THE PALEOECOLOGY OF CHAZYAN (LOWER MIDDLE ORDOVICIAN) "REEFS" OR "MOUNDS"

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REEFS AS BIOLOGIC COMMUNITIES

Geologists have commonly concerned themselves with reefs as a problem in the building and maintenance of a framework in the face of the destructive effects of wave-energy. From the point of view of the reef organisms the paramount aspect of the reef environment may well be the opportunities it provides for interactions between organisms. To use an analogy which may be appropriate on many levels, the former approach is like viewing a city as a problem in architecture, while the latter is like viewing a city in terms of social interactions. What draws people to cities is that they provide a maximum availability of functional relationships, or to use the equivalent biological term, of ecologic niches. The high population density of a city, as well as of a reef, is both the necessary condition for such functional diversity as well as an ultimate result of it. A measure of the uniqueness of a reef as a focus of energy transformation is shown by the fact that its long-term average rate of primary productivity by photosynthesis is the highest of any living aquatic ecosystem, except for short-term peaks, largely in polluted fresh-waters.

Table: Average primary productivity of aquatic ecosystems calculated from gas exchange (Odum, 1959)

Ecosystem	Production (g dry organic matter/m^2/day)
Infertile open ocean, Pacific	0.2
Shallow, inshore waters, Long Island Sound	3.2
Estuary, Laguna Madre, Texas	4.4
Fresh-water lakes (various)	0.3-9.0
Silver Springs, Florida	17.5
Coral reefs, average 3 Pacific reefs	18.2

To paleontologists fossil reefs have a two-fold importance. For one, they are a sample of the marine life of the time at its most complex and diverse. For another, they are, so far as the sessile benthos goes, a true natural community, and enable one to avoid one of the perennial questions of paleoecology: "Is this community truly in place and representative of its environment?" The answer can only be a resounding "Yes".

As with cities, one of the important problems of a reef is the pollution of its environment by its own metabolism. In particular, the depletion of oxygen and the production of nitrogenous wastes, are the most acute problems. The solution adopted by the inhabitants of modern coral reefs is the development of a symbiosis with certain phytomastigophora, termed zooxanthellae, which live in the tissues of reef organisms and have been shown to absorb nitrogenous materials. In living coral reefs zooxanthellae are present in scleractinians, sponges, and even the giant clam Tridacna. It is likely that the Scleractinia had this adaptation well back into the Mesozoic, for hermatypic Scleractinia and their reefs go back at least to the Jurassic, and they form the last part of an ecologic succession, or sere, in late Triassic reefs (Sieber, 1937). Whether this was true of Paleozoic reef organisms is not known. Certainly, calcareous algae were present in Paleozoic reefs and have continued to those of the present day. These free-living algae also contribute to oxygen replenishment and nitrogenous waste absorption. They must have been as essential to ancient reefs in this metabolic function as well as in their well-known frame-building properties.

TROPHIC RELATIONS IN THE CHAZY REEFS

The principal reef-building organisms of the Chazy reefs are stromatoporoids (Cystostroma, Pseudostylodictyon or Stromatocerium), lithistid sponges (Zittelella, Anthaspidella), tabulate corals (Lamottia or Lichenaria, Billingsaria, Eofletcheria), bryozoa (Batostoma, Cheiloporella, Atactotoechus), and calcareous algae (Solenopora, Sphaerocodium or Rothpletzella, Girvanella). In addition, a trilobite (Glaphurus) and numerous pelmatozoan fragments are found in such intimate physical association with the reef as to be likely inhabitants of its surface. The large gastropod, Maclurites, and many genera of large nautiloids, are very abundant in the pelmatozoan-brachiopod calcarenites between the reefs, and in channels cut into the reefs, but there is no direct evidence that they actually lived on the reef while it was active. However, their presence in the near vicinity suggests that they participated in the overall food chain.

Unlike modern reefs, in which macrophagous, carnivorous coelenterates are the dominant element, and feed upon an abundant fauna of small nekton, these middle Ordovician reefs are dominated by suspension feeders. This is especially true when one considers the recent reinterpretation of stromatoporoids as sponges (and therefore suspension-feeders) (Hartman and Goreau, 1966, in press, and personal communication) belonging to a little-known group that today participate in living coral reefs. The only possible non-suspension feeders in the Chazy reefs are the tabulate corals, presumably carnivorous, and the trilobite, which is possibly a detritus-feeder (if not a suspension-feeder).

The off-reef Maclurites is an archaeogastropod, and presumably grazed on algae. It is the largest of the primary consumers of the Chazy beds. The nautiloids may have fed on the Maclurites. If so, they ate the soft parts without breaking the shells, for most of the large shells are whole. The possibility that some of the nautiloids "grazed" on the sessile benthonic invertebrates should not be discounted, for these middle Ordovician cephalopods are not far removed in evolution from the late Cambrian ellesmeroceratids, whose short, relatively non-buoyant shells indicate a vagile benthonic adaptation. Although the Chazyan nautiloids had buoyant shells and were probably good swimmers, they may have retained an interest in bottom feeding. Apart from the cephalopods we have no evidence for other large carnivores.

The Chazy reefs are thus a community in which the benthos was fed primarily from suspended matter or plankton. Even the corals had very small polyps and could not have eaten anything very much larger than a few millimeters across. This is surely a reflection of the paucity of larger nekton or vagile benthos on which to feed. Only the snails and cephalopods provide a larger fauna, and may have formed a side loop to the general food chain, the cephalopods feeding primarily on the snails.

Reefs earlier than the Chazy consist only of algae, or else include certain primitive possible sponges, such as Archaeocyatha and Calathium, which were not likely to be anything other than suspension feeders. In the Silurian, corals become much more important, and one begins to see carnivorous macrophagy becoming a more important element in the trophic relationships of reef faunas. Silurian reefs are still dominated by tabulate rather than rugose corals among the carnivores, and thus consumed mainly small vagile animals. The suspension feeding element (bryozoa, stromatoporoids) is also still strong in Silurian reefs. It is not until Devonian times that the large rugose corals become a dominant element in reefs, probably not without connection with the fact that this was the first time that fish and other large nekton appear in abundance.

DEVELOPMENT OF REEF FAUNAS

Within the Chazy group the reef faunas show a progressive increase in diversity with time (Pitcher, 1964). The earliest reefs, in the lower Day Point Formation (Scott Member), are built of bryozoans only, and chiefly of one species, or at most two. These early benthic concentrations are, like their predecessors, of suspension feeders only. In the middle of the Day Point (Fleury Member) the Lamottia bistrome, introduces the oldest-known coral in the world, which is also the oldest-known sessile carnivore with a skeleton. (The only older sessile carnivore is a possible anemone from the middle Cambrian Burgess Shale, and the only older vagile carnivores are the early Ordovician starfish, and the late Cambrian and early Ordovician nautiloids). It is possibly at this moment in the history of the earth that it first became profitable for a carnivore to sit and wait for its food to come to it. This coral appears to have lived in a different environment from the bryozoa, although probably nearby. The corals are often fragmented and the fragments overgrown by bryozoa. Pitcher (1964, p. 648) considers the corals to have been transported into the area of outcrop, and there to have acquired their coatings of bryozoa.

In the latest Day Point, immediately above the Lamottia bed, bryozoan mounds again develop, not much different from before except that occasional individuals of the lithistid sponge Zittelella foreshadow the richer fauna of the Crown Point.

In all the Day Point reefs algae are seemingly missing and one can scarcely speak of these assemblages as functionally integrated communities. In the Crown Point Formation the reef faunas are more diverse, and include algae, stromatoporoids, lithistid sponges, and corals (Billingsaria, not Lamottia) along with the bryozoan species that built the earlier mounds. The algae were not immediately available to the reef animals for food, but probably performed an anti-pollutant function. They may have been eaten by soft-bodied meiobenthos which were subsequently consumed by the corals, but the principal flow of organic matter must have been from the phytoplankton directly, or through zooplankton, to the reef animals, and from there, through the intervention of bacteria, back to the benthic algae and to the phytoplankton as dissolved molecules, or recycled through the sponges in the form of whole bacteria, which may be a principal food of sponges. (Rasmont, in Florkin & Scheer, 1968, Madri, 1967). That the Crown Point environment was in general one of a high trophic level is demonstrated by the abundance of the large snail Maclurites magnus, which is virtually a guide fossil to the formation, as well as of the large nautiloids that may have fed on it. The abundance of algae outside the reef environment (dead Maclurites and nautiloid shells are frequently encrusted by them) undoubtedly provided a firm base for the overall food chain as well as a food supply for the Maclurites.

In the Valcour Formation the faunal complexity is maintained and some new species are introduced in the non-reef environments.

The Crown Point reefs are the earliest reefs that can be considered functionally-integrated communities. It is worth noting that the animals that populate them (stromatoporoids, lithistid sponges, tabulate corals, and bryozoa) are very nearly the earliest-known representatives of their respective taxonomic groups.

The abundance of sponges in the Crown Point and early Valcour reefs deserves consideration, for it can be related to the general evolution of hermatypic organisms. Sponges are not common reef-building animals. During the periods when tabulate and rugose corals were abundant, and during the periods when the scleractinians were abundant, including today, sponges were a very minor element in the construction of reefs. It is only before the corals first become abundant (before the Silurian), and also during the interval between the decline of the Paleozoic corals and the rise of the scleractinians, (Permian and Triassic), that sponges were important reef builders. This statement leaves out the stromatoporoid sponges, which managed to coexist with the Paleozoic corals through the Silurian and Devonian, though often in different reefs, and presumably in different environments. The bryozoans show a similar inverse relationship to the corals, but seem to have been sturdier competitors than the sponges. Bryozoa are still present in Silurian reefs alongside corals and stromatoporoids, though they tend to be replaced by the latter in ecologic successions (Lowenstam, 1957). In Devonian times bryozoans are rarely present in reefs, but reappear to some extent in the Permian (Zechstein of Germany) when corals declined.

In the Cambrian the calcareous Archaeocyathids participate in reefs, and in the early Ordovician, Calathium (a receptaculitid) does. The sponges of the Chazy beds are of interest in that they are lithistid demosponges with a siliceous skeleton (now completely calcified). The middle Ordovician (Chazyan and Black River) is the only time during the Paleozoic that siliceous sponges were significant frame builders. This time coincides with the first radiation of the lithistid demosponges. It may be that the higher rate at which stromatoporoids, corals and bryozoa could secrete calcium carbonate skeletons was the reason for the disappearance of lithistids from the later reefs. When the corals declined at the end of the Paleozoic it was the calcareous Sphinctozoan sponges that replaced them as important reef-builders, in Permian and Triassic times, along with the ever-present calcareous algae.

It should be noted that most lithistid sponges, although their skeletons are rigid, do not by themselves bind sediment or build up massive structures. In the Crown Point reefs sediment-binding was probably carried on only by stromatoporoids, laminar bryozoa, corals, and calcareous algae. Nevertheless, the lithistids cover, on the average, from 22% to 50% of the surface of the reefs in which they are most abundant (Pitcher, 1964, pp. 662, 675). They thus contributed significantly to the bulk of the reef mass. They also served to trap sediment. That this by itself can be a potent factor in mound formation is indicated by the late Jurassic sponge "reefs" of Germany (Roll, 1934) in which siliceous sponges built mounds apparently solely by trapping sediment and without the significant presence of binding organisms. These Jurassic mounds are the only known examples of siliceous sponge reef-like structures in post-Paleozoic times.

It is possible that some of the laminar Anthaspidella was actually of encrusting habit and may have helped to bind other skeletal material, but its role would have been minor compared to that of the more abundant binding organisms.

ECOLOGIC SUCCESSION

Ecologic succession in the Day Point reefs can hardly be said to exist, since the reefs consist only of one species of bryozoan. The encrusting of the coral Lamottia by the bryozoan Batostoma is probably not true succession if the corals are not in place. It is worth noting, however, that the Lamottia bed is immediately succeeded by Batostoma reefs which were built on the coral debris (Pitcher, 1964, p. 650) as shown by cores.

