moving currents. Proximal to the biostromes on all sides, the rocks abound in pelmatozoan remains, brachiopods and bryozoans which indicate the presence of a special environment. Frag-

ments of coral at various horizons indicate the positions of concealed biostromes in the upper 60 feet of the zone.

The largest coral structure, "Raymond's biostrome," appears 160 feet above the basal sandstone in the Pelmatozoan zone. The outcrop area is about 1880 feet long and 600 feet wide; it has an arcuate north-south trend. The overall thickness of the deposits is about 15 feet; individual beds range in thickness from 0.5 to a possible 5 feet, the average being 2 to 3 feet. Coral patches show an east-west orientation perpendicular to northerly moving longshore currents. Patches of coral are concentrated along the eastern (seaward) and southern sides of the outcrop area. *Stromatocerium* and bryozoa are found mainly to the east of the coral beds in response to the postulated eastward-moving currents. Small channels are found only to the west of the coral patches. Coral patches interfinger with adjacent sediments and are interbedded with inorganic layers. The extreme abundances of coral, stromatoporoids, bryozoa and brachiopods indicate a special environment.

The environmental conditions shown by all of the Day Point biostromes are analogous to those found in the epineritic zone of present day seas.

The stromatoporoid bioherm of the Crown Point limestone occurs about 35 feet above the base of the formation in the Fisk-Goodsell horizon. It is roughly 2295 feet long and 1120 feet wide; the approximate thickness is 35 to 40 feet. Beds above and below the bioherm appear to be reduced in thickness, while flanking beds are thickened and dip away in all directions. A further indication that the bioherm projected above the level of sedimentation are the black limestone beds which thicken away from the structure and seem to indicate stagnant bottom conditions in deeper water. Stromatoporoids and channel deposits are well displayed in plan view on the surface of the bioherm, but vertical sections are lacking. Areally the deposits show no orientation to directed water movements, and there seems to be no indication of effective wave action. The structure is composed predominantly of stromatoporoids, nautiloids, gastropods and a few brachiopods. Environmental conditions appear to be those of the epineritic zone with the shoreline to the west. The depth of water is not clearly indicated, but it probably was not great.

SOUTH HERO ISLAND

Location and Topographic Setting

South Hero Island, the largest of the Lake Champlain islands, is located approximately 5 miles southeast of Isle La Motte. It has a maximum length of 11.75 miles and a maximum width of 4.25 miles. Its axis of elongation lies nearly due north-south. The surface is generally low and flat, broken occasionally by an elongate ridge or dome-like hill. A very good detailed topographic description of the island is given by Perkins (1901–02, pps. 104–105).

Pleistocene Deposits

The glacial deposits of South Hero Island are very extensive, but notably thinner and more clayey than those of Isle La Motte. The scarcity of sand and gravel deposits is a decided problem for the townspeople, since most of the known deposits have now been all but used up. This scarcity of gravel and sand is in striking contrast to Isle La Motte where sand and gravel deposits 15 to 30 feet thick are not uncommon. The glacial deposits of South Hero Island may generally be thought of as a thin veneer of glacial clay, with occasional sandy layers, covering the island extensively. Some of the more sandy layers are abundantly supplied with marine pelecypods as noted on Isle La Motte. The fauna is also abnormal and broken shell fragments may be found almost everywhere that the land is tilled. The most common species here appear to be *Saxicava rugosa* and *Macoma groenlandica*.

Structure and Stratigraphy

Unlike Isle La Motte, where the structure is more or less simple, although not completely understood, the structure of South Hero Island is relatively complicated. The rocks are extensively faulted and, in places, complexly folded. Only that part of the island underlain by limestone is dealt with in this report; work on the remainder of the area underlain by shale, was done by Hawley (1952). The limestone-shale contacts of this paper are generally in accordance with those of Hawley but with three notable exceptions. The differences are based mainly upon interpretation without the benefit of outcrops.

1. The fault contact running south from Keeler Bay . . . the southeasterly strike of the limestone indicates that this contact must be

unconformable. This contact has previously been mapped as a fault by Quinn (1933, map, p. 121).

2. The position and nature of the contact west of Keeler Bay . . . the contact has been moved farther west to the fault mainly on the basis of the structure to the south. Perkins (1901–02, map, p. 102) also mapped this area as being underlain by shale.
3. The position of the contact along the northern border of the limestone area . . . the contact has been moved relatively north and south in accordance with the movement of the fault. Although not previously mapped, the writer feels that the fault must extend this far north.

Lithologically and paleontologically, the rocks are generally similar to those of Isle La Motte. This is especially true of the Trenton beds. Excellent outcrops occur along the shores, but outcrops inland are often spotty or missing over wide areas. The Hull and Sherman Fall beds are very difficult to distinguish lithologically in small isolated outcrops. Since many of the Trenton species are ubiquitous, small isolated outcrops may appear very similar paleontologically also. In this connection, the very characteristic massive, often white weathering Isle La Motte limestone was used to great advantage as a key horizon. The underlying *Phytopsis*-bearing Lowville beds, with one possible exception, seem to be absent on South Hero Island. Just south of Rockwell Bay there is some indication that the Valcour-Isle La Motte contact may be unconformable.

Major Structure

Only the overall aspects of the structure are discussed here. The detailed discussion of the structure is found in the discussion of the individual fault blocks.

Folding

Two major belts of folding separated by a north-south trending fault are found on the island. The fault is located near the center of the limestone area and shows upward movement of the eastern block.

The western belt of folding is characterized by north-south trending, relatively broad, open, simple folds. In all cases, the folds plunge toward the north, or are doubly plunging north and south. No closed anticlinal structures seem to be present. Superimposed on the broad structure are smaller undulations which generally plunge east or northeast.

The eastern belt of folding, east of the fault, is characterized by tighter folds, all of which plunge to the northeast. It is suggested that the fault separating the two folded belts is an easterly dipping low-angle thrust. The tight folds to the east then, probably do not extend to any great depth. This belt of folding is terminated on its eastern side by a "normal" fault, downthrown to the east.

Faulting

The faulting, so distinct in the limestone, seems to lose its identity in the shale, perhaps by plastic yielding. The dip of the faults, in almost all cases, is indeterminate, but Quinn (1933, p. 123) gives an average figure for the Champlain Valley of 65 degrees. The north-south trending faults, with the exception of the "thrust," are all downthrown to the east, a characteristic of the faults of the Champlain Valley as a whole (Quinn, p. 119). The nearly east-west trending faults are all downthrown to the south. Although the dip of the faults in this area is indeterminate, the faults will, for convenience, be referred to as "normal," since most of them probably are. This view is also maintained by Quinn (1933, p. 119).

Despite the fact that fault planes seldom, if ever, outcrop, brecciated zones are occasionally found. In many places beds of one age are visibly juxtaposed along their strike with older or younger beds. Rapidly increasing dip readings from moderate (5 to 15 degrees) to very steep (65 to 85 degrees) are often noted over short distances.

The supposed "thrust" is intersected by "normal" faults in two places along its strike. In the upthrown block of the fault leading east from Barnes Bay, the thrust appears to be offset to the east. Assuming that the offset normal faults represent the same fault and not two completely separate faults, the dip of the "thrust" plane must be to the east. Since the eastern block of the fault shows relative upward movement, the fault appears to be of the reverse type. The more complex and tightly folded belt of rocks to the east may owe their structure to thrusting movement at the time of faulting. The thrusting forces seem to have come from the southeast, for the intersection of every fold axis with the trace of the "thrust" makes an acute angle opening toward the northeast. The direction in which the thrusting forces appear to have moved is N 55° to 60° W. Hawley (1952, p. 88) has also noted belts of more tightly folded rocks separated by broad areas of gentle folding in the overlying shale. These belts of open and closed folds, noted in the shale, may well be connected with "thrusts" hitherto unrecognized in the limestone and

perhaps still unrecognized in the shale. Hawley (1952, p. 90) has also noted:

> "In every case of significant tectonic folding, the northwest limbs of the anticlines are steeper than the southeast, and often they are overturned."

This observation supports the writer's thesis that thrusting forces originated in the southeast.

The overall result of faulting has been to break up the island into several geologically separate fault blocks. Since this natural subdivision forms a convenient basis for discussion, the remainder of the geology of South Hero Island is taken up according to individual fault blocks. An index map to the fault blocks of the island may be found in the inside pocket of the back cover.

Fault Block A

This block constitutes the southwesternmost portion of the island and is, therefore, bordered on the west and south by the lake shore. It is bounded on the east by a "thrust" and on the north by a "normal" fault, downdropped to the south. The block is elongated in a north-south direction, measuring about 1.25 miles in length and 0.5 miles in width. The rocks become progressively older from north to south and expose a nearly complete section from the Crown Point limestone to the Shoreham limestone. The top of the Shoreham and the middle of the Valcour have been removed by faulting; the base of the Crown Point disappears beneath the lake at the south shore.

Structurally the rocks are folded into a shallow western anticline and an even less pronounced eastern syncline. Both structures plunge toward the north.

Crown Point Limestone

These beds constitute approximately the southern one-third of the block and appear in good exposures along the west and south shores. Outcrops of the Crown Point are fairly common inland, but the area is greatly overgrown by scrub pine. A large quarry, inland from Phelps Point, contains excellent exposures of very massive Crown Point beds. The beds are almost concealed by overgrowth now, but a very good view of one of the massive layers may be found in Perkins (1901–02, p. 128, Plate XLVII). This particular bed is 20 feet thick without a single

parting. The beds weather to a light gray, but appear dark blue-gray when freshly broken. The rocks contain few fossils, but *Maclurites magnus* is occasionally found. Along the south shore the beds contain a few specimens of *M. magnus*, and *Stromatocerium lamottense* is found in abundance.

The Crown Point continues northward from the south shore into Beech Bay where the beds are conformably overlain by the Valcour limestone. In all, about 350 feet of Crown Point beds is present in this block.

