PALEONTOLOGY OF THE CHAMPLAIN BASIN IN VERMONT

by

Charles W. Welby

Vermont Geological Survey, Charles G. Doll, State Geologist

Vermont Development Department, Montpelier, Vermont

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THE FOSSILS

At midnight in the museum hall
The fossils gathered for a ball.
There were no drums or saxophones
But just the clatter of their bones,
A rolling, rattling, carefree circus
Of mammoth polkas and mazurkas.
Pterodactyls and brontosauruses
Sang ghostly prehistoric choruses.
Amid the mastodonic wassail
I caught the eye of one small fossil.
Cheerup, sad world, he said, and winked—
It's kind of fun to be extinct.

Cover picture: Polished slab of Ordovician limestone from Isle La Motte exhibiting cephalopods.

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ACKNOWLEDGMENTS

It is with a great deal of pleasure that I mention here the names of those who have aided me in the completion of this volume. No endeavor such as this can be completed without the support and encouragement of other people, yet it is impossible to do more than note in passing their many kindnesses.

Dr. Charles G. Doll, State Geologist, suggested that I write the volume and gave much encouragement during its preparation. He also loaned from the University of Vermont collections some of the specimens that are illustrated on the plates, and he supplied several photographs, including the one on the cover. The limestone slab which was photographed for the cover is in the Fleming Museum of the University of Vermont. Professor Bruno M. Schmidt of Middlebury College loaned some of H. M. Seely's material and the thin sections made from parts of it by Professor J. J. Galloway of Indiana University. These materials are identified in the explanations of the plates. Professor Harry B. Whittington, Harvard University, identified the specimen of *Glaphurina lamottensis,* and Dr. Rousseau Flower, New Mexico Bureau of Mines, Socorro, kindly furnished illustrations of some of the Chazyan cephalopods.

With the exceptions of the specimens borrowed from the University of Vermont and from Middlebury College and the reproductions from previously published works, the fossils illustrated are from my personal collections. The drawings are based in part on specimens too poorly preserved to photograph and on several sources in the literature; thus they are in essence new drawings. I did all of the photographic work with the exception of those illustrations noted above.

Professor Richard Benton of Trinity College read the entire manuscript, making several suggestions that improved it. Mr. Earl Bailey of Trinity College aided in the photographic work, and the Department of Geology of Trinity College, Hartford, Connecticut, afforded the facilities for the project. Mr. Ogden Nash and Curtis Brown, Ltd. of New York gave permission to use the poem *The Fossils* while the Geological Society of America and the University of Kansas Press gave permission to reproduce illustrations from their publications. Specific acknowledgment accompanies the illustrations.

Vermont is noted for its fishing, a sport that annually attracts thousands to the state. Many of these people fish the waters of Lake Champlain, perhaps noting casually the ledges that outcrop along the shore. Yet, if they were to examine these ledges, they might find in them the remains (fossils) of marine invertebrate animals that lived in a sea which covered the Champlain Valley 400 to 500 million years ago. So it is possible to "fish" the bottom of this ancient sea, although the equipment required consists of a hammer instead of a fishing pole. On the following pages you will find descriptions of these animals, suggested ways of collecting them, and places to look for them.

You may find rocks containing fossils within a short distance of almost any spot in the Champlain Valley. Often you need venture no farther than the pasture across the road, or from the cottage down to the shore. More than one doorstep in the area is made of a limestone slab containing a large marine snail called ***Maclurites***. For the serious fossil-collector the lake shore can provide many hours of pleasure and delight. Time, a few simple tools, and a little curiosity concerning the world around one are all that a fossil-collector requires.

This volume is written as an introduction to the invertebrate fossils of the Champlain Valley. With this purpose in mind I present a general discussion of fossils together with illustrations and descriptions of some of the fossils commonly found in the Champlain Valley. Illustrations and more detailed descriptions of the fossils pictured on the plates are to be found in the professional publications of geologists, but these sources are not always easily accessible to the student or layman. On the other hand, while you will find many of the fossils occurring in the Champlain Valley illustrated on the plates, not all those known are so presented. Indeed, there are many fossils in the rocks of the area that have yet to be described by anyone; our understanding of many of those described will probably be changed with further investigation and study. Vertebrate remains occur only in deposits related to events of the Ice Age.

Area

Western Vermont can be divided roughly into three geological belts: (1) the relatively undeformed belt of the Champlain Lowland, (2) the deformed belt which lies east of "Logan's Line" (a belt of overthrust faults), and (3) the Green Mountain Axis. (See the Centennial Geologic Map of Vermont).

While many of the formations that outcrop in the Champlain Lowland extend eastward beyond "Logan's Line," they are badly deformed here, and many of the fossils have been obliterated. For this reason fossil-collecting has not been done as extensively in the eastern area as in the Champlain Lowland, and there are apparently fewer good localities. On the other hand, there are eastern localities where the fossils have not been destroyed, and fossil-collecting can be as profitable as along Lake Champlain. Because of the ease of collection and the relative abundance of the fossils in the rocks of the Champlain Lowland, the present work will be devoted mainly to them. A few of the fossils found in the Cambrian rocks of northwestern Vermont are illustrated also.

The most continuous as well as the best exposures of bedrock are along the shores of Lake Champlain. Here the collector has access to surfaces that are not soil covered and that are at an angle to the bedding. Away from the shore exposures of the bedrock vary in quality. The more shaly formations form low, rounded hills. The massive limestones often form low hills or low ridges, steep on one side and gently sloping on the other. On glaciated bedding surfaces outlines of fossils may often be discerned. However, collection at these localities requires an inordinate amount of time and energy. Finally, the stream valleys and gullies cutting at angles to the strike (trend) of the beds afford other exposures.

The map of Plate XVI shows some of the more prominent fossil localities known to the author. Of course, many other localities exist, for most of the Middle Ordovician limestones are fossiliferous in one place or another. Various publications of the Vermont Geological Survey, including the Centennial Geologic Map of Vermont, will give you more detailed information.

GEOLOGIC TIME

One of the geologist's contributions to man's understanding of his surroundings has been to point out the immensity of geologic time. Geological studies emphasize that the earth as we know it today is the product of events and processes that began four or five billion years ago, each succeeding event modifying the results of the earlier ones.

Geologic time is divided into successively smaller units called eras, periods, and epochs respectively; all, however, represent relative time rather than absolute time measured in terms of years. The rocks deposited during each period are referred to as a system, and those laid down during an epoch are called a series. Rocks deposited during an era have not been given a formal name. Thus rocks deposited during the whole Ordovician Period (time) are referred to as the Ordovician System. Figure 1 illustrates the subdivisions of Geologic Time.

To draw a rough analogy with United States history, the geologic periods might be likened to the Revolutionary War Period or the Civil War Period, while the deposits formed during a geologic period might be compared to the official documents, the letters, and the biographies which record the events in human history. One involves a time concept and the other the physical materials which record the passage of time.

GEOLOGIC COLUMN

The history of the earth is written in its rocks although it is only during the last 450 to 500 million years that life has left an extensive record in the rocks; even so, some pages of the record are missing—either they were never written or they have since been removed. For the most part, the geologist and the paleontologist rely upon sedimentary rocks and evidences of life contained within them to place events of the geologic past in their proper sequence.

Systematic study of the earth since the early 19th century has led to the concept of the Geologic Column. The Geologic Column is the hypothetical column of rocks assumed to have been deposited throughout all of Geologic Time. The column thus contains a record of each moment of the earth's history since the beginning of Geologic Time. In this concept it is assumed that there are rocks scattered throughout the earth which when taken together record each instant of geologic time and that figuratively, at least, they are all stacked in a column in their proper order. The local Geologic Column is the sequence of rocks within a local area. However, there may be breaks in this record because of erosion or nondeposition. This volume is concerned with the Geologic Column of the Vermont portion of the Champlain Valley and with the fossils that are contained in the rocks comprising it.

Two principles, the Law of Superposition and the Law of the Stratigraphic Succession of Faunas, have been utilized in building the Geologic Column. The first states that in a normal, undisturbed sequence the younger sedimentary rocks overlie the older. The second states that in a sequence of fossil-bearing strata the assemblages of fossils occur in a definite order. Thus with a knowledge of the sequence of fossil assemblages it is possible to place beds containing a given assemblage in their proper relative position, above or below other beds, even though all are alike with respect to rock type.

Figure 2 is the Geologic Column for the Champlain Valley of Vermont. Most of the fossiliferous horizons belong to the Champlainian Series (Middle Ordovician).

Formations

The basic physical unit for the geologist is the formation. It represents a body of rock with recognizable attributes whose distribution can be recorded on a map over a significant area. Thus within the Champlain Valley we find the Glens Falls limestone and the Day Point formation.

Several formations whose origins are closely related in one way or another may be lumped together into a unit called a Group. An example in the Champlain Valley is the Beekmantown Group. On the other hand, a formation may be subdivided into units called members. These smaller units are usually defined in terms of variations in the rocks comprising the formation. For a member to be recognized some systematic difference must be present, but a difference that is not so great as to warrant the recognition of a new formation. Usually the several members of a formation can be seen to be related in origin. An example is the Larrabee member of the Glens Falls limestone.

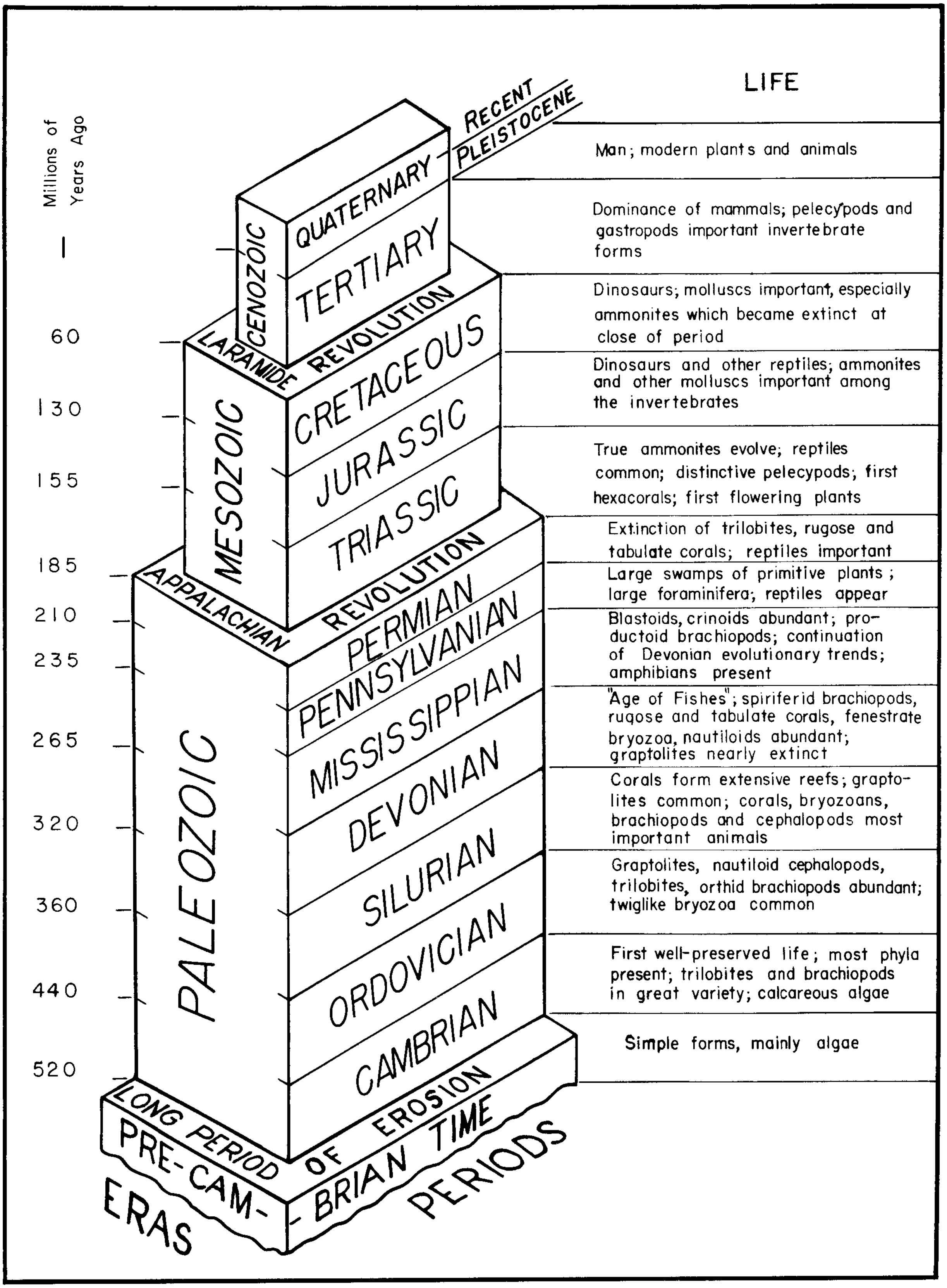
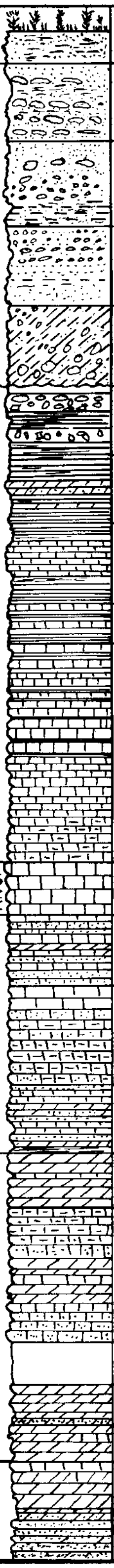


FIG. 1 GEOLOGIC TIME



Era	Series	Stage	Formation – Rock Type	Fossils
CENOZOIC	Recent		Alluvium and soils	
CENOZOIC	Pleistocene		Lake Champlain deposits	
CENOZOIC	Pleistocene		Champlain Sea deposits	Saxicava, Macoma, Yolida, Mytilus
CENOZOIC	Pleistocene		Lake Vermont deposits	
CENOZOIC	Pleistocene		Glacial deposits and scouring	
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Hathaway – Shale, chert	Radiolaria
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Iberville – Noncalcareous shale	Graptolites
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Stony Point – Calcareous shale and limestone	Triarthrus, Paucicrura, Climacograptus, Diplograptus
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Cumberland Head – Calc. shale, limestone	Triarthrus; Glens Falls forms
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Glens Falls: Shoreham member – Limestone and shale	Cryptolithus, Flexicalymene, Isotelus, Prasopora, Rafinesquina, Sowerbyella, Paucicura, Reuschella, Dinorthis, Trematis
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Trentonian Stage	Glens Falls: Larrabee member – Limestone	Flexicalymene, Encrinurus, Sowerbyella, Rafinesquina, Parastrophina, Hesperorthis
ORDOVICIAN	Champlainian Series	Mohawkian Stage – Black River	Orwell – Limestone	Stromatoporoids, Foerstephyllum, Lambeophyllum, Rhynchotrema, Maclurites
ORDOVICIAN	Champlainian Series	Chazyan Stage	Valcour – Limestone and dolostone	Mimella, Orthambonites?, Multicostella, Rostricellula, Isotelus, Glaphurus, Billingsaria
ORDOVICIAN	Champlainian Series	Chazyan Stage	Crown Point – Shaly limestone	Girvanella, Maclurites, Zittelella, Billingsaria, Rhinidictya, Dactylogonia, Mimella, Orthambonites?, Macrocoelia, Pliomerops
ORDOVICIAN	Champlainian Series	Chazyan Stage	Day Point – Limestone, dolostone, and sandstone	Lingulella, Mimella, Valcourea, Orthambonites?, Sphenotreta
ORDOVICIAN	Canadian		Bridport – Dolostone	Gastropods
ORDOVICIAN	Canadian		Bascom: Cassin – Limestone, sandy limestone, dolostone	Finkelnburgia, Polytotechia, Syntrophia, Calaurops, Plethospira, Eurystomites, Tarphyceras, Centrotarphyceras, Isoteloides, Bolbocephalus
ORDOVICIAN	Canadian		Bascom: Covered, probably limestone and dolostone	
ORDOVICIAN	Canadian		Cutting – Dolostone	Worm borings
ORDOVICIAN	Canadian		Whitehall – Dolostone, limestone	Brachiopods, cephalopods rare
CAMBRIAN			Ticonderoga – Dolostone	Algae
CAMBRIAN			Potsdam – Sandstone	

FIG. 2 CHAMPLAIN VALLEY GEOLOGIC COLUMN

Formations may have been deposited essentially simultaneously throughout their outcrop area. On the other hand, a formation may have first started to accumulate in one place before it started accumulating in another. Thus the base of the formation in the second locality is equivalent in age to a horizon somewhere above the base of the formation at the first locality. In contrast a point or moment in Geologic Time is used to mark the beginning or end of a system or series.

FOSSILS AND FOSSILIZATION

Definition of a Fossil

Before discussing the various types of fossils, the methods of collecting them, and ways of studying them, I should perhaps define more clearly the term fossil. Although most of us have some idea of what a fossil is and know at least that it represents a plant or animal whose remains have been preserved in the rocks for a long time, there are some people who apply the term "fossil" to features in rocks that are not demonstrably of organic origin as well as to what are simply artifacts. In fact, in the former case many people have assumed that certain peculiar structures are of organic origin when in reality they are not. Examples of inorganic structures that may resemble organic remains may be found among some of the concretions common in clay banks such as are exposed along Button Bay in Ferrisburg.

In a general way a fossil may be looked upon as the remains of plant or animal life which have been preserved in the rocks from some time in the geologic past. In other words, to be considered a fossil, an entity found in rocks must have the following attributes:

1. It must have been derived from a once-living organism.
2. It must provide some evidence of the physical nature of the organism, either by direct preservation of some part of the plant or animal or by some other trace.
3. It must have a certain "age." That is, it must have been buried before historic times. Those remains buried since the beginning of historic times are not generally considered fossils. The species or genus to which the plant or animal belongs need not be extinct.
4. Natural phenomena must have caused the burial and preservation of the organism or trace of it.

Formation of Fossils

With the exception of imprints of soft parts or the tracks of animals made as the creatures moved across soft sediment, most fossils come from animals possessing hard parts which resist the natural destructive forces. Rapid burial is also a necessary condition since the hard parts need to be protected from attack by other organisms, from wind, waves, and currents, and from chemical decomposition.

UNALTERED AND RECRYSTALLIZED REMAINS

Some fossils are preserved essentially unaltered. The original shell material, protected by the fine debris surrounding the shell, has not been removed by percolating water subsequent to burial, nor has recrystallization changed the shell.

Recrystallization represents a change in the arrangement of the atoms of the chemical compound which forms the shell without a change in the chemical composition of the material. Also small crystals may grow into larger ones in the process, destroying many of the delicate structures that the animal formed as it secreted its hard parts.

Unaltered fossils are found most commonly among the brachiopods and bryozoans. Stromatoporoid remains appear essentially unchanged except for deposition of calcite and dolomite in open spaces of their framework. The small pelecypod shells found in the Pleistocene marine clay and gravel deposits of the Champlain Valley are unaltered except for the leaching away of the outer layer of the shell.

Brachiopod shells and pelmatozoan fragments, particularly the latter, are often recrystallized. The original calcium carbonate acquired a new crystallographic form. Originally fibrous calcite may have changed to interlocking grains of calcite, or smaller crystals of calcium carbonate may have recrystallized into larger grains. Corals and stromatoporoids also provide examples of recrystallized material as do the shells of gastropods and cephalopods.

ALTERED HARD PARTS — PERMINERALIZATION AND REPLACEMENT

Hard parts secreted by the living animal may be changed in some manner during and after burial, either by ***replacement*** or by the filling-in of open spaces within the original shell matter, ***infiltration*** or ***permineralization.*** In the process of replacement the original shell material is carried away in solution, molecule by molecule, and a new compound is substituted for it simultaneously. Sometimes, as in the case of some petrified wood, the microscopic structure of the hard part is preserved; in other cases only the general outline of the shell remains intact, the microscopic structure having been destroyed in the replacement process. Many of the solitary corals found in the massive limestones of the Champlain Valley are preserved in this fashion; most notable, however, are the operculi of the large marine snails, ***Maclurites***, which have been replaced by chert. Pyrite also replaces the original material of brachiopods, trilobites, and graptolites. Dolomite replaces original calcium carbonate of gastropod and cephalopod shells.

Infiltration or permineralization involves the filling of the open spaces in an originally porous structure without alteration or removal of the original shell substance. Thus the shell is simply made heavier. Commonly the filling material is of the same chemical composition as that of the shell, but often it differs from that of the original shell matter. Percolating solutions or water trapped from the sea in which the organism lived may provide the source of the chemicals.

ALTERED HARD PARTS – CARBONIZATION

Action of solutions and other chemical agents may transform parts of the animals into a thin film of carbon in a process called *carbonization* or *distillation*. It is most active on hard parts composed of carbon, hydrogen, oxygen, and nitrogen compounds (for example, a lobster's exoskeleton). The nitrogen, oxygen, and hydrogen are removed during the process, leaving behind only a film of carbon. Fossil forms most commonly preserved in this fashion in the Champlain Valley are graptolites and trilobites.

TRACES OF ORGANISMS

Imprints of shells, trails made as animals moved across the bottom of the sea, borings into the bottom which later became filled, shell fillings of various sorts, and casts made from earlier-formed impressions or imprints in the mud of the bottom all form what may be called traces of organisms. These features all give some idea of the physical nature of the animal whose former existence they record, even though these fossils are not of the original hard parts or some direct derivatives of them, such as replacements.

Molds And Casts– If you have ever walked across a sandy or muddy beach and picked up a clam or scallop shell, you have perhaps noticed a depression where the shell lay. In the depression were higher and lower areas which corresponded respectively to the depressions and ridges of the shell. If perchance you were to fill the depression with some plaster of Paris or modeling clay and were then to remove it at a suitable time, the undersurface of the filling would have ridges and lower areas corresponding in position with those on the original shell. The depression is called the *mold*, and the plaster of Paris reproduction is called the *cast*. Thus it is with fossils; if by some accident a shell is impressed into the mud of the bottom or is surrounded by mud and buried by it, the impression of the shell upon the mud becomes a mold, and the filling of the mold is the cast. A cast may be a natural one formed by the removal of the original shell material followed by the infilling of the mold with mud or chemically precipitated material, or the cast may be artificial, formed when something like modeling clay, latex rubber, or plaster of Paris is poured into the depression and removed after hardening. Frequently a rock may split so that in one piece you may observe the mold of a fossil and on the surface of the other piece the cast or even the original shell (Fig. 3).

Molds can be divided into two types: internal and external. An internal mold forms when the interior of a shell such as that of a brachiopod or pelecypod or the underside of a trilobite exoskeleton is pressed into the mud. The trilobite ***Flexicalymene*** found in the Glens Falls limestone is frequently preserved in this fashion. An external mold is formed when the exterior of a shell is pressed into the mud.

If a hollow shell, such as a snail shell, is filled with mud or chemically precipitated material, the solidified filling is called a ***steinkern***. The outer surface of the steinkern reflects in reverse the ridges and depressions on the inner surface of the shell of the animal. Many examples of this type of fossil can be found among the gastropods, brachiopods, and cephalopods of the Champlain Valley limestones.

If a hollow shell such as a brachiopod shell is buried and is later dissolved away, leaving an opening, a natural replica may be formed. Percolating water can bring in a chemical which may be precipitated in the opening, filling it. If the enclosing rock is broken away, you will find a solid mass which is the filling. On the surface will be recorded surface features of the original shell while the internal structures will have been completely obliterated. If the hollow had remained and the fossil-collector had squeezed into the opening some filling like modeling clay or liquid rubber, then an artificial replica would have been formed.

Trails And Borings—Small raised ridges, generally dolomitized, may be observed on weathered bedding surfaces of some limestones. Some of these features are suggestive of worm trails or trails left by traveling bivalves. However, conclusive evidence as to their origin is not known.

In two of the formations, the Cutting dolostone and the Orwell limestone, vertical tubes occur which are believed to be the work of burrowing worms. In the basal sandy part of the Cutting they are generally recognized on weathered vertical surfaces as tapering holes oriented at approximately right angles to the bedding. These have been called *Scolithus*. Near the base of the Orwell limestone of the Central Champlain Valley or the "Lowville" limestone of the Island area, there occur small, vertical, calcite-filled tubes to which the name *Phytopsis* has been applied. Both of these features seem to have been the work of ancient boring organisms, possibly worms. No remnant of the animals responsible for them has been recognized.

Since a true explanation of the origin of borings, trails, and various tubes must await comparison with present-day structures of similar appearance,

FIG. 3. Fossilization Processes. Several types of fossils that might be found on a bedding surface; various magnifications.

A. Unaltered pelmatozoan columnals; two seen in cross-section and one longitudinally.

B. Straight cephalopod showing the internal filling in the front part with the lines marking the position of the septa. The siphuncle is filled also (compare with Plate XII, fig. 6).

C. Internal filling of a brachiopod. The shell material that covered the filling lies in the depression represented at P.

D. Cross-section of a gastropod showing the filling (steinkern) and the original shell material filling it.

E. Interior of a brachiopod showing the shell outline and the two short brachiophores of the brachial valve.

F. Impression of a brachiopod exterior. The ridges in the impression correspond to the depressions in the shell exterior. The shell making the impression is shown at O.

G. Longitudinal section of a straight-shelled cephalopod showing the original shell material and the internal filling between the septa. Compare with B.

H. Internal filling of a coiled cephalopod shown in cross-section. The shell has been destroyed leaving only the filling.

I. Brachiopod from which part of the shell material has been removed. The posterior part shows the internal filling while from near the middle of the shell forward the shell material remains. M is the impression made in the overlying layer by this shell.

J. Trilobite showing the relationship between the exoskeleton and the internal filling. The two black portions of the diagram represent original shell matter that has been carbonized while the lighter areas represent the internal filling from which the carbonized material has been removed. L represents the impression made by the trilobite on the overlying layer and in which the shell material removed from the internal filling may be found.