In the more complex Crown Point reefs no clear succession is evident though there are suggestions of it. The stromatoporoid Pseudostylidocton frequently forms small reeflets by itself, resting on pelmatozoan calcarenite. It also often forms the basal parts of larger reefs, together with subordinate ramose bryozoa. Subsequently there succeeds a more diverse fauna of the lithistod sponges Zittelella and Anthaspidella, the coral Billingsaria, the bryozoan Batostoma and a flora of Sphaerocodium and Solenopora. Some reefs on Valcour Island end with this community. Others on Isle La Motte often have a capping of Pseudostylodictyon alone. In this mature reef community the lithistid sponges and the stromatoporoids occupy by far the largest surface area. Billingsaria, bryozoans and the algae are distinctly subordinate. The stromatoporoids can be considered to form a pioneer community which initiates reef development. It apparently provides a favorable substrate for the lithistid sponges and for the encrusting corals, bryozoans and algae. The lithistid sponges (Zittelella, Anthaspidella) can be quite common in the calcarenites away from the reefs, and therefore do not need the stromatoporoids as a base. Their participation in the reef is facultative rather than obligatory. The development of this rudimentary succession may be a matter of building up into somewhat shallower water, as is suggested by the change from ramose to laminar algae. It may also be a matter of the development of a firmer substrate than is provided by the surrounding shell sand. Biotic factors, such as the availability of food, probably also enter into the picture. Laminar algae, favored in their growth by a hard substrate, may attract herbivorous meiobenthos, which may in turn provide abundant food for Billingsaria, and indirectly, more bacteria for the sponges.

In the Chazyan mounds of Quebec, a better-defined ecologic succession has been ascertained (see accompanying paper of Toomey and Finks). Here pioneer communities of the encrusting bryozoan Batostoma are succeeded by a mixed bryozoan-coral community (Batostoma, Chazydictya, Billingsaria, Eofletcheria). Finally the corals (Billingsaria or Eofletcheria) become dominant over the bryozoans at the top of the mound, perhaps a foretaste of things to come.

COMPETITION

Bryozoans tend to show a somewhat inverse relationship of abundance with reference to stromatoporoids and sponges (Pitcher, 1964, fig. 44) suggesting competition, as might be expected from the fact that they are all suspension feeders. At the top of the Crown Point, bryozoan reefs occur side by side with stromatoporoid-lithistid reefs. They tend to dominate the Valcour reefs again, almost as they did in the earlier Day Point. The variability of the proportions of reef organisms in the Crown Point from one reef to the next, also suggests that there was near-equality in competition between many of these organisms. At least one reef in the pasture on Isle La Motte is composed of 50% Billingsaria throughout (Pitcher, 1964, p. 666). Other reefs in the same pasture contain, on the surface, anyway, about 50% lithistid sponges (Zittelella, Anthaspidella). The corals and the sponges did not compete for food but they probably competed for substrate space. Occurrences of Billingsaria and Zittelella together on the flanks of reefs in this same pasture indicate that they had the same environmental tolerances.

VERTICAL ZONATION

In the early Day Point byrozoan mounds, the mounds are built of laminar Batostoma or Cheiolporella, while the interreef areas contain abundant branching Atactotoechus. This may be considered a rudimentary sort of depth zonation, with the branching bryozoa occupying the deeper quieter water, and the laminar bryozoa the rougher shallower zones. However, the total relief at any one time was scarcely more than a foot or two (see Pitcher, 1964, fig. 10) and the differences in wave energy could not have been very great. Nevertheless, the presence of branching bryozoa, along with stromatoporoids, in the basal parts of Crown Point reefs, and their replacement by laminar bryozoa higher up (Pitcher, 1964, fig. 8) suggests that there may be something to this form distribution in relation to depth. Certainly in living sponges, corals and bryozoa there is a similar confinement of branching forms to the less rough water areas.

The surface distribution of organisms on a Crown Point mound was studied by Pitcher (1964, fig. 26) from the low flanks up to its crest. This should reflect bathymetric differences. He found that the stromatoporoids were most abundant at the crest, the bryozoa most abundant somewhat lower down, and the corals and lithistid sponges most abundant still lower on the flanks with the sponges remaining abundant further down than the corals. This again would correspond to a well-known pattern of morphological distribution., with the conical or cup-shaped lithistids (Zittelella) being characteristic of quieter, deeper water, while the laminar bryozoans, corals and stromatoporoids are characteristic of rougher water. The total vertical relief involved is scarcely six feet, and except for the absence of stromatoporoids at the base and the absence of lithistids and bryozoa on the crest, all the forms occur over the whole reef. Thus the environmental differences cannot have been very great.

A more pronounced bathymetric differentiation may be shown by some of the Crown Point reefs on the southwest shore of Valcour Island, on the point of land north of the concrete boat dock. Here the flanking beds pass laterally into dark calcilutites with numerous hexactinellid sponge root-tufts and body fragments. These are much more delicate sponges and may have occupied a depressed area with genuinely quiet water peripheral to the reef.

ORIENTATION AND CURRENTS

Bryozoan mounds in the Day Point (Pitcher, 1964, fig. 19) and stromatoporoid reeflets in the Crown Point (on both Isle La Motte in the Goodsell Quarry, and on the mainland at Sheldon Lane) tend to have a roughly north-south orientation. This is parallel to the paleoshore, and the mounds may have grown either in belts of optimum depth or into the set of longshore currents. An indication that currents may be involved is shown by the fact that hexactinellid sponge root-tufts in non-reefy beds of the Crown Point at South Hero, Vermont (Pitcher, 1964, fig. 32) show the same preferred orientation on the bedding planes. Orthocone nautiloid shells are less clearly oriented in a preferred direction, but in the Crown Point of Isle La Motte and South Hero (Pitcher, 1964, fig. 32) they show a broad peak at about 45° to a N-S line, perhaps the result of some being rolled around to a position perpendicular to the current while others were swung parallel to it.

In the channels that cut the Crown Point reefs, nautiloid shells are most commonly oriented parallel to the axis of the channel, obviously parallel to currents sweeping through. Maclurites shells are also often piled together in pockets in these channels, probably as a result of current action. The channels, however, may not be strictly contemporary with the reefs they cut.

Channels

The Crown Point reefs are cut by numerous channels, mostly one to three feet wide and as much as two feet deep, filled with a black calcarenite that contrasts sharply with the light calcilutite of the reef rock. There is a considerable body of evidence that these channels may have been formed subaerially by solution, possibly by enlargement of tectonic joints, following consolidation and diagenesis of the reef rock. The entire sequence of events would have to have taken place entirely within Crown Point time, perhaps several times. The evidence is as follows:

1. The channels have sharp boundaries against the reef rock along smooth surfaces that cut through the middle of stromatoporoid colonies, lithistid sponges, and calcilutite matrix in a continuous sweep. The matrix must have been consolidated, and the lithistid sponges may have already been changed from silica to calcite, for they show no effects of differential hardness on the erosion surface.

2. The channels usually end in rounded culs-de-sac, or sometimes have an ovoid shape, suggesting either pothole-like abrasion or sinkhole-like solution. There are essentially no quartz clasts in the surrounding sediments, so that abrasion would seem to be unlikely, thus leaving solution as the alternative.

3. The channels tend to intersect at close to right angles and most frequently, though by no means universally, are oriented roughly north-south and east-west. This suggests that they may follow a tectonic joint pattern. Participants in the trip are invited to compare the form of the channels with that of solution-enlarged joints now being eroded in the same rock.

4. If the channels were surge channels present in the active reef, we would expect to find them bordered with at least some entire outlines of reef-building organisms, or where these were broken by contemporary wave-action, to find that the broken outlines, and the margins of the channel as a whole, would be irregular rather than smooth.

Because the calcarenite filling the channels contains Crown Point guide fossils identical to those beneath and to either side of the reef, and because such channeled reefs occur at more than one level within the Crown Point beds in the same area, we must assume that the entire process postulated took place repeatedly entirely within Crown Point time. If Crown Point time is assumed to be one-third of Chazy time, and that one-sixth of Ordovician time, and Ordovician time to be 60 million years long, then we have 3.3 million years for these processes to take place in. Admittedly this may be hard to swallow, and we have not had the opportunity to test the hypothesis adequately, but participants in the field trip may wish to think about these possibilities while examining the outcrops.

ITINERARY

The walking-tour will start at the north end of the picnic ground and trailer camp on the north side of Wait Bay in southeastern Isle La Motte. It may be reached by following the main north-south road down the center of Isle La Motte to its southern end, turning left (east) to the trailer park entrance, and then turning left (north) up the hill to the picnic ground. Please note that the entire trip is on private property, and that permission must be secured from the landowners for visits.

Cross the fence and walk north to the bare exposures of the Lamottia biostrome in the Fleury Member of the Day Point Formation. CAUTION! DO NOT STEP INTO SOLUTION-ENLARGED JOINTS. SOME ARE PARTLY CONCEALED BY VEGETATION. WALK ONLY ON BARE ROCK SURFACES. THE JOINTS ARE OVER A FOOT DEEP.

The hemispherical to discoidal heads of Lamottia are closely packed in a calcarenite matrix. Joints offer an opportunity to observe their orientation in section. More than half are overturned over much of the area. Many are broken. The proportion of broken ones increases to the north and east, where the biostrome passes into calcarenite with ever fewer and smaller fragments of Lamottia. In the central area of the exposure there are belts some 10 feet wide in which fragmentation, proportion of overturned specimens, and quantity of calcarenite matrix, are higher than elsewhere. These may represent surge channels. In the peripheral area to the northeast one may see much laminar Batostoma chazyensis surrounding the Lamottia fragments.

This is the type locality for the genus Lamottia Raymond, 1924. Although Raymond's description of this bed as the "world's oldest coral reef" may be disputed, it still seems to be unchallenged as the world's oldest occurrence of corals of any kind.

Walk northwestward upsection, so far as fence lines, cultivated fields, and vegetation permit. DO NOT DISTURB FENCES OR LEAVE GATES OPEN! NO SMOKING WHILE WALKING THROUGH THE FIELDS; THERE IS A DANGER OF FIRE. ALSO, PLEASE KEEP OFF CULTIVATED GROUND.

At about 2000 feet N 45° W of the Lamottia outcrop, we will find small mounds of Batostoma chazyensis at the top of the Day Point Formation. They tend to show a N-S alighment. the zoaria are mostly branching rather than laminar. Possibly this is a deeper water environment than that of the Lamottia biostrome.

Continue to walk northward to a small dirt road, then walk west along it to a T-junction with a larger dirt road. Turn left and follow it southwest to a house and barn on the right. We will enter a gate into the large pasture behind the house and barn. Mr. Ira LaBombard, the present owner of the property, has kindly given us permission to enter his pasture to study the reefs in the Crown Point and lower Valcour Formations. He has requested, as a condition of permission, that NO SPECIMENS WHATEVER be collected. PLEASE RESPECT THIS ORDER. We will have an opportunity later in the day to collect from these same beds at another locality. The fossils are so beautifully displayed here that relationships may be seen without disturbing the rock. They may be photographed very advantageously on the glacially polished surfaces.

The reefs exposed here are mainly in the Crown Point formation and are the ones intensively studied by Pitcher (1964). You may examine contemporaneous reefs by walking northeastward along strike. You may examine successively younger reefs by walking northwestward upsection (dip is about 10° NW).

The reefs are exposed as mounds of light rock. The calcarenite between the reefs, and filling the channels in the reefs, is nearly black. The reefs outcropping nearest the fence were mapped by Pitcher as his Assemblage A, consisting of the stromatoporoid Cystostroma and the alga Solenopora. Those beyond to the northwest, and covering most of the pasture up to a distinct linear rise in ground, belong to Pitcher's Assemblage B. These show interesting variations from reef to reef as well as changes in faunal distribution from flanks to tops of the mounds. The fauna consists of the stromatoporoid Pseudostylodictyon eatoni, the lithistid demosponges Zittelella varians and Anthaspidella sp., the tabulate coral Billingsaria parva, the bryozoan Batostoma chazyensis, and the calcareous algae Solenopora, Sphaerocodium and Girvanella.

The fossils may be identified readily on weathered surfaces as follows:

1. Pseudostylodictyon eatoni: Large whitish masses with fine, dark laminae forming concentric patterns about centers an inch or two apart. These concentric patterns represent the mamelons and their small size is characteristic of the species.

2. Zittelella varians: Circular, dark gray bodies two to three inches in diameter, with a central circular light area representing the matrix-filled cloaca, and radial light areas, or ovoid dots, a few millimeters wide, representing the canals. In longitudinal section, the sponge is conical, and oblique sections will show the expected intermediate shapes. Some specimens have an irregular outline in cross section.

3. Anthaspidella sp.: Similar to Zittelella in color and texture, but shaped like long sinuous bodies, an inch or so thick and several inches long, when seen in cross section. A surface view of the sheet-like sponge shows a somewhat irregular mass with-

out a cloaca. The complete sponge has a short stalk, the whole being shaped somewhat like a distorted cake-plate. The open, "spongy" texture may help when shape fails. Needless to say, the shape and geometric arrangement of the spicules in thin section is necessary for a secure identification. Not every shapeless mass is a sponge.

4. Billingsaria parva: Small, black, oval patches, a few inches across. The dark color is very distinctive. Close inspection with a hand lens will reveal the stellate outlines of the corallites with their characteristic septal ridges.

5. Bryozoa: These weather white, either as small, branching twiglets, or as laminated sheets. Identification requires thin sections, but the outlines of the zooecia are usually visible on the weathered surface and suffice to identify it as a bryozoan.