Valcour Limestone

The Valcour beds are exposed along the shore of Beech Bay and around an unnamed point into McBride Bay. A fault at Beech Bay has removed much of the middle of the formation, reducing its thickness to about 65 feet. The rocks along the shore to the south of the fault are covered for some distance with the exception of two or three small exposures of lower Valcour beds. Farther south there are good exposures in the vicinity of the Crown Point-Valcour contact. Just north of the fault a 3.5 foot bed made up almost entirely of *Stromatocerium sp.* outcrops. Only a few feet of the bed are exposed and lateral relationships are obscure. The bed may represent an organic structure such as the coral biostromes noted in the Day Point of Isle La Motte. The rocks along the south shore of McBride Bay and around the point into Beech Bay constitute the best exposure of the upper Chazy on South Hero Island. Beds, at varying intervals and of various thicknesses, abound in the remains of the brachiopod, *Rostricellula plena*. The fossiliferous layers break up very easily upon weathering, and yield some excellent and complete fossils. The intervening layers are much more resistant to weathering and produce low overhanging cliffs. The fossils show an extreme variation in size, the younger beds generally contain a larger proportion of larger shells. The muddy character of the beds and the extreme abundance of shells seems to indicate moving water. The valves are rarely separated, however, indicating that the current action probably was not great. The rocks at the end of the point are also cut by one of the numerous dikes often seen along the shore. Perkins (1901–02, p. 102) refers to this dike as number 10 and has located, by number, the other dikes on the island. Shimer (1901–02, pps. 174–184) discusses the petrology of each of the dikes located by Perkins. Two dike exposures, not mentioned by either of the above writers were also noted inland.

Lowville? and Isle La Motte Limestones

These beds, the Black River of older reports, are well exposed along the north shore of McBride Bay and may be seen here in contact with the overlying Larrabee limestone. In a pasture to the southeast the rocks again outcrop, and the contact with the underlying Valcour limestone is closely approached. The rocks are quite fossiliferous but hard and massive, and fossil-collecting is very difficult. The following fossils were identified from these beds:

Stromatocerium rugosum	aa	*Triplesia cuspidata*	rr
Lambeophyllum profundum	aa	*Hesperorthis tricenaria*	(b)rr
Favistella halli	a	*Maclurites logani*	a
Rafinesquina alternata	a	*M. logani* operculi	c

Phytopsis-bearing rocks, characteristic of the Lowville limestone, do not seem to be present in this block, nor have they been positively identified from any other part of the island. In block C, however, *Phytopsis*-like fragments were noted at the base of the Isle La Motte section. The occurrence of the Lowville limestone on South Hero Island is questionable.

At McBride Bay 19 feet of Isle La Motte is present but the base of the unit is not exposed. Back from the north point of McBride Bay the contact is offset a vertical distance of about 10 feet by three small normal faults. The westernmost fault shows a displacement of about 5 feet; the two faults to the east are smaller, showing displacements of about 3 feet. Small normal faults of this type are very common throughout the area and lead to much confusion when located away from the shore where relationships are often obscure.

Glens Falls Formation

The Glens Falls formation shows a total thickness in Block A of 102 feet. The lower member, the Larrabee, is conformable above and below and has a measured thickness of 72 feet. The upper Shoreham member is conformable below, but is terminated above by a fault at Barnes Bay. Its measured thickness is just under 30 feet. The exposures here constitute the South Hero Island section cited by Kay (1937, p. 254).

The Larrabee beds are typically fossiliferous, thin-bedded, shaly limestone. At the base of the unit at McBride Bay, the beds are somewhat heavy bedded for 2 or 3 feet. This basal massiveness was noted also in the Hill quarry at Isle La Motte. The contact is nevertheless sharp, for there is an abrupt change from the dark pure Isle La Motte limestone to the

gray shaly Larrabee beds above. The fossils identified from the Larrabee beds and their relative abundances are:

Sowerbyella sericea	c	*Rafinesquina alternata*	cc
Dinorthis pectinella	a	*Phragmolites compressus*	c
Parastrophina hemiplicata	(l)aa	*Encrinurus cybeleformis*	(b)c
Rhynchotrema increbescens	a	*Hemiarges paulianus*	(b)c
Doleroides attawanus	r	*Calliops callicephalus*	cc
Strophomena filitexta	c		

The Shoreham is composed of homogeneous dark limestone with shale partings. The base of the unit is marked by the appearance, in abundance, of *Prasopora* and *Cryptolithus*. The base of the member, as on Isle La Motte, is somewhat gradational here. Just north of the road leading east from McBride Bay some excellent exposures of the basal Shoreham beds are found. These flat outcrops constitute probably the best fossil collecting for the lower Shoreham on South Hero Island. At the west shore, the Shoreham first appears at the end of the point separating McBride and Barnes Bays; then it continues eastward along the south shore of Barnes Bay. At the southeastern shore of Barnes Bay the beds disappear beneath glacial sand and clay. The next outcrops encountered, just to the north, are those of the massive Isle La Motte beds. A fault with a minimum displacement of 120 feet intervenes. The displacement appears to increase to the east, for the Crown Point and Shoreham beds appear juxtaposed. The fossils identified from the Shoreham beds and their relative abundances are:

Prasopora orientalis	(b)cc, aa	*Rafinesquina alternata*	r
Lingula sp.	r	*R. trentonensis*	c
Zygospira recurvirostris	r	*Cryptolithus tesselatus*	(b)a, aa
Sowerbyella sericea	c	*Flexicalymene senaria*	r
Reuschella edsoni	c	*Isotelus sp.*	rr
Strophomena filitexta	cc		

Fault Block B

Block B lies directly east of block A and is bordered on three sides by mapped faults. The north and east sides are bounded by "normal" faults, the west side by a "thrust," and the south side by the lake shore. A minor, arcuate north-south trending fault runs nearly through the center of the block. The main structure is that of a syncline which plunges toward the northeast at an angle of about 10 degrees. This block contains the only occurrence of the Providence Island dolomite on South Hero Island. The other units present are the Day Point and

lower Crown Point limestones. The approximate total thickness of beds in this block is 637 feet.

Providence Island Dolomite

The Providence Island of this block is a dark bluish gray, fine-grained dolomite which weathers into bands of bluish gray or dark blue and yellow. At the south shore 0.3 miles west of the South Hero Village road, 6 feet of the Providence Island is exposed. In some places, the rock resembles a shale when weathered and in others appears banded blue and yellow. The rocks here are apparently barren of fossils. Northwest of this shore outcrop the beds are extremely brecciated and deformed, indicating the proximity of a fault. About 0.5 miles north of the south shore the Providence Island-Day Point contact outcrops in several places. The best outcrops are located in the vicinity of the faulted contact. Displacement of the contact by the fault is about 40 feet, the western block having moved downward relatively. The total thickness of the Providence Island beds here is about 250 feet.

Day Point Limestone

The Day Point beds found in Block B are the only good exposure of the Lower Chazy on South Hero Island. Since this is the only occurrence of the rocks on the island, the outcrops were studied in some detail. The detailed characters of the beds depart considerably from the rocks at Isle La Motte, but the general lithologic and paleontologic trends are similar. The rocks decrease both in sand content and in grain size upward, and there is a general increase in the proportion of fossiliferous beds upward. The more resistant sandy beds express themselves as a prominent, rather steep-sided knob rising up in the central part of the fault block. The south face of the knob contains a very excellent section of the Day Point beds. The lower 25-foot interval is siltstone with an occasional shaly parting and contains *Lingula columba* and *L. limitaris*. The next 19 feet are composed of coarse, gray, crystalline limestone. These beds contain *Isotelus harresi* and *Orthis acutiplicata*. The next 9.5 feet are a coarse quartz sandstone containing *Lingula brainerdi*. These lower 53.5 feet of beds probably correspond to the 18-foot *Lingula* zone on Isle La Motte. The succeeding 80 feet of fossiliferous, crystalline, cross-laminated limestone contain a fauna similar to that of the 61-foot *Mimella* zone on Isle La Motte. Approximately 10 feet above the base of this zone and 63 feet above the base of the Day Point, the coral *Lich-*

enaria heroensis first appears on South Hero Island. All of the coral occurs within the next 20 feet, none was found higher stratigraphically. This is the type locality of the species, but very few specimens can be found in the rocks now.

The succeeding 61-foot interval of beds contains a fauna similar to the 86-foot *Plectorthis* zone of Isle La Motte. The beds are notably more sandy than those of Isle La Motte and from bottom to top are composed of a sandy limestone, a cross-laminated limestone and a nodular limestone. The corresponding beds on Isle La Motte are predominantly pure crystalline limestone which are sandy only locally. The top 43 feet of the Day Point is composed of cross-laminated and crystalline limestone. The beds occupy a position similar to the 61-foot Pelmatozoan zone of Isle La Motte. The overall faunas of the two areas is similar, but the pelmatozoan remains for which the zone is named on Isle La Motte are less abundant on South Hero Island. The total thickness of the Day Point limestone on South Hero Island is 237.5 feet.

Crown Point Limestone

The youngest rocks in this block are represented by about 150 feet of thin-bedded, sandy limestone, the lower Crown Point. These beds are the first to depart considerably from those on Isle La Motte, both lithologically and faunally. The difference between a reef and interreef environment could easily explain the difference between these rocks and those of Isle La Motte, the rocks of South Hero being the interreef facies. There are some excellent exposures of the rocks just south of the road leading east from McBride Bay. Approximately half of the section is concealed, however, and the rocks are considerably folded. None of the zonation noted on Isle La Motte is recognizable here. *Maclurites magnus*, although present, does not occur in great numbers. The cephalopod fauna is also poorly represented. The fossils identified from these rocks and their relative abundances are

Stromatocerium sp.	c	*Raphistoma striatum*	c
bryozoa spp.	cc	*R. sp.*	c
Plectorthis exfoliata	r	*Maclurites magnus*	r to c
Mimella vulgaris	c	*Conularia triangulata*	rr
Multicostella platys	c	*Leperditia nana*	c
Clitambonites multicosta	a	*L. limitaris*	cc
Rafinesquina incrassata	c	*Eurychilina latimarginata*	c
Zygospira(?) acutirostra	c	trilobite fragments	cc
Rostricellula pristina	c	pelmatozoan columnals	c

Fault Block C

This block constitutes the southeasternmost part of the limestone area and is bordered on three sides by mapped faults. The fourth side, the south side, is bordered by the lake shore. The "normal" faults along the east and west sides are downdropped to the east, the northern border "normal" fault is downdropped to the south. The block is elongated in a northeast-southwest direction and tapers toward the northeast. The block is 3.3 miles long, 0.55 miles wide at the south end and 0.25 miles wide at the north end. All of the rocks dip to the northeast at an average angle of 12 degrees. The rocks range in age from Day Point in the south to Stony Point in the north. Very few outcrops are present in this sequence; none were found between the lowest Larrabee and the Stony Point. In every outcrop found the strike of the bedding is northwest-southeast. This seems to indicate that the contact of the limestone and the Stony Point shale to the east must be unconformable. A fault in this position has been mapped previously by only one worker, Quinn (1933, map, p. 121).