K. Graptolites, carbonized remains.

L. Impression of trilobite shown at J.

M. Impression of brachiopod shown at I.

N. Impression of straight-shelled cephalopod shown at B.

O. Brachiopod forming the impression shown at F.

P. Impression of brachiopod shown at C. The original shell material lines the impression.

Q. Impression of the steinkern shown at D.

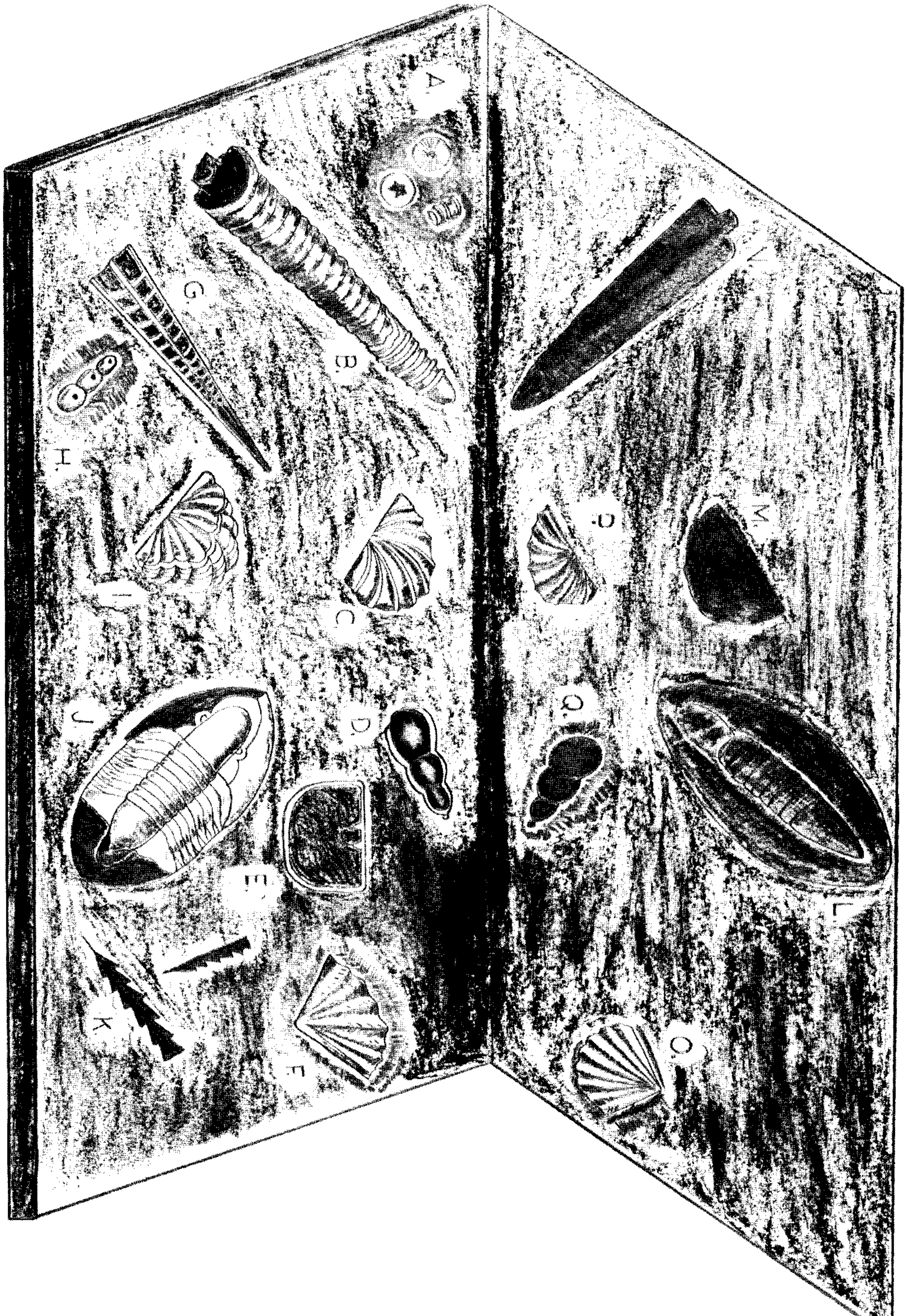


FIG. 3 FOSSILIZATION PROCESS

any explanation is, it must be remembered, little more than a conjecture.

Figure 3 illustrates several of the fossilization processes found in the Ordovician rocks of the Champlain Valley.

Use of Fossils

Fossils are useful to the student of the earth's history in a number of ways. When properly classified and identified they enable the geologist to make interpretations about the physical history of the earth, about evolution, and about the conditions under which a formation was deposited. Without fossils the geologist would have great difficulty in deciding the relative order of many events in the earth's history. Fossils properly used enable the geologist to determine the relative ages of two or more formations and to decide, for example, whether a sandstone was being deposited in one area before, at the same time, or after a shale was deposited in another. From such knowledge the geologist is able to draw reasonable conclusions about the distribution of the sea and land at sometime in the geologic past. Such conclusions often have economic importance in exploration for oil and gas or mineral deposits.

Fossils also give us a time dimension in our understanding of the development of life. From the study of fossils and the changes that the animals they represent underwent with the passage of geologic time, we have a better understanding of the process of evolution than we might otherwise have. The zoologist studying evolution is concerned with the animals as they are and the processes that might cause them to change. If he understands fossils and what they can tell him, he can see a much broader picture of evolution than otherwise might be the case. Fossils clearly indicate that evolution has taken place, but they do not supply the mechanism, although they suggest some possibilities.

COLLECTING FOSSILS

Fossils record the changes of life that have occurred with the long passage of geologic time, and because of this fact, they are important as a means of establishing the relative ages of formations. Thus fossils are of value only if they can be placed accurately in the sequence of rocks from which they came. Whenever fossils are collected, a record of the location should be made on the spot, both on a slip of paper which is kept with the collection until final labels are prepared and in a field notebook. The field records should include such information as the location, the date, the formation, and the collector; if a field locality number has been assigned, this should be included also. If possible the location should be plotted on a United States Geological Survey quadrangle map kept specifically for this purpose. Any collector who does not carefully and accurately record the locality description is wasting his time. Plate XVI shows some collecting localities in the Champlain Valley.

One of the prime requisites for fossil collecting is the goodwill and interest of the landowner on whose property you may wish to collect. You should never enter upon private property without first obtaining permission; care must be exercised that buildings, fence lines, and other equipment are not damaged and that all gates are closed or left as found. On both field labels and permanent labels you should acknowledge the owner of the property from which the collection was made. Collecting in state parks is generally forbidden.

Tools

The following paragraphs describe tools and techniques which I have found useful in collecting fossils from the limestones of the Champlain Valley. Sometimes all that may be required of you is the energy to break large blocks down into smaller ones; on other occasions you may have to utilize quarrying techniques. Only a general outline of some techniques can be given, each collecting experience providing slightly different problems.

Perhaps one of the best tools is patience. Some of the limestones are tough and yield their fossils only grudgingly, but if you have sufficient patience, you can obtain many interesting and valuable specimens from them.

Newspapers form a handy and convenient means of wrapping collections for carrying them home; paper bags are more convenient, but not necessary. A label with the locality description and number and other pertinent information on it should be placed in each paper bag or bundle of newspaper-wrapped material. While newspaper is generally adequate for wrapping even the most delicate of specimens, I have found that soft tissue paper, such as facial tissue, protects delicate fossils in a better manner than newspaper. A collecting bag with a shoulder strap or a small knapsack is also useful.

Other items a collector should have are paper for labels, a notebook for recording pertinent data, a geologist's hammer, and a hand lens. The hand lens should provide at least a 10-power magnification, and you should use it frequently when scanning rocks for fossils. Many of the fossils found in the rocks of the Champlain Valley are so small that they are easily overlooked by the naked eye. Often rare fossils will appear as mere specks, or only a small part of one may protrude above the surface of a slab.

A good hammer is indispensable. A geologist's or pointing hammer with a pick point on one end is especially useful in the resistant, massive limestones while a geologist's or bricklayer's hammer with a chisel edge is better for attack on the shaly formations. A chisel-edged hammer will enable you to pry the rocks apart along bedding planes while the pointed type of head will permit you to concentrate the whole force of a blow at one point. Both types of hammers can be obtained at hardware stores. Heavier sledge hammers are also useful in breaking large blocks down into smaller blocks. A word of caution, however, about the choice of hammers. You should never break rocks with a hammer that is not specifically manufactured for rock-breaking as small pieces of steel may fly off other types of hammers, endangering the eyes.

Stone-cutter's chisels which can be used as wedges and prying tools as well as for cutting are indispensable. One should be approximately 1 inch in diameter; smaller ones can be used for less heavy quarrying. A star drill is another useful tool for attacking the massive limestones.

Finally a pair of safety goggles should be part of the equipment. Tiny pieces of limestone fly in all directions, many with sufficient velocity to injure an eye permanently.

Whether you will have to quarry out blocks along joints and bedding planes or simply to break up the beds along exposed edges depends upon the particular formation. In some cases you may wish to isolate a specimen on a pedestal and then free it by breaking across the pedestal beneath it. The method of attack upon each exposure is a matter for individual judgment at the time and place of collecting.

You should clean your material in the field only enough to make transporting it easy. The tools and instruments used in the field are generally too crude to permit an efficient cleaning job, and valuable specimens may be ruined in an attempt to clean too closely without the use of proper tools.

Collection of a relatively large quantity of material is deemed advisable generally; it is usually easier to examine the material in the laboratory or at home, discarding the unwanted or worthless material at leisure, than to try to clean and sort it in the field. Also an opportunity to visit the locality may not present itself again.

Curating

If the fossils are to be meaningful to you, and especially to people who view your collection, they must be cleaned and placed in some sort of organized arrangement. Otherwise, the collection becomes nothing more than another set of curios. It is easy to lay aside a collection, letting it gather dust on a shelf, but much of the enjoyment of fossil-collecting comes from the preparation and identification of the fossils and from the study of them as organisms that once lived.

Once you bring a collection in from the field, you should record the locality in a permanent record book and prepare permanent labels. At this time you should also assign a permanent locality number to the collection. To keep a complete record, you should transcribe this number onto the field labels and record it in your field notebook.

Once the fossils are cleaned, you should indicate their locality by printing on them, using a fine pen point and India ink, a code number which ties them to the permanent record book and the permanent label. Sometimes it is necessary to put a small spot of paint or colored nail polish on the fossil to serve as a surface on which to print the number. A thin coat of shellac over the number protects it from wear. The permanent locality number may suffice if the several specimens from one locality are to be kept together. Included on the permanent label should be the name of the fossil, the locality, the collector, the date of collection, the permanent locality number, and the landowner's name.

CLEANING FOSSILS

It has been my experience that the fossils must be dug out of the limestones mechanically. The skills and judgment required to remove a fossil or to isolate one in a piece of limestone comes only with experience; the various limestones have different properties when it comes to preparation of fossils, and only experience can suggest how to handle each situation as it arises. A large amount of common sense must be applied.

The chunks and pieces brought in from the field are most conveniently broken down into smaller pieces on a small anvil or block of steel. A small hammer such as a mineralogist's hammer should be used. A piece of railroad rail is useful as an anvil. Small sandbags for supporting the pieces of rock as they are being worked on are also handy. A large pair of pliers or wire cutters is also useful on occasion.

Some of the tools that I have found useful in digging fossils from the Champlain Valley limestones include a Burgess "Vibra-tool," a quarter-inch portable electric drill with various sizes of drill bits and burrs, several types of scratchers made from old drill bits which have been mounted in wooden handles, needle files of Swedish steel, and "X-acto" knife blades. Worn-out dental tools are excellent for scratchers and detailed cleaning. A center punch is useful not only in the laboratory but also in the field. This particular instrument is most effective where the force required to remove a chip must be concentrated at a point.

Small brushes of several types are part of the necessary equipment. Some are used as applicators for dilute acid and for washing away dust. An old toothbrush of moderate stiffness is useful for brushing a work area clean.

I have used a propane torch on occasion to develop cracks around a fossil or to cause the fossil to pop out of the matrix. The fossil may be isolated on a pedestal by means of digging with a drill, a knife blade, or some other sharp instrument. After the fossil is on the pedestal, the hottest part of the flame is applied to the area beneath the fossil until the rock is red hot. Then cold water is thrown on the heated area or the whole rock is dropped into a container of cold water. It may be necessary to repeat the treatment several times. If the fossil has not broken off during the heating process, the sudden chilling may cause it to break off. In many instances I have succeeded in opening a crack across the pedestal without actually separating the fossil from the matrix beneath. When this situation occurs, a wide-edged tool can be applied to the vicinity of the crack and tapped lightly with a hammer. On the other hand, when the rock is heated, the fossil may leave the underlying limestone like a bullet from a gun.

Dilute hydrochloric acid (3% or less) may be used for etching out some of the silicified corals and for bringing out the outlines and details of some of the other forms. The acid leaves a waxy appearance on the fossils, and it should be used with caution. Larger specimens may be placed in a shallow dish with the acid; for smaller specimens the acid may be applied with a dropper or brushed on with a small brush. Dilute acetic acid reacts more slowly and does not leave a waxy appearance.

As the specimens are removed from the matrix material, they can be sorted by phylum, if not into smaller classification divisions. Such a splitting is a preliminary step to identification of the specimens.

ORGANIZING A COLLECTION

Organization of a collection depends largely upon your interests. Perhaps the two most common types of organization are the Systematic Collection and the Stratigraphic Collection. In the former type of collection all the specimens from one phylum are grouped together. For example, all the trilobites are put together and all the brachiopods are placed together. Usually there is a stratigraphic arrangement within the basic outline of such an organization. The plates at the end of this volume have a systematic arrangement. In a Stratigraphic Collection the specimens are arranged according to the formation from which they were obtained, and the collection is most often organized so that the oldest fossils come first in the collection.

You may wish to specialize in one phylum. Various other possibilities will come to your mind as you work with the materials that you collect. Also you may obtain ideas from some of the references listed in the bibliography. The basic purpose of the collection is to have it tell a story.

NAMING FOSSILS

All of us are familiar with the similarities and differences between various trees; we can distinguish a cat from a dog or a blue mussel from a clam. However, a tree or a clam may be called by one common name in one part of the world and by a different name in another part, depending upon the language and customs of the regions. To avoid the difficulties inherent in the use of common names or names that include lengthy descriptions of the animals, Linne' proposed in the 18th century that each animal and plant be given a name composed of two parts: the generic and trivial parts. Furthermore, to overcome the difficulties of the many languages, he suggested that Latin, a dead language be used.

Following Linne''s scheme, paleontologists will give a fossil a two-part name which is Latinized whether it was actually derived from Latin or not. An example is the name of the common Glens Falls trilobite, *Isotelus gigas.*

The first word of the name is always capitalized and is called the generic name. The second word is called the trivial name and is never capitalized. Taken together the two words give the name of the species; when a particular genus is referred to, the generic name alone may be used. However, the trivial name is never used by itself, for without the generic name it means nothing. Usually the author of the name follows the trivial name, being written in standard print: *Isotelus gigas* Dekay. The generic and trivial names are printed in italics.

Further work may show that the species was initially placed in the wrong genus. While the generic name may change, the trivial name remains as given by the person who first described the species. If the species is placed in a different genus, the original author's name is then placed within parentheses. The same trivial name may be used for species belonging to different phyla, but in general this practice is discouraged as it leads to much confusion.

Starting with the species, a hierarchy of classification has been developed. Species which are alike in certain respects are grouped together into a Genus; genera which have certain similarities are brought together into a Family; families which are similar are grouped into a Class, and finally classes are grouped into a Phylum. The several phyla which display characteristics which we have come to associate with the group of organisms called animals are placed in the Kingdom Animalia while the plants are grouped into the Kingdom Plantae. Various subdivisions and other groups are utilized by scientists to give refinement to the scheme. Given below is the complete systematic classification of ***Maclurites magnus*** Lesueur, a fossil common in the Crown Point limestone.

Kingdom	Animalia
Phylum	Mollusca
Class	Gastropoda
Order	Archaeogastropoda
Family	Macluritidae
Genus	*Maclurites*
Trivial	*magnus*
Individual	The individual specimen

Species Name: ***Maclurites magnus*** Lesueur

THE FORMATIONS

Each formation displays characteristics which enable the geologist to set it apart from other formations in the area. The purpose of this section is to acquaint you with the general appearance of each formation. I have made no attempt to discuss the many variations that each displays; for the details of each formation the reader should consult the several publications which describe the geology of the area. Only those formations containing fossils in relative abundance within the Champlain Valley are discussed. For the complete Geologic Column of the area you are referred to Fig. 2.

Cassin Formation

The Cassin formation, named for the type locality of Fort Cassin at the mouth of Otter Creek, consists of two general lithologies. The lower one is a fine-grained, sandy limestone which is generally bluish-gray in color on a fresh surface. The most outstanding characteristic of this part of the formation is its tendency to weather into a series of alternating brownish-weathering ridges and slight depressions, giving a sort of banded or ribbed appearance to a weathered vertical surface. The thickness of the bands or layers averages somewhat less than 1 inch. If you study closely some of the exposures of this part of the formation, you will see an abundance of trilobite fragments. These were rolled around prior to final deposition. Small disk-like pebbles of sandy limestone like that comprising the ridges of the weathered surfaces may also be seen in the same horizons. A good exposure of this part of the formation may be seen on the road from Charlotte to Thompsons Point, approximately half a mile west of the Rutland Railway tracks (Locality 1, Plate XVI).

The upper part of the Cassin formation consists of light-bluish-gray-weathering, very fine-grained limestones which occur in beds from 1 to 3 feet thick. Near the top of the sequence the limestones have thin, black, platy layers distributed through them. These limestones resemble closely the limestones of the younger Crown Point formation with which they have sometimes been confused.

Trilobites and brachiopods are locally very abundant in the lower part of the Cassin formation; gastropods and cephalopods occur in proportionately greater abundance in the upper, lighter weathering, finer grained limestones than in the lower part.

East of "Logan's Line," or the Champlain Thrust, in the Middlebury Synclinorium, the equivalent of the Cassin formation is found in the upper part of the Bascom formation; the two units of the Cassin formation can be seen in outcrops east, north, and northeast of Shoreham Village. In this area the Bascom formation has at its base very fine grained limestones, light bluish-gray in color, which contain outlines of fossils.

Bridport Dolostone

Overlying the Cassin formation is the Bridport dolostone. East of the lowland area of the Champlain Valley, the Beldens formation, which is equivalent to the Bridport, overlies the Bascom formation.

The Bridport dolostone consists of interbedded dolostone and limestone; locally the limestones comprise the bulk of the formation. The formation may be recognized by the characteristic tan-weathering color of the dolostone beds and their general black coloration on a fresh break. Also, the dolostone beds are scored by irregularly arranged grooves; the overall appearance of these beds is that of "thread-scored beeswax." The interbedded very light-gray-weathering limestone beds contain fossils in some places; however, they are usually fragmental and very difficult to extract. Small gastropods are the most evident forms. The general outlines of the fossils may be brought out by etching a polished surface, or they may be seen on weathered surfaces of the limestones. Occasional calcareous shales contain small gastropod and pelmatozoan fragments.

The Weybridge member of the Beldens formation, a unit composed of thin-bedded, sandy limestone, contains many fossil fragments; as yet this unit has not been studied in detail paleontologically, and it is not unlikely that some interesting and valuable forms may be found to occur within it. The Beldens formation is largely limestone, in places extensively marbleized, with interbedded tan-weathering dolostone beds.

Day Point Formation

Overlying the Beekmantown Group of formations is the Chazyan Group comprised of the Day Point formation, the Crown Point limestone, and the Valcour formation. Within the lowland area of the Champlain Valley all three formations are recognizable, but to the east, near the Champlain Thrust, the Valcour formation disappears, being replaced by beds of the Crown Point-type. In the same region the Day Point thins to only a few feet.

The Day Point formation is fossiliferous throughout most of its extent. The lowest beds are yellowish-orange-weathering, silty dolostones and dolomitic siltstones. In the Vermont exposures south of Burlington the dolomitic beds pass upward into thin-bedded, nodular-weathering limestones which are a medium-bluish-gray. Some of these limestones present a general dull-appearing luster in a fresh break; others seem to sparkle. Interbedded are olive-gray, noncalcareous shales and medium- and fine-grained quartz sandstones. The sandstones occur in the lower half of the formation. Many, but not all, of the limestones are composed of fossil debris, some coarse-grained, some fine-grained.

The most spectacular displays of the Day Point formation are to be found on the islands of South Hero and Isle La Motte. The lower portions of the formation are sandy, fine-grained calcareous sandstones and sandy limestones; upward the formation grades into thin-bedded and locally thick-bedded limestones with pockets and local areas of sandy limestones. Both medium- and thin-bedded limestones occur in this part of the formation. The rocks are composed of fossil fragments of various sizes held together by crystalline calcite. The most interesting features of this part of the Day Point are the "reef" structures found on Isle La Motte, at The Head and 0.35 mile southwest of Holcomb Point (localities 3 and 4, Plate XVI). The structures are low mounds composed of the coral *Lichenaria* *heroensis* (Raymond) (Plate III); algae, stromatoporoids, bryozoans, and brachiopods.

In the lowest, yellowish-orange-weathering, sandy and silty limestones and dolostones of the formation the fossils are chiefly species of the brachiopod *Lingulella (Lingula* of older reports). Figures 22-25 of Plate V show some of these from along the south shore of The Head, Isle La Motte (Locality 3, Plate XVI). Above the *Lingulella*-bearing beds the fauna of the limestones is varied, and an abundance of various forms may be found.

Crown Point Limestone

The most widespread of the three formations comprising the Chazy Group, the Crown Point limestone, is typically medium- and dark-bluish-gray on a fresh surface. It weathers to various shades of light and medium gray and bluish gray. Some of the beds are thin; others range up to 20 feet thick. Generally a vertical surface perpendicular to the bedding gives the impression that the rocks of the formation are massive. Thin, black, platy layers of quartz silt and buff-weathering laminae of dolomitic silt are distributed through the formation, being locally very abundant, elsewhere less prominent. These thin layers branch and come together again in an irregular manner, giving to a vertical weathered surface the appearance that links of chain laid on the surface might impart.

Medium- and coarse-grained fossil-fragmental limestones are important components of the formation, but very fine-grained limestones formed from lime mud are also important.

Close inspection of weathered surfaces shows minute black specks rising above the general surface. These are fossil fragments. Larger fragments are also recognizable. On bedding surfaces outlines of the large gastropod *Macurites magnus* Lesueur and its subconical-appearing operculum (Plate IX) provide clues to the identity of the limestones. Local sandy areas are found in the formation, forming in places short cross-laminated lenses within the limestones.

"Reef" structures are found in the Crown Point on Isle La Motte. These are composed of stromatoporoid and algal mounds around which shells and shell fragments from brachiopods, bryozoans, pelmatozoans, cephalopods, and gastropods accumulated. Perhaps the best-exposed "reef" is located east of the road 2 miles south of Isle La Motte Village (Locality 8, Plate XVI). Other "reef" structures are found at the Grand Isle-South Hero line along U. S. Route 2 (Locality 11, Plate XVI), but here the "reefs" are thinner than those on Isle La Motte and have a large number of fossil sponges (Plate II).

Valcour Formation

In places the Valcour limestones resemble closely the underlying Crown Point limestones; however, the general lack of the black, silty laminae or the buff, silty dolomitic laminae in the Valcour together with slight differences in the color of fresh surfaces and the colors of weathered surfaces will enable you to distinguish the two formations from one another. Furthermore, the limestones of the Valcour are more obviously composed of shell fragments cemented together with calcite than are the limestones of the Crown Point. Irregular patches of silty, yellowish-orange-weathering dolostone are found through the formation. Comparison of fresh surfaces of very fine-grained limestones comprising the Valcour with fresh surfaces of limestones from the Crown Point discloses that the Valcour limestones have a sparkling luster whereas similar-textured limestones of the Crown Point possess more of a dull luster. The irregular patches of yellowish-orange-weathering dolostone are often found associated with areas which might be termed "reefy", implying the presence of small mounds composed of fossils and shell debris. Some of the limestones with sparkling luster weather very light buff in contrast with the more bluish coloration of many other Valcour limestones and with the typical Crown Point beds.

"Reefy" horizons occur on Isle La Motte, lying in a thin band above the Crown Point reefs south of Isle La Motte Village and east of the main road in the area (Locality 8, Plate XVI), and small organically formed mounds may be seen along the south shore of Rockwell Bay on South Hero (Locality 17, Plate XVI). Between the mounds are channels filled with shell debris.

Occasional sandy horizons, strongly cross-laminated or cross-bedded are distributed through the Valcour; other parts of the formation resemble closely the overlying Orwell-"Lowville"-Isle La Motte sequence of beds, being dark-gray to black, extremely fine-grained, and massively bedded.

Orwell Limestone
("Lowville" and Isle la Motte Limestones)

The sequence of beds which overlies the Valcour limestones consists of a lower very light-gray-weathering, light-gray to chocolate-colored, smooth-weathering, smooth-fracturing limestone and a medium-gray-weathering, dark-gray to black, generally smooth-fracturing limestone. Both types of limestones are massive, and individual beds average between 1 and 2 feet in thickness. Typical of the beds of the sequence are the layers of fossil fragments, largely brachiopod and gastropod fragments, which occur as layers 1 to 2 inches thick in the massive limestones. Operculi and outlines of *Maclurites logani* (Plate IX) are common associates. Scoring, almost rectilinear in pattern, gives many weathered surfaces a blocky-appearance.

The lighter colored limestone lies between the Valcour (or Crown Point where the Valcour is absent) and the darker limestone. It is characterized by vertical, calcite-filled tubes which have been called *Phytopsis* and which are thought to represent worm borings.

The unit has been called the "Lowville" formation on Isle La Motte and at other places in the northern Champlain Basin. The limestone overlying it on Isle La Motte has been termed the Isle La Motte limestone. In the Central Champlain Valley area and east of "Logan's Line" the two units have been lumped together under the name Orwell limestone.

Good exposures of the two units may be seen north of Jordan Bay—in the old Hill Quarry—on Isle La Motte, near Porter Cemetery in the western part of Ferrisburg township, and on the west shore of Long Point in Ferrisburg. The lower light-colored limestone is not present everywhere, having a sporadic distribution.

Fossils are extremely difficult to extract from the Orwell limestone, although in some places diligent work and search will provide good specimens. The accumulation of corals and stromatoporoids in the 18-inch bed on Button Island, Ferrisburg, is particularly notable.

Glens Falls Limestone

Perhaps the most fossiliferous formation of all those found in the Champlain Basin is the Glens Falls limestone. Beds of the formation provide a wide variety of fossils. Almost every outcrop of the Glens Falls has fossils in it, but, obviously, some localities are more fossiliferous than others.

The Glens Falls limestone is a sequence of shaly and silty limestones and interbedded shales; the components weather dark gray to bluish black in many exposures; in other exposures the rocks are olive-gray on a weathered surface. Most of the beds making up the formation are less than a foot thick, but sequences of massive beds up to 18 inches or 2 feet thick are not uncommon. Layers of shale, usually only a few inches thick and notably thinner in most instances than the limestones, separate individual limestone beds. The limestones protrude on weathered vertical surfaces while indentations mark the position of the less resistant shales. The contacts of the individual beds are irregular, giving a crenulated appearance to vertical surfaces.

Layers of fossils may be easily recognized in the unfolded sequences of the Champlain Valley; where the formation is intensely folded east of "Logan's Line," the fossil layers define the bedding, in contrast to the cleavage which suggests bedding in many cases. In open fields blocks of limestone up to the size of bricks mark the presence of the formation beneath the soil cover.

The Glens Falls is divided into two members, a lower Larrabee member and an upper Shoreham member. The limestone beds of the Larrabee member generally tend to be thicker than the individual limestone beds of the Shoreham member, and the individual shale beds of the Larrabee are more clearly separated from the limestone beds. The gum-drop-shaped bryozoan *Prasopora* and the trilobite *Cryptolithus tesselatus* (Plates IV and XIV) are typically found in the Shoreham member.

Cumberland Head Formation

The Cumberland Head formation represents a transition from the Glens Falls limestone to the Stony Point shale, which overlies the Cumberland Head. The limestones of the Cumberland Head are bluish-black and resemble in many respects the limestones of the Glens Falls. However, the individual beds tend to be somewhat thicker than those of the Glens Falls, and the interbedded shales form thicker beds also. Generally speaking, the Cumberland Head formation is less fossiliferous than the Glen Falls. Shales are more prominent in the Cumberland Head.

The best exposures of the formation are on Isle La Motte and South Hero. In the central part of the Champlain Valley the transition zone may be seen in several places, but the formation has not been mapped as the Cumberland Head. North of Arnold's Bay in Panton and along the shore north of West Bridport (Locality 34, Plate XVI) the transition zone is fossiliferous.

Stony Point Formation

Dark, bluish-gray, calcareous shales which break in a splintery manner are the major component of this formation. Thin, bluish-weathering, black limestone beds separated by very thin layers of clay-rich material are also important components of the formation. Individual shale beds may be as much as 18 inches thick; generally the limestone beds, even where they form the bulk of the formation, are only a few inches thick. These limestones differ from the limestones of the Cumberland Head and Glens Falls formations in being more bluish on weathered surfaces and by possessing very thin, light-colored laminae which appear most often on the water-washed surfaces adjacent to the lake. The limestones also appear more dense on a fresh surface than the limestones of either the Glens Falls or Cumberland Head formations.

The fossils found in the Stony Point occur mostly in the calcareous shales. The most common forms are the trilobite *Triarthrus beckii* (Plate XIV) and various graptolites (Plate XIV). Some of the brachiopods found in the Glens Falls range up into the Stony Point, although they are generally rare.

Iberville Formation

This formation is essentially unfossiliferous, although a few fragments of graptolites have been found in it. Black, platy, thin-cleaving, noncalcareous shale makes up the bulk of the formation. Also important in it are orange-brown-weathering dolomitic siltstones up to a foot or more in thickness and yellowish-orange-weathering dolostones. The lower part of the formation, a transition from the underlying Stony Point, contains interbedded noncalcareous and calcareous shales with thin yellowish-orange and brownish-orange-weathering, black dolostone beds.