6. Solenopora: White concentric circles, often sparry. A few inches across. This is the most common form of Solenopora seen on the reef surfaces.

7. Girvanella: Small black ovoid bodies, less than an inch in length. These are oncolites, or algal-coated shell fragments.

8. Maclurites magnus: Large coiled shells a few to several inches across. No septa. The shell substance is white in cross section.

At the rise in ground is a one-foot stromatolitic layer with many orthocone cephalopods. Pitcher called this his Assemblage C and assumed it was laid down as a blanket during a relative drop in sea level. It forms a dip slope through which appear, apparently, the tops of Assemblage B mounds, as well as small mounds of Batostoma chazyensis alone which Pitcher called Assemblage D. At the west end of this cuesta-like feature, nearest the main road, a good cross section of an Assemblage B mound is exposed (see Plate 2).

Down the dip slope, above a ten-foot interval of grey calcarenites, are mounds in the lower part of the Valcour Formation. Theyare composed of Batostoma campensis, together with the alga Solenopora. Some Zittelella may be found. The bryozoa are clearly dominant.

Walk northeastward along strike for about a half-mile, observing Crown Point mounds as you go. You will eventually reach the Goodsell Quarry, operated by the Vermont Marble Company. The quarry is opened in the lower beds of the Crown Point which are relatively lacking in reefs except for small stromatoporoid-algae mounds. The quarry has been intermittently active, and the stone, which makes a beautiful black marble when polished, has been widely used as an interior trim. The rock weathers light gray, and has also been used locally as a dimension stone. It was used to build the old border fort, Fort Montgomery, visible from the Rouses Point bridge.

CAREFULLY avoiding falling into the water-filled quarry, one may observe vertical sections through stromatoporoid-algal mounds and their relationships with the surrounding calcarenite (see Plate 5). By tracing laminae from the mounds into the surrounding sediment, one can see that the mounds never stood more than a foot or two above the sea floor at any one time, though the total thickness is much greater because of the persistence of the mound population on the same spot. On the quarry benches, especially the glacially polished upper surface, one may see plan views of mounds and note their tendency to a N-S lineation. On these surfaces also, especially when wet down, one may see orthocone and other nautiloid shells, and Maclurites shells, overgrown by algal coatings.

This ends our examination of the Isle La Motte exposures. On our way back we will stop at the Sheldon Lane section, south of Chazy, where we may collect from the Crown Point and lower Valcour, in essentially the same facies.

The Sheldon Lane beds dip north. We will begin with cross-bedded upper Day Point (Fleury) calcarenite at the south end and walk through the entire Crown Point section including reef mounds with the same fauna as in LaBombard's pasture. North of the road is an old quarry in which the lower Valcour is well exposed.

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We wish to thank Mrs. Malvina Bruley and Mr. Ira LaBombard of Isle La Motte, for permission to visit the classic exposures of reefs on their respective properties. Their cooperation has made this excursion possible.[1]

[1] I am indebted to Mr. Rodney V. Balasz for information concerning possible channels in the Lamottia biostrome, and to my paleontology class for mapping some of the channels in the various reefs in the fall of 1968 (RMF).

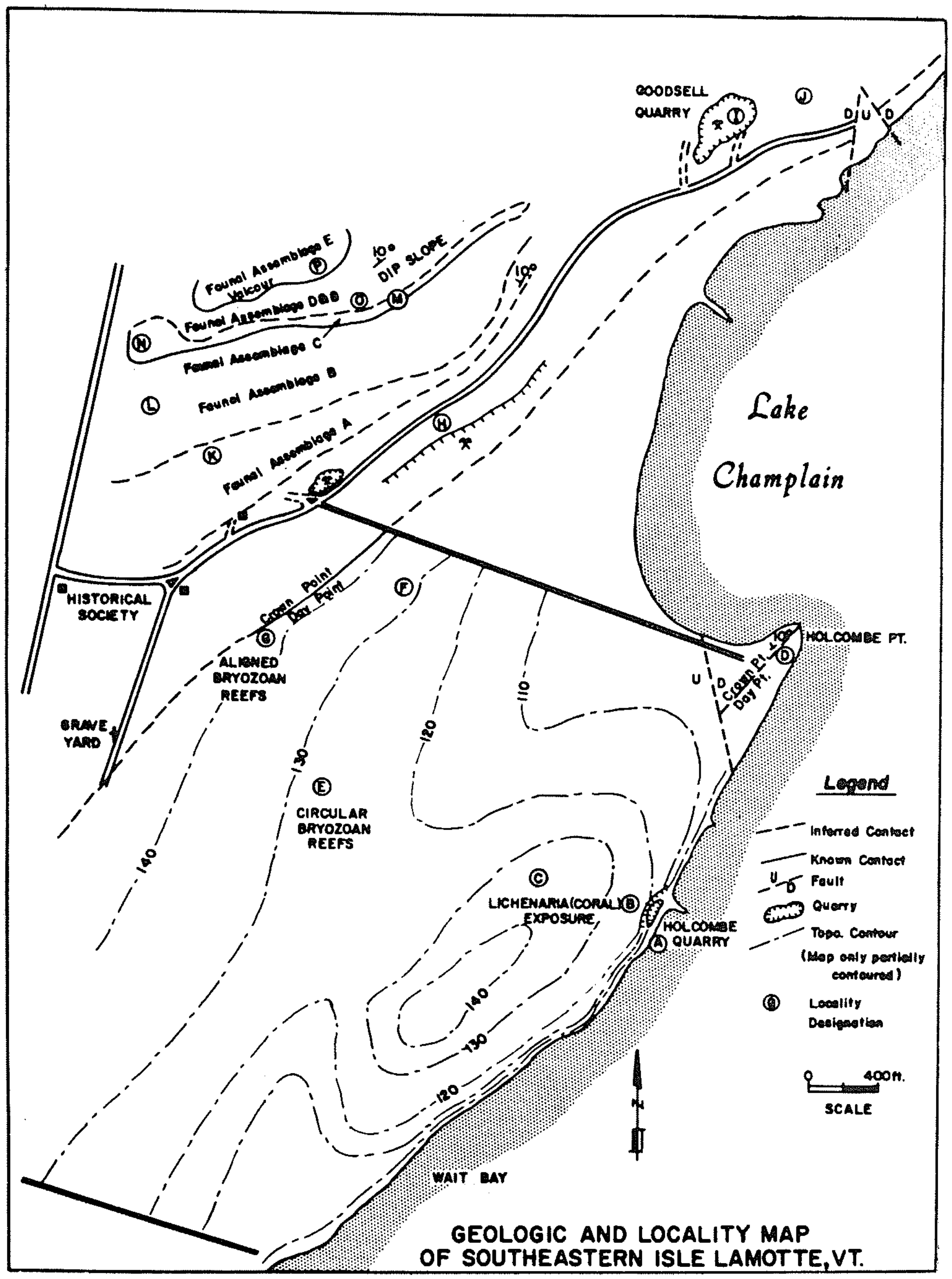


Figure 1. Geologic and locality map of Southeastern Isle La Motte, Vermont. After Pitcher, 1964.

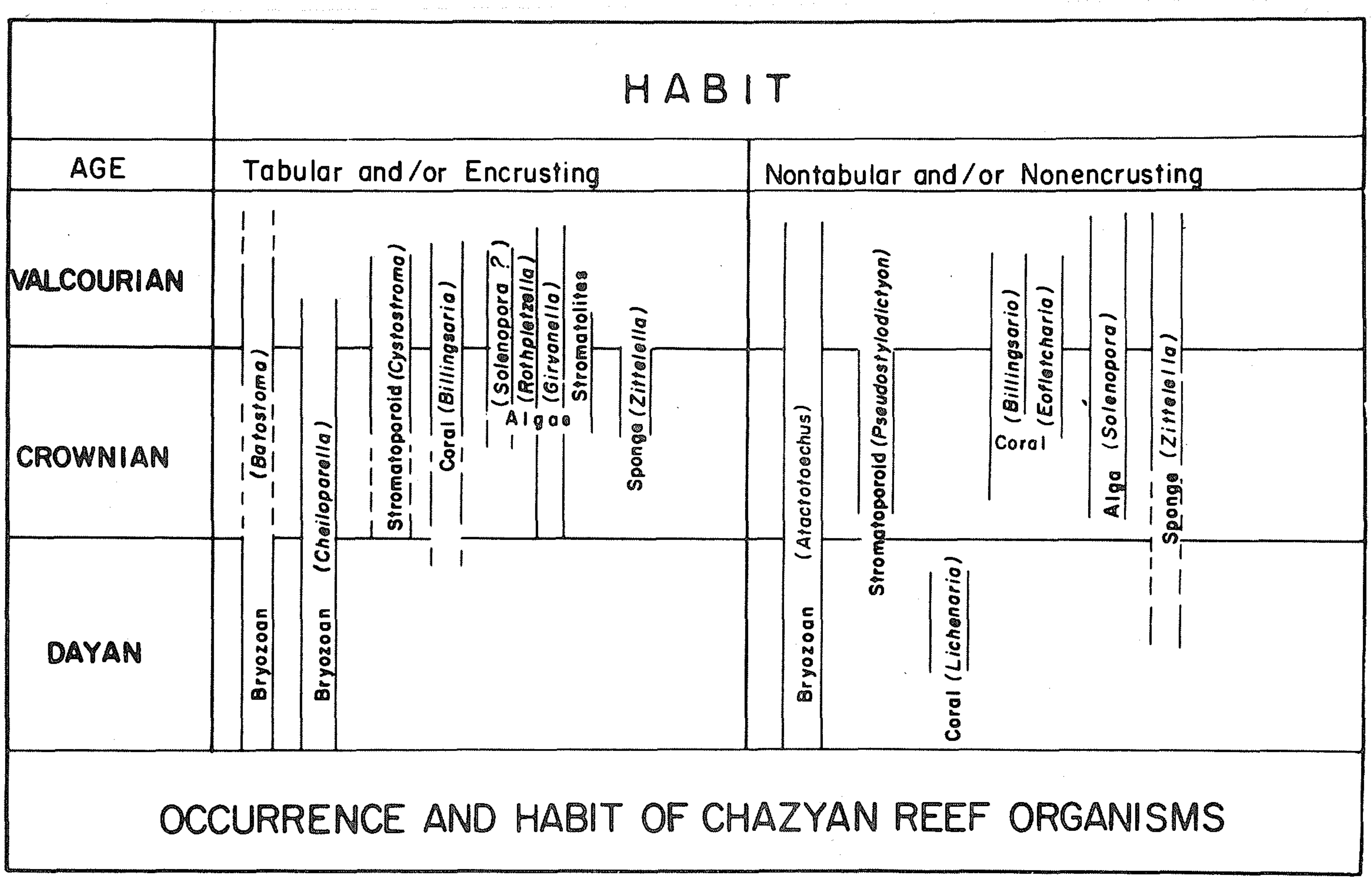
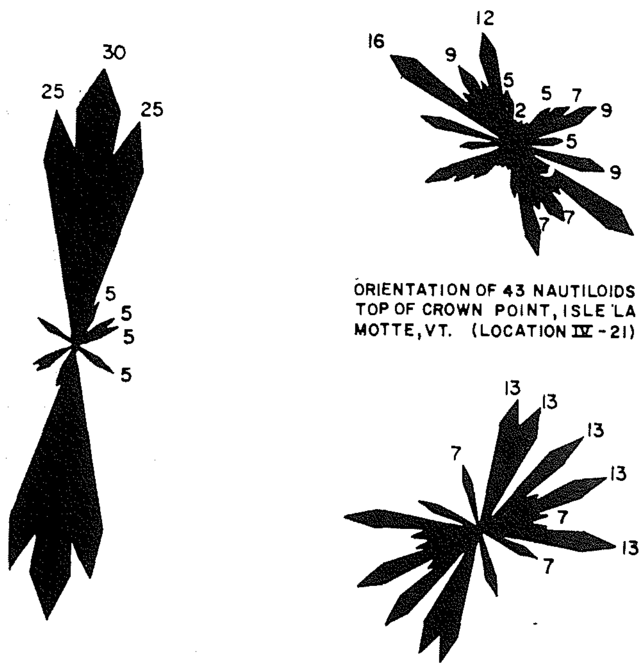


Figure 2. Occurrence and habit of Chazyan Reef organisms. After Pitcher, 1964.



ORIENTATION OF 20 SPONGE ROOT TUFTS TOP OF CROWN POINT, SOUTH HERO, VT. (LOCATION III - 6)

ORIENTATION OF 43 NAUTILOIDS TOP OF CROWN POINT, ISLE LA MOTTE, VT. (LOCATION IV - 21)

ORIENTATION OF 15 NAUTILOIDS TOP OF CROWN POINT, SOUTH HERO, VT. (LOCATION III - 6)

Figure 3. Orientation of Crown Point sponge root-tufts and nautiloids. After Pitcher, 1964.