Day Point Limestone

The lower Chazyan beds outcrop only at one place in this block, a small knob about 0.2 miles north of the south shore. The beds are composed of black shaly rock underlain by buff weathering sandy beds containing *Lingula brainerdi*. Below these beds is an easterly dipping limestone containing *Zittelella varians*. The beds appear to be upper Day Point in age.

Crown Point Limestone

The next outcrop encountered, about 0.3 miles north of the Day Point exposure, is a small well glaciated exposure of the Crown Point "reef" facies. The rocks are composed almost entirely of *Stromatocerium lamottense* and *S. eatoni*. The exposure is small and lateral relationships are concealed, but the rocks display many of the characteristics of the Isle La Motte bioherm exposure. About 0.2 miles farther north, the upper Crown Point beds are exposed. The rocks are rather massive, dark, well glaciated limestone containing the following fossils:

Stromatocerium sp.	c	*Zygospira(?) acutirostra*	c
Zittelella varians	a	*Raphistoma striatum*	c
Plectorthis exfoliata	r	*Maclurites magnus*	r
Mimella vulgaris	r	*Leperditia nana*	c
Rostricellula pristina	c	*Eurychilina latimarginata*	c

Valcour Limestone

Approximately 0.1 miles farther north typical Valcour beds outcrop. The youngest exposed rocks are a blue-black limestone which weathers to a banded gray and yellow. The rocks appear to be barren of fossils. Beds similar to these outcrop just below the Isle La Motte at McBride Bay. The underlying beds, however, are very fossiliferous and contain an abundance of *Rostricellula plena*. Several of the layers here have the "birds eye" appearance. The uppermost beds are seen in contact with the overlying Isle La Motte limestone just to the northwest.

Isle La Motte Limestone

The Isle La Motte beds outcrop just west of the South Hero Village road 0.95 miles north of the south shore. Both the Valcour and Larrabee limestones outcrop here, but the contacts are somewhat gradational and difficult to place. The thickness of the Isle La Motte is about 40 feet, the thickest completely exposed sequence on South Hero Island. The very base of the section contains *Phytopsis*-like fragments and may possibly represent the Lowville limestone. Elsewhere on the island the Lowville appears to be missing. The lower part of the section also contains an abundance of small gastropods, *Loxoplocus serrulatus* and *L. perangulatus*. The rocks appear light pale gray or gray upon weathering, but fresh surfaces are dark blue-black in color. The rocks are generally massive, but the middle of the section is somewhat thin bedded (Pl. 13, fig. 2). Several thin layers are composed entirely of finely broken fossil fragments. The fossils contained in these beds are

Phytopsis sp.	?	*Maclurites logani*	c
Stromatocerium rugosum	r	*Loxoplocus serrulatus*	(b)a
Lambeophyllum profundum	cc	*L. perangulatus*	(b)a
Favistella halli	c		

Larrabee Limestone

About 10 feet of the basal Larrabee beds are exposed overlying the Isle La Motte section. The beds are somewhat massive near the base, but rapidly become thin bedded and shaly. The shaly beds contain a prolific brachiopod, trilobite and bryozoan fauna.

The remaining units in this block, the upper Larrabee, Shoreham and Cumberland Head beds do not outcrop but are undoubtedly present. The overlying Stony Point beds do, however, outcrop south of Keeler Bay. The unexposed beds have been placed on the map according to the average dip of the subjacent formations.

Fault Block D

This block has an average width of 1 mile and a maximum length of 2.6 miles. It is bounded on the northwest and south by "normal" faults and on the east by a "thrust." The west side is bounded by the lake shore. Just north of the center of the block an east-west trending "normal" fault of small (25 feet) displacement shows downward movement to the south. The northwest boundary of the block is slightly offset by a southeast trending strike-slip fault. The main structure is synclinal which, at higher elevations, is doubly plunging north and south. Superimposed on this major structure are minor folds and crenulations. Outcrops over much of the area are spotty and poor, but potentially complete sections of the Valcour, Isle La Motte, Larrabee and Shoreham limestones are present.

Crown Point Limestone

The Crown Point is not well exposed, but about 125 feet of the uppermost beds are found in the southeastern corner of the block. The rocks are composed of massive sandy limestone which occasionally contains the following fossils:

Girvanella ocellata
Stromatocerium sp.
Zittelella varians
Plectorthis exfoliata
Mimella vulgaris
Rostricellula pristina
Raphistoma striatum
Maclurites magnus
Spyroceras clintoni

Valcour Limestone

The Valcour outcrops along the west shore south of Rockwell Bay and superjacent to the Crown Point beds. The rocks south of Rockwell Bay include only the upper 125 feet of beds. The rocks generally dip toward the northeast at an average angle of 8 or 9 degrees. Most of the beds contain fossils, but some of the massive crystalline layers are completely barren. The fossiliferous calcarenites weather to a mottled yellow and light gray. The yellow color seems to be due to concentrations of finer calcareous sand. Along the south shore of Rockwell Bay the Valcour is a massive, cross-bedded, sandy calcarenite containing an abundance of *Rostricellula plena*. The dip of the beds is northeast. The dip angle steadily decreases to the south but the northeasterly direction is maintained. Farther south, the beds approach horizontality or dip at a very low angle to the southeast. The rocks then show signs of faulting, and the

dip rapidly increases to a maximum of 20 degrees southeast. This maximum dip diminishes within a very few feet, and just south of the fault the beds again dip uniformly to the northeast at about 2 or 3 degrees. The few outcrops inland from the shore also show northeasterly dips. The attitude of the rocks has been unduly emphasized because a local unconformity between these and the overlying beds seems in evidence. The following fossils were identified from these upper beds:

Solenopora compacta	cc	*Leperditia nana*	c
Stromatocerium moniliferum	cc	*Pliomerops canadensis*	cc
Plectorthis exfoliata	r	*Homotelus obtusus*	c
Rostricellula plena	(t)a, aa	Pelmatozoan columnals	cc

Another exposure of Valcour is found south of Sawyer Bay on Chippen Point (unnamed on the map). Only about 2.5 feet of the uppermost beds are exposed. The outcrop appears at the surface by virtue of a small anticlinal warping which plunges nearly due east at 4 or 5 degrees. Fossils are not abundant, but the following forms were identified:

Girvanella brainerdi	*Solenopora compacta*
Zittelella varians	*Rostricellula plena*

In the southeast corner of the block only the very basal Valcour beds are exposed. The rocks are very sandy and very much less fossiliferous than the underlying Crown Point. Although the top of the unit is not exposed here, the thickness of the Valcour (calculated from average dip) is probably about 220 feet.

Isle La Motte Limestone

The Isle La Motte in this block has nearly the same areal extent as the underlying Valcour. The rocks outcrop inland from the shore north of Sawyer Bay, but form the shoreline to the south. The northernmost outcrop is located just north of the Rockwell Bay road. The rocks are typically massive and well jointed, weathering to a light gray or buff. These few outcrops contain the greatest number of well-preserved specimens of *Trocholites ammonius* found on South Hero Island. This fossil is probably more abundant than generally reported, for under conditions of poor preservation the fossil is easily confused with the gastropod *Maclurites logani*. The dip here is just a little north of east and both the upper and lower contacts are concealed. Throughout the area east of Rockwell Bay poorly exposed, scattered outcrops of Isle La Motte appear. Just north of the easterly striking "normal" fault the beds ap-

pear in low southeasterly sloping ridges. The Valcour-Isle La Motte contact is covered here. In the vicinity of the fault, the Isle La Motte beds are offset and indicate a stratigraphic throw of 25 feet. Just south of the fault, along the east side of the road, the Isle La Motte outcrops and dips toward the east.

Along the north side of Sawyer Bay, the beds have changed their attitude and dip toward the southeast. On the south side of the bay the beds dip toward the northeast, thus indicating a shallow easterly plunging synclinal structure. On Sawyer Island, west of Sawyer Bay, the rocks belong to the Valcour formation and contain an abundance of nautiloids. South from Sawyer Bay the shore rises in 20- to 25-foot vertical walls, producing good, but inaccessible, exposures of the Isle La Motte.

North of Sawyer Bay, the predominant dip shown by the Isle La Motte beds is east or southeast. The predominant dip direction of the subjacent Valcour beds in this same area is northeast. The indication seems to be that the contact is unconformable. South of Sawyer Bay, however, the contact appears to be conformable or at most only disconformable. These facts lead the writer to the conclusion that the intervening Lowville beds may have been removed locally by uplift and subsequent erosion. Areas only a short distance away, such as the section discussed in Block C to the southeast, may possibly be underlain by the Lowville beds.

The remaining exposures of the Isle La Motte limestone are found along the east side of the block. Nearly due west of South Hero Village the Isle La Motte beds hold up the south side of a prominant knob. The rocks have undergone a great amount of stress and contain no fossils. The physical characteristics of the rocks, however, unmistakably mark them as part of the Isle La Motte formation. The dips are high, 40 to 90 degrees, and the rocks possess innumerable calcite veins. A similar, but smaller exposure, is found somewhat to the southwest.

A composite list of the fossils found in the Isle La Motte beds of this block is as follows:

Stromatocerium rugosum	c	*Loxoplocus (Donaldiella) sp.*	r to c
Favistella halli	c	*L. (Lophospira) sp.*	r to c
Lambeophyllum profundum	a	pelmatozoan columnals	c to cc
Maclurites logani	c		

Larrabee Limestone

The Larrabee has the greatest areal extent of any unit in this block. The rocks have a thickness of approximately 75 feet. Many good ex-

posures of the beds are present, but much of the area mapped as Larrabee is concealed. In some places the dip of the beds is the same or nearly the same as the slope of the land surface, and a single horizon may outcrop over a considerable area. There are no outcrops at all in the northernmost portion of the block, and the presence of the Larrabee there is a matter of conjecture. South of the Rockwell Bay road, however, some excellent exposures of Larrabee are found. The outcrops along the east side of the block are poorer since they have been subjected to greater faulting stresses. Most of the outcrops occur in small, 1- to 2-foot, step-like ridges separated by glacial cover. The rocks are generally thin shaly limestones separated occasionally by a thin, pure limestone layer. They appear dark blue when freshly broken, and weather to a light gray.