Pleistocene Deposits

Glacial and glaciofluvial deposits, fresh-water lake deposits, and marine clays, sands, and gravels represent the Pleistocene. Only the marine sands, gravels, and blue clays contain fossils. From them come thin-shelled marine invertebrates. Often the shells occur in thin layers. The general appearance of many of the sand and gravel deposits suggests a present-day beach deposit.

Vertebrate remains are known from Pleistocene deposits of Vermont. Perhaps the most famous of the vertebrate remains is the skeleton of a whale, *Delphinapterus vermontanus* (Thompson), found in blue clays of the Champlain Sea. The whale was discovered in the blue clays exposed in a railroad cut made in Charlotte, about 12 miles south of Burlington, in August of 1849. The skeleton is on display in the State Museum at Montpelier. Figure 2, Plate XV, is a copy of the picture of the skeleton presented by Perkins in his discussion of the whale (Perkins, G.H., 1908, p. 76-112).

The deposits formed in Lake Vermont and Lake Champlain when its water was higher, as well as the deposits formed by streams running from the melting glacial ice masses, may yield remains of mammals that inhabited the region in the late Pleistocene. To date only elk horns have been found, these being discovered in Grand Isle. The horns are on display in the Fleming Museum at the University of Vermont in Burlington. A mastodon tusk was found in Richmond and a mammoth tooth was discovered in Mt. Holly more than a hundred years ago.

PLANTS

Champlain Valley plant fossils consist of the remains of algae which are broadly related to many of the seaweeds living in the oceans today. The plants extracted carbon dioxide from the sea water, causing precipitation of calcium carbonate both within and around the algal masses. When the organic matter rotted away, small tubelets were left within the individual calcium carbonate masses, showing the arrangements of the filaments. Some forms once described as *Stromatocerium*[1] are now thought to be algae, and encrustations

[1]This fact was first brought to my attention in a letter written by Professor J. J. Galloway of Indiana University to Professor Bruno M. Schmidt of Middlebury College, dated October 9, 1954, and filed with thin sections of some of the "*Stromatoceria*" in the Middlebury College collections.

believed to be of algal origin, stromatolites, are important locally, as in the Crown Point limestones about half a mile north of Porter Cemetery in the western part of Ferrisburg and in the Valcour formation north of Rockwell Bay, South Hero. *Stromatocerium*-like growths which may be algal growths are prominent in the Orwell about half a mile north of Panton Village.

The algal forms that are most common are *Girvanella, Solenopora* and similar-appearing forms, and *Cryptozoön.*

Girvanella

Girvanella is abundant in the Crown Point limestones and appears on weathered surfaces as oval-shaped, laminated structures up to the size of a quarter, giving an observer the impression that eyes are peering at him from out of the rocks. Individuals may occur as isolated specimens or in great clusters. *Girvanella* specimens are subspherical to ovate in shape; pellet-shaped and bean-shaped are terms that might be applied to them. The plant apparently grew as a series of tube-like filaments around which the calcium carbonate was precipitated.

Often the individual algal mass began growing around a quartz grain or encrusted a shell or shell fragment (Plate I, fig. 4). Scattered through the limestones as a rule, individuals are also found concentrated in laminae up to several inches thick or in patches within thick limestone beds. Concentrations of the individuals are usually closely associated with layers in which other fossils are common also. The great clusters of *Girvanella* are best developed in medium- to coarse-grained fossil-fragmental limestones.

Several species of *Girvanella* have been recognized in the Crown Point limestones. The form was once described in some of the early reports of the Vermont State Geologist as a sponge, and the species are described in these reports (Seely, 1902). Figure 5, Plate I, illustrates a typical occurrence of this alga.

Solenopora

This alga is subglobular in shape and consists of a series of radiating tubes, some of which have a few partitions across them. The individual body of the alga may be up to 2 inches in diameter, and the individual tubes may range up to 0.5 mm in diameter. The genus is found in the Chazyan and Mohawkian rocks of the Champlain Valley (Fig. 2); it is apparently related to the living red algae. Plate I, fig. 3 illustrates the internal structure of this form. Figures 1 and 2 of Plate I illustrate another genus which appears to be related to *Solenopora* and which occurs in the reefy zones of the Day Point formation on The Head, Isle La Motte.

Cryptozoön

Cryptozoa are not important in any of the rocks exposed within the Champlain Basin of Vermont. These plants formed cabbage-like, irregular masses of arching layers. The matlike mass of the individual colony seems to have been built of layers of threads around which lime was secreted. Recrystallization of the lime has destroyed the internal structures of most of the masses; hence, identification of the individual species relies upon the external shape and configuration of the mass, that is, on the growth form.

No reefs or large accumulations of this genus have been recognized within the Vermont portion of the Champlain Basin, but the form illustrated in Plate I, fig. 6 came from the limestones of the Cassin formation at Thorp Point in Charlotte. Large accumulations of *Cryptozoön* are found near Saratoga Springs, New York.

"Stromatocerium" lamottense Seely and *"Stromatocerium" eatoni* Seely appear to be algae of the *Cryptozoön*-type rather than true stromatoporoids.[1] These forms are illustrated on Plates I and II; figure 3, Plate II illustrates *"Stromatocerium" lamottense* in growth position in the face of the Fisk Quarry near the southeast corner of Isle La Motte.

Brandon Lignite Deposits

About half a mile south of Forest Dale on the Forest Dale-Rutland road and 250 feet east of it, on the Horn property, is a deposit of lignite (brown coal) from which an extensive collection of leaves, fruits, seeds, and twigs and branches has been obtained. The fruits have been described by Perkins (1904), and more recent work has been done by Barghoorn and Spackman (1950). A bibliography of the work done on the lignite is provided by these latter authors.

Studies of the fossils from this horizon indicate

[1]See footnote, p. 15

that a warm, temperate climate existed in the Vermont area during the middle part of the Tertiary, a climate similar to that found today in the southeastern part of the United States.

The lignite occurs near the concealed contact of the Lower Cambrian Cheshire quartzite and the Dunham dolostone. A stream or streams flowing westward from the Green Mountains apparently transported plant remains and debris into a small forest swamp or swampy pond at the foot of the slope. Subsequently, silt covered the plant-bearing layer, recording an open-water phase for the pond, a time when the pond may have become larger.

Small pieces of twigs and branches, leaves, and fruits may still be found at the locality but perhaps not so easily as at one time in the past.

PORIFERA

The sponges are generally considered the most simple of the multicelled animals, being essentially little more than colonies of single cells. The individual animal, radially symmetrical when viewed from the top, consists of fleshy and skeletal material surrounding a hollow area; the individual is perforated by canals (or pores) which bring water, and thus food, into the hollow interior (the cloaca) of the animal. There are no internal organs. Cells on the surface of the interior of the animal extract food from the water and move the water with the waste products out of the top of the animal through the osculum. Figure 4 is a diagrammatic sketch of the basic plan of a simple solitary sponge, and Plate II, fig. 6 is a natural vertical section through an elongate sponge from the Crown Point formation in South Hero.

The skeletal framework of the animal consists of spicules of various sizes and shapes which may be composed of calcium carbonate, silica, or spongin. The framework of the sponge most common in the Chazyan rocks of Vermont, *Zittelella,* is massive, being formed by a fusion of the spicules. Shapes of sponges vary widely, and for many of the early sponges, such as those found in the Champlain Valley, the shape of the individual, together with minor structural features, is the only basis for classification and identification of the animal. Within the Porifera finger-like, pear-shaped, globular and hemispherical shapes are common.

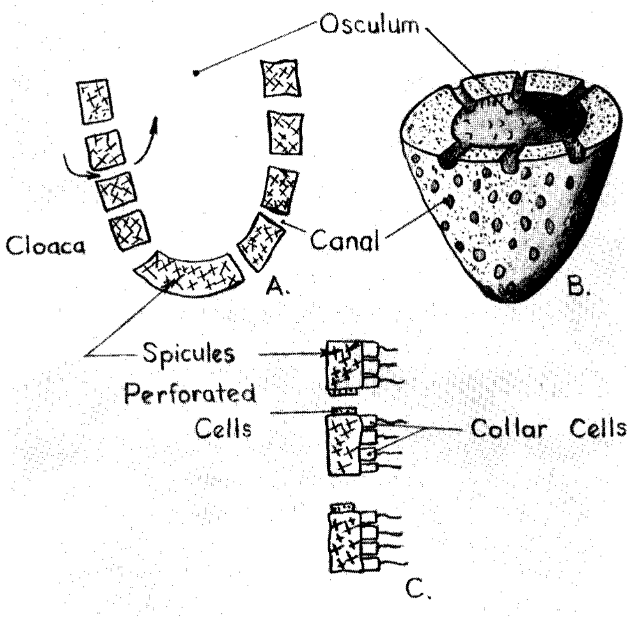


FIG. 4. Porifera. Simple solitary sponge, diagrammatic. A. Vertical section with arrows showing direction water currents move. B. Oblique view of complete animal. C. Enlargement of wall to show diagrammatically the collar cells which line the inner portion of the wall and the outer wall with its spicules.

Sponges may be preserved by the filling of the hollow spaces within the skeletal framework by mud or lime ooze. The skeletal parts are impressed upon the soft materials, and if during ensuing time the original skeletal material is destroyed, the fossil is nothing more than a mass of solidified mud in the shape of the original animal but with lines showing the former position of the skeletal material. If the sponge had a massive structure, as in the case of *Zittelella,* then the original material may be preserved, and the hollow spaces will be filled with the solidified mud or lime ooze. Such fillings are usually a different color on a weathered surface than is the original skeletal material. On weathered specimens canals will appear as small lines or grooves radiating outward from the hollow center of the animal (Plate II, fig. 4).

Zittelella (Plate II, figs. 4 and 5) is the sponge that has been found most frequently in the rocks of the Champlain Valley. It is recognized by its general conical or funnel shape accompanied by lines representing canals which radiate out from the central, once-hollow region of the animal. Reported occurrences seem to be mostly in the Crown Point limestone. *Eospongia,* a sponge closely resembling *Zittelella,* has also been reported, but it is apparently not so abundant as *Zittelella;* other sponges have been recognized but not identified.

COELENTERATA

Included within the Phylum Coelenterata are several diverse groups of animals including the hydroids, Portuguese man-of-war, jelly fish, sea anemones, and corals. Of these, only the corals are important in the Champlain Valley rocks. Stromatoporoids and conularids, extinct forms of life, are commonly placed with the coelenterates. Graptolites have in the past been placed in this phylum, although recent work indicates that they do not belong here. For convenience all three groups will be described along with the corals without any implication as to where they belong in the scheme of invertebrate classification.

In the Champlain Valley the corals and graptolites are well represented in several formations. Stromatoporoids are locally abundant in the Chazyan formations as well as in the Orwell limestone. Conularids seem restricted to the Glens Falls limestone.

Corals (Class Anthozoa)

Corals are flower-like animals whose bodies are radially symmetrical when viewed from above. Like the Porifera they possess a central digestive cavity which lacks internal organs, but other features set them apart from the sponges, including the level of organization of the cells. Food enters at the top of the animal through a tentacle-surrounded mouth. After the nutrients have been removed from the water, the animal evacuates the waste products through the same opening.

The individual animal secretes a stony (calcium carbonate) support around himself (exoskeleton) which may be horn- or tube-shaped. Radial partitions, called septa (singular, *septum),* reflecting the folding of the body of the animal, divide the exoskeleton into vertical compartments. Various horizontal plates and laminae may further divide the individual exoskeleton. A shallow depression in the top of the exoskeleton, the calyx, marks the location where the animal lived.

Corals are both solitary and colonial in habit. Colonial corals form colonies (coralla) composed of great numbers of individuals that are linked together by the outer portion of their exoskeletons.

The arrangement of the septa, their size and order of appearance, and the various types of horizontal partitions are important in classifying the corals. Figure 5 illustrates some of the important features of the corals and the terminology used in describing them.

Two orders of corals are represented in the Ordovician rocks of the Champlain Basin: the Tetracoralla or Rugose Corals (Fig. 5A) and the Tabulata (Fig. 5C). Both groups became extinct at the end of the Paleozoic Era; the Tabulata are the earliest known true corals.

TETRACORALLA

The name Tetracoralla refers to the fact that the cup (corallite) secreted by the members of this group is divided into quadrants by four septa; the first two septa secreted are diametrically opposite one another and are termed the cardinal septum and the counter septum, respectively. A pair of septa, called the alar septa, were secreted at approximately right angles to the plane of the first two septa and about halfway between them. Following the secretion of these four septa, the animal secreted additional septa in a regular pattern, maintaining the tetrameral arrangement. Positions of the septa are marked on the exterior portion of the exoskeleton by grooves.

Some of the tetracorals formed thin, curved plates, the tabulae, across the corallite and beneath the depression in which the animal lived. Various deposits, including lime mud, fill the space between the plates now. *Streptelasma,* a common mid-Ordovician tetracoral, exhibits these; *Lambeophyllum* (Plate II), another common mid-Ordovician form, lacks them.

The earliest and simplest tetracorals appear in the middle Ordovician rocks, and the members of this group found in the Chazyan and later limestones of the Champlain Valley represent the earliest-known genera of this group. While many of the later genera developed extensive wrinkles on the exterior of the corallite, the simple forms found in the Champlain Valley seem to have generally lacked these structures or to have developed them only to a limited degree.

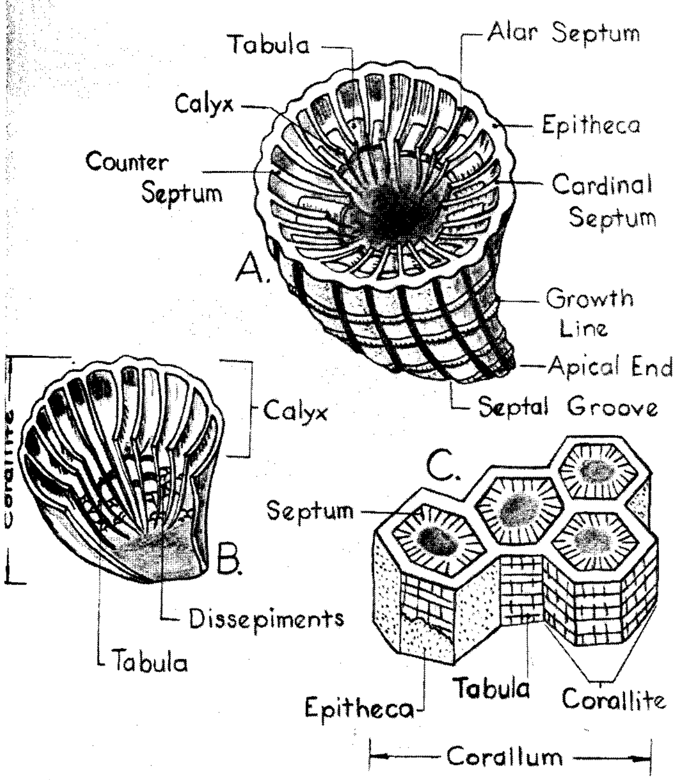


FIG. 5. Corals. A. Oblique view showing diagrammatically the major structural features of a typical cup coral (tetracoral) corallite; resembles *Lambeophyllum* (x 3). B. Cut-away view of a tretracoral corallite showing septa, tabulae (arched horizontal plates crossing open spaces between septa) and dissepiments (short, arched plates which individually do not cross the spaces between septa) (x 3). C. Corallum of tabulate coral resembling *Foerstephyllum* (x 2.5).

Early members of the tetracorals were solitary in their existence. Generally they occur as individual specimens or as small groups of individuals. Champlain Valley tetracorals appear as small, an inch or less in diameter, conical bodies which are somewhat lighter colored than the enclosing limestone. Specimens that have been silicified stand slightly above the general weathered surfaces of the limestones. Cross-sections seen on weathered surfaces may resemble a many-spoked wheel from which the axle has been removed, leaving only spokes, loose in the center and attached at the rim. Figure 5 illustrates diagrammatically important features of the tetracorals.

TABULATA

The Tabulata have been given the name because of the series of horizontal plates (tabulae, Fig. 5C) that cross the corallite of the individual animal.

Colonial in habit, the tabulates formed colonies (a single colony is called a corallum) composed of large numbers of individuals. Individual colonies range from a few inches to over 18 inches in diameter. Most of the tabulate corals found in the Champlain Valley built corallites which are polygonal in cross-section and which lack septa or have only very small ones. The number of septa and their arrangement, together with the shape and size of the corallites are important in the identification of these animals. Figure 5C is a diagrammatic illustration of a typical tabulate coral.

The tabulate corals are associated with the reef structures of Isle La Motte, and they are also found as isolated coralla in some of the massive limestones of the Orwell limestone and the Chazy Group. ***Lichenaria*** (Plate III), found in the Chazyan "coral reefs" of Isle La Motte, is believed to be the oldest known coral genus (Moore, Lalicker, and Fischer, 1952).

Most prominent, perhaps, of the tabulate corals is the genus ***Foerstephyllum*** (called ***Columnaria*** and ***Favistella*** in some of the earlier reports). The polygonal shape of the corallites and their arrangement within the corallum together with the close-spaced tabulae suggest the appearance of a honeycomb, hence the name "honeycomb coral" (Plate III).

Thin sections are required for detailed studies of the tabulate corals. However, generic identifications can be made on most of the materials found in the Champlain Valley by examination of etched polished surfaces; frequently, weathering agents have accomplished the etching.

STROMATOPOROIDEA

On weathered surfaces of the massive limestones in which these fossils usually occur, they appear as dark encrustations built about a center (Plate III, fig. 1), in some cases resembling gigantic cabbages which have been sectioned. Also these animals appear on the surfaces of the limestones as expanding masses of encrusting material or laminae, expanding from a base and with laminae which are convex upward.

Most of the stromatoporoids from the Champlain Valley have been assigned to the genus *Stromatocerium,* although Galloway (1957) has defined several previously undescribed genera from the Chazyan rocks of Isle La Motte. Apparently *Stromatocerium eatoni* and *S. lamottense* (Seely, 1904) are actually algal structures (Plates I and II).

The calcareous colonies of the stromatoporoids consist of layers of calcium carbonate laminae separated by short (less than 1 mm long) vertical pillar-like or other structures. The colonies are massive or encrusting, ranging from a few inches up to several feet in diameter. Seen in cross-section, the light-colored laminae stand out, the darker material often being lime mud filling between the laminae; the colonies tend to break parallel to the laminae.

In the group of stromatoporoids to which *Stromatocerium* belongs the laminae consist of a series of discontinuous plates. The vertical pillars between the laminae dominate the structure. Unfortunately the differences are rarely visible to the naked eye, and they can be discerned only with microscopic examination of thin sections. To the naked eye the average specimen of *Stromatocerium* appears as a well laminated structure. The diagram of Fig. 6 illustrates some of the important structures of the stromatoporoids.

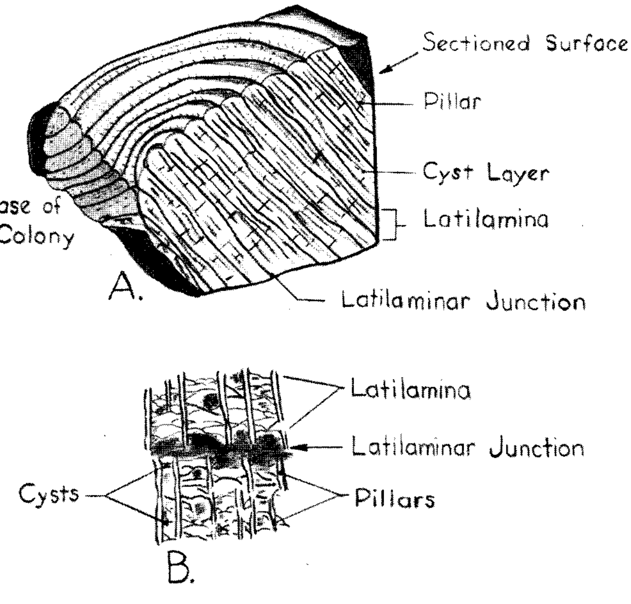


FIG. 6. *Stromatocerium rugosum* Hall. A. Oblique view of part of a colony to show the major structural elements. Based on a specimen from the Orwell limestone, Button Island (x 1). B. Enlarged section to show details of the structure. Note particularly the discontinuous cyst layers and the vertical pillars (x 6).

Stromatoporoids are abundant on Isle La Motte in association with the Chazyan reef complex. According to Galloway (1957, p. 397, 421), the forms on Isle La Motte represent the earliest known stromatoporoids. In the central part of the Champlain Basin stromatoporoids occur in the Orwell limestone north of Panton, and an excellent display is present on the west edge of Button Island in Ferrisburg where a bed 18 inches thick is composed of heads of *Stromatocerium* and tabulate corals. Occasional specimens may also be found in the limestones of the Chazy Group and the Orwell-Isle La Motte limestones. The larger colonies, at least, seem to have had a preference for relatively quiet water conditions in which extremely fine grains of calcium carbonate could settle to the bottom. Also, the environment appears to have been free of land-derived sediment.

Conularia

This enigmatic group of animals is now believed to belong to the coelenterates and to be closely related to the jelly fish. Specimens usually are flattened, carbonized remains and in the Champlain Valley come from the Glens Falls limestone. Figure 7 is a reconstruction of a conularid from the Glens Falls, and Plate III, fig. 11 illustrates a typical occurrence.

Conularids are an extinct group of marine animals that had a shell of phosphate-strengthened chitin. The shells were pyramidal or flattened conical with four well-defined sides. The larger end was an opening around which there may have been tentacles and which could be closed by means of four flaps, one attached to each side. The pointed end of the shell was attached to the substratum except in a few forms which apparently were floaters. The sides of the shell are marked by minute grooves and ridges, both longitudinal and transverse. A groove extends the length of the middle of each face, and at the corners a narrow furrow extends the length of the shell. The shell is thin, and apparently it was flexible, for many of the specimens found are flattened.

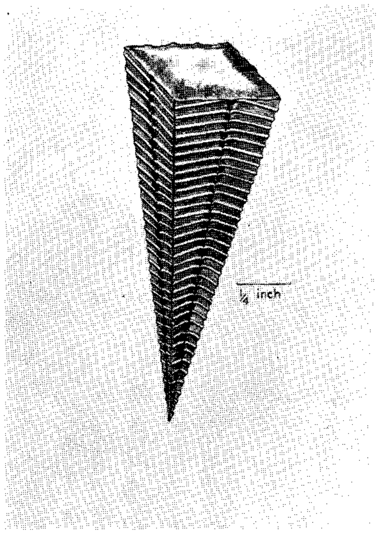


FIG. 7. *Conularia.* Illustration shows form restored to its quadrangular cross-section. Most specimens of this genus are found in the Glens Falls limestone and are crushed. Characterized by its pyramidal shape and transverse ribs. Based on *Conularia trentonensis.*

Conularids are recognized in the Glens Falls limestone by the triangular shape of the flattened shell together with the fine lines which run transverse to the long dimension of the triangle.

GRAPTOLITES (CLASS GRAPTOLITHINA)

Remains of these colonial animals appear as black, carbonaceous films on bedding planes of shales forming the upper part of the Glens Falls, the Cumberland Head, the Stony Point, and the Iberville formations. In not a few instances the carbonaceous films have been replaced by the brass-colored iron sulfide, pyrite, and the graptolites are recognized only by their general outline. Calcite also replaces or masks the carbonaceous films frequently. Care must be exercised in differentiating calcitized remains from spots of calcite often found along the bedding planes of the shales. Marks and scratches of various origins may also be easily mistaken for graptolites.

Graptolites have long been an enigma, being placed most commonly with the coelenterates. Recent studies suggest that the group belongs more properly to the Hemichordata, a group of animals intermediate between invertebrates and true vertebrates; other evidence seems to support a grouping with the coelenterates as is done here.

Graptolites were colonial animals which secreted a series of cups (thecae) arising out of an axial support. Individual animals whose exact nature we do not know lived in the cups.

The Class Graptolithina contains several orders; however, only two are important as fossils: the Dendroidea and the Graptoloidea. Colonies of most dendroid graptolites are fan-shaped, trellis-like networks composed of branches connected by cross-bars. The individual animals, some of which had special functions, lived in several types of cuplike depressions along the branches. All of the graptolites found in the Champlain Valley thus far belong to the Graptoloidea, which are recognized by their general saw-blade appearance. Figure 8 illustrates a typical graptoloid graptolite, 8A showing how the form appears on the

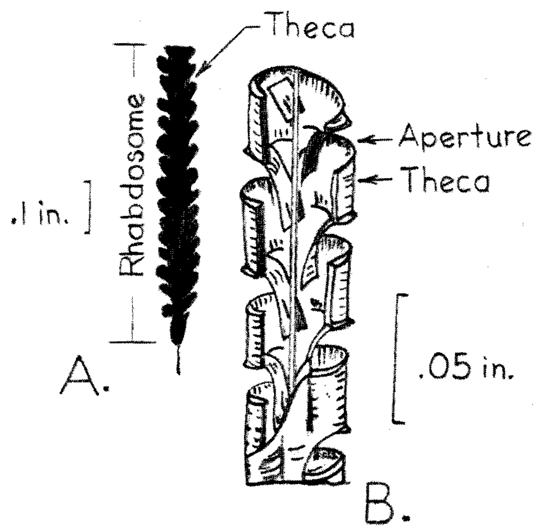


FIG. 8. Graptolite. A. Nearly complete rhabdosome which has been flattened and carbonized, as it appears on the bedding plane of a shale. B. Part of a rhabdosome sectioned to show several thecae and their relations to one another. B from *Treatise on Invertebrate Paleontology*. Courtesy Geological Society of America and University of Kansas Press.

surface of the black shales and 8B illustrating how the undeformed, unaltered colony probably appeared. Graptolites common in the Stony Point shales are illustrated on Plate XIV.

Thecae of the graptoloid graptolites are all the same. Colonies may be composed of one or two rows of thecae, depending upon the particular genus. Thus some appear much like miniature saw blades, as alluded to above, while others look more like a double-edged file.

The remains of the graptolites found in the Champlain Valley shales are mostly scattered colonies; it is known, however, that the colonies may have been attached to a float of some sort. Most graptolites appear to have drifted about the sea, subjected to the vicissitudes of the currents. Although their remains are not found exclusively in black shales, they occur with greater frequency in this type of rock than in any other. Apparently the environment in which the black shale formed was particularly favorable for their preservation. A lack of oxygen on the ocean bottom limited the number of scavengers which could destroy the delicate structures as they settled onto the bottom.

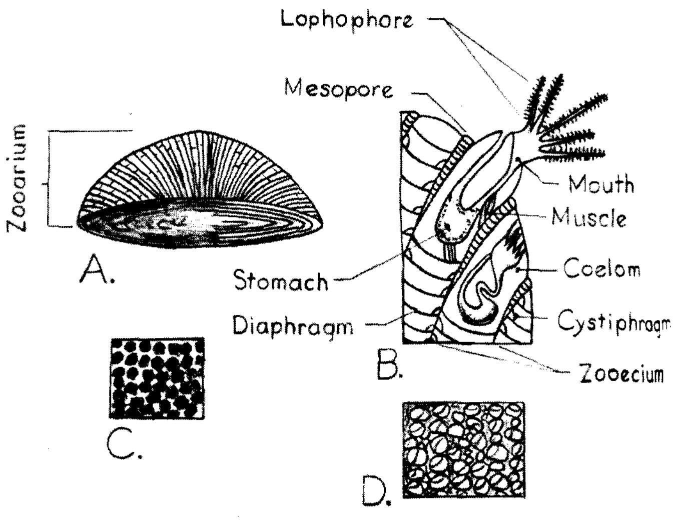


FIG. 9. Bryozoa—Treptostomata, ***Prasopora***. A. Oblique view of a vertically sectioned zooarium showing the manner of upward growth of the zooecia and the base of the colony (x 0.5). B. Enlargement of several zooecia showing details of the structure; animals restored diagrammatically (x 24). C. Section tangential to the surface of the zooarium (x 7.5). D. Cross-section as viewed in a thin section with light coming through from below. Curved lines crossing the zooecia represent curved diaphragms which have been cut obliquely by the section (x 10).