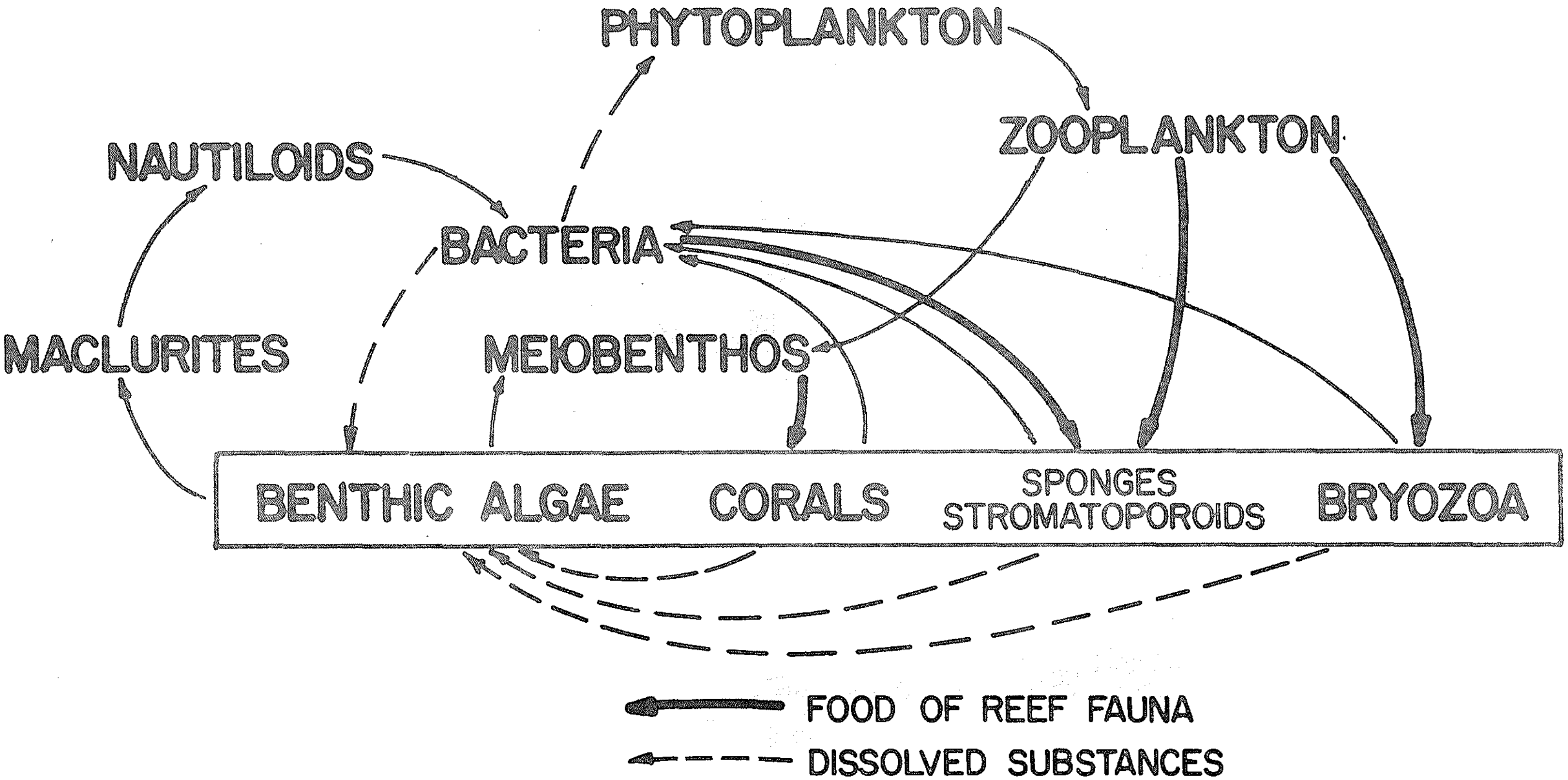


FIGURE 4. SIMPLIFIED FOOD-CHAIN OF CROWN POINT REEFS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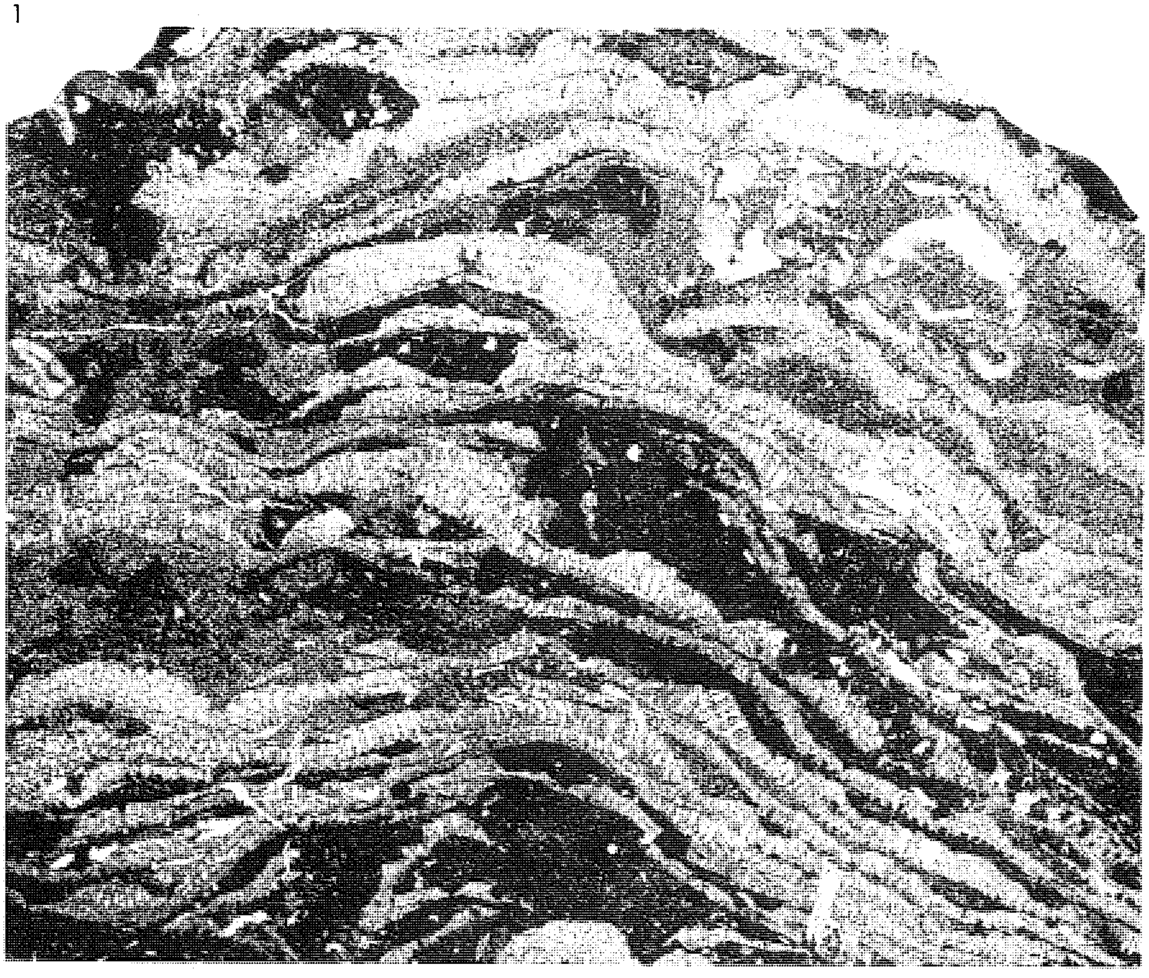
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PLATE 1

Figure 1 — Outcrop photograph of the surface of a Middle Ordovician (Chazyan) bryozoan mound exposed in the Day Point Formation (uppermost Fleury Member) on Isle La Motte, western Vermont. Note general lineation of the bryozoan colonies; length of hammer approximately 14 inches.

Figure 2 — Thin section photomicrograph (X3) of characteristic bryozoan mound rock that forms conspicuous mounds in the uppermost Day Point Formation, Fleury Member, on Isle La Motte, western Vermont. The mound rock is primarily composed of consecutive sheets or layers of the colonial trepostome bryozoan Batostoma chazyensis Ross, separated by lime mud layers containing relatively abundant, although quite small, dolomite rhombs (small grey flecks).

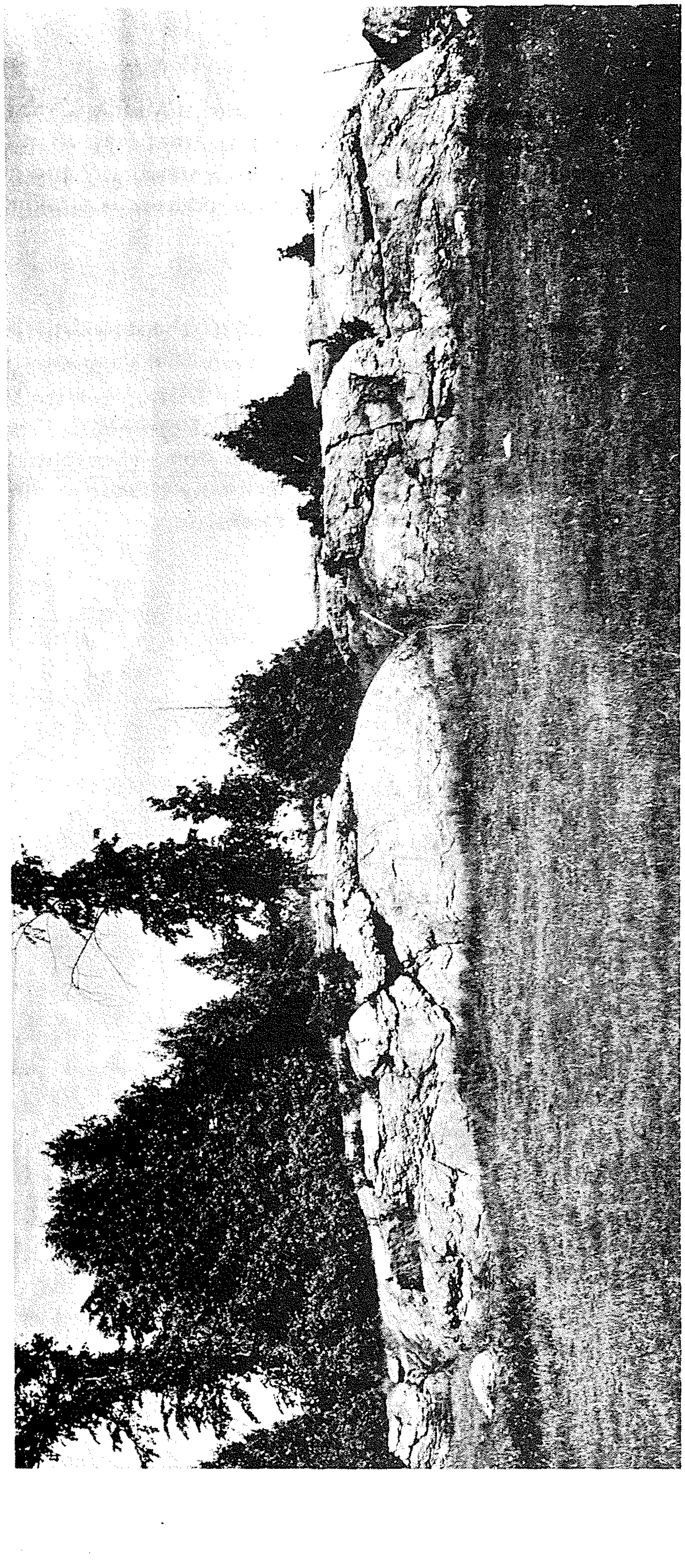

PLATE 2

Outcrop photograph of a series of typically small-sized Crown-pointian (Middle Ordovician-Chazyan) mounds exposed in La-Bombard's Pasture, Isle La Motte, western Vermont. Rounded mound structures are composed of lime mud containing abundant algae, sponges, stromatoporoids, and trepostome bryozoans. The beds filling-in the surface irregularities and capping the mounds are dominantly composed of relatively coarse-textured pelmato-zoan debris (see Plates 3 and 4). The length of the sledge hammer located on the right-hand side of the prominant mound is approximately 3 feet.