Southeast of Sawyer Bay the rocks are exposed in small ridges and the underlying major synclinal structure is well expressed. Superimposed on the major structures are small north-south trending flutes or crenulations. The beds are highly fossiliferous and the fossils show excellent preservation. Along the eastern border of the block, overlying the Isle La Motte beds, the Larrabee is extensively exposed. The beds hold up the north side of the high prominent knob previously located in the discussion of the Isle La Motte. The topographic expression along the north side of the knob admirably expresses the underlying rock structure. The "thrust" runs along the east side of the knob, and immediately adjacent to the fault on the west the beds are vertical or nearly so for a distance of about 25 feet. The remaining structures in sequence to the west are the severed western limbs of an anticline, a syncline, and an anticline. All of the structures plunge north, and none can be traced north of the Sawyer Bay road. The structural relations just outlined are simplified, for minor faults of small displacement are very numerous. Somewhat north of the McBride Bay road a few outcrops may be found which indicate that the major structure is again secondarily crenulated. The trend of the crenulations is slightly northeast-southwest. These structures are too small to be noted on the map, but they are important in that they explain, in part, the wide areal extent of such a thin (75 feet) unit as the Larrabee.

The fossils identified from the Larrabee beds of this block are noted below:

Escharopora sp.	cc	*Parastrophina hemiplicata*	r
Eridotrypa sp.	a	*Doleroides attawanus*	r
Pachydictya acula	c	*Strophomena filitexta*	cc

Lingula sp.	c	*Rafinesquina alternata*	c to a
Trematis terminalis	c	*Resserella rogata*	c
Sowerbyella sericea	a	*Loxoplocus (Lophospira) bicincta*	a
Dinorthis pectinella	cc	*Sinuites sp.*	r
Hesperorthis tricenaria	c	*Encrinurus cybeleformis*	r to c

Shoreham Limestone

The Shoreham beds outcrop mainly along the synclinal axis of the block. Outcrops of the basal beds are rarely found; hence the precise areal extent of the beds is difficult to ascertain. The pattern of Shoreham outcrop is controlled mainly by the major synclinal structure, but topography and minor structural features modify it. One place of special interest is in the vicinity of the "normal" fault which offsets the beds. The fault is of small displacement, 25 feet, and is downdropped to the south. The width of outcrop north of the fault shows an increase rather than a decrease, as it should in the upthrown block. The structure to the north is more open than that to the south of the fault, and this apparent structural amomaly is more apparent than real. In order to explain the different intensities of folding north and south of the fault, one may assume that a period of folding, in this case thrusting from the southeast, took place after the "normal" faulting. This would allow the two blocks to react independent of one another to the later folding forces. The rocks of the overthrust mass bordering the northern block are predominantly shale while those bordering the southern block are predominantly limestone. The greater competency of limestone to transmit stresses may possibly account for the slightly tighter folding displayed by the southern block.

In general, the rocks are quite fossiliferous and contain all of the typical Shoreham fossils. The better exposures of lower Shoreham are located north of the "normal" fault. An exceptionally fossiliferous upper Shoreham outcrop may be found 0.2 miles south of the Sawyer Bay road. In particular abundance here are the remains of the brachiopods *Dinorthis pectinella* and *Sowerbyella sericea*. *Strophomena filitexta* and fragments of the trilobites, *Isotelus sp.* and *Flexicalymene senaria* are very common.

Cumberland Head Formation

The Cumberland Head outcrop, too small to be mapped, is located within the 220 foot contour along the axis of the major syncline just south of the Sawyer Bay road. The beds consist of 2 or 3 feet of very shaly rock and contain no fossils. Immediately below these shaly beds

are thin-bedded limestones containing Shoreham fossils. The very shaly nature of the outcrop is but one example of the lateral, as well as vertical, lithologic variations shown by the Cumberland Head beds.

Fault Block E

Block E forms a triangular-shaped area which is elongated in a northeast-southwest direction. The block is about 2.3 miles long and measures 1.2 miles along its northern border. The north and east sides are bounded by "normal" faults downdropped to the south and east respectively. The west side is bounded by an easterly dipping "thrust." The limestone of this block shows the most intense larger scale folding of any limestone area on the island. Two readily recognizable folds are present, and there is good evidence for at least three others. The fold axes are somewhat more sinuous than shown on the geologic map and plunge to the northeast at an average angle of 10 to 15 degrees. The southern part of the block is abundantly supplied with outcrops, but north of the Rockwell Bay road not a single exposure was found.

Crown Point Limestone

The Crown point beds of this block are considerably more sandy than those encountered elsewhere on the island. The uppermost 60 to 70 feet of beds are massive sandy limestone comparable to the writer's 40 to 80 feet of "Upper Limestones" on Isle La Motte. The underlying 155 to 165 feet of beds are composed of sandy, thin-bedded limestone separated by shaly interbeds. These beds, although considerably thicker, are somewhat comparable to the 0 to 40 feet of Fisk-Goodsell beds of Isle La Motte. The increased thickness of the beds seems to indicate an environment of more rapid deposition, one in which a bioherm could not exist. The fossils identified from the lower thin bedded limestone are

Stromatocerium sp.	r to c	*Raphistoma striatum*	a
Zittelella varians	cc	*R. sp.*	cc
Plectorthis exfoliata	c	*Maclurites magnus*	r
Mimella vulgaris	r to c	*M. sp.*	cc
Multicostella platys	c	*Lonchodomas halli*	r to c
Clitambonites multicosta	r to c	*Sphaerexochus parvus*	r to c
Zygospira(?) acutirostra	cc	trilobite fragments	a
Rostricellula pristina	c	pelmatozoan columnals	c

The superjacent thick-bedded limestone contains the following forms:

Girvanella sp.	aa	*Maclurites magnus*	aa
Raphistoma striatum	c	*M. sp.*	a
R. sp.	c	pelmatozoan columnals	cc

In addition to the above-listed forms the upper beds also contain several of the brachiopod species listed for the underlying thinner beds. The forms are much less abundant and require diligent searching for identifiable specimens. Faunal inconsistencies between the rocks here and those on Isle La Motte may be attributed to the differences between a reef and interreef environment. The Chazyan seas were a time of active "reef" (bioherm and biostrome) development, and, without keeping this fact in mind, it is often difficult, if not impossible, to correlate the rocks even over very short distances.

The structure of the rocks in the southern apex of the block is that of a slightly asymmetrical syncline overturned to the northwest. This synclinal structure is not readily apparent in the field, for it is masked by minor superimposed crenulations and cut by small faults. The anticlinal structure, encountered a little to the northwest, is also overturned to the northwest. This structure is somewhat more readily recognizable, for the rocks are more closely folded.

Valcour Limestone

The Valcour is very well exposed throughout the synclinal area but is only poorly represented in the anticlinal area to the northwest. The rocks are very sandy and the upper 55 to 60 feet of beds are cross-laminated calcarenite which, in places, is nearly a coquinite. The indication here is for a rather strong current action, but the cross laminae are variously inclined and show no preferred current direction. The thickness of the unit as a whole is about 230 feet. In a few places, the section is poorly exposed and near the middle several feet are completely concealed. *Rostricellula plena* is present throughout the section, but is most abundant in the lower part. *Eospongia sp.* and *Solenopora compacta* are common near the middle and sparingly present or absent near the top and at the base. The upper detrital limestone contains an abundance of poorly preserved small gastropods and brachiopods.

Isle La Motte Limestone

These beds are poorly exposed and almost completely devoid of fossil remains. The very massive, white-weathering nature of the beds and their stratigraphic position in the field leave little doubt as to their age. The thickness of the section is indeterminate due to poor exposure.

Larrabee Limestone

The Larrabee is very well exposed along the synclinal axis, but completely concealed to the northwest. The beds are composed of fossil-

iferous, thin-bedded, shaly limestone which is in sharp contrast to the massive underlying Isle La Motte beds. The synclinal structure is well expressed throughout these and the overlying Shoreham and Cumberland Head outcrops. The contact with the Shoreham is gradational lithologically; the lower contact is probably sharp but not exposed. The thickness of these Larrabee beds is about 75 feet. The fossil content of the rocks is very similar to that given for the beds in block D. It is interesting to note that faunal inconsistencies between areas of outcrop within the Trenton group of rocks appears to be more a function of exposure than actual faunal differences. This is in great contrast to the Chazyan series where faunal differences appear to be a function of actual environmental change.

Shoreham Limestone

The Shoreham shows a thickness of about 43 feet in the area of the synclinal axis but is completely concealed to the northwest. The rocks consist of interbedded shale and more or less pure, fine-grained limestone. The rocks are well exposed from top to bottom, but the best outcrops appear near the base. One outcrop near the base contains an abundance of the trilobite *Cryptolithus tesselatus*. The fossils are all fragmental, and the rocks unusually shaly for the occurrence of this form. With the exception of an occasional fragment of *Prasopora*, no other fossils occur in this outcrop. The exposure probably represents a washed-in, death assemblage. No faunal list will be given here, for the overall faunal aspect of the Shoreham here is much the same as that noted elsewhere on the island.

Cumberland Head Formation

The Cumberland Head beds of Block E are found in two areas. The best exposures immediately overlie the Shoreham beds. A much smaller area is located along the western border of the block, a little south of the Rockwell Bay road. The rocks have been brought to the surface by faulting and, judging from the structure to the south, probably lie along the southeast limb of a northeasterly plunging anticline. There are no exposures to the north or immediately to the south of this outcrop, but the area is considered to be underlain by folded shale of the overlying Stony Point formation. These Cumberland Head beds, steeply dipping due to their proximity to the fault, are almost completely barren of fossils. The beds do, however, contain very rare occurrences of *Isotelus*

gigas and *Diplograptus amplexicaulis*. About 10 feet of beds are exposed here.