BRYOZOA

Bryozoans are an interesting group of animals for study, and they are very abundant in some places (Localities 3, 29, Plate XVI). Even though you may become discouraged when you first encounter them, the development of a familiarity with them will soon reward you with some interesting specimens. With very little effort specimens of bryozoans can be prepared for study.

A great variety of these animals, including a large number of species as yet unrecorded or undescribed, may be found in the Champlain Valley limestones. Varieties range from lace-like types to those that are massive and resemble sticks preserved in the limestones. One form, *Prasopora*, resembles a large gumdrop.

Bryozoans (the name means "moss animal" and refers to the moss-like appearance of some living and fossil forms) are colonial animals. The individual animal, the ***polypide*** or ***zooid***, lives in a chamber or ***zooecium*** which is part of the colony or ***zooarium***. When the animal dies, the zooecium appears as a hole in the colony. Shape of the zooecium, the position of the zooecia of the colony with respect to one another, as well as certain internal structures are important in the classification and identification of the fossil forms. ***Prasopora*** is illustrated in Fig. 9, 9B being a diagrammatic reconstruction used to illustrate the relationship of the individual animal to the zooecium and zooarium.

Table 1 summarizes the classification and the important features utilized in identifying the several orders of bryozoa. Only the Cryptostomata and the Treptostomata are found in the rocks of the Champlain Valley. Representatives of the Cyclostomata may be present also, although they have not as yet been reported. Most of the forms found thus far belong to the Order Treptostomata. The best specimens come from shaly layers of the Glens Falls formation and from some of the fossil-fragmental limestones of the Chazyan formations.

Detailed study and identification of bryozoans require preparation of thin sections[1] and study with a microscope; however, generic identifications of many Champlain Valley forms can be made from polished surfaces which have been etched slightly with acid. Such etching brings out the internal features where the specimen has been polished to sufficient depth in the colony. Slightly etched exterior surfaces bring into relief many of the important features of the surfaces of the colonies. Dilute acetic or hydrochloric acid may be used. Except for examination of the most minute detail of the etched surfaces, a process which requires a microscope, a 10-power hand lens may be effectively used. The etching process followed by examination with a hand lens is good for field identification.

Treptostomata

Most treptostomates built calcareous, twig-like, branching colonies (Plate IV, figs. 20-22), flat, branching colonies (Plate IV, fig. 1), flat encrusting colonies (Plate IV, figs. 5-8), or hemispherical to rounded colonies (Plate IV, figs. 15-19). This group is most often referred to as the "stony bryozoans," although other orders do have genera which built twig-like colonies.

The individual animal lived in a zooecium that appears as a long prismatic or cylindrical tube. The tubes of the colony are packed against each other tightly. In some genera it is difficult to separate the wall of one zooecium from the walls of adjacent tubes. Straight or nearly straight partitions cross the tubes at approximately right angles to the axis of the tube. The partitions apparently represent floors where the animal paused before building the zooecium farther. Partitions which do not cross the tube completely may be present also; these are strongly curved. Some genera have partitions that are strongly arched upward, crossing the tube completely.

Study of a longitudinal section of a typical treptostomate colony shows that in the inner axial region, which may comprise one-half to two-thirds of the zooecium, the partitions are more widely spaced than in the outer slightly darker part. Slender angular tubes (mesopores) which are closely partitioned by approximately horizontal plates appear in the outer zone of the zooarium, accompanying the change in spacing of the partitions in the individual zooecia. Other features, some appearing as tubules, also may be observed in this outer portion of the zooarium.

The aperture is at the exterior end of the zooecium and apparently had no cover. Individual zooecia may be of considerable length in a direction parallel to the axis of a colony with the partitions being fairly widely spaced along their length. However, at the place where the partitions begin to become closely spaced, the tube turns relatively abruptly toward the surface of the colony. Figure 10 illustrates a typical ramose or branching treptostomate; Figure 9 shows diagrammatically the common treptostomate of the Glens Falls formation, *Prasopora*.

Cryptostomata

Colonies of this order consist of branching, ribbon-like, delicate fronds and branching stem-like forms (Plate IV, figs. 2, 3, 13, 14 and 23). Zooecial tubes of the cryptostomates are shorter than those of the treptostomates, but like the treptostomate zooecia they are divided into an inner region of relatively widely spaced partitions and an outer region of relatively closely spaced partitions. Unlike the treptostomates whose aperture is at the end of the tube, the Cryptostomata possess a vestibule or short tube-like opening between the true aperture and the opening on the surface of the colony. Thus the zooecia are separated from the exterior by a layer deposited above the level at which the animals generally lived. Between the zooecia and the

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[1]Thin sections of bryozoans may be prepared in the following manner. A small piece of the bryozoan is broken off the colony, and a smooth flat surface is ground on the piece using carborundum and water on a piece of plate glass. Initial grinding may be done with 100 grit, and a final polish placed on the surface by grinding first with 200 grit and then 320 grit. The flat surface is then mounted on a microscope slide using Canada Balsam as the adhesive. Other types of mounting media are available, but stick Canada Balsam is very convenient and quick-setting. Care must be exercised so that the balsam is not overcooked.

Once the cement has dried, the bryozoan fragment is ground down on the glass plate using successively 100, 200, and 320 grits. You should shift to the 320 grit when the fragment becomes translucent, and use this grit size until the details of the internal structures are apparent. The 1000 grit size is used for final grinding. Once the fragment has become transparent, very gentle grinding is required lest the fragment disintegrate. When the fragment reaches the required thinness, you should cement a cover glass over it. With a little practice you will be able to make good thin sections of bryozoans in a matter of minutes.

Cover glasses, microscope slides, and mounting media may be obtained at one of the various scientific supply houses.

Order	Colony Shape	Zooecium Shape and Composition	Zooecium Aperture and Associated Structures
Ctenostomata	Small, delicate, tubular, rootlet—or thread-like	Tubular or conical; horny or membranous	Operculum present
Cyclostomata	Widely variant from delicate to irregularly massive	Tubular, thin-walled, minutely porous; calcareous	Circular and in terminal position; no operculum
Treptostomata	Variable, but most commonly massive	Long, curved, circular or polygonal in cross-section; thin-walled inner region and thicker walled outer region; calcareous	Circular or polygonal and in terminal position
Cryptostomata	Generally delicate; some forms twig-like or lace-like	Cylindrical, short; thin-walled inner region, thicker walled outer region; calcareous	Round aperture; vestibule above a half partition or bend in tube; aperture at base of vestibule; operculum present
Cheilostomata	Delicate; slender branches and networks; some massive varieties	Short, saclike; conical, tubular, prismatic and other variants; membranous, chitinous, or calcareous	Usually anterior, but not terminal; round; operculum present

ZOAN CHARACTERISTICS

	Horizontal Partitions (Diaphragms)	Mesopores and Other Special Structures	Age Range
	None	None	Ordovician to Recent
ion;	Rarely present	May or may not be present	Ordovician to Recent
	Abundant, closely spaced in outer mature region and more widely spaced in axial immature region	Mesopores, small spines; small elevations on surface of colonies in some genera	Ordovician to Permian
ve e;	Common to abundant; closely spaced in outer mature region and more widely spaced in axial immature region	Mesopores, small spines occur in some genera; more commonly spaces between tubes are filled with minute openings or deposits of solid calcareous material	Ordovician to Permian
inal;	None	No mesopores; several types of accessory zooids	Jurassic to Recent

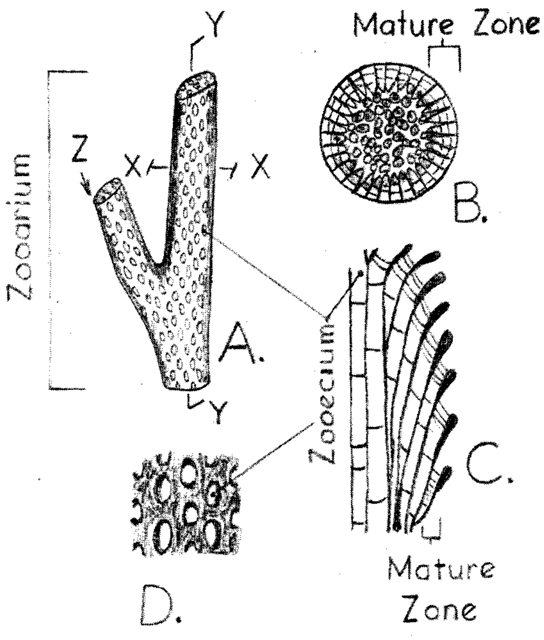

FIG. 10. Bryozoa—Treptostomata. Based on *Eridotrypa*. A. Zooarium (x 2). B. Cross-section of zooarium at XX. Zooecia in inner immature zone are seen in cross-section while zooecia that have turned toward the exterior of the colony in the outer mature zone are oblique to the plane of the section (x 3.5). C. Longitudinal section indicated by YY showing the manner of growth of the zooecia and the inner immature zone with the outer mature zone (x 6.5). D. Tangential section at Z (x 6.5).

surface of the colony the vestibule is partially obstructed by incomplete horizontal partitions (Fig. 11). These may be observed in sections at right angles to the axis of the frond or branch, and the presence of these features aids in differentiation of the twig-like cryptostomates from the twig-like treptostomates.

Zooaria of many cryptostomates consist of relatively straight branches which are connected by crossbars, or the colonies may consist of sinuous branches which fuse together where they meet. Thus there are openings or "windows" in the structure. Figure 11, based on *Rhinidictya fenestrata* (Hall) from the Crown Point formation, illustrates some of the significant features of the ramose Cryptostomata.

Zooecial and zooarial surface characteristics of most cryptostomates are distinct enough to permit their utilization in classification and identification; however, in the case of the solid, twig-like varieties thin sections and/or polished etched surfaces are essential for proper identification.

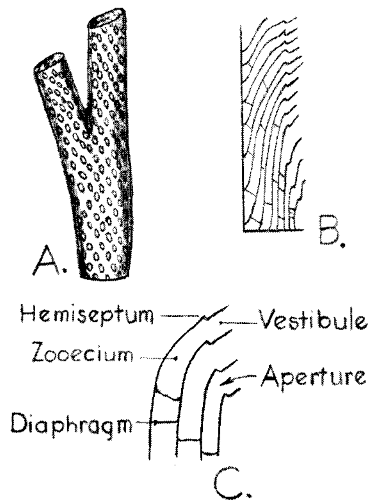

FIG. 11. Bryozoa—Cryptostomata. A. Surface of zooarium (x 2.5). B. Longitudinal section (x 4). C. Detail of longitudinal section showing hidden aperture at base of vestibule (x 15).

BRACHIOPODA

Among the most interesting fossils found in the Champlain Valley limestones are the brachiopods. A great diversity of forms can be found, even in one formation. These animals were important denizens of the Paleozoic seas, and they provide geologists with many important fossils. The nature of the soft parts and the early growth stages of living members of the phylum suggest a relationship with the bryozoa.

Detailed studies of the shell interior are required for a complete understanding of brachiopods. However, the average collector can identify most of the important genera and many of the species found in the Champlain Valley by using the external characteristics of the shells alone.

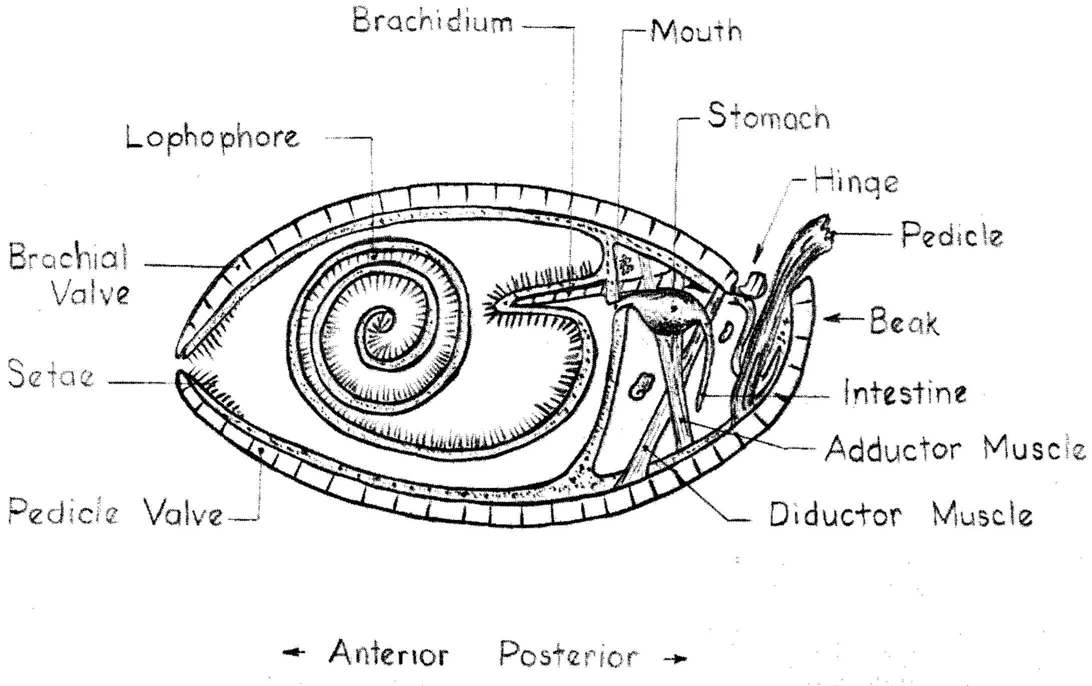

FIG. 12. Brachiopoda. Major anatomical features seen in an anterior-posterior vertical section; diagrammatic and much enlarged.

The animal lives in a two-part shell (the two parts are termed valves) which can be split into two mirror-image halves along a plane extending from the front of the animal to the back. This plane stands at right angles to the plane between the two valves. The valves are hinged along the back (posterior) edge of the shell while the front (anterior) end is where the shell opens. Pelecypods (e.g., clams or mussels) are likewise bivalved, but the plane of symmetry passes between the two valves of the shell, the hinge area of the shell being on top of the animal, or in a dorsal position.

With some exceptions, brachiopods are attached to the mud or rock of the ocean floor by means of the pedicle. This is a fleshy stalk attached to one of the valves, the pedicle valve. The pedicle usually extends out through an opening in the posterior part of the pedicle valve, but in shells of some genera the pedicle opening lies partly in one valve and partly in the other. Various modifications of the pedicle opening and variations in the relationship of the pedicle opening to other structures in the hinge area of the shell are used in classifying and identifying the animals.

The two valves of the shell are called the pedicle valve, as noted above, and the brachial valve. The latter valve carries the supports, or brachia, for the lophophore, a part of the food-gathering system. When the brachiopod attaches himself so that the plane between the valves parallels the surface on which the animal lies, the smaller brachial valve is usually the lower one and the larger pedicle valve the upper. However, the conventional orientation used when illustrating these animals is with the pedicle valve below the smaller brachial valve as in Fig. 12.

Two general groups or classes of brachiopods are recognized, the Inarticulata and the Articulata. Valves of the shells belonging to the former group are held together by muscles attached to the interior of the valves; the shells of the second class possess hinge structures which consist primarily of two teeth in the pedicle valve and corresponding sockets for them in the brachial valve. Figure 12 shows the main anatomical features of an articulate brachiopod.

Shells of most inarticulate brachiopods are composed of a combination of calcium phosphate and chitinous organic matter together with minor amounts of other chemicals.

Inarticulate shells are oval or circular in outline and asymmetrically conical or flat in profile. Upon fossilization the shells become carbonized. When you see one of the inarticulates in the limestones and shales, they are usually black, and generally they have a shiny luster; in some respects their shiny surfaces and black color suggest anthracite coal fragments. (See Plate V, figs. 22-24, 35; Plate VI, fig. 29; Plate VII, figs. 6, 7.)

Articulate brachiopods secrete shells of calcium carbonate. Three types of shells are found among these brachiopods. Punctate shells have small holes extending from the interior of the valve nearly to the exterior; impunctate shells lack these holes. In the third type, the pseudopunctate shells, small rodlike bodies of calcite lie at right angles to the surface of the shell. When these bodies weather out, they leave behind small holes resembling those found in the punctate shells. These rods are restricted to the inner layer of the two-layer brachiopod shell while the holes of the punctate forms extend into the outer second layer of the brachiopod shell. *Sowerbyella* and *Rafinesquina,* two common forms in the Glens Falls limestone, are pseudopunctate.

While study of the interior of the shells is necessary for any systematic study of the brachiopods, identification of the various genera within limited geographic areas and geologic ranges can be made largely on the basis of the external features of the shell. Figure 13 illustrates some of the terms used in describing a brachiopod shell. Such things as the general shell outline as viewed from above, the position of the maximum width with relation to the hinge line, the cross-sectional shape, the type of surface ornamentation, the relative convexity of the two valves, the amount of slope on the flat planes along the hinge line (the interarea, Fig. 13), and the nature of the pedicle opening and associated structures are all important. Surface ornamentation includes costae, ribs, plications, fold and sulcus, and growth lines. The number of costae or plications per millimeter along the anterior margin of the shell as well as the manner in which the new costae or ribs are added as the shell enlarges are other important features of the brachiopod shell. Costae may be added by splitting of the costae or by the placing of a new one between two earlier formed ones.

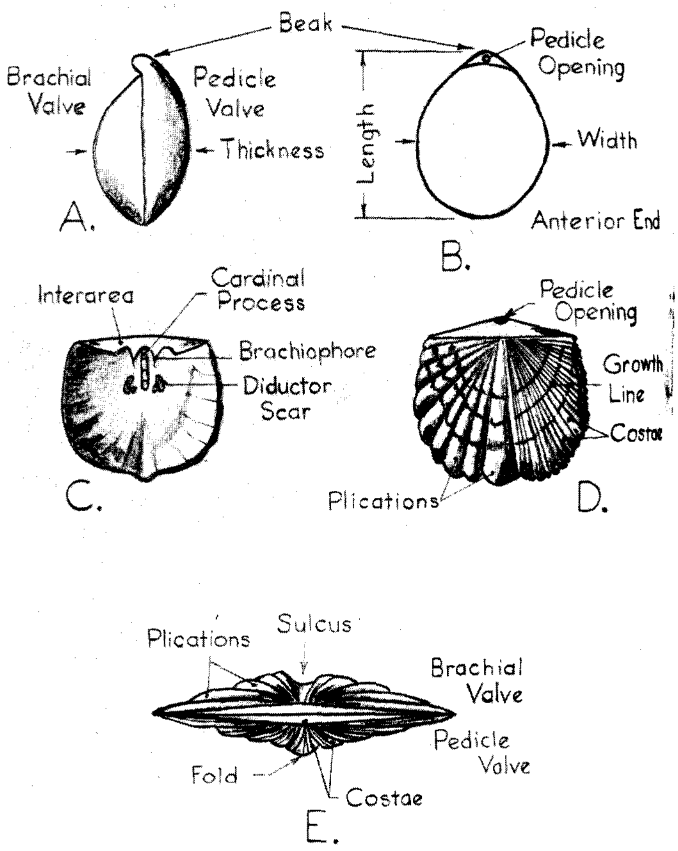

FIG. 13. Terminology of Brachiopod Shells. A. Side view. B. Top view looking down on the brachial valve. C. Interior of brachial valve showing supports for the lophophore and the muscle scars. D. External features of the shell, top view looking down on a brachial valve; a composite. E. Posterior view of a composite shell showing surface ornamentation of various types and the interareas along the hinge line. All diagrammatic and approximately natural size.

With rare exceptions, internal structures of the brachiopods found in the Champlain Valley can not be easily studied because of the manner in which the animals are preserved. However, *Rafinesquina* and *Sowerbyella* specimens may be found in the Orwell and Glens Falls formations oriented so that the inner part of the valve is upward and thus exposed on the bedding surface (Plate VII, fig. 2).

In such instances it is sometimes possible to see the dentition and other hinge line and internal structures or to bring them out through careful etching with weak acid.

Table 2, in pocket, lists the superfamilies of brachiopods which may be expected in rocks of the Champlain Valley. Brief descriptions of these groups may also be found in the table together with sketches of typical representatives of each superfamily. It should be noted, perhaps, that other schemes of classification are in use, but for this work the treatment of the various lineages as superfamilies seems best. There are other superfamilies which are not described in the table because representatives of them do not occur in the rocks of the Champlain Basin.

MOLLUSCA

The Phylum Mollusca is divided into five classes; three of these classes, the Gastropoda, Cephalopoda, and Pelecypoda, provide the bulk of the fossil representatives of the phylum. Rocks of the Champlain Valley abound with remains of the first two groups while pelecypods are less common. Pelecypods are locally abundant in marine deposits of the Pleistocene, usually as partially leached, white, very fragile shells (Plate VII).

With the exception of the Pleistocene remains, most of the fossil Mollusca occur as internal fillings and as casts. It is not uncommon, however, to find some gastropods with the original shell material intact or altered by recrystallization only. Frequently the presence of original shell matter surrounding the filling of a cephalopod may be recognized, but rarely is it possible to expose the shell matter. The refractory nature of the limestones in which the fossils are found makes separation of the shell material from the matrix difficult. When the fossils are cleaned, the shell breaks away from the filling and goes with the matrix. Gastropods may be broken out of some of the impure limestones with part of their shell matter intact.

Commonly cross-sections of gastropods and cephalopods are exposed on a bedding surface or a vertical surface of the limestones (Plate IX, fig. 7). Major internal structures of the cephalopods may be studied in specimens which have weathered differentially (Plate XI, fig. 6; Plate XII, fig. 3).

Class Pelecypoda

Among modern-day representatives of this class are clams, oysters, and various mussels. Shells of Pelecypoda living in Lake Champlain today are frequently washed up on the shore, and these bivalved animals may on occasion be seen crawling along the bottom in shallow-water areas, leaving behind trails which resemble some of the so-called worm trails found in the bedrock of the Champlain Valley.

Like brachipods, the pelecypods secrete a shell composed of two parts, or valves. Unlike the brachiopods, however, the plane of symmetry of most pelecypod shells lies between the two valves so that the two valves are externally mirror images of one another. Forms like the oyster have evolved in such a manner that one of the valves is much larger than the other; so not all pelecypods are equivalved.

The two valves are held together along the hinge line by a system of teeth and sockets together with muscles or ligaments. If you hold the shell so that you are looking along the hinge line with the most sharply curved portion of each valve pointing away from you, the left valve is on your left and the right valve is on your right. With the shell so oriented you are sighting from the back (posterior) of the shell toward the front (anterior) part as the animal lived (Fig. 14).

Identification of the pelecypods at the generic and specific levels depends much upon the external ornamentation of the shell and its shape. Only by study of the interior of the shell, especially the dentition and the muscle scars, is it possible to place members of the class in the higher systematic positions. Because of the manner in which the Ordovician pelecypods are preserved, the internal features are not generally found; however, dentition and sometimes muscle scars may be observed in specimens of the Pleistocene varieties. Plate VII, figs. 20-28 illustrate pelecypods found in the Champlain region.

Class Gastropoda

Gastropods are second only to the insects in terms of the variety and number of species that have occupied various parts of the earth. Representatives have been found at great depths in the ocean and at high altitudes; snails and slugs of one kind or

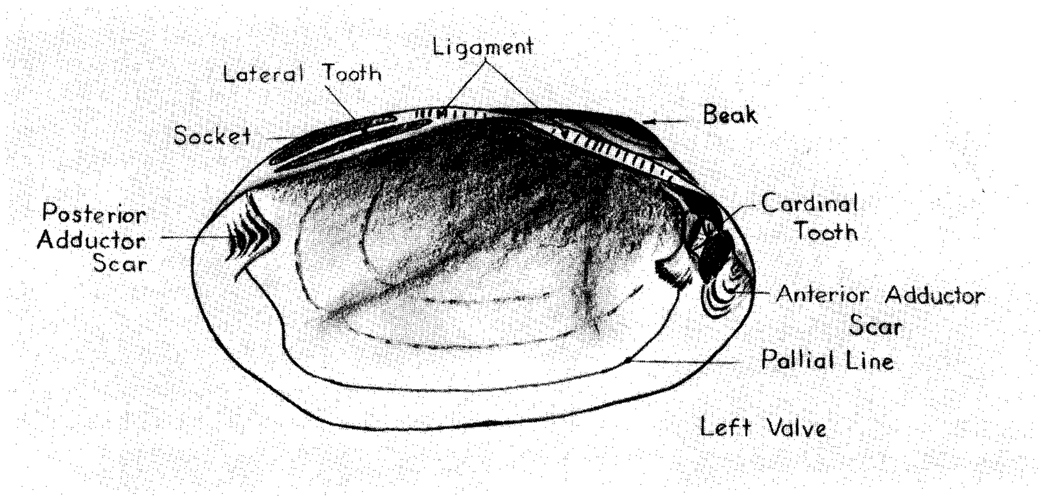

FIG. 14. Terminology of Pelecypod Shells. Interior of a left valve (x 1). Based on the shell of one of fresh-water mussels *(Lampsilis)* from Lake Champlain.

another exist in almost every terrestrial, fresh-water, or marine habitat.

A garden snail may be used to typify the Class Gastropoda. The body of the animal lies within a single, coiled shell. When the animal is feeding or moving about, part of the body protrudes from the shell which is carried on the back of the animal. Its body consists essentially of a visceral area within the shell, a well-defined head with tentacles and eyes, and a foot on which the animal creeps. Shells or conchs of gastropods are generally coiled, reflecting the growth patterns of the animal that lives within. In a general way the shell may be visualized as a cone (e.g., ice cream cone) which has been twisted or coiled about an axis. A few members of the class lack shells; others possess shells that are straight, while still others possess shells that coil erratically. A few are cap-shaped. All gastropod shells lack transverse partitions, and this fact distinguishes them from the cephalopod shells.

Important terms used in describing gastropod shells are illustrated in Fig. 15. The coiling pattern, the spiral angle, the cross-profile of the shell and of the individual whorl, the manner in which successive whorls contact the earlier formed ones, the ratio of the number of whorls to the shell height, and the characteristics of the apertures are important items utilized in generic and specific identifications. Ornamentation such as knobs, spines, and ribs may also be used, but these features are of relatively minor importance.

Certain gastropods bear a horny lid or cover, called an *operculum,* on the foot. The purpose of the cover is to close the aperture of the shell when the animal withdraws completely into the shell, forming a protection against enemies. Usually the operculum is composed of material that is easily destroyed. A few genera grew operculi that could be preserved with relative ease. One of these genera is *Maclurites*, and the silicified operculi of this genus are common fossils in the limestones of the Crown Point and Orwell formations. Plate IX, figs. 8 and 9 are pictures of two *Maclurites magnus* operculi from the Crown Point formation. This type of fossil has been called *Ceratopea* by some paleontologists.

Most specimens of the larger gastropods found in the Champlain Valley limestones are internal fillings (Plate VIII). If any of the original shell remains, it breaks away from the steinkern when the rock is broken. However, once in a while you may break away the limestone from a specimen of *Maclurites* and find the original shell material preserved around the internal filling (Plate IX). You may find large *Maclurites* specimens, up to 8 inches across, in the Crown Point and Orwell limestones. On surfaces of the Crown Point, Glens Falls, and Orwell limestones cross-sections of small gastropods may often be seen, but you may collect good specimens only with great difficulty.