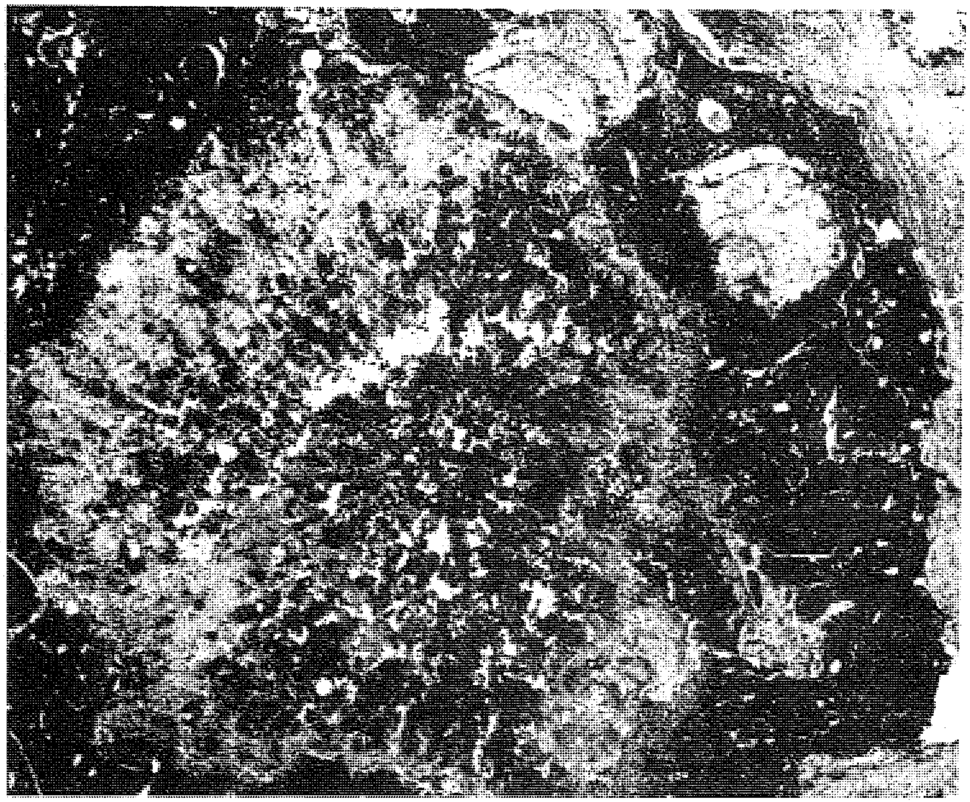

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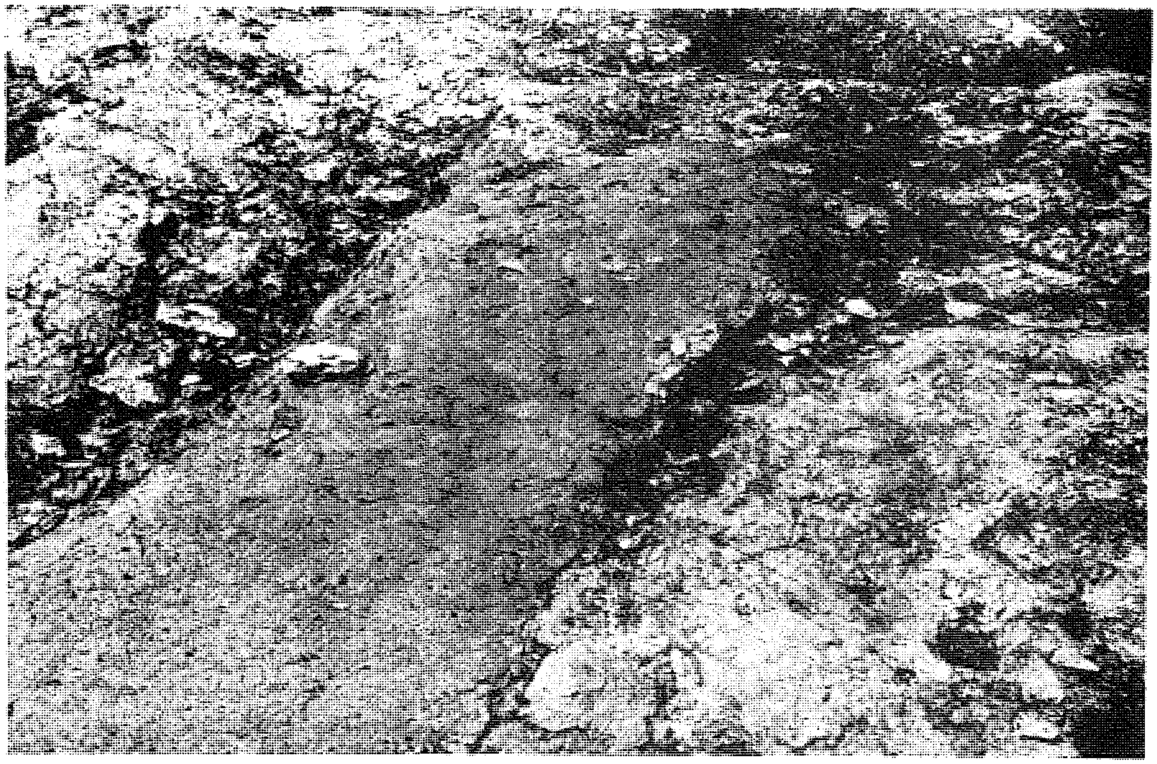
PLATE 3

Figure 1 — Thin section photomicrograph (X3) of a transverse cut through the sponge Zittelella in what is typically Crownpointian mound rock, LaBombard's Pasture, Isle La Motte, western Vermont. Note overall muddy character of the rock, and the appearance of an encrusting bryozoan? on the outer surface of the sponge.

Figure 2 — Thin section photomicrograph (X14) of Crownpointian mound rock with relatively abundant encrusting (bead-like segments) algae of the genus Sphaerocodium, LaBombard's Pasture, Isle La Motte, western Vermont. Again, note the dominantly muddy character of the rock. Scattered small grey flecks are floating dolomite rhombs.



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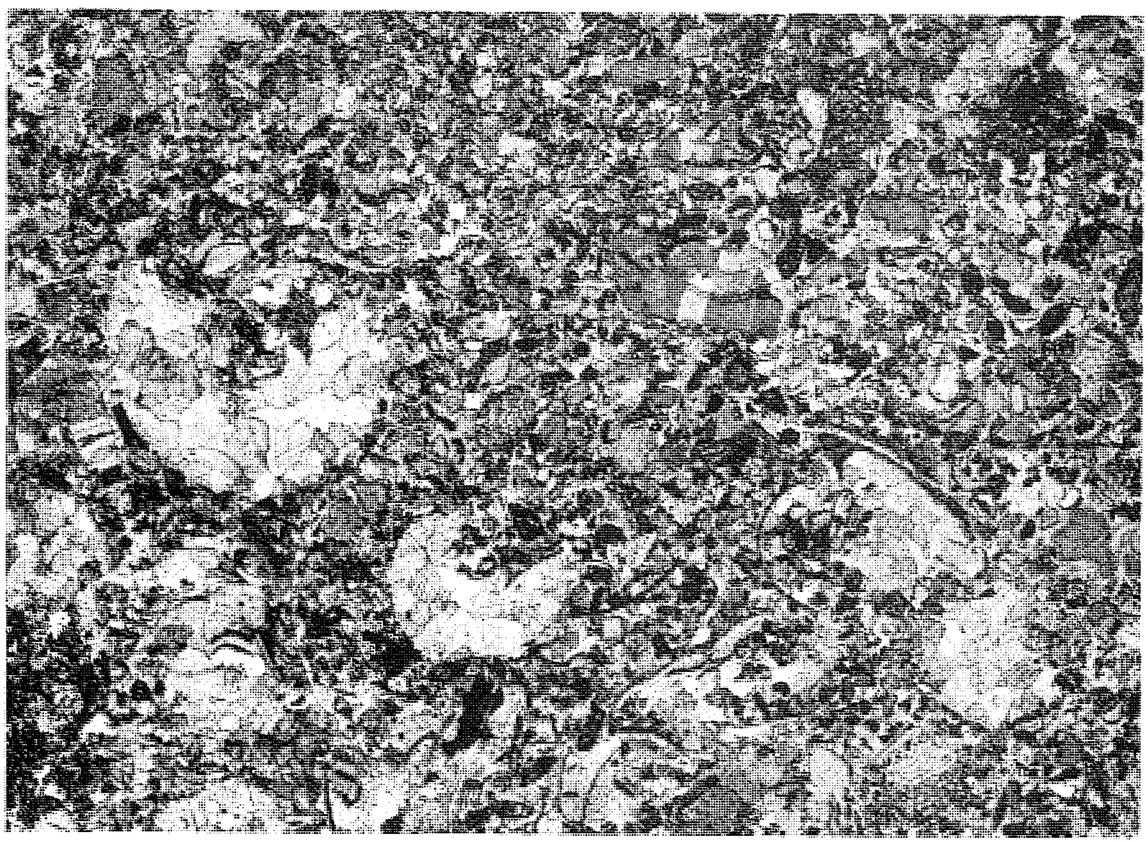

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PLATE 4

Figure 1 — Outcrop photograph of a channel cutting mound rock in the Middle Ordovician (Chazyan) Crown Point Formation, west of the Goodsell Quarry, Isle La Motte, western Vermont. The width of the channel is approximately 18 inches. Note lighter-colored mound rock on either side of darker-colored channel rock.

Figure 2. — Thin section photomicrograph (X4) of channel rock from the above locality. Rock is primarily a pelmatozoan calcarenite, although intraclasts (small rounded dark grains), bryozoan and brachiopod fragments are also present. Cavities or original void spaces filled with secondary granular sparry calcite are also common within the channel rock.

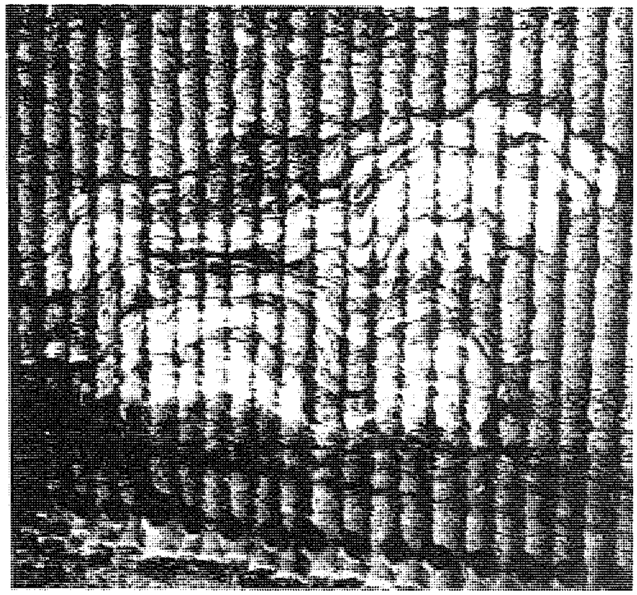

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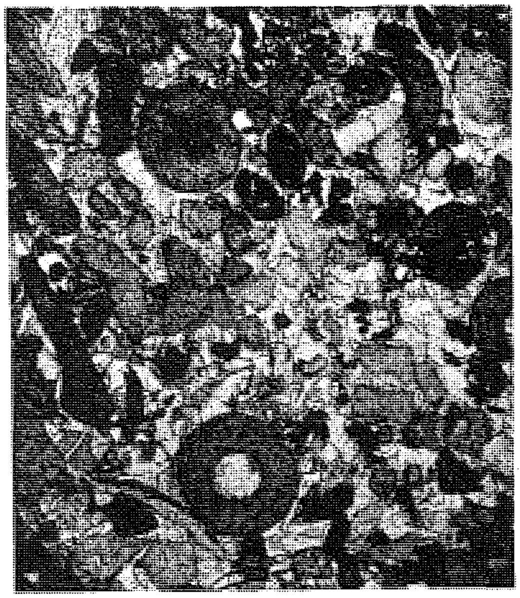
PLATE 5

Figure 1 Stromatoporoid (Pseudostylodictyon?) mound exposed on the south wall of Goodsell Quarry (June, 1962); Middle Ordovician (Chazyan) Crown Point Formation, Isle La Motte, western Vermont. Stromatoporoid mound is approximately 4 feet in width 2 1/2 feet in height.

Figure 2 Thin section photomicrograph (X4) of a vertical section of the stromatoporoid Pseudostylodictyon? chazianum (Seely) from the lower part of the Crown Point Formation, LaBombard's Pasture, Isle La Motte, western Vermont. Specimen shows characteristic thin laminae separated by pronounced layers of lime mud.

Figure 3 Thin section photomicrograph (X4) of a horizontal section of the stromatoporoid Pseudostylodictyon? eatoni (Seely) showing mamelons of various sizes, from the lower part of the Crown Point Formation, LaBombard's Pasture, Isle La Motte, western Vermont.