The larger area of outcrop to the southeast exposes 40 to 50 feet of the lower beds. The upper beds and the upper contact are concealed. The best outcrops are located south of the Sawyer Bay road, but a few outcrops may be found just to the north. The northern outcrops are composed almost entirely of dark calcareous shale with occasional 1- to 2-inch limestone partings. The base of the unit is composed of interbedded shale and limestone very similar to the underlying Shoreham beds. Indeed, it is often difficult to tell with which unit one is dealing in poorly-exposed or unfossiliferous outcrops. The beds, however, are fossiliferous and contain the following fossils:

Prasopora orientalis	c	*Rafinesquina sp.*	c
Diplograptus amplexicaulis	c	*Loxobucania punctifrons*	?
Lingula sp.	c	*Cryptolithus tesselatus*	r
Sowerbyella sericea	cc	*Flexicalymene senaria*	cc
Zygospira(?) recurvirostris	r	*Isotelus gigas*	c
Resserella rogata	c	pelmatozoan columnals	a

These beds also mark one of the two localities on South Hero Island displaying the "scour and fill" structures discussed in connection with the Cumberland Head beds of Isle La Motte. The structures, although lower in the section here, appear to be exactly the same in every detail as those previously described.

Fault Block F

Block F is a small triangular-shaped area bordered on the northeast and southeast by "normal" faults downdropped to the southwest and northwest respectively. The west side of the block is bordered by the lake shore. A steeply dipping, northwest-southeast striking strike-slip fault cuts across the southern corner of the block. The fault plane outcrops at the west shore (Pl. 14, fig. 1) and dips toward the northwest. Structural evidence indicates that the northern block has moved relatively southeastward. The stratigraphic units present are the Shoreham limestone, the Cumberland Head, and Stony Point formations. With the exception of a few Cumberland Head outcrops, all of the exposures of the rocks are located along the west shore.

Figure 1. Steeply dipping, strike-slip fault outcropping along the shore south of Gordon Landing. Beds to the left are Cumberland Head, those to the right are Shoreham. Looking northeast, west shore South Hero Island.

Figure 2. Twenty-foot exposure of the Shoreham just south of Plate 14, figure 1. Looking northeast, South Hero Island.

Shoreham Limestone

All of the Shoreham outcrops occur along the north shore of Rockwell Bay and along the west shore of the island south of the strike-slip fault. Near the fault, and a little to the south, the beds have a moderate northeasterly dip (Pl. 14, fig. 2). The dip decreases progressively southward (Pl. 15, fig. 1), and the beds become essentially horizontal. The typical Shoreham lithology, interbedded shale and homogeneous limestone, is especially well displayed by these flat-lying beds (Pl. 15, fig. 2). Very minor block faulting, shown in the last-mentioned photograph, is quite common in these beds. Just north of Rockwell Bay, a somewhat larger (4 or 5 feet of displacement) fault may be seen cutting the Shoreham beds (Pl. 16, fig. 1). A total of 53 feet of beds are present from the fault southward into Rockwell Bay. *Cryptolithus* is only sparingly present in these beds, and the base of the member is difficult to place. Some of the southernmost beds may be upper Larrabee in age. The area mapped as Shoreham northeast of the strike-slip fault is not actually substantiated by faunal evidence, although two outcrops were found here. One outcrop, northeast of the road, contained no fossils, the other, southeast of the road, contained only ubiquitous Trenton species. The rocks of both outcrops are composed of interbedded shale and limestone and indicate dips of 2 or 3 degrees to the northwest. The Larrabee beds, although not mapped, probably occur here also.

Cumberland Head formation

The Cumberland Head section exposed along the lake shore has previously been referred to by Cushing (1905, p. 376) and Kay (1937, p. 274). The section begins at the strike-slip fault and continues north for approximately 0.3 miles. The lower 30 odd feet are composed mainly of limestone with thin interbeds of shale. The overlying 115 feet are composed predominantly of dark shale although limestone interbeds are common. This section also marks the second occurrence on South Hero Island of the "scour and fill" structure previously noted in the Cumberland Head beds. The structures occur stratigraphically higher than those of Block E and somewhat lower than those on Isle La Motte. The structures could be of stratigraphic value should they prove to be confined to the Cumberland Head lithology. Near the base of the section at the road, the beds are very shaly and unlike those exposed along the west shore. North of this roadcut a number of exposures, all very shaly,

Figure 1. Shoreham beds immediately south of Plate 14, figure 2. Shows gradual decrease in dip toward the south. Looking north, South Hero Island.

Figure 2. Close-up view of Plate 15, figure 1. Just to the right and left of the hammer are small-scale normal faults. This is the typical Shoreham lithology. Looking east, South Hero Island.

PLATE 16

Figure 1. Small normal fault in the Shoreham beds on the north point of Rockwell Bay. The hammer (center) indicates the calcite-filled fault zone. The displacement indicated is 4 or 5 feet. Looking just north of east. South Hero Island.

Figure 2. Drag-folded and distorted upper Larrabee beds at the north point of Wilcox Bay. White areas (lower left) are calcite-filled fractures. Looking east, South Hero Island.

point up the lateral as well as vertical variation shown by the Cumberland Head formation.

The fossils noted in the rocks along the shore are given below:

Prasopora orientalis	(b)c	*Rostricellula sp.*	r to c
Zygospira recurvirostris	(l)c, a	*Rhynchotrema increbescens*	cc
Sowerbyella sericea	c	*Loxobucania punctifrons*	c to a
Resserella rogata	cc	*Flexicalymene senaria*	cc
Rafinesquina trentonensis	c	*Isotelus gigas*	cc
R. alternata	aa	pelmatozoan columnals	a
R. sp.	c		

The remainder of the block, north to Gordon Landing, is underlain by dark shale and interbedded limestone of the Stony Point formation (Kay 1937, p. 274). The thickness of the section given by Kay is 215 feet. The Cumberland Head-Stony Point contact is based upon lithologic criteria and is arbitrarily drawn where the rocks show a marked increase in shale content. The shortcomings of a lithologically-defined contact become self-evident when the rocks are poorly exposed. The relatively unfossiliferous nature of the Stony Point beds, however, renders any paleontologic definition of a contact at best only a zone. This zone would be one in which the abundant (usually) and typical Cumberland Head fossils progressively disappear.

Fault Block G

Block G is bordered on the south and east sides by faults and on the north and west sides by the lake shore. The southern border "normal" fault is downdropped to the south. The eastern border "thrust" fault loses its identity upon entering the shale and is mapped, therefore, as only partially bordering the block. The portion of the block dealt with in the report has a maximum length and width of 2.4 and 1.6 miles respectively.

The structure of Block G is broad, open, and undulatory with an overall dip toward the north. Due to the undulating nature of the beds relatively thin stratigraphic units outcrop over wide areas. Along the west shore, the undulations are so pronounced as to produce isolated areas of older and younger strata within the Shoreham area of outcrop.

Larrabee Limestone

The Larrabee beds outcrop for about 0.8 miles along the shore north from Gordon Landing. The dip of the beds is quite variable, ranging from less than 1 to about 6 degrees. The rocks are very fossiliferous and

show a progressive, but not uniform, change from shaly limestone to interbedded limestone and shale. At the first appearance of *Cryptolithus tesselatus*, considered to be the base of the Shoreham, the proportion of limestone to shale is about 4:1. The fossils obtained from these shore outcrops are

Lingula sp.	c	*Rafinesquina alternata*	cc
Sowerbyella sericea	cc	*Endoceras annulatum*	c
Dinorthis pectinella	c	*E. proteiforme*	cc
Strophomena filitexta	a	*Flexicalymene senaria*	c

Along the eastern side of the block outcrops are spotty and generally poorly exposed. An interesting exposure, lithologically similar to the Valcour but containing Trenton fossils, is found in the southeasternmost area of outcrop. The rocks are composed of moderately coarse, light gray, crystalline calcarenite with sandy yellow stringers and pockets. The beds are replete with specimens of *Rhynchotrema increbescens*, and occasionally *Rafinesquina alternata* is found.

Shoreham Limestone

The best exposures of the Shoreham are along the west shore of the island, but a few outcrops are found along the eastern border. The beds to the east are proximal to the fault and steeply inclined to the east or southeast. Several of the beds contain typical Shoreham fossils. Throughout the central area of outcrop few, if any, exposures are present. Due to the undulatory nature of the beds, it is quite possible that rocks, other than Shoreham, lie concealed directly beneath the surface cover.

At the west shore 0.5 miles south of Wilcox Point the *Cryptolithus*-bearing rocks appear and run north for 0.15 miles. The beds show varying amounts of inclination from nearly flat lying to a maximum of 6 degrees. The dip direction is to the north or northwest. At a point 0.4 miles south of Wilcox Point and for a distance of 0.25 miles northward, the dark shale and interbedded limestone of the Cumberland Head beds outcrop at the shore. The rocks are well supplied with Cumberland Head fossils and form a syncline slightly overturned to the south. The Shoreham beds again appear at the shore just south of Wilcox Point and make up the shoreline to and including Wilcox Point itself. The Wilcox Bay area is underlain by Larrabee beds which have been brought to the surface by anticlinal folding and subsequent erosion. The structure plunges to the southeast at a very low angle.

At Wilcox Point and along its north shore the Larrabee beds on the

north limb of the anticline (the north shore of Wilcox Bay) dip to the northeast at an average angle of 24 or 25 degrees. The rocks show signs of great disturbance and are filled extensively with calcite veins along the strike (Pl. 16, fig. 2). At Wilcox Point a thrust plane outcrops which shows a dip of 25 degrees N50°E (Pl. 17, fig. 1). The thrust has not disturbed the overall stratigraphic sequence, for Shoreham beds lie unconformably above Larrabee beds. The structure of the overthrust Shoreham beds was synclinal prior to faulting, and the axis of the syncline now lies somewhat north of Wilcox Bay well up on the north limb of the Wilcox Bay anticline.

The Shoreham beds in this area are generally replete with fossils indicative of their age. The maximum thickness of the unit noted along the west shore is about 40 feet.

Cumberland Head Formation

The youngest beds present in this block are the dark, interbedded limestone and shale of the Cumberland Head formation. The rocks are best exposed along the west shore. These shore outcrops also maintain the undulatory character so well expressed by the beds immediately to the south. The rocks are less fossiliferous and more shaly than any of the Cumberland Head sections thus far discussed. Fossils do not occur uniformly throughout the section but are found in isolated pockets. Fossils become less abundant toward the top and specimens of the Stony Point fossil, *Triarthrus beckii*, are uncommonly abundant. The base of the section is very shaly, and nowhere is there such a predominance of limestone as noted near the base of the section in Block F. There are few outcrops inland from the shore, and those present indicate little about the stratigraphic relationships. Lateral and vertical lithologic variations and the general absence of fossils nearly precludes stratigraphic inference from these outcrops inland from the shore. For this reason and because of the general lack of outcrops the upper contact, north of Grand Isle Station, is mapped as questionable. It should be noted here that the contact shown is that of the writer's and not Hawley's (1952, map). The contact shown by Hawley is located somewhat to the north.