In some of the coarse-grained, fossil-fragmental limestones of the Day Point and Valcour formations

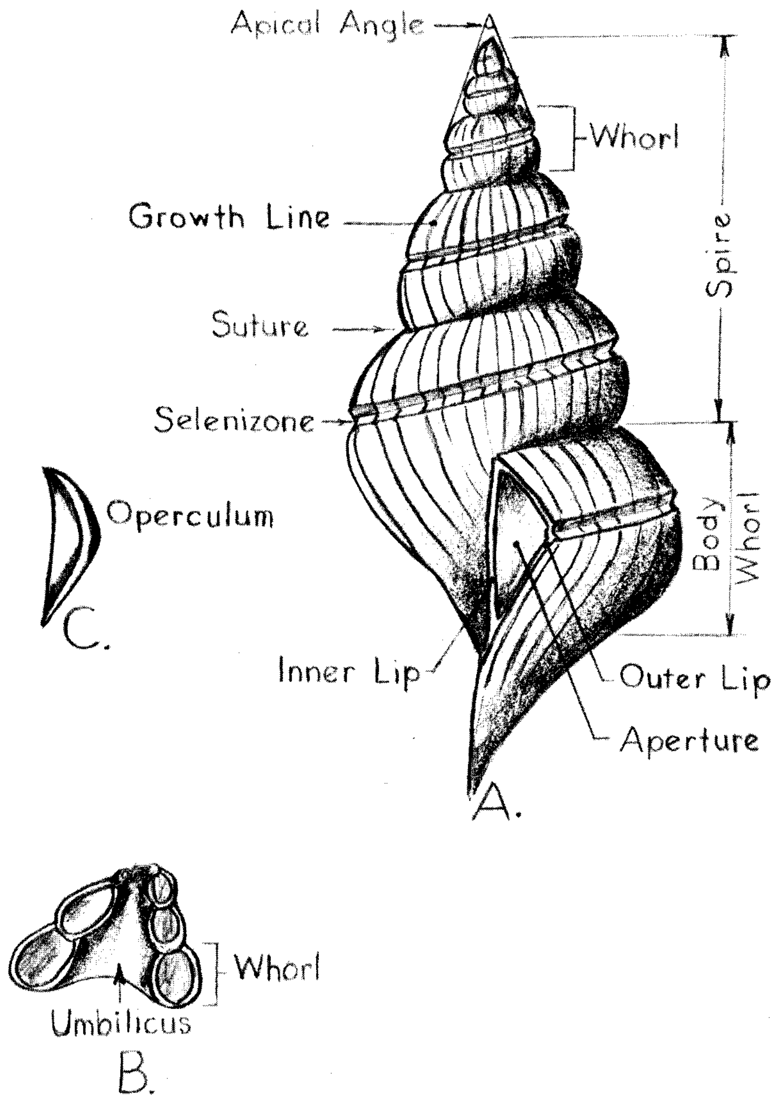

FIG. 15. Terminology of Gastropod Shells. A. Composite high-spired shell. B. Vertical section showing open area surrounded by the shell (umbilicus). C. Operculum, the cover for the aperture.

small gastropods occur locally in abundance (Plate IX, figs. 1 and 2), and occasional specimens of the smaller gastropods may be found in a good state of preservation in some of the other formations.

CLASS CEPHALOPODA

Animals belonging to the Class Cephalopoda are exclusively marine. The soft parts are divided into a body and a head which bears a pair of eyes and tentacles. Unlike the pelecypods and the gastropods, the cephalopods lack a foot. Among members of the group are the squid, the octopus, and the Pearly Nautilus, which is the living representative of a lineage that occupied the Paleozoic and Mesozoic seas in great numbers and variety. We will be concerned here only with the externally shelled varieties which were the Cambrian and Ordovician ancestors of *Nautilus*, the nautiloids. The ammonoids which became important in the middle and upper Paleozoic and blossomed in the Mesozoic did not appear until the Silurian. Understanding and interpretation of the nautiloids from Cambrian and Ordovician rocks are based largely upon the features seen in *Nautilus*. Figure 16 illustrates cephalopod morphology, both for the coiled varieties and the straight-shelled types.

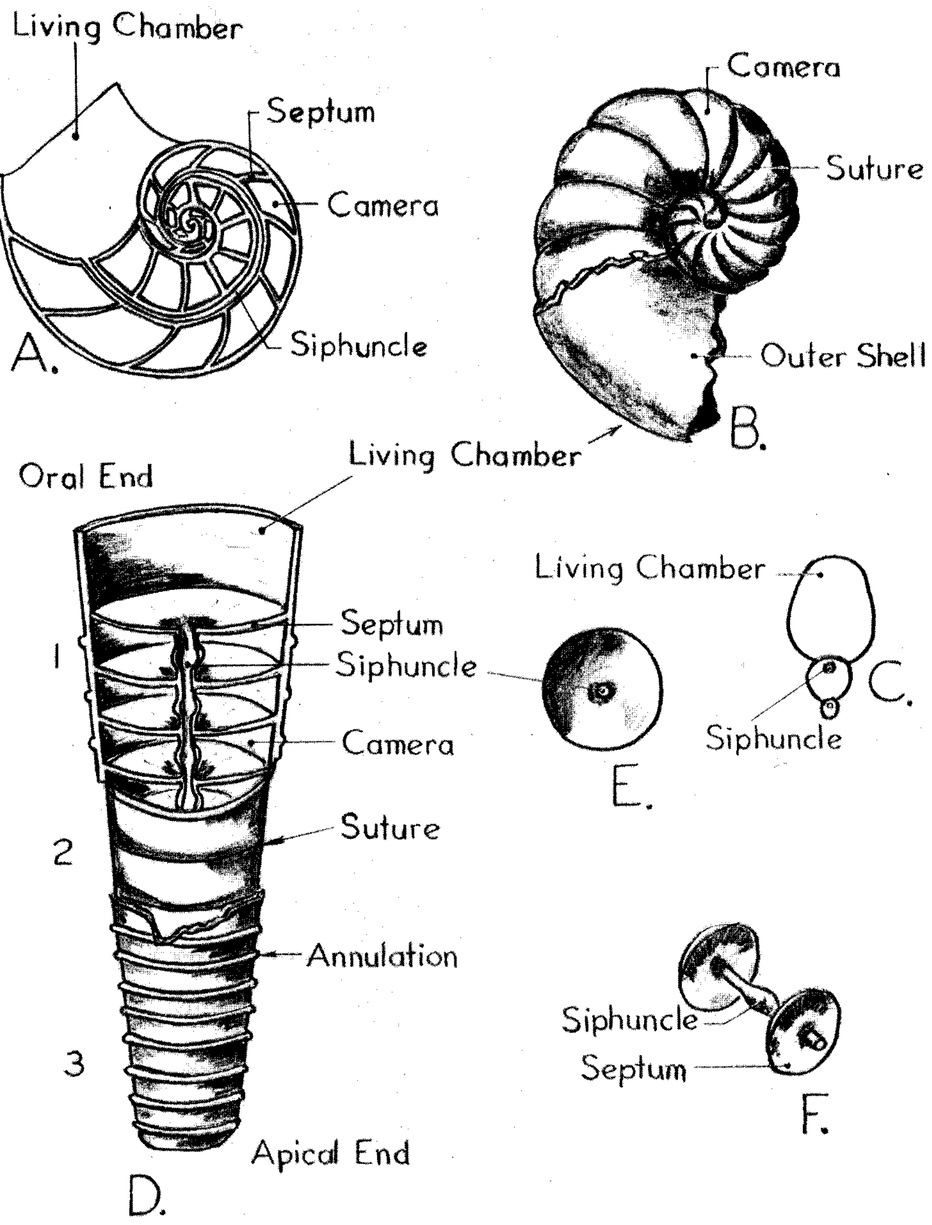

FIG. 16. Cephalopoda. All approximately natural size. A. Section of a coiled nautiloid. B. Surface view of a coiled nautiloid with the shell removed to show the sutures and filling of the camerae. C. Cross-section of a coiled nautiloid at right angles to the plane of coiling. Note the impression of the later whorls on the earlier formed ones. Sections like this are not uncommon in the Cassin formation. D. Straight-shelled nautiloid. (1) Horizontal section showing septa, the siphuncle, the unfilled camerae or chambers; (2) surface with the outer shell removed so that the sutures and filled camerae are visible; (3) outer surface of the shell showing surface ornamentation in the form of annulations. E. Front view of a septum from D. F. Oblique view of two septa and the connecting siphuncular segment showing the expansion of the siphuncle between the septa, from D.

Some gastropods and cephalopods are superficially alike in external appearance. However, when one looks closely at specimens from each class, he discovers that the gastropod and cephalopod shells bear certain obvious differences. As noted earlier, the gastropod shell is undivided by partitions; in contrast, the cephalopod shell has a series of transverse partitions, called septa (singular, *septum),* which divide the shell into chambers, or camerae. As comparison of Figs. 15 and 16 will show, the gastropod shell coils to the rear in relation to the animal living within while the nautiloid shell coils toward the front of the animal, or toward the aperture.

The septa are simple, saucer-shaped, thin plates whose maximum curvature is toward the apex or posterior end of the shell. Intersection of the septa with the exterior shell is marked by a line called the suture. Sutures of nautiloids are simple circles or gently undulating circles if the septa are bent slightly. Projected out as a line on a flat piece of paper, the sutures vary from straight lines to slightly wavy ones. The sutures are not visible on the external portion of the shell.

During life *Nautilus* extends a fleshy tube, the siphon, to the posterior part of the shell. Where the tube penetrates the septa, collar-like *septal necks* are formed. Similar structures are found in fossil nautiloids and are important in classifying and identifying them.

Some nautiloids secreted almost continous tubes or ring structures around the siphon. Others modified the siphuncular openings in different ways. The position, size, and cross-sectional shape of the siphuncle are important items in the classification and identification of the nautiloids. Any deposits made by the animal in and adjacent to the siphuncle are important too, as are deposits made in the chambers. Detailed classification of the nautiloids requires the preparation of sections of siphuncular structures.

Nautiloids sectioned by weathering and exposed on bedding planes of the limestones may occasionally be found (Plate XI, fig. 6; Plate XII, fig. 3). If you examine these specimens closely, you may be able to observe some of the siphuncular structures. Perhaps one of the more easily seen of these structures is the cone-in-cone structure, called endoconic, found in the general subgroup of the nautiloids known as the Endoceroids (Plate XI, fig. 6).

Studying the nautiloid group as a whole you will note that there are all gradations between shells which are regularly expanding straight cones (Plate XI, figs. 1-3), slightly arcuate but regularly expanding shells (Plate XII, fig. 2), straight and arcuate shells which expand abruptly in the front one-half or one-third (Plate X, figs. 1 and 5), and coiled forms (Plates X and XI). The varieties which expand abruptly in the anterior part of the shell give the impression of being short and stumpy.

The growth plan of a nautiloid is another feature important for identification, as are the cross-sectional shape of the shell, the shape of the septa and the accompanying configuration of the sutures, the number of septa per unit length of the shell, and the taper of the cone.

Fossil cephalopods of the Champlain Valley are found as fillings with the outer shell removed (Plate XII, fig. 6), as fillings surrounded by the outer shell, as siphuncles only (Plate XI, fig. 6), and as naturally sectioned specimens seen on the bedding surfaces of some of the more massive limestones that have been glaciated. Limestones of the Cassin, Crown Point, and Valcour formations contain cephalopods; the Cassin is especially noted for its cephalopod fauna. Most of the Crown Point and Valcour forms are the straight cone type of cephalopod while many of the Cassin forms are coiled (Plates X-XII). The Glens Falls formation yields in places some rather large specimens, one of which is shown in fig. 6, Plate XII.

TRILOBITA

Appearing suddenly in the Lower Cambrian, full-blown and seemingly well advanced along their evolutionary trail, the trilobites swam and crawled about the early Paleozoic seas in great numbers. The lineage reached its acme of development in the Ordovician and then declined to extinction at the end of the Paleozoic. Because of their great numbers and the fact that they shed their exoskeletons several times during their lives, much as the lobsters do today, remains of trilobites are common in the Ordovician rocks of the Champlain Valley.

Trilobites are usually placed within the Phylum Arthropoda, for they resemble in many respects certain members of this phylum such as the lobsters, crabs, and crayfish. They are usually considered to be a class of the arthropods.

Practically all of the fossiliferous formations of the Champlain Valley contain trilobite remains; it is not uncommon to find whole specimens, although fragments are much more common. The Chazyan and Glens Falls limestones yield some very good specimens, ranging in size from 0.25 inch to approximately 6 inches in length.

The preserved parts of trilobites consist of the dorsal covering and certain hard parts from the underside of the animal. The dorsal covering corresponds to the hard parts on the back of a lobster, although the segmentation is considerably different. When trilobites died or shed their external covering, mud filled the open spaces once occupied by flesh. Many of the fossils are thus internal molds or are impressions. Any of the original material that remains has usually been carbonized. Sometimes disarticulated and distorted specimens of larger trilobites are mistaken for "fossil fish," the

TABLE 3 TRILOBITE ORDERS

Order	Position of Facial Suture	Other Features	Age range	Representative Vermont Genera (See Plates XIII, XIV)
Protoparia	Around margin of the cephalon	Semicircular cephalon, usually with large eyes; thorax with many segments, somewhat spinose in appearance; rudimentary pygidium	Lower Cambrian	*Olenellus*
Proparia	Posterior part of suture intersects margin of cephalon in front of angle between back and side margins of cephalon, crossing the dorsal surface of the cephalon	Cephalon generally ovoid in outline; glabella bulbous and crossed by furrows; relatively large eyes; well-defined axial and pleural lobes; pygidium outline similar to that of the cephalon, but it is smaller and has transverse furrows; generally a smooth carapace	Middle Cambrian to Upper Devonian	*Pliomerops*
Opisthoparia	Intersects rear margin of cephalon, crossing the dorsal side	Generally ovoid to semicircular cephalon; otherwise much like previous two orders; wide variation in details, however; largest number of known trilobites belong here	Lower Cambrian to Permian	*Isotelus* *Triarthrus* *Flexicalymene*
Hypoparia	Marginal position; does not cross dorsal side of cephalon	Small eyes, or no eyes; small, well-developed pygidium; glabella well defined; large portion of cephalon may be pitted	Lower Ordovician to Upper Devonian	*Cryptolithus*
Eodiscida	Marginal or as in the Proparia	Usually no eyes; only 2 or 3 thoracic segments; relatively large annulated cephalon; pygidium and cephalon of approximately equal size; maximum length about 0.5 inch	Lower and Middle Cambrian	*Pagetides*
Agnostida	No facial sutures	Maximum size about 0.3 inch; no eyes; two thoracic segments; relatively large pygidium is subcircular in outline as is cephalon	Lower Cambrian to Upper Ordovician	*Homagnostus*

segmentation suggesting to some the bony structure of a fish. Reference to Fig. 17 will give you some of the important terms used in describing trilobites.

Trilobites are divided longitudinally into three divisions or lobes, the axial lobe in the center and two side or pleural lobes. From this three-fold division arose the name trilobite. Beginning at the anterior end, you can see that the exoskeleton is divided into a head or cephalon, a segmented thorax or body, and a tail or pygidium. The several segments of the thorax articulated in much the same fashion as the segments of the carapace of a lobster articulate. For each segment there was a pair of appendages, seldom preserved. Each appendage was split into two parts. One part functioned as walking or swimming legs while the other part was seemingly used for breathing. The mouth of the animal was on the under or ventral side, and in front of it was a plate called the hypostome (Plate XIII, fig. 17) which may be found occasionally.

On top of the cephalon a pair of eyes surveyed the surroundings. A few trilobites were blind, there being no evidence of eyes, while others had eyes located at the end of stalks which protruded above the cephalon. The eyes were complex, consisting of a large number of lenses; if you are fortunate, you may find a specimen with the eyes so preserved that the nature of the eye structure is apparent.

Among the features utilized in classifying and identifying trilobites are the overall outline of the animal, the relative sizes of the cephalon and the pygidium, the shape of the glabella, various ornamental features about the cephalon, the presence or absence of eyes, the number of segments in the thorax, and the position of the facial suture. Facial sutures may cross the cephalon to intersect the posterior margin, may cross the cephalon so that they intersect the lateral margin of the cephalon in front of the angle between the posterior margin of the cephalon and its side, or they may not appear on the top of the cephalon but lie along its margin.

The trilobites are generally looked upon as a class of the arthropods. In one classification scheme six orders are recognized, the position of the facial suture being the primary feature used to differentiate the members of one order from those of another. Of course, other aspects of the exoskeleton are used in the classification. Some families of trilobites are well known; others are less well known and their relationships to other families of trilobites are still under considerable investigation.

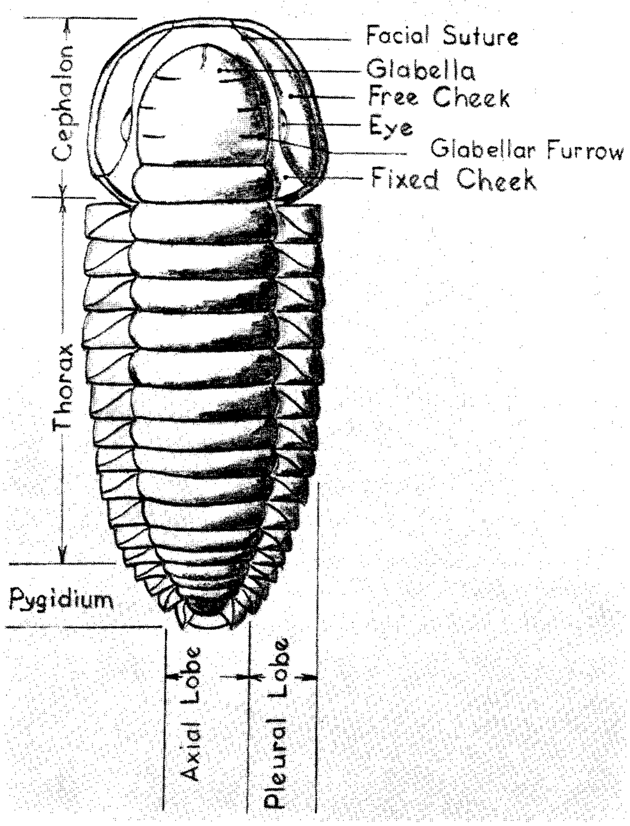

FIG. 17. Trilobite. Major structural features of the trilobite exoskeleton. Based on *Triarthrus*, which is found in the Stony Point shales (x 2).

For the purposes of this volume the descriptions of the several orders as defined above provide an introduction to the trilobites. These descriptions are given in Table 3. Details of the families belonging to the several orders, as well as more detailed descriptions of the representative genera, may be found in some of the specialized references given in the bibliography.

OSTRACODA

Small bivalved arthropods known as ostracods are locally common in the rocks of the Champlain Valley. These animals are microscopic in size, ranging from 0.5 to 4 mm in length. They can usually be recognized with a hand lens, although

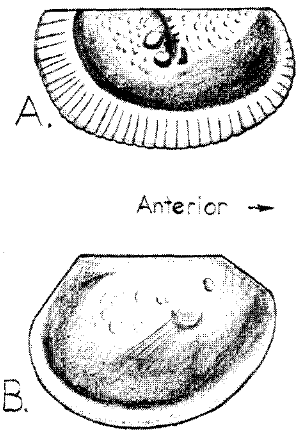

FIG. 18. Ostracoda. Drawings of the right valves of two ostracod genera which are common in the Champlain Basin rocks.
A. *Eurychilina latimarginata* Raymond (x 14).
B. *Leperditia limulata* Raymond (x 3.5).

positive identification of genera may require the use of a microscope.

Ostracod bodies are vaguely segmented and are covered by a carapace which is composed of two elliptical valves hinged along the back or dorsal side of the animal. Thus, in some respects the covering resembles that of certain pelecypods. In a very general sense, ostracods resemble small shrimp that have been crammed into a very small shell.

Paleontologic classification and identification of ostracods depends upon the shape of the carapace and features seen on it. Specimens from the Champlain Valley sediments tend to be dark-colored and smooth. They are easily overlooked, but scrutiny of freshly broken limestones with a hand lens will often disclose the presence of these minute bean-shaped objects. Ostracods are perhaps the one fossil that can be collected from limestones and calcareous shales of the Bridport dolostone.

Figure 18 shows drawings of two of the ostracods that are found in the Chazyan rocks, *Eurychilina* and *Leperditia.*

ECHINODERMATA – PELMATOZOA

Representatives of the Echinodermata, the phylum which includes the starfish, the sand dollar, the brittle stars, and the feather stars (crinoids), found in the Ordovician rocks of the Champlain Valley are the cystoids, the blastoids, and the crinoids. All of these animals belong to the Subphylum Pelmatozoa whose members are attached to the ocean bottom by a system of rootlike appendages. Only the crinoids are living today, the cystoids and the blastoids having lived only during Paleozoic time. All three groups first appear in the Ordovician.

The main part of the animal lived in a budlike or subglobular cup called the theca or calyx. Plates of assorted sizes and shapes put together in various ways comprise the theca. The number, shape, and arrangement of the plates are important for identification and classification of the animals. Echinoderms generally exhibit a five-fold radial symmetry.

The cup or theca, the stem for attachment, and the arms or appendages comprise the three main parts of the animals. The stem consists of a series of washer-like plates which gave the animal flexibility, permitting it to sway and move with the currents. Rootlike extensions of the stem afforded a grip on the bottom. Appendages rising from the theca directed food toward the mouth which lay in the upper surface of the cup. Relations of the appendages to the theca as well as the nature of the appendages themselves are important for classification of these animals.

The dorsal part of the animal was at the end of the cup to which the stem is attached. The ventral portion faced in an upward direction when the animal was in a normal growth position. This arrangement is opposite to that found in the starfish where the mouth faces downward. Figure 19 illustrates some of the important parts of a pelmatozoan.

Echinodermata are generally poorly represented in the Ordovician rocks of Vermont except as detached columnals and plates, which are abundant. The columnals are the washer-like fossils found in most of the limestones; some of the plates possess round centers while others have star-shaped centers. Most of the columnals are round, but some are pentagonal. Occasionally part of a stem or arm may be found; relatively complete specimens are present but rare. I have seen a few relatively complete specimens in the limestones of the Glens Falls formation, one of which is illustrated on Plate XIV.

Hudson (1904, 1907) has described pelmatozoans from the Chazyan rocks of Valcour Island where they are abundant in some horizons while Raymond (1906) gave localities on Valcour Island and on the adjacent New York shore where they have been found. Undoubtedly examination of the rocks on the Vermont side of Lake Champlain specifically for these animals would disclose more than have been reported thus far.

Cystoids

The general shape of the cystoid body is spheroidal. Numerous irregularly arranged plates comprise the calyx. An important feature of the cystoids is the pores which penetrate the plates. Arrangement of the pores is utilized in classification and identification of the cystoids. The most common cystoid found in the Chazyan rocks of the Champlain Valley is *Malocystites.* Usually it is so poorly preserved that it appears as small (5 mm or less) black pellets in the limestones and can be recognized only with great difficulty. The pores appear as small pits on the surface of the pellets. Another cystoid, *Bolboporites americanus,* is shown in Plate XIV, fig. 24.

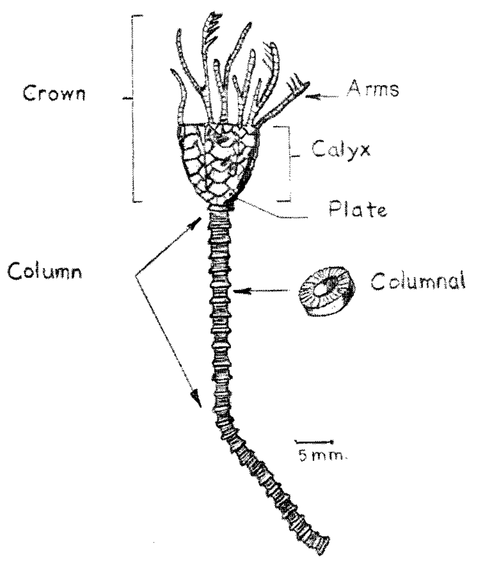

FIG. 19. Crinoid. Various structural features, including the plates of the calyx. *Schizocrinus nodosus* Hall, after Hall (1847). This fossil may be found in the Glens Falls limestones.

Blastoids

Blastoids apparently had only short stems or lacked them altogether; their appendages were small and thin. The appendages lined the food grooves which traversed the upper part of the theca, rising directly from them. Budlike in form, the blastoid theca consists of 13 or 14 plates which are uniformly arranged in all members of the group. Plates from the primitive blastoid ***Blastoidocrinus*** are locally abundant in some of the Day Point rocks. One notable locality is in the upper part of the Day Point formation at The Head on Isle La Motte. Plate XIV, fig. 23 illustrates one of these plates. They have been mistaken for one of the small rugose corals in the past.

Crinoids

Crinoids are characterized by the large number of plates comprising the cup-like calyx. These plates range in number from 13 to over 200 and generally are arranged with a five-fold symmetry. Branched appendages rise from the side of the calyx.

Occasional relatively complete specimens of the small crinoid *Schizocrinus nodosus* Hall and similar forms may be found in the Glens Falls beds. Other crinoids are undoubtedly present also, but as yet not reported. Plate XIV, figs. 25 and 26 illustrate one of these crinoids.

SELECTED REFERENCES

General References

COLLINSON, C. C., 1959, Guide for beginning fossil hunters, Educational Series 4, Illinois State Geological Survey, Urbana, Ill.

DUNBAR, C. O., 1959, Historical geology, John Wiley and Sons, New York.

FENTON, C. L., 1937, Life long ago, The John Day Co., New York.

GOLDRING, WINIFRED, 1931, Handbook of paleontology for beginners and amateurs, part 2, Handbook 9, New York State Museum, Albany, New York.

——————————, 1950, Handbook of paleontology for beginners and amateurs, part 1, Handbook 9, 2nd Edition, New York State Museum, Albany, New York.

HEAL, EDITH, 1930, How the world began, Thomas S. Rockwell Co., Chicago.

LA ROCQUE, A. AND MARPLE, M. F., 1955, Ohio Fossils, Ohio Division of Geological Survey, Bulletin 54, Columbus, Ohio.

MATTHEWS, WILLIAM H. III, 1960, Texas fossils, an amateur collector's handbook, Guidebook 2, Bureau of Economic Geology, The University of Texas, Austin, Texas.

________________, 1962, Fossils, an introduction to prehistoric life, Barnes and Noble, Inc., New York.

MOORE, R. C., 1958, Introduction to historical geology, 2nd Edition, McGraw-Hill Book Co., New York.

PANGBORN, M. W., 1957, Earth for the layman, American Geological Institute, Rept. 2, Washington, D. C.

PERRY, T. G., 1959, Fossils, prehistoric animals in Hoosier rocks, Circular 7, Indiana Dept. Conservation, Geol. Survey, Bloomington, Ind.

RAYMOND, P. E., 1950, Prehistoric life, Harvard University Press, Cambridge, Mass.

SHIMER, H. W., 1933, Introduction to study of fossils, The Macmillan Co., New York.

SIMPSON, G. G., 1953, Life of the past, Yale University Press, New Haven, Conn.

STOKES, W. L., 1960, Essentials of earth history, Prentice-Hall, Inc., Englewood Cliffs, N.J.

UNKLESBAY, A. G., 1955, Common fossils of Missouri, University of Missouri Bulletin, Handbook 4, Columbia, Mo.

Also various encyclopedias under Fossils and Paleontology.

Specialized References

BEERBOWER, J. R., 1960, Search for the past, Prentice-Hall, Inc., Englewood Cliffs, N.J.

COOPER, G. A., 1956, Chazyan and related brachiopods: Smithsonian Inst., Misc. Collections v. 127, parts I and II.

EASTON, W. H., 1960, Invertebrate paleontology, Harper and Bros., Inc., New York.

GALLOWAY, J. J., 1957, Structure and classification of the Stromatoporoidea: Bull. American Paleontology, v. 37, no. 164, p. 345-480.

HALL, J., 1847, Containing descriptions of the organic remains of the lower division of the New York system, equivalent to the Lower Silurian rocks of Europe: Paleontology of New York, v. 1.

MOORE, R. C., LALICKER, C. G., AND FISCHER, A.G., 1953, Invertebrate fossils, McGraw-Hill Book Co., New York.

MOORE, R. C. EDITOR, 1953-1961, Treatise on invertebrate paleontology, Geological Society of America and the University of Kansas Press, Lawrence, Kansas. Issued in several parts.