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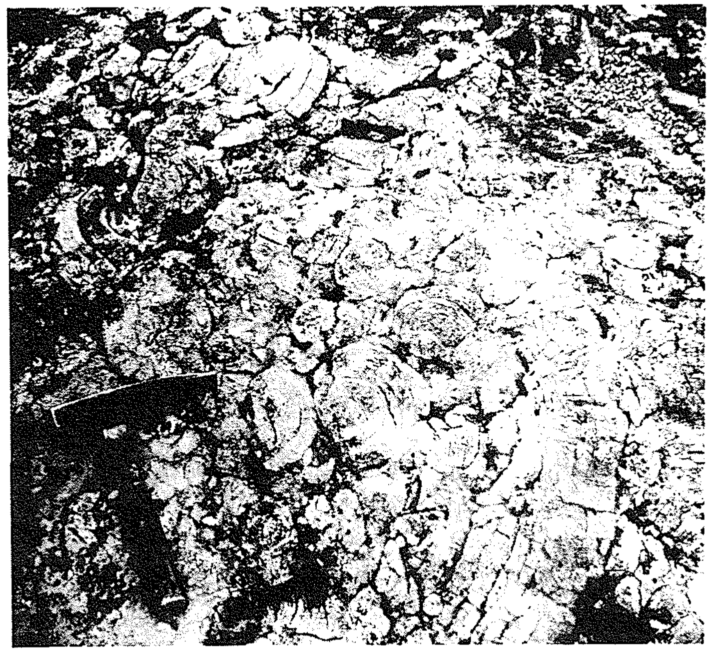

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Figure 1 Thin-section photomicrograph (X8) of a pelmatozoan grainstone from a channel associated with the Lamottia buildup ("Lamottia reef" of Raymond), Day Point Formation (Middle Chazyan) middle Fleury Member, Isle La Motte, western Vermont. Note abundance of pelmatozoan ossicles (probably cystoid and/or blastoid), and the dominant sparry calcite matrix; many of the pelmatozoan ossicles have calcite overgrowths. The small black grains are intraclasts and/or Girvanella pellets (diagnostic structures not seen at this magnification).

Figure 2 Outcrop photograph of the Lamottia accumulation ("Lamottia reef") located near the center of the buildup. Note jumbled mass of coral "heads" which appear to be heaped together and overturned, probably due to wave and/or current sorting. Length of hammer is 11 inches; Day Point Formation, middle Fleury Member, southeastern Isle La Motte, western Vermont.

Figure 3 Thin-section photomicrograph (X4) of the muddy rock matrix between the massive Lamottia "heads". Rock can be classified as a skeletal wackestone. Note large fragment of the tabulate coral Lamottia heroensis Raymond set within a muddy matrix with included intraclasts and abundant skeletal debris. Thin-section taken from rock near the center of Raymond's "oldest coral reef" within the Day Point Formation, Middle Fleury Member, southeastern Isle La Motte, western Vermont.

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MIDDLE ORDOVICIAN (CHAZYAN) MOUNDS*, SOUTHERN QUEBEC, CANADA: A SUMMARY REPORT

by

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INTRODUCTION

Data relative to the biotic composition, petrology, and gross morphology of four small Middle Ordovician mounds exposed in southern Quebec, Canada, are summarized. It is noted: (1) that the Quebec Chazyan mounds are probably uppermost Crownpointian-to lowermost Valcourian in age, (2) the known outcrop distribution of these mounds is very patchy, (3) the mounds are very small scale structures, and (4) the biotic composition appears to be relatively simple. Brief comparison is made with the Chazyan mounds exposed in the Lake Champlain region of the northeastern United States, and marked differences in biotic composition, gross morphology, and occurrence are stated. It is thought that the mounds probably grew and thrived in relatively shallow marine waters, within a depth range of perhaps a few tens of feet.

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*The term mound is herein defined as an organic carbonate buildup, commonly of relatively small size, devoid of obvious bedding features, and containing a biota different from the usually bedded surrounding sediments. Used in this sense, the Chazyan mounds are thought to have been centers of organic activity whose fossil skeletons are assumed to be in growth position, and whose growth directly influenced surrounding sedimentational and biotic patterns because of their relative relief in relationship to the surrounding sea floor. The term "reef", used in a present-day sense, i.e., a wave resistant structure composed principally of hermatypic corals welded together by lime secreting algae, is rejected for the Chazyan mounds discussed here since the biotic potential necessary to build and perpetuate a massive dominantly wave resistant structure did not exist this early in geologic time.

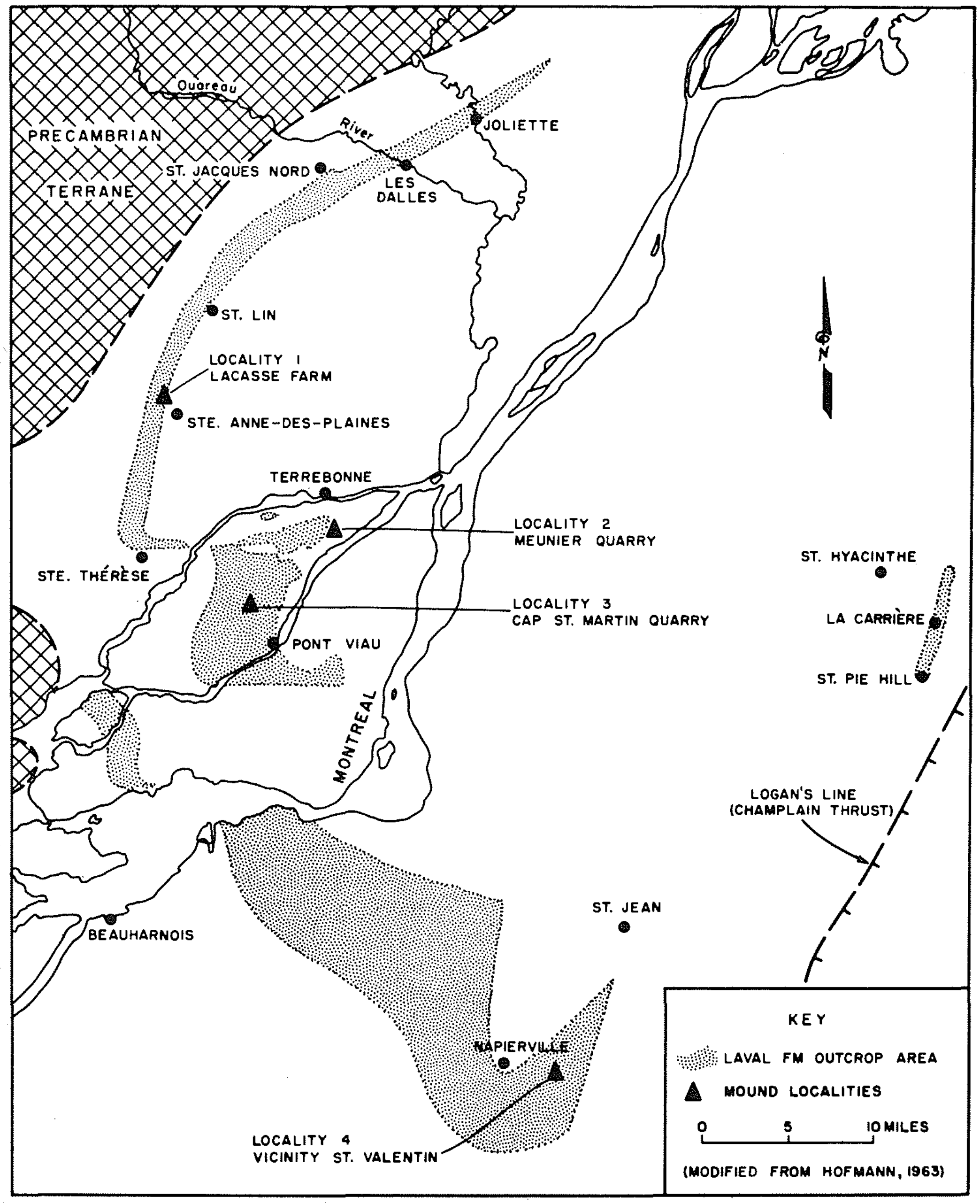

Fig. 1 Regional locality map of southern Quebec, showing the locations of known Chazyan mound outcrops.

STRATIGRAPHY OF THE QUEBEC CHAZYAN

Carbonate mounds are exposed in the Middle Ordovician (Chazyan) Laval Formation of southern Quebec, Canada, see Fig. 1. According to the data presented by Hofmann (1963, p. 273) this formation attains a thickness of 970 feet approximately 20 miles northeast of Three Rivers, Canada. Towards the Montreal region the formational thickness ranges from 205 to 390 feet, whereas south of St. Jean the thickness ranges from 450 to 670 feet. The thickness isopach contour map given by Hofmann (p. 274) shows a somewhat northerly trend.

Hofmann (1963, p. 271-273) informally subdivided the Laval Formation into three distinctive lithologic units: (1) the lower Laval consisting of quartz-sandy beds, (2) the middle Laval of shaly limestones and calcarenites, and (3) the upper Laval beds of predominantly argillaceous calcisiltite, which gradually becomes more dolomitic towards the top. Within this lithologic subdivision two main biostratigraphic units are recognized: (1) an upper division (upper Laval beds) in which the brachiopods _Rostricellula plena_ (Hall) and _Linguella_? sp. are very abundant, and (2) a lower, pre-_Rostricellula plena_ division (= middle and lower Laval) characterized by the cystoid _Bolboporites americanus_ Billings. The carbonate mounds are confined to a stratigraphic position at the top of the _Bolboporites_ Zone (Hofmann, p. 280). These structures have only been recognized in outcrop and their distribution appears to be very spotty (Fig. 1).

Stratigraphically, the _Rostricellula plena_ Zone can be correlated with the Valcour Formation of the Lake Champlain region of northeastern New York and western Vermont. The Chazyan section below the _Rostricellula plena_ Zone of the Laval Formation is characterized by several fossils, amongst which are the forms _Bolboporites americanus_ and the brachiopod _Sphenotreta acutirostris_ (Hall), species originally found by Raymond (1906), and thought by him to be restricted to the lower Chazy and lower parts of the middle Chazy. On this basis Hofmann (p. 290) considers that the middle and lower Laval Formation may be correlated with the Day Point-Crown Point Formations, undivided. Although Pitcher (1964, p. 658) in his study of the evolution of the Chazyan mounds in the Lake Champlain region thought that the mounds which he examined at Terrebonne (Locality 2) were definitely Valcourian (upper Laval) in age due to the presence of the trepostome bryozoan _Batostoma campensis_ Ross, found with the brachiopod _Rostricellula plena_, a reliable Valcourian indicator. However, the mound exposure near St. Valentin (Locality 4) carries abundant _Batostoma chazyensis_ Ross, a form that Pitcher believes is restricted to the Crown Point and Day Point Formations (middle and lower Laval), see Pitcher, 1964, p. 674. Accordingly, Pitcher (p. 639) correlates the St. Valentin mound exposure with the upper Crown Point Formation of the Lake Champlain region.

MOUND FACIES

The distribution of four known Chazyan mound outcrops in southern Quebec, Canada, is shown in Fig. 1. All of the mounds are relatively small structures, not exceeding 7 feet in height, and usually less than 50 feet in width. All have somewhat irregular form (see Fig. 2) and are not simple dome-shaped features. The mounds are totally devoid of bedding structures, although bedded sediments of different lithologies underlie, overlie, and abut and grade into the mounds. Some of the off-mound lithologies dip away from the mound at 10 to 25 degrees, which rapidly decreases to zero degrees a relatively few feet away from the mound.

Petrologically, the mounds can be classified as trepostome bryozoan (Batostoma) and/or tabulate coral (Eofletcheria and/or Billingsaria) boundstones (Dunham, 1962). The more muddy portions of the mound would be classified as skeletal wackestones indicating a general absence of a binding biota. The mound rock matrix is dominantly muddy, although scattered floating dolomite rhombs and a few mud intraclasts can usually be recognized. Accessory biotic components common to the mound rock are the red alga Solenopora, sponge spicules, pelmatozoan debris (cystoid and blastoid), trepostome bryozoans (Atactotoechus and Chazydictya), brachiopods (Hebertella and/or Rostricellula), gastropods, trilobites and ostracodes. The beds that overlie, underlie, abut, and grade into the mound are usually relatively mud-poor coarse pelmatozoan packstones/grainstones with some bryozoan fragments and mud intraclasts. The channel rock, well developed at Locality 4 (vicinity of St. Valentin) is identical to the latter (see Figure 4). Most of the non-mound rock skeletal grains, principally pelmatozoan debris, contain pronounced calcite overgrowths. A summary of pertinent mound attributes for each outcrop locality is given in Table 1.