The thickness of the section considered Cumberland Head by the writer is 165 feet. The fossils contained in this section are much the same as listed for the Cumberland Head previously, but the forms occur in much less abundance. This section does contain a moderate abundance of *Triarthrus beckii, Diplograptus amplexicaulis* and *Mesograptus mohawkensis*.

Figure 1. Thrust zone on north point of Wilcox Bay about 25 feet north of Plate 16, figure 2. The upper beds are Shoreham, the lower distorted beds are Larrabee. Looking just south of east. South Hero Island.

Figure 2. View along the axis of the anticline shown in middle right of Plate 18. The near middle background is the synclinal depression, just beyond is the severed anticlinal limb. Looking north. South Hero Island.

Fault Blocks H and I

Of the two remaining blocks, only block H is of much consequence. Block I, as far as can be determined, is underlain only by Cumberland Head beds. It is a small wedge 1.7 miles long and 0.37 miles wide along its south side, and is bordered on all three sides by "normal" faults. There are but 5 or 6 outcrops in the block, all quite shaly and containing very few fossils. The presence of *Diplograptus amplexicaulis* and *Mesograptus sp.* seems to indicate that the beds belong to the Cumberland Head formation. The few outcrops present show moderate to high dips, and the beds are often greatly contorted. The thickness of the beds is indeterminate.

Block H is quite interesting, both stratigraphically and structurally. The block is bordered on the west by a "thrust" and on the east and south by "normal" faults downthrown to the east and south respectively. That portion of the block dealt with here is 3.4 miles long and 1.3 miles in maximum width. Structurally the block consists of two well-defined, northeast-southwest striking folds. A less well-defined synclinal structure is located in the northwest portion of the block. Superimposed on the major structure are minor crenulations elongated both northeast-southwest and northwest-southeast. Locally, the rather simple overall structure becomes extremely complex.

The rocks become progressively younger toward the north and range in age from Crown Point to Cumberland Head. Outcrops are generally good throughout the middle of the block, but in the extreme southern portion and in approximately the northern one-third of the block bedrock is poorly exposed. None of the units is well enough exposed to indicate its thickness and stratigraphic boundaries are often difficult to locate precisely.

Crown Point Limestone

The Crown Point beds occur over a rather wide area in the southern portion of the block. The two best areas of outcrop are located just west of the synclinal axis and farther west along the axis of the anticline. The rocks as a whole are massively bedded, light gray weathering, sandy calcarenites. Most of the common Crown Point species are present in the rocks, but the following forms are particularly persistent throughout the outcrop area:

Stromatocerium lamottense
S. eatoni
Rafinesquina incrassata
Maclurites magnus
Raphistoma striatum
pelmatozoan columnals

The synclinal structure rapidly opens southward from the Isle La Motte outcrops and is barely recognizable throughout the Crown Point. To the west, however, the underlying anticlinal structure is beautifully expressed by the Crown Point outcrops. In one or two places a single outcropping ridge wraps completely around from one anticlinal limb to the other. Most of the outcrops west of the anticlinal axis are very close to the fault and display high dips. In some cases the beds even appear to be overturned.

Valcour Limestone

The Valcour is best exposed north and southeast of the northernmost Crown Point beds and west of the southernmost Isle La Motte beds. The rocks are, for the most part, sandy, very massive, coarsely crystalline calcarenites. The rocks, as elsewhere, are not overly fossiliferous unless the beds replete with *Rostricellula plena* are exposed. The more common fossils found in the beds are

Solenopora compacta
Stromatocerium moniliferum
Plectorthis sp.
Rostricellula plena
Pliomerops canadensis
Homotelus obtusus
pelmatozoan columnals

The Valcour beds along the western limb of the syncline are only slightly inclined toward the east or northeast. The major structure is not too well indicated, but the superimposed minor crenulations are readily apparent. The anticlinal structure is very well expressed by the lower Valcour beds to the northwest. Some of the best exposures are found outcropping in the elevated reentrant along the south side of Pearl Swamp.

Isle La Motte Limestone

The easily recognizable massive, white-weathering beds of the Isle La Motte limestone were extremely useful as a horizon marker in working out the structure of this block. Outcrops are not continuous throughout the area mapped as Isle La Motte, but they are sufficient to outline the structure, and to indicate the complexity of it.

The northernmost outcrop is located north of Pearl Swamp just west of the anticlinal axis. The rocks have undergone considerable stress in folding and are shot through with calcite veins. The following fossils were identified from the beds here:

Favistella halli
Lambeophyllum profundum
Maclurites logani
Trocholites ammonius?

PLATE 18

An air view, looking southeast, of the Isle La Motte beds exposed along the Hoyt Bay road. The major synclinal axis follows an arcuate (convex downward) path from upper right to lower left in the photo. South Hero Island.

The next outcrop is located to the southeast just west of the main road. The rocks weather to a very light gray or white and show the typical massive bedding. The beds are not conspicuously fossiliferous, but close inspection reveals the typical Isle La Motte species. Just southeast of the Pearl and main road intersection, extremely massive, almost white-weathering beds outcrop for several yards. The rocks are apparently barren of fossils but are overlain by the shaly thin-bedded Larrabee beds. Judging from the stratigraphic position and physical characteristics of the rocks, one can have little doubt about assigning them to the Isle La Motte.

The most extensive and best exposed outcrops are located along the east side of the block between the Hoyt Bay and Donaldson School roads. A view from the air of the southernmost exposure is shown in Plate 18. The photo explains better than words the complexity of structure and physical character of the rocks. The sinuous eastern border fault delimits the eastern (upper in the photo) edge of the outcrops and is traced for a short distance by the fence north of the road. The southeasternmost beds (upper right in the photo) wrap around to the east and define the major synclinal axis. The beds in the right center of the photo define the nose of a minor north-plunging anticline, and immediately to the left, a north plunging minor syncline may be made out. The rocks in the lower left corner of the photo constitute the west limb of a somewhat larger anticline cut by the eastern border fault nearly along the fold axis. Plate 17, figure 2 is a ground view looking north along the axis of the first-mentioned minor anticline and shows the dip of the beds. The topographic synclinal depression may be seen to the east and in the middle background, the west limb of the severed anticline.

In addition to minor folding the rocks are further complicated by numerous minor faults. En echelon, calcite-filled "gash fractures" (Pl. 19, fig. 1) probably indicating subjacent strike-slip movement, are common in these outcrops. Plate 19, figure 2 is a close up view of a more complex set of these fractures.

Three more isolated outcrops occur along the eastern border of the block, northeast of this southernmost exposure. The northernmost outcrop appears to be a northeasterly plunging, tightly folded anticlinal structure cut obliquely across its eastern limb by the eastern border fault. The two outcrops to the south are more open northwesterly plunging anticlinal structures cut nearly normal to their structural axes. The rocks, in places, are highly brecciated and cut by minor faults. The

PLATE 19

Figure 1. Calcite-filled en echelon "gash" fractures in the Isle La Motte beds shown in Plate 18. Looking just north of east. South Hero Island.

Figure 2. Close-up view of a complex set of "gash" fractures in the Isle La Motte beds. Just north of Plate 19, figure 1.

sum total of the minor structure indicates that the major syncline is greatly fluted and complicated by secondary folding and faulting.

In some of the less deformed rocks fossil preservation is very good (Pl. 20, fig. 1). The fossils identified from these beds are

Stromatocerium rugosum
Favistella halli
Lambeophyllum profundum
Rafinesquina alternata
Hesperorthis tricenaria
Maclurites logani
Actinoceras sp.
Trocholites ammonius

Larrabee Limestone

The Larrabee beds outcrop over a considerable area and are probably well exposed from top to bottom. The very base of the unit can be seen overlying the Isle La Motte limestone on the western limb of the severed anticline shown in Plate 17, figure 2. This is the only outcrop which actually exposes the base of the member.

At the Donaldson School and the main road intersection lower Larrabee beds containing a fair abundance of *Sowerbyella*, *Dinorthis* and *Strophomena* are exposed. North of this outcrop, both east and west of the main road, several good exposures of the rocks can be seen. The outcrops east of the road are synclinal in structure and lie just south of *Cryptolithus*-bearing basal Shoreham beds. The rocks west of the main road are much lower in the section and contain such species as *Encrinurus cybeleformis* and *Hemiarges paulianus*. A number of small anticlinal and synclinal structures can be seen here, all of which plunge to the northeast at an angle of about 11 degrees. Several outcrops are present west of here which indicate the underlying anticlinal structure.

A composite faunal list for these rocks would include all of the species listed previously for the Larrabee limestone.

Shoreham Limestone

The Shoreham beds outcrop widely and seem to form a thin veneer at the surface. In the westernmost exposures the underlying synclinal structure is expressed in several outcrops. Dip readings, taken proximal to the "thrust," are very high and all toward the northwest. Near the south end of the Simms Point road several outcrops, replete with lower Shoreham species, are exposed. This horizon can be followed eastward across the anticlinal axis, then southeastward to, and a little beyond, the synclinal axis. In the eastern area of outcrop only two exposures of the Shoreham rocks were found. One of these exposures is located along the

PLATE 20

Figure 1. Two well-rounded coralla of coral (*Favistella halli*) in the Isle La Motte beds in Plate 18. Both coralla are located just above the hammer. South Hero Island.

main road about one mile south of Grand Isle Village. The rocks outcrop in a stream bed and may be followed for a short distance east of the road. The rocks are composed of interbedded dark shale and homogeneous limestone and contain few fossils. Diligent searching revealed the following Shoreham species:

Sowerbyella sericea
Reuschella edsoni
Cryptolithus tesselatus

The northernmost outcrop is located along the first road leading east from the main road south of Grand Isle Village. The beds are composed of finely banded calcarenite and seem to contain no fossils. The age of the beds is questionable, and they could, with equal facility, be placed in the overlying Cumberland Head formation.