SHIMER, H. W. AND SHROCK, R. R., 1944, Index fossils of North America, John Wiley and Sons, New York.

SHROCK, R. R. AND TWENHOFEL, W. H., 1953, Principles of invertebrate paleontology, McGraw-Hill Book Co., New York.

ULRICH, E. O. AND COOPER, G. A., 1938, Ozarkian and Canadian Brachiopoda: Geological Society of America Spec. Paper 13.

ULRICH, E. O., FOERSTE, A. F., AND MILLER, A. K., 1943, Ozarkian and Canadian Cephalopods, Part 2: Brevicones: Geological Society of America Spec. Paper 49.

ULRICH, E. O., FOERSTE, A. F., AND FURNISH, W. M., 1942, Ozarkian and Canadian Cephalopods, Part 1: Nautilicones: Geological Society of America Spec. Paper 37.

ULRICH, E. O., FOERSTE, A. F., FURNISH, W. M., AND UNKLESBAY, A. G., 1944, Ozarkian and Canadian Cephalopods, Part 3: Longicones and Summary: Geological Society of America Spec. Paper 58.

ULRICH, E. O., SCHUCHERT, C., AND OTHERS, 1895, Paleontology of Minnesota, v. 3, parts 1 and 2: The Geological and Natural History Survey of Minnesota 1892-1896, Minneapolis, Minn.

References to Champlain Basin Fossils

BARGHOORN, E. S., JR. AND SPACKMAN, W., JR., 1950, A preliminary study of the flora of the Brandon lignite: American Jour. Science, v. 247, p. 33-39.

ERWIN, R. B., 1957, The geology of the limestone of Isle La Motte and South Hero Island, Vermont, Vermont Geological Survey, Bull. 9.

FLOWER, R. H., 1955a, Status of Endoceroid classification: Jour. Paleontology, v. 29, p. 329-371.

________________, 1955b, New Chazyan orthocones: Jour. Paleontology, v. 29, p. 806-830.

________________, 1958, Some Chazyan and Mohawkian endoceratida: Jour. Paleontology, v. 32, p. 433-458.

FOYLES, E. J., 1926, Locality list of Vermont invertebrate fossils: Vt. State Geologist Rept. 15, p. 163-190.

HUDSON G. H., 1904, Contributions to the fauna of the Chazy on Valcour Island, Lake Champlain: N. Y. State Paleontologist Rept., 1903, p. 270-295.

__________, 1907, On some Pelmatozoa from the Chazy limestone of New York: N. Y. State Museum Bull. 107, p. 97-102.

KAY, G. M., 1937, Stratigraphy of the Trenton group: Geological Soc. America Bull., v. 48, p. 233-302.

PERKINS, G. H., 1904, The Brandon lignite: Vt. State Geologist Rept. 4, p. 153-161.

__________, 1908, Fossil Cetacea of the Pleistocene of the United States and Canada: Vt. State Geologist Rept. 6, p. 76-112.

RAYMOND, P. E., 1902, The Crown Point section: Bull. of American Paleontology, v. 3, no. 14.

__________, 1905, The fauna of the Chazy limestone: American Jour. Science, series 4, v. 20, p. 353-382.

__________, 1906, The Chazy formation and its fauna: Annals of Carnegie Museum, v. 3, p. 498-598.

__________, 1908, Gastropods of the Chazy formation: Annals of Carnegie Museum, v. 4, p. 168-225.

__________, 1910, Trilobites of the Champlain Valley: Vt. State Geologist Rept. 7, p. 213-248.

__________, 1911, The Brachiopoda and Ostracoda of the Chazy: Annals of Carnegie Museum, v. 7, p. 215-259.

__________, 1916, The Pelecypoda of the Chazy formation: Annals of Carnegie Museum, v. 10, p. 325-342.

__________, 1924, The oldest coral reef: Vt. State Geologist Rept. 14, p. 72-76.

RUEDEMANN, R., 1906, Cephalopods of the Beekmantown and Chazy formations of the Champlain Basin: N. Y. State Museum Bull. 90, p. 389-611.

__________, 1921, Report on Trenton fossils from the so-called Trenton and Utica beds of Grand Isle, Vermont: Vt. State Geologist Rept. 12, p. 90-100.

SEELY, H. M., 1902, Some sponges of the Chazy formation: Vt. State Geologist Rept. 2, p. 150-161.

__________, 1904, The Stromatoceria of Isle La Motte, Vermont: Vt. State Geologist Rept. 4, p. 144-152.

__________, 1906, Contribution to the geology and paleontology of Vermont: Vt. State Geologist Rept. 5, p. 174-187.

__________, 1910, Preliminary report on the geology of Addison County: Vt. State Geologist Rept. 7, p. 257-313.

WELBY, C. W., 1961, Bedrock geology of the Central Champlain Valley of Vermont, Vermont Geological Survey Bull. 14.

WHITE, T. G., 1899, Ordovician faunas in the Lake Champlain Valley: Geological Soc. America Bull., v. 10, p. 452-462.

WHITFIELD, R. P., 1886, Notice of geological investigations along the eastern shore of Lake Champlain, conducted by Prof. H. M. Seely and Pres. Ezra Brainerd of Middlebury College, with descriptions of new fossils discovered: American Museum Nat. History Bull., v. 1, p. 293-345.

__________, 1889, Observations on some imperfectly known fossils from the Calciferous sandrock of Lake Champlain and descriptions of several new forms: American Museum Nat. History Bull., v. 2, p. 41-65.

__________, 1890, Observations on the fauna of the rocks at Fort Cassin, Vermont, with descriptions of a few new species: American Museum Nat. History Bull., v. 3, p. 25-39.

__________, 1897, Description of new species of Silurian fossils from near Fort Cassin, Vermont, and elsewhere on Lake Champlain: American Museum Nat. History Bull., v. 9, p. 177-184.

GLOSSARY

ADDUCTOR MUSCLE – one of the muscles used to close the shell of a brachiopod or pelecypod.

ANTERIOR – the front or fore part.

APERTURE – the opening of a shell through which the animal may communicate with his surroundings.

ANUS – the opening at the end of the digestive tract through which waste products are discarded from the body.

APICAL ANGLE – in gastropods, the angle formed by tangents drawn to the sides of the shell; the angle is a measure of the height of the spire.

BEAK – in brachiopods and pelecypods, the sharp, pointed projection where the shell began its growth.

BILATERAL – means that the body or shell can be divided into two halves which are mirror images of one another.

BINOMIAL NOMENCLATURE – a system of nomenclature used by scientists wherein two names are given the object, a generic name and a trivial name.

BIVALVED – shell consisting of two parts, or valves.

BLASTOID – one of the stalked echinoderms (pelmatozoan); has a budlike calyx composed of 13 plates; is extinct.

BRACHIDIUM – in brachiopods, interior projections from the beak region of the brachial valve for support of the lophophore.

BRACHIAL VALVE – in brachiopods, the valve which has the supports for the lophophore; usually the lower valve when the plane between the valves parallels the bottom to which the brachiopod is attached.

BRACHIOPOD – marine invertebrate whose shell consists of two valves, the plane between them being at right angles to the plane of symmetry which is oriented in a dorsal-ventral direction.

BRYOZOAN – aquatic, bilaterally symmetrical, unsegmented colonial animals; individuals characterized by tentacles and a tube-like body which has a U-shaped digestive tract.

CALCAREOUS – composed of, or containing calcium carbonate or lime.

CALCITE – mineral composed of calcium carbonate ($CaCO_3$).

CALYX – in corals, the bowl-shaped depression at the top of the skeleton; in pelmatozoans the lower cup-shaped part of the body containing the soft parts.

CANAL – pores in the structure of sponges for ingress of water.

CARAPACE – hard, protective covering forming the exoskeleton of some invertebrates, especially applied to arthropods (trilobites and ostracods).

CARBONIZATION – fossilization process in which organic material is converted to carbon or coal.

CAST – the product formed by the filling of a cavity.

CEPHALON – in trilobites, the forward segment of the body with the eyes on the upper (dorsal) side and the mouth on the lower (ventral) side.

CEPHALOPOD – marine invertebrate animal with well-defined head and eyes and with tentacles around the mouth; shelled types have transverse partitions called septa.

CHEEK – in trilobites, part of the cephalon; fixed cheek is attached to the glabella; free cheek is the outer part of the cephalon and is separated from the fixed cheek by the facial suture and is often gone from fossils. Loss of free cheek apparently was part of the molting process as the individual grew.

CLOACA – in sponges (Porifera), the hollow opening inside the walls of the animal.

COELENTERATE – animals with primary radial symmetry and with no digestive tract; have tentacles with stinging cells around mouth. Corals are the most prominent fossils of this phylum.

COLLAR-CELLS – cells with a whip-like tail guarded by a cylindrical wall; the cells line the interior surface of the sponge cloaca, extracting food and moving the water taken in through the canals.

COLONIAL – a mode of life for some invertebrates in which the individuals live in close association with one another and are more or less interdependent; colonial corals and bryozoans.

COLUMELLA – a small axial pillar found in the corallite of corals; in gastropods the pillar formed when successive coils of a conispiral shell join.

COLUMN – in pelmatozoans, the jointed stem made of washer-like plates which is attached to the base of the cup-like feature in which lie the soft parts of the animal.

COLUMNAL—a washer-like segment of the stalk or column of a pelmatozoan.

CONCRETION—an irregular mass in a sedimentary rock; usually forms by chemical precipi-; tation around a central core; sometimes mistaken for a fossil, or the core may be a fossil.

CORAL—marine invertebrate that lives on the bottom and secretes an exoskeleton of calcareous material; member of the Class Anthozoa, Phylum Coelenterata.

CORALLITE—skeleton formed by an individual coral; may be single or one of a colony.

CORALLUM—hard parts of a coral colony.

CORRELATION—process of demonstrating the equivalence in age of strata, and/or placing those not equivalent in age in their proper age relationship.

COSTA (plural, COSTAE)—in brachiopods and pelecypods, a thickening of the shell which is radially disposed away from the beak area; affects the outer surface of the shell only, unlike a plication which affects both surfaces.

CROWN—term applied to the cup and the arms of the pelmatozoans.

CYST—in the stromatoporoids, a small curved plate, several of which overlap and join one another to form the laminae.

CYSTIPHRAGM—in bryozoans, small curved plates that do not cross completely the zooecial tube.

CYSTOID—one of the pelmatozoans; body outline is spheroidal or saclike, and the body itself is composed of numerous irregularly arranged plates which have pores in them; extinct.

DENDRITIC—branching like a tree.

DENTITION—in brachiopods and pelecypods, means the arrangement of teeth and sockets along the hinge line of the shell.

DIAPHRAGM—in bryozoans, a gently arched plate that crosses the zooecia.

DIDUCTOR MUSCLE—one of the muscles used in opening the shell of a brachiopod; leaves scars on the floor of the pedicle valve and is attached to special structures beneath the beak of the brachial valve.

DOLOMITE—a mineral composed of calcium magnesium carbonate ($CaMg(CO_3)_2$).

DOLOSTONE—term for a rock composed 50 percent or more of the mineral dolomite; also known as dolomite.

DORSAL—of or pertaining to the back of the animal.

ECHINODERM—a member of the Phylum Echinodermata. Animals in the phylum are characterized by a five-fold radial symmetry; included in the phylum are the cystoids, blastoids, crinoids, starfishes and sand dollars.

ENDOSKELETON—internal structure which supports the animal.

EPITHECA—in corals the outer wall of the corallite which is secreted by the outer layer of the living matter.

EQUIVALVED—the two valves of the shell are about equal and are mirror images of one another except for hinge structures.

EXOSKELETON—the external covering of the invertebrates; term used particularly with reference to the corals and the trilobites.

FACIAL SUTURE—the line along which the cephalon of a trilobite breaks; separates the free cheeks from the fixed cheeks. Some trilobites do not have one.

FAUNA—an assemblage of animals living in a particular place at a certain time. The term Flora is used in the case of plants.

FOLD—term used in describing brachiopod shells; a major elevation, usually rounded, of the shell and affecting both the inner and outer shell surfaces; located along the mid-line of the shell.

FORAMEN—term used to describe the opening located near the beak of the pedicle valve of brachiopods. The pedicle passes through the shell in this opening.

FORMATION—a body of rock that may be mapped and which may be distinguished chiefly on the basis of the type of rock and certain observable physical characteristics.

FOSSIL—organic remains that have been naturally buried and preserved in the earth's crust for a considerable length of time and which show some evidence of the physical nature of the animal or plant.

GASTROPOD—a member of the Class Gastropoda, Phylum Mollusca; a land- or water-dwelling invertebrate which has a single-valved shell. The shell is coiled and composed of calcium carbonate.

GEOLOGY—the science of the earth.

GEOLOGIC AGE—the time when an object existed or an event took place, expressed in terms of the Geologic Time Scale; e.g., an Ordovician brachiopod.

GEOLOGIC MAP—a map on which is shown the distribution of rock outcrops, various structural features, mineral deposits.

GEOLOGIC RANGE—the length of time that an organism or group of organisms existed, expressed in terms of geologic time.

GLABELLA—the axial portion of the cephalon of trilobites; generally elevated above the rest of the cephalon.

GLABELLAR FURROW—an indentation in the glabella which generally lies at an angle to the axis of the glabella.

GROWTH LINES—lines on shells of invertebrates marking various stages in the growth of the shell.

GRAPTOLITE—an extinct, marine, colonial animal which had chitinous hard parts.

HEMISEPTUM—small projection from the wall of cryptostomate bryozoans which separates the outer vestibule from the inner portion of the zooecium.

HINGE LINE—in brachiopods and pelecypods, the line along which the two valves of the shell articulate; is dorsal in position in the pelecypods and posterior in the brachiopods.

HYPOSTOME—a plate, generally somewhat forked, that was next to and anterior of the mouth of a trilobite; usually only observed as a disarticulated plate in association with other trilobite fragments.

IMMATURE ZONE—in treptostomate and cryptostomate bryozoans, a thin-walled inner portion of the zooecial tube where the diaphragms are generally relatively widely spaced.

INEQUIVALVED—valves of the shell are not alike in shape or size, or both; as in the brachiopods.

LATILAMINA—in stromatoporoids, the larger laminar layers composed of a series of laminae and separated from adjacent latilaminae by a thin zone of crowding of the laminar structure or by a layer of sediment deposited when this part of the colony was inactive.

LIGAMENT—in pelecypods, an elastic organic structure which opens the shell; found in the hinge area.

LIMESTONE—rock composed 50 percent or more of calcium carbonate; fossil-fragmental limestone is one composed dominantly of broken debris formed from fossil shells.

LIVING CHAMBER—in members of the Phylum Mollusca, the forward chamber of the shell where the animal lives; particularly applied to cephalopods.

LOBE—in trilobites, one of the tripartite longitudinal divisions of the exoskeleton; axial lobe and the two side or pleural lobes. In cephalopods, a flexure of the suture which is convex toward the apical or posterior portion of the shell.

LOPHOPHORE—in bryozoans, a tentacle-bearing fleshy ring which surrounds the mouth; in brachiopods, a tentacle-bearing appendage which is attached to the wall separating the intestine-bearing cavity from the anterior portion of the shell.

MANTLE—in the brachiopods and mollusks, a layer of fleshy material (tissue) which contains cells secreting the shell.

MATURE ZONE—thick-walled, outer portion of a bryozoan colony, recording a slow-growing stage in the history of the zooecia; in the cryptostomates and the treptostomates. Structures associated with the zooecia become more complex here; mesopores appear, and the diaphragms crossing the zooecia become more closely spaced.

MESOPORE—in bryozoans, tubes smaller than the main tubes or zooecia and appearing in the mature zone; usually have many closely spaced diaphragms.

MOLD—a hollow or depression in a rock caused by the impression of a shell on the sediment when it was soft. The high and low spots in the depression correspond with the low and high spots on the surface of the shell. In a sense it is a negative of the original shell. If the shell is filled with mud, then an internal mold, or steinkern, is formed which shows in obverse the interior surface of the shell.

MUSCLE SCARS—in brachiopods and pelecypods particularly, the depressions on the inner surface of the valves where muscles were attached. Their number, position, and shape are important in classifying the animals.

OPERCULUM—a lid or covering for the aperture; found in gastropods and some bryozoans.

ORAL—refers to the mouth or to the apertural end of the shell.

OSCULUM—in sponges, the large rounded vent which surmounts the cloaca and provides the means of egress for the waste-bearing water.

PALEONTOLOGY—in the broadest sense, means study of ancient life; commonly considered as dealing with animals only and thus is divided into invertebrate paleontology and vertebrate paleontology; study of ancient plants is referred to as paleobotany.

PALLIAL LINE—a narrow line on the interior of pelecypod shells marking the position where the mantle is no longer attached to the shell in a direction away from the hinge line (that is, in a ventral direction). Parts of the mantle between this line and the outer edge of the shell are not attached to the shell.

PALLIAL SINUS—an indentation in the posterior part of the pallial line marking the position of a space for partial retraction of the siphons.

PEDICLE—the fleshy stalk which brachiopods use for attachment to the ocean bottom or for burrowing into the soft sediments.

PEDICLE OPENING—opening in the pedicle valve for the pedicle. It is modified by various structures. See Foramen.

PEDICLE VALVE—the valve to which the pedicle is attached, in brachiopods; normally it is the upper valve when the plane between the valves is parallel to the surface to which the brachiopod is attached and is the larger of the two valves usually.

PELECYPOD—a bivalved, water-dwelling invertebrate in which the two valves are hinged along the dorsal margin in a direction parallel to the anterior-posterior axis of the animal. The valves thus cover the right and left sides of the animal.

PERMINERALIZATION—filling of the open spaces in the shell by mineral matter without removal of any of the original shell material.

PILLAR—vertical structure penetrating the horizontal laminae of stromatoporoids.

PLANISPIRAL—a method of coiling such that the mid-line of the shell drawn on its outer circumference always lies in the same plane; that is, coiled in one plane.

PLEURAL—refers to the side; in trilobites refers to the side lobes of the thorax and pygidium; see lobe.

PLICATION—a ridge-like feature showing on the surface of a brachiopod or pelecypod shell, but affecting both the external and internal surfaces of the shell; plications radiate out from the beak.

POLYP—cup-shaped or cylindrical, tentacled, water-dwelling coelenterate; for example, the corals.

POLYPIDE—in the bryozoans, the individual animal which lives in the zooecium; see zooid also.

POSTERIOR—to the rear or situated behind something; opposite of anterior.

PYGIDIUM—the posterior portion of the trilobite exoskeleton; formed by the fusion of several of the segments; a tail piece.

RECRYSTALLIZATION—alteration in the atomic structure of a mineral to produce a different crystal form and thus a different mineral without change in the chemical composition.

REEF—a mound-like structure growing up from the sea bottom and built by various types of invertebrates usually.

REPLACEMENT—a type of fossilization wherein the original shell material is removed in solution accompanied by almost simultaneous deposition of a different substance.

RHABDOSOME—a whole graptolite colony which grew by budding from the initial cup and its contained animal.

SADDLE—in cephalopods, the bend in a suture which is convex toward the aperture of the shell.

SELENIZONE—in gastropods, a well-defined band paralleling the coiling of the whorl; it is caused by a notch or slit in the outer lip of the aperture and marked by sharply bent growth lines.

SEPTUM (plural, SEPTA)—a dividing wall or partition; in cephalopods, partitions transverse to the axis of the shell; in corals, the vertical plates which divide the corallite radially.

SIPHON—in pelecypods, a tube extending from the posterior portion of the mantle; one is used to bring water into the body of the animal, and the other is used to send the water out of the body. In cephalopods, a fleshy tube passing through the septa and connecting the body cavity of the animal with the earliest-formed chambers of the shell. It contains blood vessels and is an extension of the body of the animal.

SIPHUNCLE—in cephalopods, the segmented calcareous tube which surrounds the siphon when the animal is alive. It is formed by backward extensions of the septa and connecting structures.

SPECIES—the basic unit of the scientific classification of animals and plants; unit group composed of individuals which have near identity of form (except for sex differences) and which as a group can be distinguished from other similar assemblages. In living organisms the ability of the individuals belonging to the same species to interbreed and produce fertile offspring is a further part of the definition; individuals belonging to different species can not have fertile offspring.

SPICULE—one of the skeletal elements of a sponge; spike-like or dart-like in form but may have several prongs.

STEINKERN—the internal filling of a shell; an internal mold.

SULCUS—the broad downward flexure in the surface of a brachiopod shell; it affects both the outer and inner shell surfaces and is located along the anterior-posterior mid-line of the shell.

SUTURE—in gastropods, the line of juncture between successive whorls as seen on the exterior of the shell; in cephalopods, the line formed by the intersection of a septum and the inner surface of the shell wall; in pelmatozoans, the line along which two plates of the calyx meet.

SYMMETRY—regularity of form or arrangement with reference to corresponding parts; *bilateral symmetry* is the duplication of parts on each side of a vertical anterior-posterior plane, the parts being mirror images of one another; *radial symmetry* is the systematic and symmetrical arrangement of parts about an axis, usually dorso-ventrally oriented.

TABULA—one of the more or less horizontal interior plates or platforms found in the corals and related animals. Generally it reaches across the open space from one vertical component of the structure to an adjacent one.

TAXONOMY—that branch of science dealing with classification; in the case of plants and animals the classification is according to natural relationships insofar as it is possible to determine them.

THECA—in graptolites, a cup or tube which forms a part of the rhabdosome or colony; in pelmatozoans, the main body (or calyx) which holds the soft parts of the animal.

THORAX—term used in describing the portion of the trilobite body that lies between the cephalon and the pygidium.

TRILOBITE—an extinct marine arthropod which possessed a segmented body enclosed in a dorsal exoskeleton which was divided longitudinally into three divisions or lobes.

TRIVIAL NAME—the second name in the binomial system; name added to the generic name to indicate the species.

TYPE SPECIMEN—the individual specimen on which the original description of a species is based.

UMBILICUS—an opening in coiled shells formed when the whorls are not completely in contact. In the gastropods the umbilicus is usually located at the base of the shell, but in some forms it is on the apical side (for example, *Maclurites*). Planispirally coiled cephalopods have two umbilici which are located on the sides of the shell so that their axis coincides with the axis of coiling.

UMBO—in pelecypods, the prominent convexity of the shell located ventrally a short distance from the beak; in brachiopods, a similar convexity located a short distance anteriorly of the beak.

VALVE—one of the pieces comprising the shell of an animal; pedicle and brachial valve of brachiopods and left and right valves of pelecypods.

VENTRAL—of or pertaining to the abdomen; hence the lower surface.

VESTIBULE—in cryptostomate bryozoans, the outer part of each zooecia; is separated from the part in which the animal lived by a small projection, the *hemiseptum*.

WHORL—used in describing a coiled shell; a complete turn or volution of the shell.

ZOOARIUM (plural, ZOOARIA)—in bryozoans, the colony composed of a large number of individual animals.

ZOOECIUM (plural, ZOOECIA)—in bryozoans, the tube or chamber in which lives the individual animal.

ZOOID—individual bryozoan animal; see polypide also.

PLATE I

ALGAE AND PORIFERA

1. Cf. *Hedstromia.* Alga which appears lighter colored than the surrounding limestone and is smoother weathering, a characteristic that seems true of many of the algae and algae-like materials. Close examination with lens discloses minute pits which are the position of the tubes left when the organic filaments decayed. Occurs as thin (0.25 inch) irregular crust or mat; may be a variety of *Solenopora* (see below). From Valcour formation, approximately 0.4 mile west of South Hero Station (x 1).
2. Cf. *Hedstromia.* Vertical thin section showing tubes or filaments of specimen illustrated in Fig. 1 (x 4). See Fig. 12 also.
3. *Solenopora compacta* (Billings). Section parallel to the radiating tubes of the colony, showing the typical wavy concentric bands which are presumed to represent seasonal growth; probably a red alga. Colonies usually occur as subglobular masses from 1 inch to 2 inches in diameter. Figure made from thin section in H. M. Seely collection of Middlebury College; locality given as "C-Chazy, Isle La Motte" (x 6).
4. *Girvanella* sp. surrounding small cephalopod shell. Alga apparently used shell as nucleus, growing in laminae about it. Valcour formation, north slope of hill which is 0.6 mile southwest of South Hero Station (x 2).
5. *Girvanella* sp. Small, subglobular, pellet- or bean-shaped, laminated; common in Crown Point limestone; relationship to living algae not definitely known. From Crown Point limestones on east side of small hill about 1.25 miles west of Charlotte Village and south of Wings Point road (x 1). See Plate II, Fig. 12, also.
6. *Cryptozoön* sp. Composed of irregular concentric laminae formed by precipitation of lime around the plant filaments which had a matlike form. Usually recrystallization has destroyed most of the internal structure. From Cassin formation, Thorp Point, Charlotte (x 0.5).

The "*Stromatocerium*" specimens illustrated in Figs. 7-9 are algal forms, perhaps related to *Cryptozoön;* see also Plate II, Figs. 1-3; Plate XV, Figs. 3,4.

7. "*Stromatocerium*" *lamottense* Seely. Part of a larger mass. Body massive, composed of white, wavy laminae from 2 to 5 mm thick which are in turn composed of thinner laminae 0.2 to 0.3 mm thick. The larger laminae are separated black and dark-gray lime mud. Individual masses are up to 2 or more feet in vertical dimension; specimen in H. M. Seely Collection, Middlebury College; Crown Point limestone, Goodsell Quarry, Isle La Motte (x 1). See also Fig. 3, Plate II and Fig. 4, Plate XV.
8. "*Stromatocerium*" *lamottense* Seely. Photograph made from a thin section cut from the specimen illustrated in Fig. 7, illustrating detail of the laminated structures. White-colored streaks are lime mud and dolomitic material which are opaque. Slide 8-3 made by J. J. Galloway and J. St. Jean in 1954, and in the H. M. Seely Collection, Middlebury College (x 12.5).
9. "*Stromatocerium ?*" *moniliferum* Seely. Thin section of a specimen in the H. M. Seely Collection, Middlebury College, prepared by J. J. Galloway and J. St. Jean in 1954. The colony is formed of hemispherical masses composed of 1 cm-wide parallel columns which appear on weathered surfaces and are characterized by broadly arched transverse bands. The thin section shows the arcuate nature of the cells comprising the column and faintly the beaded structure which typifies this form and which was pointed out by Seely (1904) in his initial description. Locality given as "C-Chazy, Isle La Motte" (x 12.5).
10. Cf. *Saccospongia.* Thin section cut at right angles to the axis of the specimen shown on Plate II, Fig. 6. Cloaca to right in the white area of the photograph; gray lines and spots represent the canals while the white areas are the opaque material of the skeleton. Crown Point limestone, "reefy zone" near top of formation, 0.7 mile S. 50° E. of Pearl railroad crossing, Grand Isle (x 2.5).
11. *Zittelella varians* (Billings). Thin section cut at right angles to the axis of the specimen. Light-gray areas represent the canals and the white areas the opaque calcareous material comprising the skeleton. Section from a specimen collected at the same locality as the one illustrated in Fig. 10 (x 2.5). See also Plate II, Figs. 4 and 5.
12. Cf. *Hedstromia.* Thin section cut parallel to the surface of the specimen shown in Figs. 1 and 2 (x 3).
13. Stromatolite. Thin section of one of the presumably organically formed, layered structures found commonly in the Chazyan rocks. Recrystallization has destroyed all the internal structure, and only the gross lamination which is best brought out on weathered surfaces appears. South shore Rockwell Bay, South Hero (x 4).