Paleoecologically the mound rock can be dominated by either one of two prevailing biotic components. Either the mound is composed predominantly of tabulate corals (Eofletcheria and/or Billingsaria), as at Localities 1 and 4, or the mound biota may be primarily composed of sheet-like encrusting trepostome bryozoans (Batostoma), as at Localities 2 and 3 (see Table 1).

When the mound biota is dominated by tabulate corals, one or two growth forms are usually characteristic. Eoflectheria incerta (Billings), the dominant species at Locality 1, commonly forms a series of colonies growing one upon another. The colonies are less than 1 foot in length and up to 6 inches in height. These colonies thin towards their edges and appear to be circular in plan view. On the other hand, Billingsaria parva (Billings) the dominant species at Locality 4, usually forms flat-lying colonies no more than 12 inches in length and only two inches in height. At the other two localities, Localities 2 and 3, where tabulate

LOCALITIES	GENERAL DIMENSIONS	ROCK TYPES	PRIMARY MOUND BUILDERS	MOUND DETRITUS CONTRIBUTORS	DESCRIBED BY
1. Lacasse Farm	Height: 5 ft. Width: 30-50 ft. Length: about 700 ft.	Mound mainly a tabulate coral boundstone with pelletoidal & intraclastic wackestone; Overlying and underlying beds are coarse pelmatozoan packstones	Eoflectcheria incerta* Billingsaria parva Batostoma sp.	Hebertella vulgaris Rostricellula plena Indet. gastropods	MacGregor (1954 p. 44-46); Clark (1960, Fig. 1D)
2. Meunier Quarry	Height: 7 ft. Width: 8 ft.	Mound mainly a bryozoan boundstone; Overlying and underlying beds are coarse pelmatozoan packstones	Batostoma campensis* Eoflectcheria incerta	Malocystites murchisoni Rostricellula plena Hebertella sp. Solenopora sp. Sponges (spicules)	MacGregor (1954 p. 23); Hofmann (1963, p. 281); Pitcher (1964, p. 373)
3. Cap St. Martin Quarry	Height: 1 ft. Width: $2\frac{1}{2}$ ft.	Mound mainly a bryozoan boundstone; Overlying and underlying beds are coarse pelmatozoan packstones	Batostoma campensis* Billingsaria parva	Blastoidocrinus carchariadens Hebertella vulgaris Rostricellula plena Solenopora sp.	MacGregor (1954, p. 43)
4. Vicinity St. Valentin	Height: 6 ft. Width: 30 ft. Length: 120 ft.	Mound mainly a tabulate coral boundstone; Overlying and underlying beds are bryozoan and pelmatozoan grainstones with intraclasts; Channels are pelmatozoan packstones	Billingsaria parva* Batostoma chazyensis Chazydictya sp.	Rostricellula plena Indet. gastropods Indet. ostracodes Solenopora sp. Sponges (spicules); Channels contain many: Atactotoechus? sp. Chazydictya sp. Batostoma sp.	Hofmann (1963, p. 280-281); Pitcher (1964, p. 667); and original observations

*Dominant biotic element present as the primary mound-builder

TABLE 1 Comparison of Some Chazyan Mound Attributes, Southern Quebec, Canada corals are only of secondary importance they may be found as either small bun-shaped colonies up to 12 inches long and 9 inches high, or as flat-lying colonies up to 9 inches long and only 2 inches high. The encrusting sheet-like bryozoan Batostoma overgrows many of the tabulate corals and probably functions as a binding and cementing agent that readily stabilized the primary mound builders--the tabulate corals.

When the dominant mound organism is bryozoans, as at Localities 2 and 3, the encrusting trepostome bryozoan Batostoma campensis Ross, appears as consecutive sheets stacked one above the other in conspicuous layers less than one-half inch in thickness. Layers of muddy sediment occur between the bryozoan colonies and usually contain varying amounts of floating dolomite rhombs. In appearance, this series of bryozoan sheets make up cabbage-head masses piled one on top of another. The result of this stacking of bryozoan colonies is the formation of a distinctive, somewhat massive, unbedded, irregular mass of boundstones. Small colonies of the tabulate corals Eoflectcheria and Billingsaria may occur within the mound proper or on the tops of the mound.

Figure 5 schematically shows the biotic attributes of a composite Middle Ordovician (Chazyan) mound community. Principally, this figure shows which organisms are present within the mound community, what their contribution to the perpetuation of the mound structure might be, and their vagility and specific feeding types. As such, this diagram presents a functional grouping of the participating biotic elements within the mound community. In the Chazyan mounds of southern Quebec, the role of the primary mound builders is a relatively simple one, since all that appears to be necessary is a colonial organism possessing reasonable constructional ability. In this instance, the tabulate corals Billingsaria parva (Billings) and Eofletcheria incerta (Billings) satisfy this requirement. To further insure perpetuation of the constructional aspect of the mound, sheet-like trepostome bryozoans, especially species of the form Batostoma, encrust and bind the coral heads together, and in doing so, thus reinforce and strengthen the structural unit. In some cases encrusting trepostomatous bryozoans may be the sole dominant biotic element forming some of the mounds, especially the very small mounds. It thus appears that when bryozoans are the sole primary builders there is a definite limitation as to their size building potentialities. It is to be noted that all of these primary mound building organisms are cemented sessile benthos, and all are suspension feeders.

The detritus contributors live on, within, and around the mound and are an integral segment of the mound community. Of especial note are the abundant cystoids and blastoids which probably formed "meadows" around, about, and also lived within the mound itself. Their importance in a biological sense cannot be underestimated, since they undoubtedly affected sedimentational and biological patterns around the mound. Most apparently, acting as a baffle element in trapping finer sediment which normally might by-pass the area, but more importantly, their very presence created additional ecological niches within which a host of other organisms could flourish, and in essence be able to transform the immediate mound area into a center of organic activity. Other detritus contributors include the red alga Solenopora, sponges, bryozoans--specifically trepostomatous types, pedunculate brachiopods, gastropods, trilobites, and ostracodes. Obviously, there were probably other organisms, in particular those without preservable hard parts. However, it is difficult to estimate what percentage of the total biota would define this category. Perhaps, if reliably known it probably would not be an appreciable percentage, especially in Middle Ordovician time when a good many of the potential ecologic niches on a mound were probably not fully exploited even by the indigenous biota. It should be emphasized that these are the organisms that contribute the bulk amount of mound detritus. In vagility they range from cemented and rooted forms to nektonic creatures, and feeding types represented bridge the gamut from suspensions feeders to carnivores and autotrophs.

In summary, interpolation of the data presented by MacGregor (1954), Hofmann (1964), Pitcher (1964), and original observation, a generalized sequence of the mound building events, as exemplified by the four Chazyan mounds of southern Quebec, may be recorded as follows:

(1) an initial stage consisting of a limesand (packstone/grainstone) substrate usually containing abundant rhynchonellid brachiopods (Rostricellula), some cystoids (Malocystites), and cryptostome bryozoans (Chazydictya);

(2) the inclusion of small scattered patches of encrusting trepostome bryozoans (Batostoma);

(3) discontinuous thin layers of the tabulate coral Billingsaria growing over and encrusting the earlier bryozoans and the lime sand substrate, associated with relatively small colonies of the tabulate coral Eofletcheria filling-in available interspaces;

(4) sheet-like encrustations of the bryozoans Batostoma and Chazydictya encrusting the tabulate corals and binding some of the coral heads together;

(5) piling-up, one on top of another, of tabulate coral colonies (usually only one form being dominant in a particular mound), and the binding together of the corals by the encrusting brozoans thus strengthening and welding together the mound structure.

It should be noted that many of the smaller Chazyan mounds, usually those that range in size from somewhere under three feet in length and two feet in height, are composed almost entirely of encrusting bryozoans and hence, do not show this evolutionary sequence as noted above.

It is thought that the mounds grew and thrived in relatively shallow waters, within a depth range of perhaps a few tens of feet. The mound facies (boundstones/wackestones) appears to have been deposited under quiet water conditions, and it is probable that most of the fine mud present within the mounds was accumulated and deposited mainly by the baffling action of rather commonly occurring pelmatozoans. The off-mound packstones appear to represent more agitated water environments, whereas the coarse grainstones, usually adjacent to the mounds, suggest relatively high energy open-circulation conditions. There is no substantial evidence to support Hofmann's contention (1963, p. 281) that the mounds were subaerially exposed and eroded. On the contrary, most evidence seems to indicate permanent submergence for these small, geologically short-lived mounds.

COMPARISON WITH THE CHAZYAN MOUNDS OF THE LAKE CHAMPLAIN REGION

Mound structures occur quite commonly in the Middle Ordovician (Chazyan) rocks of the Lake Champlain region of northeastern New York, and western Vermont and have been reported by Oxley (1951), Erwin (1957), Oxley and Kay (1959), and Pitcher (1964). In this area, the Chazyan is subdivided into three formations: Day Point, Crown Point, and Valcour (in ascending order). The maximum thicknesses of the Day Point and Crown Point Formations are in the general vicinity of Valcour Island, New York, where each formation exceeds 300 feet; the greatest thickness of the Valcour Formation occurs on South Hero Island, Vermont, where it is approximately 200 feet (Oxley and Kay, 1959, p. 840).

The mounds are usually oval in shape with widely variable dimensions. In general, they range in size from small masses 1 to 3 feet in length and 2 feet in height, to an average of approximately 25 feet in height and up to 300 feet in length. The mounds of the Day Point Formation are the smallest in size, whereas the Crown Point mounds are the largest and best developed; the dimensions of the Valcour mounds lie somewhat between these two extremes.

Pitcher (1964) has demonstrated that the Chazyan mounds show distinct changes in organic composition through time. The early Chazyan Day Point mounds were primarily constructed by trepostome and cyclostome bryozoans, which built relatively small linearly aligned mound structures. The mound core of carbonate mud and skeletal debris (boundstone) differs from the cross-bedded, mud-free skeletal packstones/grainstones surrounding the mounds.

The middle and upper Chazyan (Crown Point and Valcour) mounds can be subdivided into five principal biotic component variants. These can be considered as primary mound builders with distinct and variable gradations existing amongst them. The primary mound builders are: (1) algae (Girvanella, Sphaerocodium, Solenpora, and possibly Nuia), (2) lithistid sponges ("Zittelella" and others), (3) tabulate corals (Billingsaria), (4) bryozoans (Batostoma and others), and (5) stromatoporoids (Cystostroma and Pseudostylodictyon). The mound core matrix is muddy and can be classified as a boundstone. Surrounding and overlying the mounds are well sorted calcarenites that can be classified as pelmatozoan grainstones or packstones, in which Girvanella pellets and Solenopora colonies are conspicuous elements. Channels have been cut through many of the mound structures, and these form a rather prominent anastomosing pattern. On Isle La Motte, where channels are particularly well developed in the Crown Point mounds, they stand out quite distinctively from the surrounding massive gray-colored mound structures. The channels are usually brownish in color, and this is believed due to the higher dolomite content of the calcarenites. The various mound biotas are believed to have existed contemporaneously, and appear to have been closely associated throughout middle and upper Chazyan time. Significantly, Pitcher (1964, p. 659) observed that there is distinct vertical biotic differentiation within any single mound. It appears that stromatoporoids are usually dominant through scattered biotic elements at the base and tops of a mound, but they are usually very sparse within the middle portion. In the Crown Point mounds, exposed in Patnodes Pasture on Isle La Motte, stromatoporoids are particularly common on the upper surfaces, and as such may represent the dominant element of a climax community. This seems to be substantiated by shallow cores taken by Pitcher, which show that the stromatoporoids do not extend for any depth below the surface.

Compared to the mounds of southern Quebec, those of the Lake Champlain region are much more abundant, and they are stratigraphically present throughout most of the Chazyan interval. Most importantly, the Lake Champlain mounds are biotically more complex and diversified, and exhibit a progressive sequence in the evolutionary development of mound building organisms not recorded from any other locale. Petrologically, the presence of mound rock types (boundstones) and offmound calcarenites (packstones/grainstones) are identical to that observed in the four Chazyan mounds of southern Quebec. However, channel cuts through the mounds, a feature perhaps closely analogous to modern-day reef surge channels, are a much more extensive and commonly occurring feature on the Lake Champlain mounds, especially those in the Crown Point Formation.

ACKNOWLEDGEMENTS

We are particularly grateful to Dr. Max Pitcher of Continental Oil Company for personally guiding us to and helping to collect the St. Valentin mound exposure, and for loaning the senior writer his collection of thin-sections that were prepared from the Terrebonne mounds. Dr. June Ross of Western Washington State College gave invaluable aid with identifications of the bryozoans.