Cumberland Head formation

Little can be said about the Cumberland Head formation in Block H, because the beds are seldom found outcropping. The best exposure found

is located in the church yard just south of Grand Isle Village. The beds are composed mainly of dark calcareous shale and contain few, if any, fossils. Two similar, but smaller, outcrops were also found to the west. If nothing else, these exposures show that the Cumberland Head formation in this block extends considerably farther north than those of block G to the west. This apparent offset may be a function of folding as interpreted by Hawley (1952, map). It is the writers opinion, however, that the offset is due to faulting wherein the beds of the upthrown eastern block have moved northward in the direction of dip. This opinion seems to be supported by the rock structure to the south.

Summary

The structural geology of South Hero Island shows that two major belts of folding, separated by a north-south trending fault, are present. The western belt of folding is characterized by relatively broad open folds which plunge toward the north or are doubly plunging north and south. No closed anticlinal structures seem to be present. The eastern belt of folding is characterized by tighter folds, all of which plunge toward the northeast. These tighter folds probably do not extend to any great depth. In both areas, smaller undulations are superimposed on the larger structures.

It is suggested that the fault separating the two belts of folding is an easterly dipping, low-angle thrust. The north-south trending faults of the area appear to be normal and all show downward movement toward the east. The east-west trending faults also appear to be normal and all show downward movement toward the south. Numerous minor unmapped faults are also present in the area. The sum total of faulting on the island has produced a rather complex series of fault blocks, all more or less tilted to the north. The different intensities of folding are attributed to thrusting forces originating in the southeast and moving approximately N 55° to 60° W.

The stratigraphy of the rocks indicates that the Chazyan and Trenton seas occupied an area of tectonic unrest. The frontispiece is a columnar section based upon the sections studied on South Hero Island and Isle La Motte.

Ripple-marked bedding surfaces and widespread outcrop areas indicate that Providence Island time was one of extensive shallow seas. The dolomitic nature of the rocks indicates that the seas were probably restricted.

The early Chazyan seas show a transgression toward the south and west. This is better shown on Isle La Motte, but the transgression is supported on South Hero Island also. Environmental conditions analogous to those found in the epineritic zone of present day seas seem to have existed throughout Chazyan time. Faunal inconsistencies over very short distances as well as organic structures themselves in the Chazyan rocks indicate the existence of reef and interreef environments.

The massive dolomitic deposits of the Lowville and Isle Lamotte seas appear to indicate restricted shallow water conditions. Lagoonal conditions produced by local upwarpings may have been the environment in which these rocks were deposited. Local unconformity and the absence, or at best only questionable presence, of Lowville beds on South Hero Island may indicate warping of the sea bottom and subsequent erosion during Lowville and Isle Lamotte times.

The interbedded shale and limestone of the early Trenton seas indicate further tectonic instability. The faunal inconsistencies between equivalent Larrabee and Shoreham outcrops appear to be more a function of exposure than one of actual lateral environmental change. The tectonic environment indicated by the rocks was probably one of small but repeated pulsations of the ocean bottom. These pulsations appear to have produced minor transgressions and regressions of the contemporaneous seas.

The deposits of the Cumberland Head seas show a more severe tectonic environment both in time and space. Wide variation in both lithology and paleontology were noted. The black shale and dark interbedded limestone appear to represent much deeper water. Stagnant bottom conditions may have obtained in places, for the darker and more shaly parts of the formation consistently show an inverse relationship to actual fossil numbers as well as numbers of fossil species.

Providence Island

The geology of Providence Island, shown on the geologic map, is the work of Brainerd and Seely (in Perkins 1901–02, pp. 139–142; map, Plate LV.). Access to the island was not available to the writer during the course of the field work. Although some other work has been done on the island, that of Brainerd and Seely appears to be the most complete as well as the most reliable. The stratigraphic units reportedly present are the Canadian rocks, Providence Island dolomite (type section) and

some underlying beds, and portions of the Day Point, Crown Point and Valcour limestones.

The island is unequally divided by a northeast-southwest trending fault which shows upward movement of its eastern block. This fault and the "thrust," just to the northeast on South Hero Island, show the same anomalous relative movement and may be continuous beneath the waters of the lake. Should this supposition be true, a still greater sinuosity of the "thrust" trace is demonstrated and a low-angle thrust must certainly be suspected.

The larger portion of the island lies southeast of the "thrust" and is underlain by the Providence Island dolomite and older Canadian rocks. The beds all dip gently to the northeast at an angle of about 5 degrees. The total thickness of Canadian rocks on the island is reportedly 450 to 500 feet. Brainerd and Seely further indicate that these beds are relatively highly fossiliferous. This is in great contrast to the nearly barren Providence Island beds along the south shore of South Hero Island.

Northwest of the "thrust," the island is underlain by rocks of both Canadian and Chazyan age. Some faults, probably normal, slice these rocks into a number of small wedges (see map, Plate LV; Perkins 1901–02, p. 139). The beds show moderate to high dips (7 to 43 degrees) in a north or northeasterly direction.

The northernmost rocks of the island are of Crown Point age and are separated from the Day Point beds, immediately to the south, by one of the minor normal faults. The total thickness of the Day Point and Crown Point beds is given as 230 feet. The dip of the Crown Point beds here and at Phelps Point, 0.15 miles to the north, is similar in direction but somewhat different in magnitude. The Phelps Point dips range from 3 to 8 degrees, those on Providence Island range from 11 to 13 degrees. A minor fault may separate the two areas.

The two westernmost promontories along the northwest side of the island are underlain by rocks of Valcour age. No figures concerning the thickness of the beds were given. Brainerd and Seely do indicate, however, that the beds contain an abundance of the characteristic Valcour brachiopod, *Rostricellula plena*.

REFERENCES

BAIN, G. W., 1934, Calcite marble: Econ. Geol., vol. 29, no. 2, pp. 121–139.

BASSLER, R. S., 1950, Faunal lists and descriptions of paleozoic corals: Geol. Soc. Amer. Memoir 44, 315 pp.

BRAINERD, EZRA, and SEELY, H. M., 1896, The Chazy of Lake Champlain: Amer. Mus. Nat. Hist. Bull., vol. 8, pp. 305–315.

CUSHING, H. P., 1905, Geology of the northern Adirondack region: N. Y. St. Mus., Bull. 95, pp. 271–453.

HAWLEY, L. D., 1952, Ordovician shales and submarine slide breccias of the northern Champlain valley in Vermont: Ph.D. thesis (unpublished) Columbia University.

HUDSON, G. H., 1931, Fault systems of the Champlain valley, New York: N. Y. St. Mus., Bull. 286, pp. 5–81.

KAY, G. M., 1937, Stratigraphy of the Trenton group: Geol. Soc. Amer., Bull. 48, pp. 233–302.

OKULITCH, V. J., 1936, Some Chazy corals: Trans. Roy. Soc. Can., 3rd ser., sec. IV, vol. 30, pp. 59–73.

PERKINS, G. H., 1901–02, The geology of Grand Isle: Rept. Vt. St. Geol., no. 3, pp. 102–173.

——, 1903–04, The geology of Grand Isle County: Rept. Vt. St. Geol., no. 4, pp. 103–143.

QUINN, A. W., 1933, Normal faults of the Lake Champlain region: Jour. Geol., vol. 41, no. 2, pp. 113–143.

RAYMOND, P. E., 1923–24, The oldest coral reef: Rept. Vt. St. Geol., no. 14, pp. 72–76.

RUEDEMANN, RUDOLF, 1921, Age of the black shales of the Lake Champlain region: N. Y. St. Mus., Bull. 227–228, pp. 63–130.

SEELY, H. M., 1903–04, The Stromatoceria of Isle La Motte, Vt.: Rept. Vt. St. Geol., vol. 4, pp. 144–156.

SHIMER, H. W., 1901–02, Petrographic description of the dikes of Grand Isle: Rept. Vt. St. Geol , no .3, pp. 174–183.

SHROCK, R. R., 1948, Sequence in layered rocks: McGraw-Hill, New York, 507 pp.

—— and TWENHOFEL, W. H., 1953, Principles of invertebrate paleontology: McGraw-Hill. New York, 816 pp.

GEOLOGIC MAP AND STRUCTURE SECTIONS OF ISLE LA MOTTE, VERMONT

(Bulletin No. 9)

EXPLANATION

ORDOVICIAN SYSTEM
- Champlainian Series
  - Mohawkian Stage
    - Trenton Group
      - Stony Point Fm. — Omsp
      - Cumberland Head Fm. — Omc
      - Shoreham Ls. — Oms
      - Larrabee Ls. — Oml
      - Isle Lamotte Ls. — Omb
      - Black River Group
      - Lowville Ls.
  - Chazyan Stage
    - Valcour Ls. — Ocv
    - Crown Point Ls. — Occ
    - Day Point Ls. — Ocp
- Canadian Series
  - Providence Island Dol. — Ocp

SYMBOLS

- strike and dip of beds
- horizontal beds
- exposed and inferred contacts
- fault showing downthrown block
- reverse fault showing overthrust side
- organic structures
- extent of glacial cover