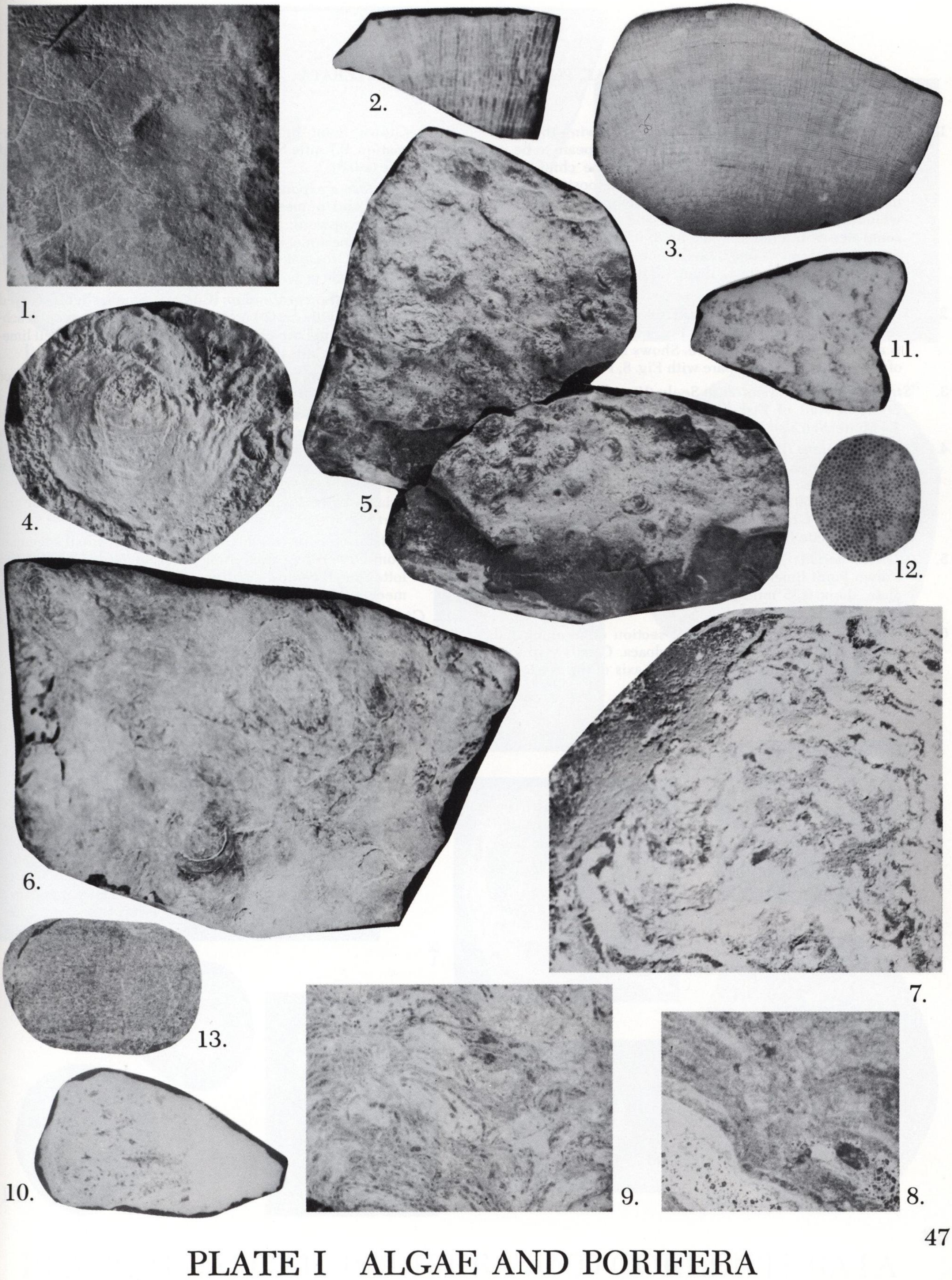

PLATE I ALGAE AND PORIFERA

PLATE II

ALGAE, PORIFERA AND COELENTERATA

1. *"Stromatocerium" eatoni* Seely. Colony showing the small laminated centers of growth. This form appears to be related to *"Stromatocerium" lamottense*, the chief difference being the lack of black lime mud deposits between the laminae in *"S." eatoni*. Colony composed of laminae which are from 2 to 5 mm thick and which are in turn composed of thinner laminae up to 0.3 mm thick. Colony as a whole is only a few inches thick. Northwest corner of Crown Point reefy zone, about 1.5 miles south of Isle La Motte Village (x 0.5).
2. *"Stromatocerium" eatoni* Seely. Thin section cut normal to surface of specimen shown in Fig. 1 along the edge which is at the bottom of the picture. Shows laminated structure of the alga (x 12.5). Compare with Fig. 8, Plate I.
3. *"Stromatocerium" lamottense* Seely. View of several specimens in wall of Fisk Quarry, southeast corner of Isle La Motte. See also Plate XV, Fig. 4.
4. *Zittelella varians* (Billings). Top view of specimen showing radiating canals and top of cloaca which has been filled with dolomitic lime mud. "Reefy zone" in Crown Point limestones 150 yards west of U. S. Route 2 and 250 yards north of the Grand Isle-South Hero townline, Grand Isle (x 1). See Plate I, Fig. 11, also.
5. *Zittelella varians* (Billings). Side view of specimen from Crown Point limestones exposed on shore of Lake Champlain about 0.35 mile south of Grosse Point, Ferrisburg (x 0.75).
6. Cf. *Saccospongia.* Natural vertical section of an elongated, cylindrical sponge with a deep cloaca. Canals visible as lines running at right angles to the axis of the specimen. Crown Point limestone, "reefy zone" near top of formation, 0.7 mile S. 50° E. of Pearl railroad crossing, Grand Isle (x 0.5).
7. *Streptelasma expansum* Hall. Conical corallum with gentle curve and numerous septa; corallum expands relatively rapidly upward; few or no horizontal structures. Crown Point limestone, 900 feet west of Triangulation Point 131, east of Grosse Point, Ferrisburg, Port Henry, N.Y.–Vt. Quadrangle (x 1).
8. *Lambeophyllum profundum* (Conrad). Small, slightly curved corallum with septa poorly developed; calyx deep, reaching almost to base of corallum; lacks tabulae. Orwell limestone, south side of Wings Point, Charlotte (x 2).
9. *Lambeophyllum profundum* (Conrad). Vertical view of specimen shown in Fig. 8 (x 3).
10. *Lambeophyllum profundum* Hall. Top view of small specimen. Small conical corallum with numerous septa which meet in the center but which are not twisted; lacks tabulae; counter septum to left, alar septa vertical, cardinal septum absent. Crown Point limestones, 900 feet west of Triangulation Point 131, east of Grosse Point, Ferrisburg, Port Henry, N.Y.–Vt. Quadrangle (x 1.5).
11. *Streptelasma corniculum* Hall. Top view of small specimen from Orwell limestone, south side of Wings Point, Charlotte. Small conical corallum with numerous septa which meet in the center and are twisted; lacks tabulae (x 2).
12. *Girvanella* sp. Print from a thin section; white areas are opaque limy material, and small round, darker areas are the filaments; same locality as Fig. 10 (x 13). See Plate I, Fig. 5, also.

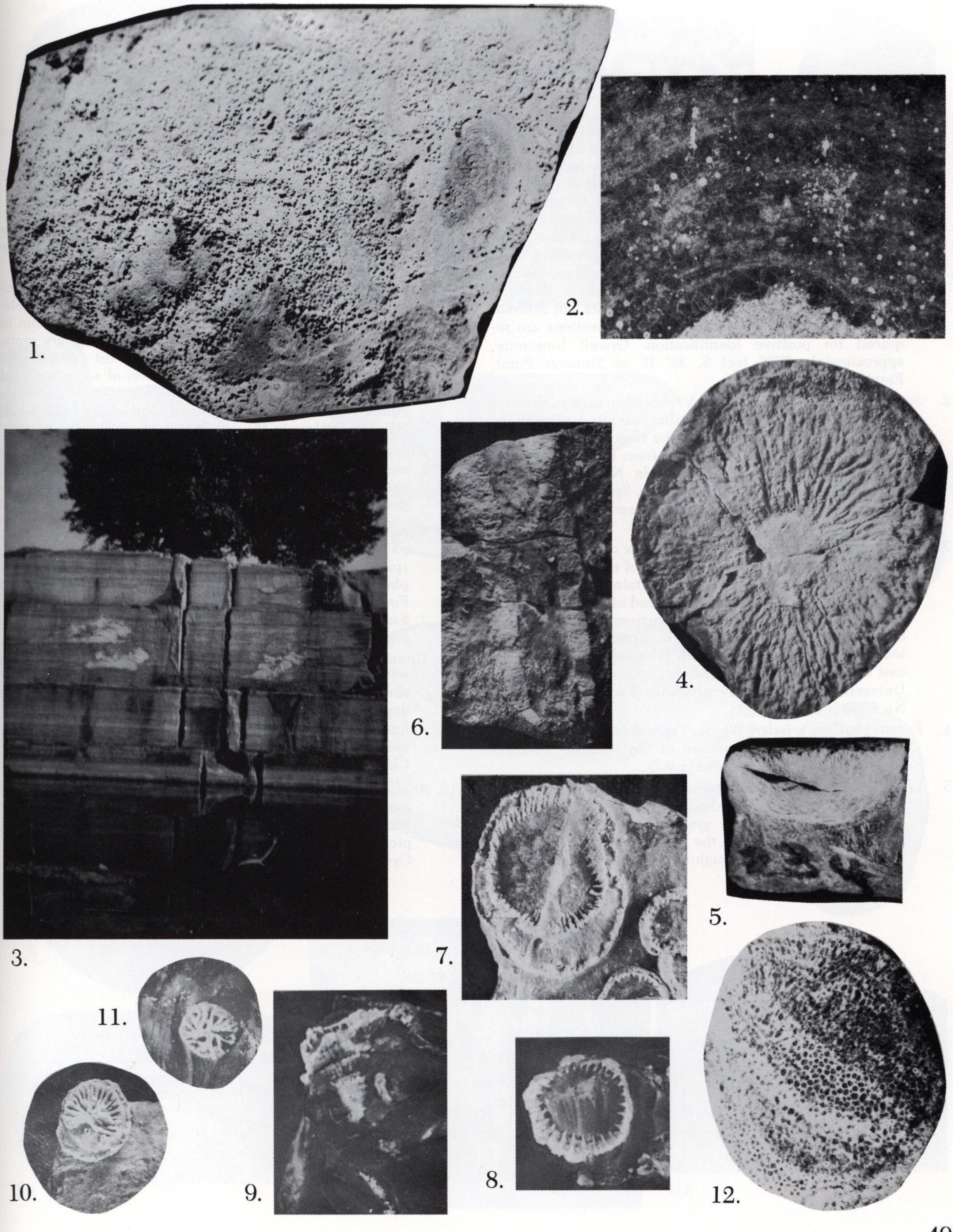

PLATE II ALGAE, PORIFERA AND COELENTERATA

PLATE III

COELENTERATA AND BRYOZOA

1. *Stromatocerium rugosum* Hall. Figure shows the typical beehive shape of this form. Colony consists of a series of laminae formed by cystose plates which are mostly broad and flat and edge to edge or overlapping at the ends; vertical pillars which are long and continuous and which appear only in thin sections cross the cystose plates. Many other laminate fossils occur in the limestones of the Champlain Valley and have been called *S. rugosum* or *Stromatocerium* because of their external appearance which resembles *Stromatocerium rugosum*. However, as noted on Plates I and II, some of these forms are not *Stromatocerium*, but algal forms instead. Thin sections are required for positive identification. Orwell limestone, approximately 3700 feet S. 32° E. of Summer Point, Ferrisburg (x 1).
2. *Stromatocerium rugosum* H all. Vertical thin section showing the details of the laminae (latilaminae) and the pillars. Recrystallization has destroyed the structure in the right-hand side of the picture. Section from H. M. Seely Collection, Middlebury College, Slide No. 4-22; Orwell limestone, Button Island, Ferrisburg. Specimen probably came from "reefy" 18-inch bed exposed on west side of Button Island (x 16).
3. *Foerstephyllum wissleri* Welby. Top view of part of the type specimen showing polygonal shape of the corallites and the minute septa. Corallum is flat, attaining a diameter of from 6 to 18 inches, and is composed of corallites which are generally hexagonal in cross-section and which are in contact throughout their length. Specimen is from a locality 700 feet N. 88° W. of Triangulation Point 131, east of Grosse Point, Ferrisburg, and is in the Harvard University Museum of Comparative Zoology collections, No. 9359 (x 1).
4. *Foerstephyllum wissleri* Welby. Vertical section of the type specimen showing the nature of the corallite budding and the spacing of the tabulae (x 0.7).
5. *Lichenaria heroensis* (Raymond). Relatively large, subspherical to biscuit-shaped colonies which on weathered surfaces show concentric growth patterns. Minute pin-sized raised areas mark the position of the corallites. Corallites in contact throughout length have moderately closely spaced tabulae, but lack septa. "Reefy zone" of Day Point formation, The Head, Isle La Motte (x 0.5).
6. *Lichenaria heroensis* (Raymond). Polished vertical section of another specimen from locality given in Fig. 5 (x 1).
7. *Lichenaria heroensis* (Raymond). Vertical thin section showing in detail the nature of the budding of the corallites and the spacing and nature of the tabulae. Same locality as for Fig. 5 (x 5).
8. *Billingsaria parva* (Billings). Colony small, sometimes attaining diameter of two or three inches, but being relatively flat. Closely packed corallites about 0.75 mm in diameter with eight primary and eight secondary septa; in center of corallite is a relatively solid vertical axial structure (columella); the combination of septa and axial structure give the weathered surface of the corallum a stellate appearance. South end of south shore of Rockwell Bay, South Hero (x 16).
9. *Foerstephyllum halli* (Nicholson). Vertical section of specimen from Orwell limestone on Button Island, Ferrisburg, showing nature of corallite growth and tabulae (x 1). Compare with *Foerstephyllum wissleri*.
10. *Foerstephyllum halli* (Nicholson). Cross-section showing packing and hexagonal shape of corallites and their small, spine-like septa (24 in number). This species has been placed in several genera, most notably *Columnaria* and *Favistella*, but it clearly does not belong in either one. Same specimen as in Fig. 9 (x 2). Compare with *Foerstephyllum wissleri*.
11. *Conularia trentonensis* Hall. Elongate, pyramidal shell with a cross-section that is quadrangle-shaped; surface of shell is ribbed at right angles to axis. Sides of the shell expand from the apex at an angle of about 25°. Specimen figured is badly crushed, but shows the transverse ribs meeting at a corner. Glens Falls limestone, McNeil Bay, Charlotte (x 2).
12. *Anolotichia* sp. Cyclostomata. Thin section showing part of a colony. At right edge of picture cross-sectional shape of zooecia may be seen while in center and to left edge the picture shows longitudinal sections. Valcour formation, Cystid Point, Valcour Island (x 10).

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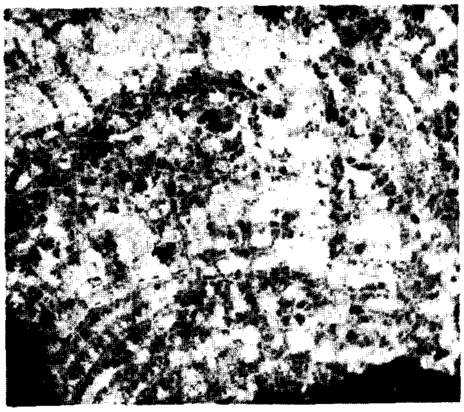

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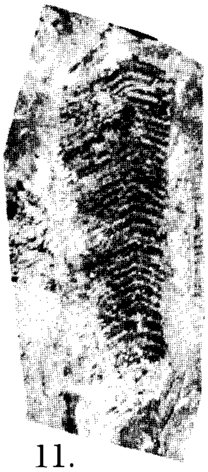

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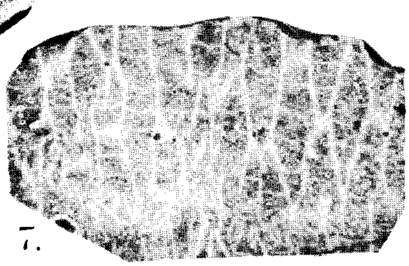

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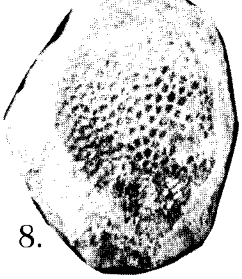

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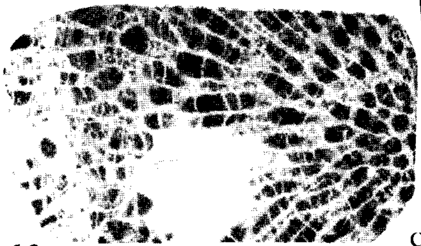

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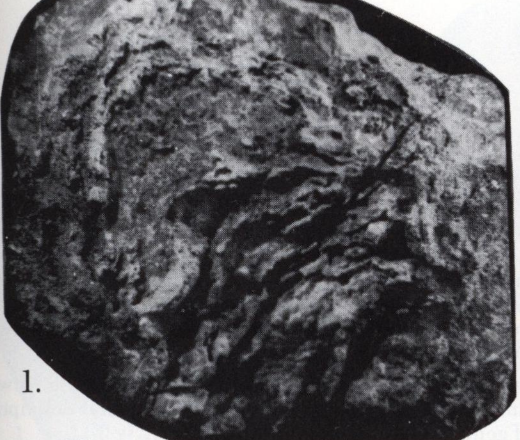
PLATE III COELENTERATA AND BRYOZOA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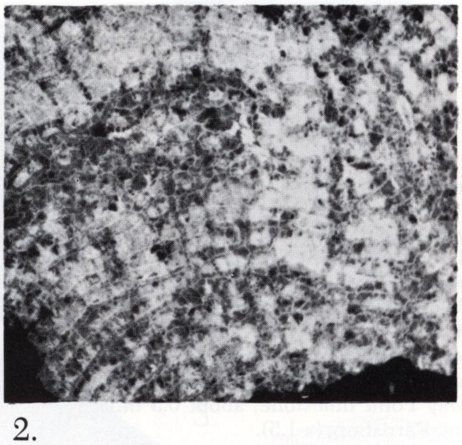
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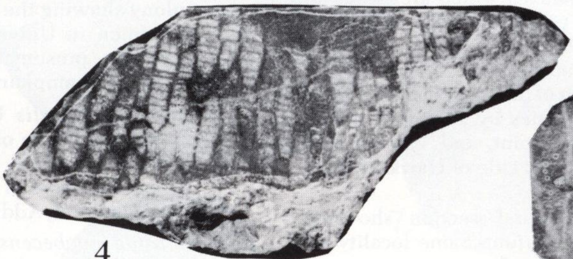
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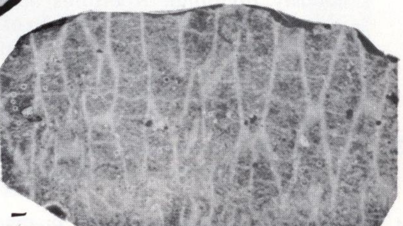
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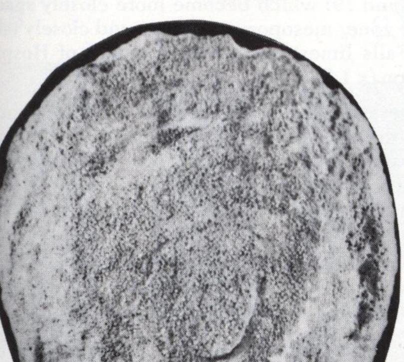
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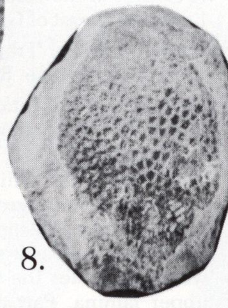
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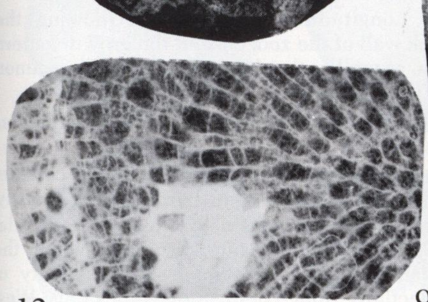
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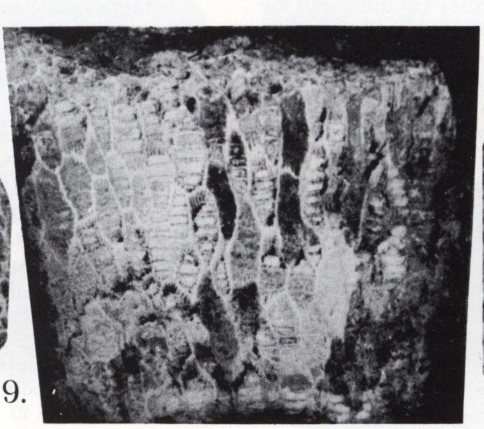
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PLATE III COELENTERATA AND BRYOZOA

PLATE IV

BRYOZOA

1. ***Phylloporina incepta*** (Hall). Treptostomata. Branches which come together leaving loops in the structure of the colony. Zooecia open on one side of the branch, the back side being striated and without apertures. ***Phylloporina*** has 4 to 8 rows of apertures while a similar-appearing form, ***Subretepora,*** has only 2; some of specimens reported as ***Phylloporina*** may belong to the latter genus which is not as well known. ***Phylloporina*** has angular zooecial tubes which are separated by mesopores with many close-spaced tabulae. Picture is of impression of ***Phylloporina*** in Day Point limestone, about 0.5 mile south of Summer Point, Ferrisburg (x 1.5).

2. ***Rhinidictya fenestrata*** (Hall). Cryptostomata. Zoarium consists of thin, straight-edged branches which are wider at right angles to the zooecia than parallel to them and which divide into two branches as the colony grows (dichotomously dividing). Apertures appear on surface of the colony in series along the length of the branch, each series being separated from adjacent series by a sinuous ridge. Common in Day Point, Crown Point, and Valcour formations. Day Point formation, south side of Hawkins Bay, Ferrisburg (x 2).

3. ***Rhinidictya fenestrata*** (Hall). Natural section showing pattern of zooecia within the zooarium. Same locality as Fig. 2 (x 2).

4. ***Rhinidictya fenestrata*** (Hall). Picture made using cellulose peel of a polished and etched section as a negative; same locality as Fig. 2 (x 4).

5. ***Atactoporella*** sp. Treptostomata. Surface of colony which is encrusting. Characteristically the apertures appear petal-like because of indentation by some of the smaller structures of the colony. Valcour formation, approximately 1 mile southeast of Grosse Point, Ferrisburg (x 4).

6. ***Stromatotrypa*** sp. Treptostomata. Colony showing superposition of laminae. Rockwell Bay, South Hero (x 1).

7. ***Stromatotrypa*** sp. Detail of part of the surface of the colony shown in Fig. 6, showing ovate shape of the zooecia, and the laminae (x 2).

8. ***Stromatotrypa*** sp. Thin section showing the manner in which the zooecia grow upward, and the laminar structure of the colony. Mesopores are the small, closely tabulate tubes that appear a short distance below the white line which separates the two laminae; they continue into the upper lamina. Part of colony illustrated in Fig. 6 (x 9).

9. ***Dianulites*** sp. Treptostomata. Surface of one of the subhemispherical, biscuit-shaped colonies; close inspection of the illustration will show the pin-sized zooecia as white specks. Valcour formation, southeast corner, Valcour Island (x 1).

10. ***Dianulites*** sp. Cross-section of zooecia showing angular shape of the zooecia; some of smaller apertures represent mesopores which are comparatively large. Same locality as the specimen of Fig. 9 (x 10).

11. ***Dianulites*** sp. Thin section cut parallel to the zooecia showing the thin-walled nature of the zooecia, the general lack of diaphragms, and the relatively large mesopores. Same locality as specimen of Fig. 9 (x 10).

12. ***Batostoma*** sp. Treptostomata. Surface of colony which consists of irregular branches; zooecial apertures subcircular; zooecia thick-walled in the outer region and accompanied by numerous, irregular mesopores. Orwell limestone about 1.6 miles north of Panton near crest of ridge (x 2).

13. ***Escharopora*** sp. Cryptostomata. Surface of colony, showing typical diamond-shaped zooecial apertures which are arranged in intersecting series. Zooarium thin, elongated with zooecia rising from center out to two sides. About 1.6 miles north of Panton Village, near crest of ridge of Orwell limestone (x 4).

14. ***Rhinidictya*** sp. Cryptostomata. Surface of colony in Orwell limestone. See Fig. 2 explanation for general description of genus. Locality the same as for Fig. 12 (x 3).

15. ***Prasopora orientalis*** Ulrich. Treptostomata. Top view of colony showing the gumdrop appearance of the zooarium. Specimen in University of Vermont collections, locality unknown, presumably from the Glens Falls limestone of the Lake Champlain islands (x 0.7).

16. ***Prasopora orientalis*** Ulrich. Natural section of a zooarium showing the base of the colony and the manner in which the zooecia grew upward from the base. Glens Falls limestone, shore of Lake Champlain about 0.5 mile north of Crane Point, Addison (x 1).

17. ***Mesotrypa quebecensis*** Ami. Treptostomata. Top view of a colony. The colony is circular in plan and only slightly arched, much like a small biscuit. The zooecial apertures appear as small pinhead-sized holes in the surface of the colony. The zooecia possess obliquely curved diaphragms (see Figs. 18 and 19) which become more closely spaced in the mature zone; mesopores common and closely tabulate. Glens Falls limestone, south of mouth of Hospital Creek, Addison (x 1.5).

18. ***Mesotrypa quebecensis*** Ami. Cross-section of a colony showing nature of the zooecia. The light-colored, semicircular areas in the center of the zooecia are the curved diaphragms which have been cut obliquely by the section. Specimen from Glens Falls limestone exposed on Crane Point, Addison (x 10).

19. ***Mesotrypa quebecensis*** Ami. Vertical section of colony showing the zooecia with their diaphragms and the mesopores. Same specimen as shown in Fig. 18 (x 10).

20. ***Eridotrypa*** sp. Treptostomata. Colony showing stick-like appearance and the nature of the branching, together with the elliptical shape of the zooecial apertures. Shore of Lake Champlain about 0.5 mile north of Crane Point, Glens Falls limestone (x 2).

21. ***Eridotrypa*** sp. Longitudinal thin section showing the relatively thick wall of the zooecia and the growth pattern of the zooecia, as well as the diaphragms. Same specimen as shown in Fig. 20 (x 6).

22. ***Eridotrypa*** sp. Cross section of zooecia. Same specimen as shown in Fig. 20 (x 6).

23. ***Stictopora ramosa*** Hall. Cryptostomata. Slender colonies which are ribbon-like and which divide dichotomously. Zooecia open on both surfaces of colonies and are relatively long; no mesopores; interspaces between the apertures relatively wide. Specimen in University of Vermont collections from Glens Falls limestone, West Bridport (x 2).