MacGregor (1954) in an unpublished thesis had originally described three of the four mound localities (Localities 1-3) and presented pertinent paleoecologic observations as to the overall biotic composition of these Chazyan mounds. MacGregor's observations pertaining to the mound exposures near Ste. Anne-des-Plaines (Locality 1) have subsequently been summarized by Clark (1960, p. 26-27, Fig. 1D). Data from all of the above localities, including those of Pitcher (1964), along with original observations made at Localities 2 and 4 have been consolidated and interpolated within this summary.

A. MOUNDS OF SOUTHERN QUEBEC, CANADA

1. SIZE: Relatively small features, <7 feet in height and 50 feet in width

2. STRATIGRAPHIC POSITION: Restricted to within a very narrow stratigraphic interval of the Chazyan; mounds present at only four outcrop localities; unknown in the subsurface, would probably be too small to detect; Hofmann (1963, p. 291) shows the mounds restricted to the uppermost part of the middle Laval Formation (Crown-pointian) and extending into the lower portion of the upper Laval Formation (Valcourian); Pitcher (1964, p. 638-639) believes that the mounds in the vicinity of St. Valentin correlate with the upper Crown Point (middle Middle Chazyan) whereas those near Terrebone (vicinity Meunier & Cap St. Martin Quarries) are Valcourian (upper Middle Chazyan)

3. PETROLOGY: Mounds may be classified mainly as trepostome bryozoan and/or tabulate coral boundstones associated with skeletal wackestone intervals; overlying and underlying beds are coarse pelmatozoan packstones/grainstones with some bryozoans; tidal or surge channels are pelmatozoan/bryozoan packstones with intra-clasts; channels only well developed at the St. Valentin locality

4. BIOTIC COMPOSITION: Relatively simple; may be dominated by either tabulate corals (Eofletcheria and/or Billingsaria) with trepostome bryozoans, or trepostome bryozoans (Batostoma) with tabulate corals (Eofletcheria and/or Billingsaria); accessory biotic components include algae (Solenopora), sponges (spicules), blastoids, cystoids, trepostome bryozoans (Atactotoechus & Chazydictya), brachiopods (Hebertella and/or Rostricellula), gastropods, ostracodes, and trilobites

B. MOUNDS OF THE LAKE CHAMPLAIN REGION, NEW YORK & VERMONT

1. SIZE: Much variability in size; from very small to relatively large

2. STRATIGRAPHIC POSITION: Abundantly scattered throughout the Chazyan (Day Point, Crown Point, & Valcour); best developed and most numerous in the Crown Point interval on Isle La Motte, western Vermont; unknown in the subsurface

3. PETROLOGY: Day Point mounds are primarily bryozoan boundstones associated with pelmatozoan and bryozoan packstones/grainstones; Crown Point mounds are algal-sponge-stromatoporoid boundstones with associated pelmatozoan packstone channels; Valcour mounds are mainly algal-trepostome bryozoan boundstones with associated bryozoan-brachiopod packstones; channels best developed in the Crownpointian

4. BIOTIC COMPOSITION: Very complex; the Day Point mounds are mainly composed ot trepostome (Batostoma) and cyclostome (Cheiloporella) bryozoans; the Crown Point & Valcour mounds can be subdivided into five principal biotic component variants with distinct and variable gradations existing amongst them. The primary mound builders are: (1) algae (Girvanella, Sphaerocodium, Solenopora, and possibly Nuia), (2) sponges ("Zittelella" & others), (3) tabulate corals (Billingsaria), (4) bryozoans (Batostoma & others), & (5) stromatoporoids (Cystostroma and Pseudostylodictyon); accessory components include cystoids, blastoids, brachiopods, trilobites, ostracodes

TABLE 2 Comparison Of The Chazyan Mounds In Southern Quebec With Those Of The Lake Champlain Region

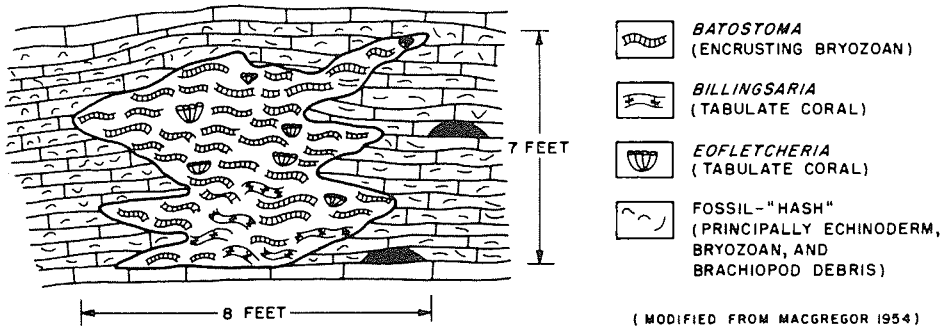

Fig. 2 Generalized diagram of a mound exposed in a quarry near Terrebonne (Locality 2).

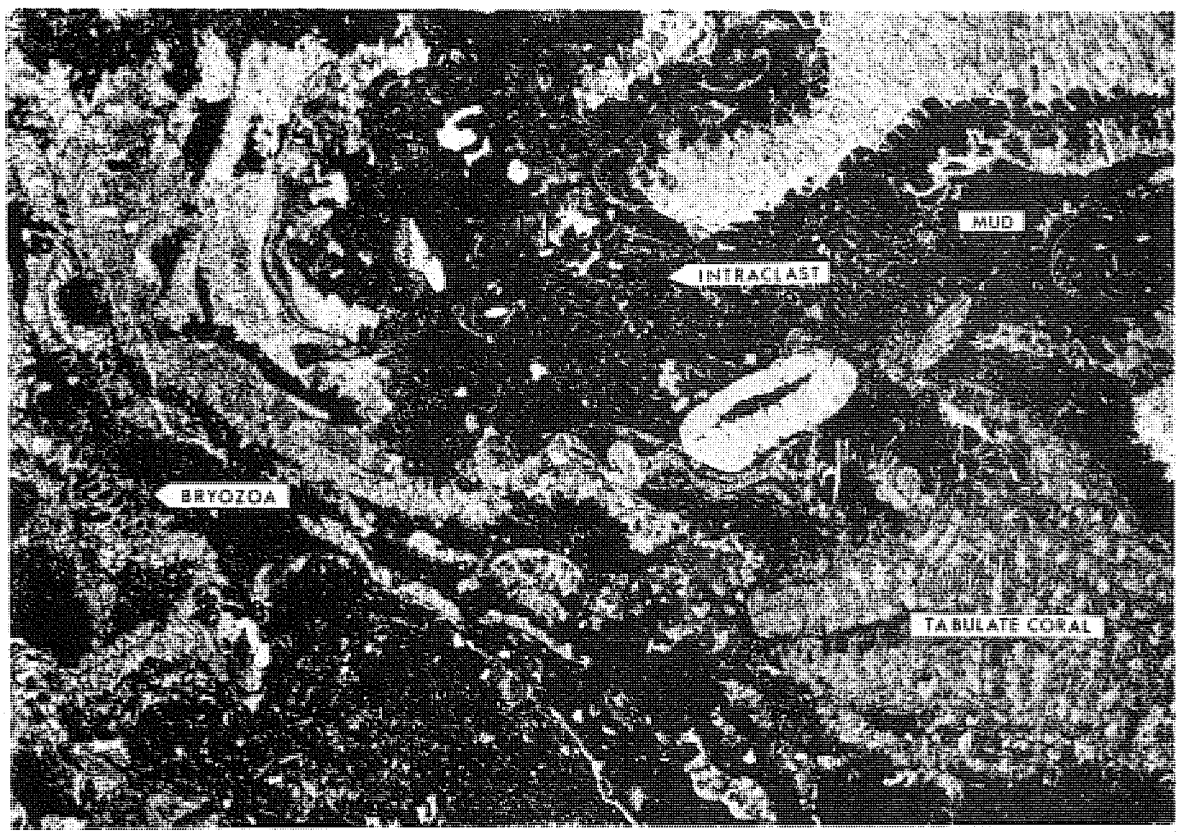

Fig. 3 Thin-section photomicrograph (X4) of mound rock (boundstone) Laval Formation, at Locality 4 (vicinity of St. Valentin), southern Quebec, Canada. Note the relatively abundant remains of the tabulate coral Billingsaria parva (Billings), encrusting bryozoans, and varied shell debris. Matrix is primarily a fine-grained mud containing scattered dolomite rhombs (small white flecks) and a few mud intraclasts.

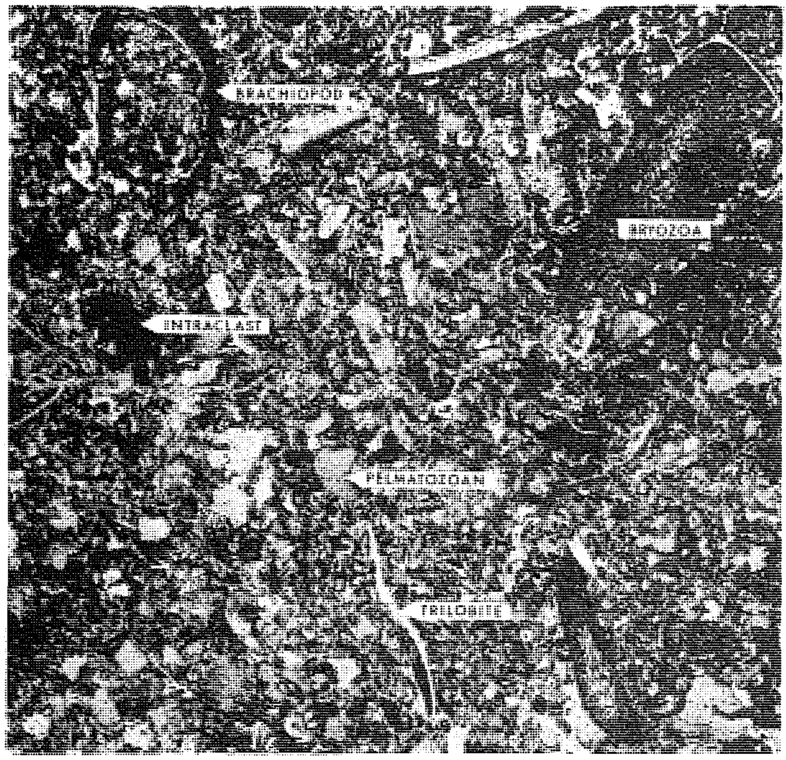

Fig. 4 Thin-section photomicrograph (X4) of channel rock (packstone) Laval Formation, at Locality 4 (vicinity of St. Valentin), southern Quebec, Canada. Note abundance of pelmatozoan debris (many grains with calcite overgrowths), along with conspicuous trepostome bryozoans (cf. Chazydictya sp.), brachiopod and trilobite fragments. Mud intraclasts commonly occur within the channel rock.

CHAZYAN MOUND COMMUNITY (SOUTHERN QUEBEC, CANADA)

CONTRIBUTION	ORGANISM	VAGILITY	FEEDING TYPE
PRIMARY BUILDERS	1. TABULATE CORALS a. *BILLINGSARIA PARVA* (BILLINGS) b. *EOFLETCHERIA INCERTA* (BILLINGS)	CEMENTED	SUSPENSION FEEDERS
	2. TREPOSTOME BRYOZOA a. *BATOSTOMA* SPP.	CEMENTED; ENCRUSTING	SUSPENSION FEEDERS
DETRITUS CONTRIBUTORS	1. PELMATOZOANS a. *MALOCYSTITES MURCHISONI* BILLINGS b. *BLASTOIDOCRINUS CARCHARIAEDENS* BILLINGS	ROOTED	SUSPENSION FEEDERS
	2. TREPOSTOME BRYOZOA a. *CHAZYDICTYA* SP. b. *ATACTOTOECHUS* ? SP.	CEMENTED	SUSPENSION FEEDERS
(DECREASING ABUNDANCE)	3. BRACHIOPODS a. *ROSTRICELLULA RAYMONDI* COOPER b. *R. PLENA* (HALL) c. *HEBERTELLA VULGARIS* RAYMOND	ROOTED	SUSPENSION FEEDERS
	4. OSTRACODES	VAGRANT BENTHONIC; NEKTONIC	DEPOSIT FEEDERS AND / OR SCAVENGERS
	5. TRILOBITES	VAGRANT BENTHONIC; NEKTONIC	DEPOSIT FEEDERS, SCAVENGERS, CARNIVORES
	6. RED ALGAE a. *SOLENOPORA* SP.	CEMENTED	AUTOTROPHIC
	7. SPONGES	ROOTED	SUSPENSION FEEDERS
	8. GASTROPODS	VAGRANT BENTHONIC	DEPOSIT FEEDERS, SCAVENGERS

Fig. 5 Biotic attributes of a composite Middle Ordovician (Chazyan) mound community, southern Quebec, Canada.

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