PLATE 1

Geology by Robert B. Erwin
1954-1955
Published 1957

VERMONT GEOLOGICAL SURVEY
Charles G. Doll, State Geologist

Topography by U.S.G.S.
Rouses Point Quadrangle - 1939

SCALE

1 ½ 0 1 2 3 4 MILES

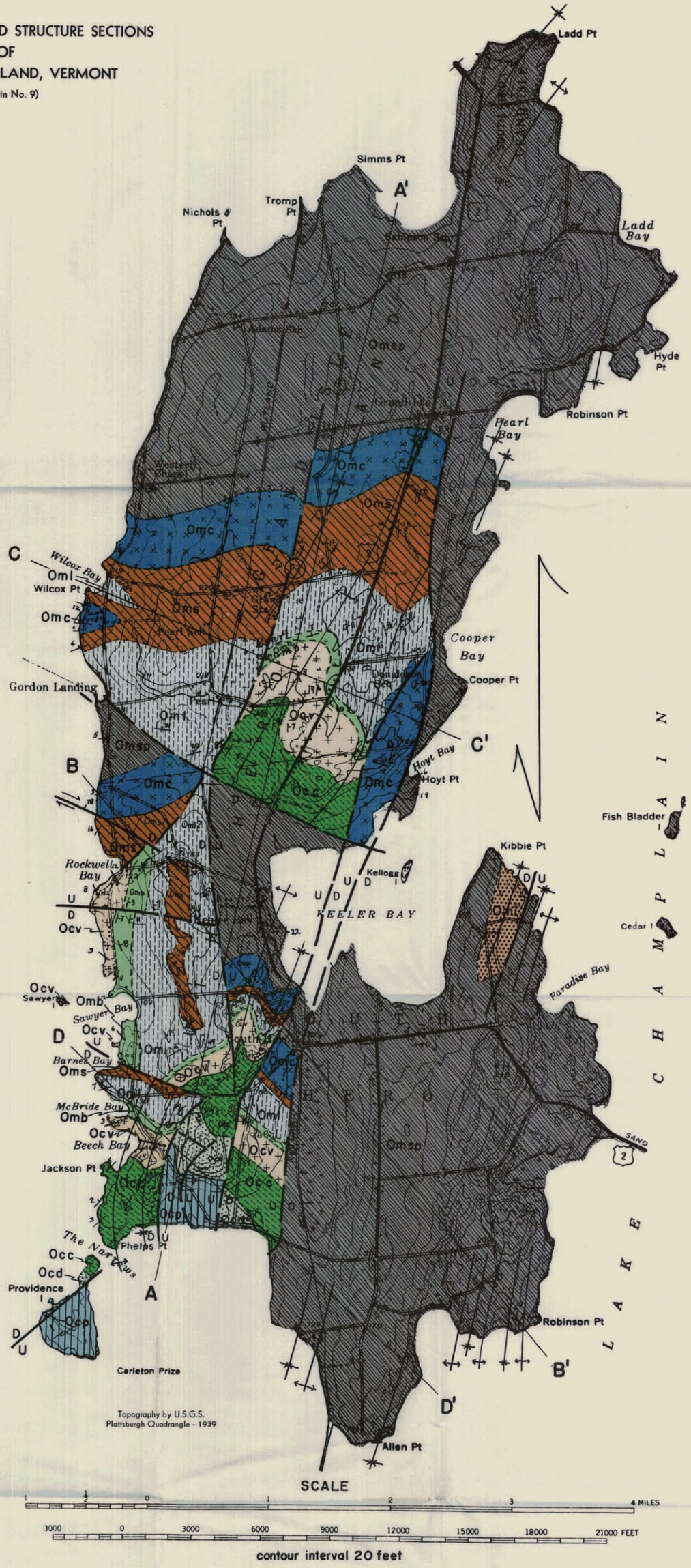
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

contour interval 20 feet

A A'

GEOLOGIC MAP AND STRUCTURE SECTIONS OF SOUTH HERO ISLAND, VERMONT

(Bulletin No. 9)



EXPLANATION

ORDOVICIAN SYSTEM
- Champlainian Series
  - Mohawkian Stage
    - Trenton Group
      - Iberville Fm. — Oml
      - Stony Point Fm. — Omsp
      - Cumberland Head Fm. — Omc
      - Shoreham Ls. — Oms
      - Larrabee Ls. — Oml
      - Isle Lamotte Ls. — Omb
      - Black River Group
      - Lowville Ls. ?
  - Chazyan Stage
    - Valcour Ls. — Ocv
    - Crown Point Ls. — Occ
    - Day Point Ls. — Ocd
  - Canadian Series
    - Providence Island Dol. — Ocp

SYMBOLS

- strike and dip of beds
- exposed and inferred contacts
- fault, dip indeterminate
- strike-slip fault
- synclinal axis
- anticlinal axis

PLATE 2

Geology by Robert B. Erwin
1954-1955
Published 1957

VERMONT GEOLOGICAL SURVEY
Charles G. Doll, State Geologist

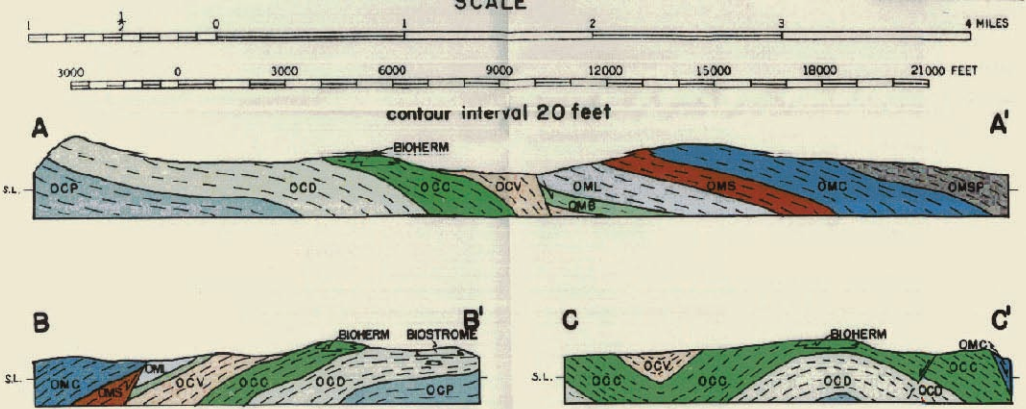
Topography by U.S.G.S.
Plattsburgh Quadrangle - 1939

SCALE

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

contour interval 20 feet



VERTICAL EXAGGERATION = 7.5X

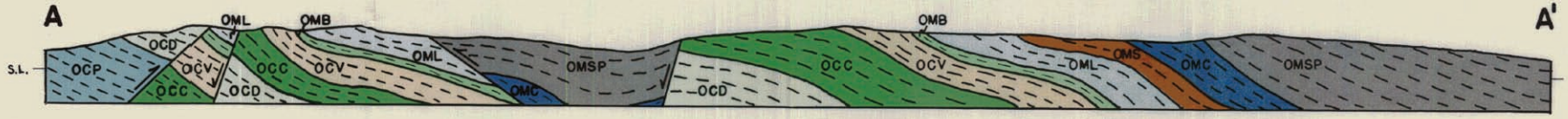
HORIZONTAL EXAGGERATION = 1X

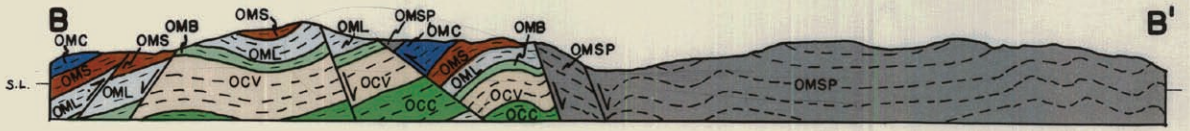
SCALE

1 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

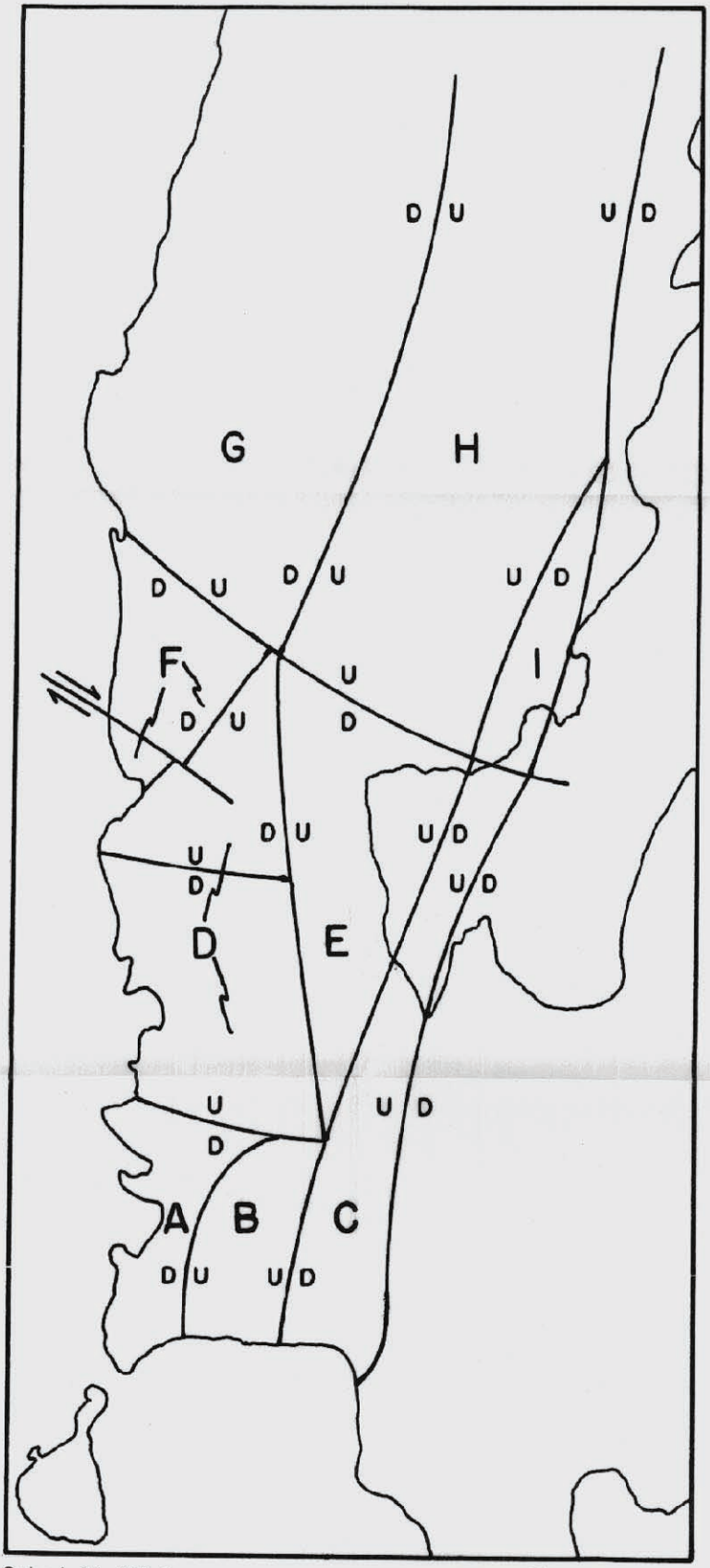
contour interval 20 feet





VERTICAL EXAGGERATION = 7.5X
HORIZONTAL EXAGGERATION = 1X

INDEX MAP TO SOUTH HERO FAULT BLOCKS



Geology by Robert B. Erwin
1954-1955
Published 1957

PLATE 2a

VERMONT GEOLOGICAL SURVEY
Charles G. Doll, State Geologist

(Bulletin No. 9)