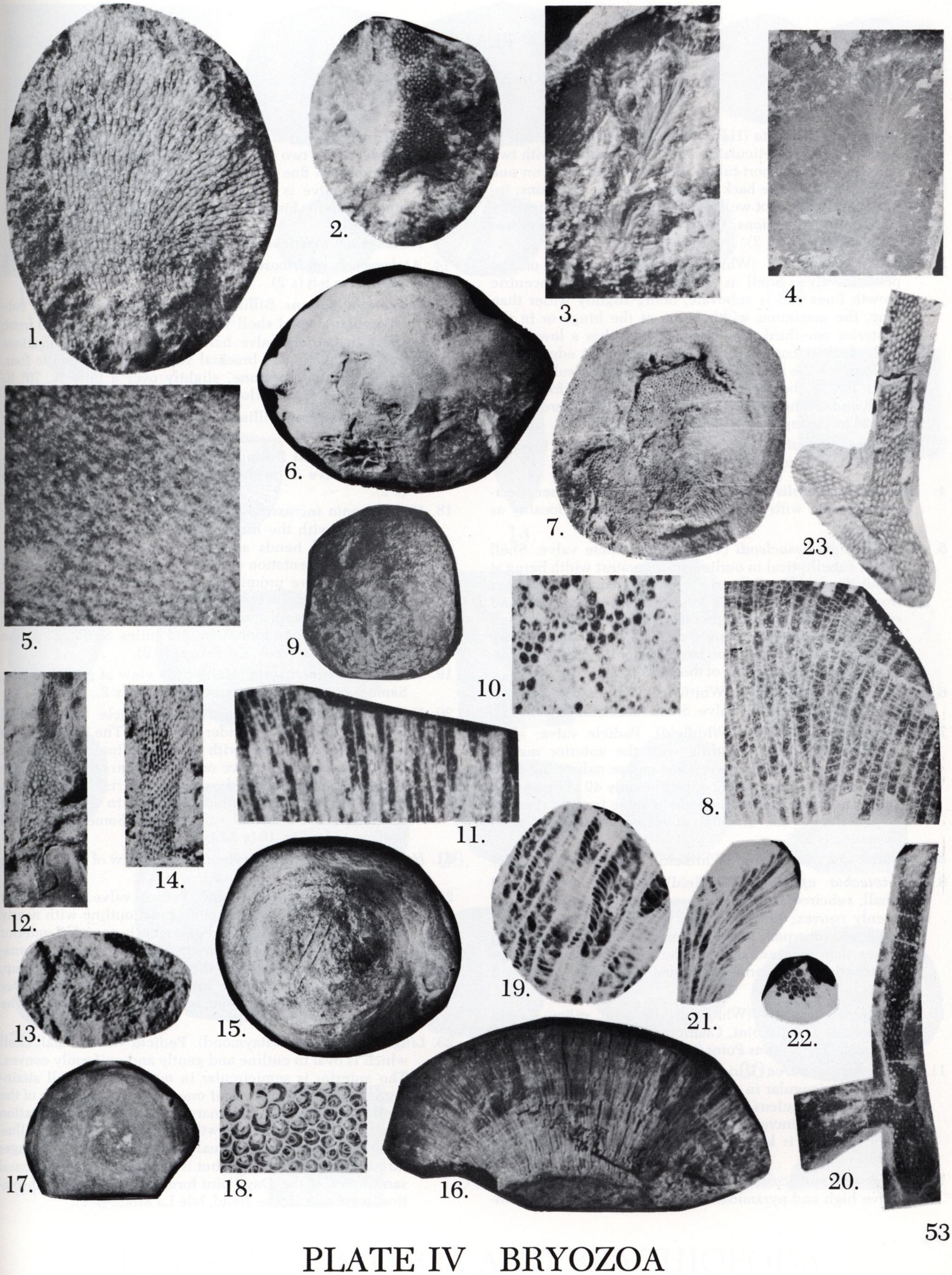


PLATE IV BRYOZOA

PLATE V

BRYOZOA AND BRACHIOPODA

1. *Subretepora fenestrata* (Hall). Treptostomata. The genus is characterized by reticulate, cylindrical branches with two or more rows of short-tubed zooecia which open on one side (the front); the back side is marked by striations; internal characters not well known. Specimen in University of Vermont collections; Glens Falls limestone, Larrabees Point, Shoreham (x 2).
2. *Syntrophia lateralis* (Whitfield). Internal filling of the pedicle valve. Shell is smooth except for concentric growth lines and is subovate, being slightly wider than long, the maximum width being at the hinge or in the posterior one-third. The brachial valve has a low broad fold which is conspicuous only at the front edge of the shell while the pedicle valve has a shallow sulcus. The shell has a shouldered appearance. Cassin formation, north end of Thorp Point, Charlotte, about 200 yards south of road to Thompsons Point (x 1).
3. *Syntrophia lateralis* (Whitfield). Internal filling of brachial valve. Same locality as Fig. 2 (x 1).
4. *Syntrophia lateralis* (Whitfield). Side view of another specimen. Shown with pedicle valve to left. Same locality as Fig. 1 (x 1).
5. *Finkelnburgia? macleodi* (Whitfield). Pedicle valve. Shell small, subelliptical in outline with greatest width being at about the middle of the shell. Straight costae radiate out from the beak, there being 34 to 36 of these. Every second or third one is slightly higher than those in between. Shell partially exfoliated. Cassin formation, west shore Thorp Point, Charlotte, south of large bostonite dike that outcrops at northwest corner of the point (x 2).
6. *Finkelnburgia? macleodi* (Whitfield). Clay cast made from impression of brachial valve. Same locality as Fig. 5 (x 2).
7. *Diparelasma cassinense* (Whitfield). Pedicle valve; shell roundly elliptical in outline with the anterior margin being broadly rounded; very fine costae radiate out from the beak area, there being approximately 40 of these on a shell. In lateral profile the pedicle valve is more strongly arched than is the brachial valve; occurs in the Cassin formation (x 2).
8. *Diparelasma cassinense* (Whitfield). Brachial valve (x 2).
9. *Polytotechia apicalis* (Whitfield). Pedicle valve; shell small, subcircular in plan view; pedicle valve gently and evenly convex; brachial valve wider than long. Closely crowded, subequal, very fine costae with some becoming larger than adjacent ones as the anterior margin is approached. Cassin formation, same locality as for Fig. 5 (x 2).
10. *Polytotechia apicalis* (Whitfield). Brachial valve. Cassin formation, Thorp Point, Charlotte, about 500 yards south of road to Thompsons Point (x 2).
11. *Finkelnburgia parva* Ulrich and Cooper. Pedicle valve; shell subtriangular in shape with a slightly incurved beak and a narrow sulcus. Ornamentation consists of very fine costae which increase by intercalation. The species is very rare and is known only from the Cassin formation (x 3).
12. *Ateleasma? multicostum* (Hudson). Pedicle valve; pedicle valve high and pyramidal in shape with a high flat cardinal area which is at approximately right angles to the plane between the two valves; surface ornamentation consists of numerous fine costae which increase by splitting. The brachial valve is flat. Occurs in the Crown Point limestones chiefly but is known from the Valcour formation also (x 2).
13. *Ateleasma? multicostum* (Hudson). Brachial valve (x 2).
14. *Ateleasma? multicostum* (Hudson). Side view, pedicle valve is to left (x 2).
15. *Camerella varians* Billings. Pedicle valve. Smooth, subtriangular-shaped shell with greatest width toward front; sinus in pedicle valve has from one to three plications and the fold in the brachial valve has from two to four. Crown Point limestone, slightly over a mile N. 70° E. of Cedar Island, Charlotte (x 3).
16. *Camerella varians* Billings. Brachial valve. Same locality as for Fig. 15 (x 3).
17. *Camerella varians* Billings. Side view of another specimen, pedicle valve is on the left. Same locality as for Fig. 15 (x 2).
18. *Dactylogonia incrassata* (Hall). Pedicle valve. Shell wider than long with the hinge width being almost twice the length. Shell bends abruptly in posterior one-quarter; surface ornamentation consists of very fine costae, some of which are more prominent than others, and of fine concentric lines which with the costae give the shell surface a cancellated appearance. This species is found in the Chazyan. Valcour formation, 1.3 miles S. 55° E. of the mouth of Otter Creek, Ferrisburg (x 2).
19. *Dactylogonia incrassata* (Hall). Side view of pedicle valve. Same specimen as illustrated in Fig. 18 (x 2).
20. *Hesperorthis ignicula* (Raymond). Pedicle valve. Shell oval in outline, being wider than long. The pedicle valve is strongly convex and with a high cardinal area which is slightly incurved. Surface ornamentation consists of from 16 to 25 simple, rounded costae which rise near the beak in two series, one beginning slightly to the anterior of the other. The brachial valve is flat. Same locality and horizon as for Fig. 18 (x 2.5).
21. *Hesperorthis ignicula* (Raymond). Side view of pedicle valve shown in Fig. 20.
22. *Lingulella brainerdi* (Raymond). Pedicle valve. This species is characterized by its subpentagonal outline with nearly straight lateral margins and only gently rounded anterior margin. Fine concentric growth lines are the chief ornamentation. May be found throughout the Chazy Group, but most common in the lower sandstones of the Day Point formation. Day Point formation, west side of The Head, Isle La Motte (x 1).
23. *Lingulella columba* (Raymond). Pedicle valve. Small shell which is oval in outline and gently and uniformly convex. The anterior is semicircular in outline, the shell attaining its greatest width about one-third of the length of the shell from the anterior margin. Surface ornamentation consists of concentric growth lines. The specimen illustrated is largely an internal mold. The species ranges through the Chazy Group but is most common in the basal sandstones of the Day Point formation. Day Point formation, west side of The Head, Isle La Motte (x 1).

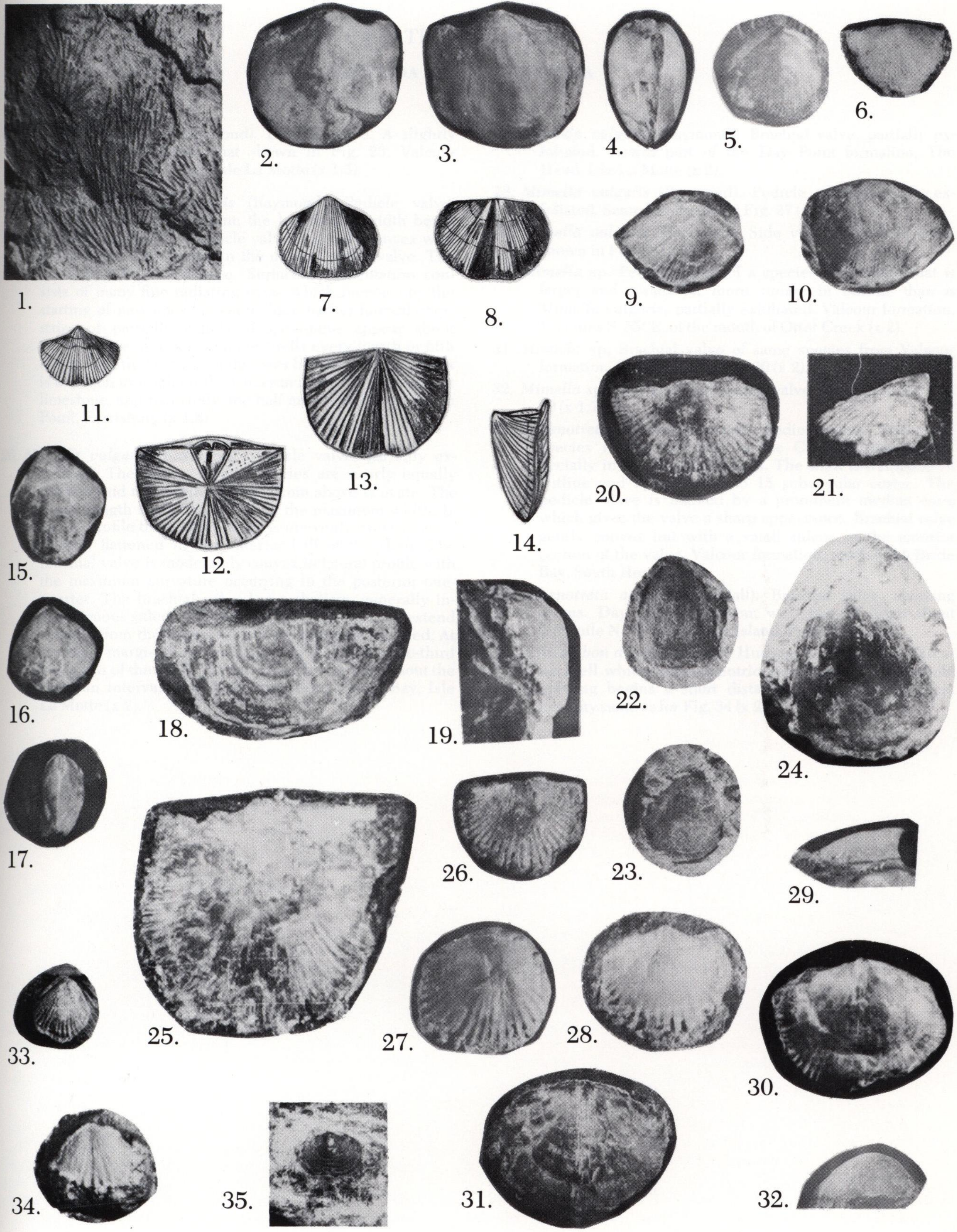


PLATE V BRYOZOA AND BRACHIOPODA

PLATE V (Continued)

BRYOZOA AND BRACHIOPODA

24. *Lingulella columba* (Raymond). Pedicle valve. A slightly larger specimen than that shown in Fig. 23. Valcour formation, Jordan Point, Isle La Motte (x 1.5).

25. *Macrocoelia champlainensis* (Raymond). Pedicle valve. The shell is nearly equant, the length and width being about the same. The pedicle valve is evenly convex with the highest point being in the middle of the valve. The brachial valve is concave. Surface ornamentation consists of many fine radiating striae which increase by the starting of new ones between older, earlier formed ones; striae of partially exfoliated specimens appear about equal in size, but on complete shells every fourth or fifth one is slightly larger than the ones between. This species is common throughout the Chazyan interval. Crown Point limestone, approximately one-half mile S. 55° E. of Grosse Point, Ferrisburg (x 1.8).

26. *Mimella vulgaris* (Raymond). Pedicle valve, partially exfoliated. The valves of this species are nearly equally convex, and the outline as seen from above is ovate. The hinge length is slightly less than the maximum width. In lateral profile the pedicle valve is unevenly convex, being slightly flattened in the anterior half of the shell. The brachial valve is moderately convex in lateral profile with the maximum curvature occurring in the posterior one-quarter. The brachial valve has a shallow, generally inconspicuous sulcus. The fine costae on both valves extend directly from the beak area and are narrowly rounded. At the front margin there are from 6 to 9 in about one-third the width of the shell. The form is common throughout the Chazyan interval. Day Point formation, Fleury Bay, Isle La Motte (x 2).

27. *Mimella vulgaris* (Raymond). Brachial valve, partially exfoliated. Lower part of the Day Point formation, The Head, Isle La Motte (x 2).

28. *Mimella vulgaris* (Raymond). Pedicle valve, partially exfoliated. Same locality as for Fig. 27 (x 2).

29. *Mimella vulgaris* (Raymond). Side view of pedicle valve shown in Fig. 28 (x 2).

30. *Mimella* sp. Pedicle valve of a species of *Mimella* that is larger and somewhat more square in outline than is *Mimella vulgaris;* partially exfoliated. Valcour formation, 1.3 miles S. 55° E. of the mouth of Otter Creek (x 2).

31. *Mimella* sp. Brachial valve of same species from Valcour formation. Locality as for Fig. 30 (x 2).

32. *Mimella* sp. Side view of brachial valve. Locality as for Fig. 30 (x 1.7).

33. *Sphenotreta acutirostris* (Hall). Pedicle valve. This small species is very common in the Chazyan interval, especially in the Day Point beds. The shell is triangular in outline and has from 10 to 15 subangular costae. The pedicle vlave is marked by a prominent median costa which gives the valve a sharp appearance. Brachial valve gently convex but with a small sulcus in the anterior portion of the valve. Valcour formation, south of McBride Bay, South Hero (x 2).

34. *Sphenotreta acutirostris* (Hall). Brachial valve, showing sulcus. Day Point formation, west face of ridge about 0.75 mile N. 20° E. of Dean Island, Ferrisburg (x 2).

35. *Schizambon duplicimuratum* Hudson. Pedicle valve. Circular shell which has concentric growth lines. The pedicle opening begins a short distance in front of the beak. Locality same as for Fig. 34 (x 2).

PLATE VI

BRACHIOPODA AND PELMATOZOA

1. *Multicostella platys* (Billings). Exfoliated brachial valve. This species is common in the Chazyan. Subrectangular shell which in profile is fairly flat. Both valves are convex, the brachial valve being less convex, or nearly flat and having a shallow sulcus. The surface is marked by fairly coarse costae which increase by the appearance of the later formed costae between the earlier formed ones; there are from three to four per millimeter at the anterior margin. Crown Point limestone, crest of ridge 1.25 miles S. 70° E. of mouth of Otter Creek (x 2).
2. *Multicostella platys* (Billings). Silicified small pedicle valve. Crown Point limestone, shore of Lake Champlain, 0.35 mile south of Grosse Point, Ferrisburg (x 2).
3. *Multicostella platys* (Billings). Small pedicle valve, partially exfoliated. Crown Point limestone, same locality as Fig. 1 (x 2).
4. *Orthambonites acutiplicatus* (Raymond). Partially exfoliated pedicle valve. Shell almost circular in outline with the width at the hinge being not quite equal to the greatest width. From twelve to fifteen relatively coarse costae mark the surface of the shell, being separated by spaces that are wider than themselves. The two valves show approximately equal convexity, and the exfoliated pedicle valve has a slight shouldered appearance. Lower part of Day Point formation, The Head, Isle La Motte (x 2).
5. *Orthambonites acutiplicatus* (Raymond). Partially exfoliated brachial valve. Locality same as for Fig. 6 (x 2).
6. *Orthambonites? exfoliata* (Raymond). Pedicle valve, partially exfoliated. The valves of this species have nearly equal convexity with the pedicle valve generally being slightly more convex. The hinge line is about equal to the widest part of the shell. There is a slight suggestion of a low fold in most pedicle valves while the brachial valve shows a suggestion of a low sinus. Ornamentation consists of from thirty to forty straight costae. The costae of this form are coarser than those of *Mimella vulgaris* with which it can easily be confused. *Orthambonites? exfoliata* is common throughout the Day Point, Crown Point, and Valcour formations but is most common in the Day Point. Day Point formation, Fleury Bay, Isle La Motte (x 2).
7. *Orthambonites? exfoliata* (Raymond). Brachial valve from upper part of the Day Point formation, Fleury Bay, Isle La Motte (x 2).
8. *Ptychopleurella porcia* (Billings). Pedicle valve after Raymond (1911). Small shell with relatively coarse costae and high interarea on the pedicle valve (x 2).
9. *Rostricellula major* (Raymond). Pedicle valve. Oval-shaped shell with from twelve to fourteen strong plications. Fold and sinus are absent or barely represented. The middle plication of the fold is the strongest. This form has been found throughout the Chazyan interval, but it seems most common in the Valcour formation (x 1).
10. *Rostricellula major* (Raymond). Brachial valve (x 1).
11. *Rostricellula plena* (Hall). Pedicle valve showing the prominent sulcus. Subtriangular shells with a wide shallow sulcus and a sharp fold on the brachial valve. There are from seventeen to twenty-four well-developed plications which are crossed by the lines of growth with a crenulated pattern. This form seems restricted to the upper part of the Valcour formation. Valcour formation, west end of point between Beech and McBride Bays, South Hero (x 1).
12. *Rostricellula plena* (Hall). Pedicle valve from 75 yards west of U. S. Route 2, approximately 1.4 miles S. 75° E. of Pearl railroad crossing, Grand Isle (x 1).
13. *Rostricellula plena* (Hall). Brachial valve showing the prominent fold. Same locality as for Fig. 11 (x 2).
14. *Rostricellula plena* (Hall). Side view with pedicle valve on left. Same locality as for Fig. 11 (x2).
15. *Rostricellula pristina* (Raymond). Brachial valve showing the low fold. This is a small species of the genus. Shell oval in outline, both valves are of about equal convexity and there are from 10 to 14 well-developed plications with four of them being on the fold. The species ranges throughout the Chazyan, being more common in the Valcour than elsewhere. Valcour formation, in creek, 1.2 miles N. 25° E. of West Bridport (x 3).
16. *Rostricellula pristina* (Raymond). Pedicle valve showing the low sulcus which develops near the front margin of the shell (x 3).
17. *Valcourea strophomenoides* Raymond. Brachial valve showing the general semicircular shape of the small shell, the shallow sulcus, and the nature of the direct costae. The shell is thin with a convex brachial valve; the pedicle valve is convex near the posterior margin but becomes flat to concave toward the front of the shell. Numerous fine costae radiate across the shell. This species is common throughout the Chazyan interval. Valcour formation, 1.33 miles S. 55° E. of the mouth of Otter Creek (x 2).
18. *Valcourea strophomenoides* Raymond. Pedicle valve showing the convexity toward the posterior margin. Same specimen as shown in Fig. 17 (x 2).
19. *Hesperorthis tricenaria* (Conrad). Pedicle valve. The pedicle valve is noticeably more convex than the brachial valve which is flat or slightly concave. The interarea of the pedicle valve turns and faces the brachial valve. The form may be found in the Orwell and Glens Falls limestones. Orwell limestone, crest of ridge, about 1.6 miles north of Panton Village (x 1).
20. *Hesperorthis tricenaria* (Conrad). Pedicle valve (x 1).
21. *Hesperorthis tricenaria* (Conrad). Brachial valve (x 1).
22. *Rhynchotrema minnesotense* Sardeson. Pedicle valve. Small, globular-shaped shell with 12 to 14 costae. Subtriangular in outline with the anterior corners rounded off. Low fold in the brachial valve and corresponding sulcus in the pedicle valve. Three or four costae in the sulcus. Occurs in the Orwell limestone and its equivalents. Orwell limestone, same locality as for Fig. 19 (x 1).
23. *Rhynchotrema minnesotense* Sardeson. Brachial valve showing a fold. Location as for Fig. 19 (x 1).
24. *Strophomena incurvata* (Shepard). Pedicle valve. Moderately large shell semicircular in outline but with the ends of the hinge line wing-like. A sharp inward curvature just anterior of the hinge line marks the edge of the shell. Pedicle valve concave but with area just anterior of pedicle opening arched laterally. Brachial valve is shallowly convex. Ornamentation consists of concentric

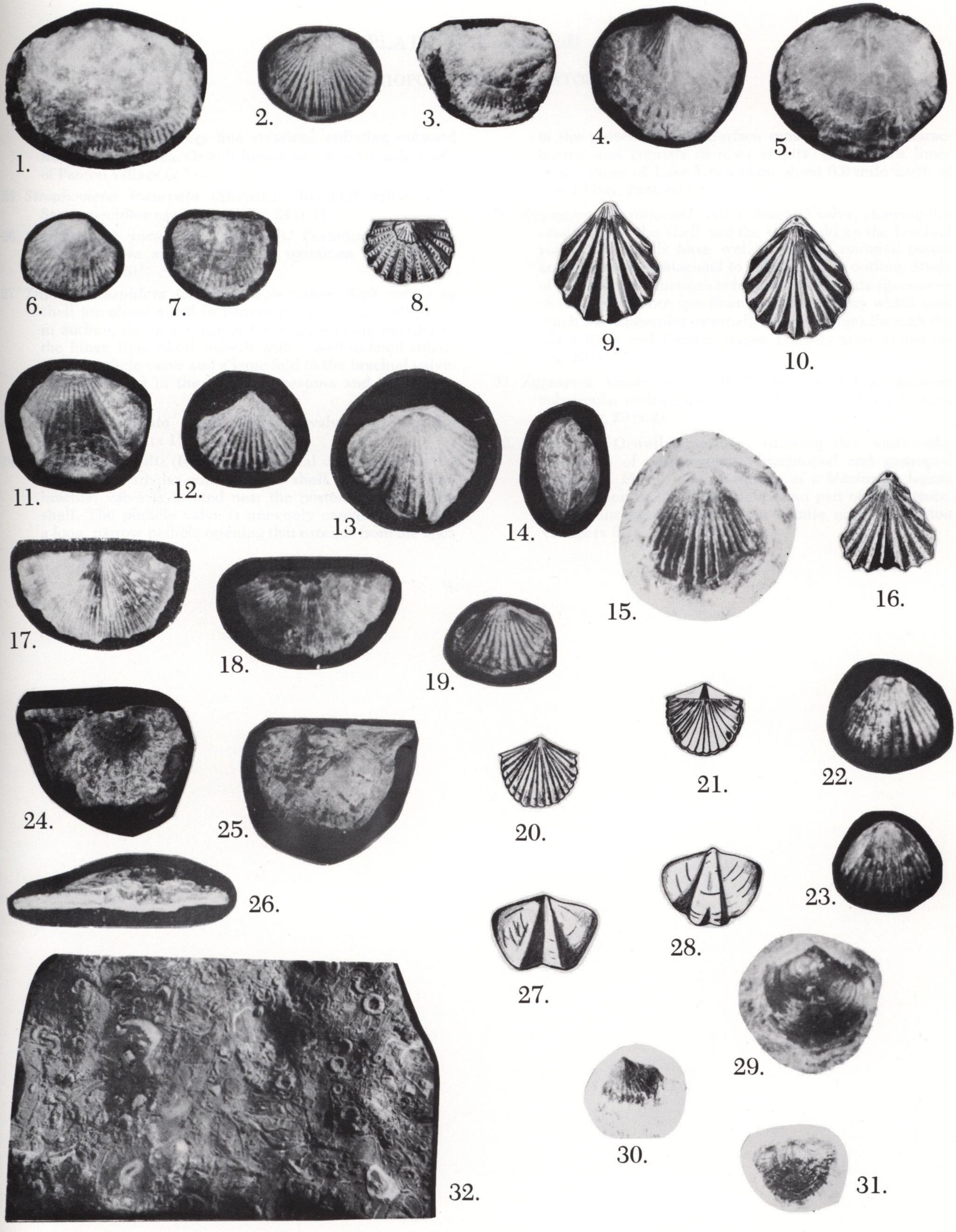


PLATE VI BRACHIOPODA AND PELMATOZOA

PLATE VI (Continued)

BRACHIOPODA AND PELMATOZOA

growth lines and very fine striations radiating outward from the beak area. Orwell limestone, about a mile north of Panton Village (x 1).

25. *Strophomena incurvata* (Shepard). Brachial valve (x 1). Same specimen as shown in Fig. 24 (x 1).

26. *Strophomena incurvata.* (Shepard). Posterior view with pedicle valve at bottom. Same specimen as shown in Fig. 24 (x 1.5).

27. *Triplesia cuspidata* Clark. Pedicle valve. Both valves of shell are about equal in convexity; the shell is elliptical in outline, the major axis of the ellipse being parallel to the hinge line. Shell smooth with a well-defined sulcus in the pedicle valve and a large fold in the brachial valve. May be found in the Orwell limestone and its equivalents (x 1).

28. *Triplesia cuspidata* Clark. Brachial valve showing the prominent fold (x 1).

29. *Trematis terminalis* (Emmons). Brachial valve showing the general subcircular outline of the shell. The beak of the brachial valve is located near the posterior edge of the shell. The pedicle valve is unevenly convex possessing a long, narrow pedicle opening that extends from the apex to the posterior edge. Surface ornamentation is characteristic and consists of rows of pits. Glens Falls limestone, shore of Lake Champlain about 0.9 mile north of Arnold Bay, Panton (x 3).

30. *Zygospira recurvirostris* (Hall). Brachial valve, showing the small size of the shell and the sharp fold on the brachial valve. The shells have well-developed rounded costae and vary from pentagonal to subcircular in outline. Study of the internal structures is required to separate specimens of this genus from specimens of other genera which look much like *Zygospira* externally. Genus ranges through the Black River and Trenton stages. Locality same as that for Fig. 29 (x 2).

31. *Zygospira recurvirostris* (Hall). Pedicle valve, showing subcircular outline, and, faintly, the sulcus. Same locality as for Fig. 29 (x 2).

32. Surface of Orwell limestone, showing the washer-like columnals of pelmatozoans, brachiopod and gastropod fragments. Part of a cross-section of a *Maclurites logani* can be seen in the lower right hand part of the picture. Orwell limestone, ridge about a mile north of Panton Village (x 0.7).

PLATE VII

BRACHIOPODA AND PELECYPODA

1. *Rafinesquina trentonensis* Conrad. Pedicle valve showing general shape of the shell, which is wider than long, and the gentle convexity of the pedicle valve. Surface ornamentation consists of unequal costae, larger ones separating finer ones; pseudopunctate nature of shell is often shown on partially exfoliated specimens by pits which are arranged in rows from the posterior margin to the front of the shell. Species found in the Orwell limestone and its equivalents and the Glens Falls limestones. Sometimes called *R. alternata.* Orwell limestone, Button Island, Ferrisburg (x 1).

2. *Rafinesquina trentonensis* Conrad. Interior of the pedicle valve showing lobate shape of muscle scar area which is outlined by the low ridges at posterior part of the shell. Orwell limestone, about a mile north of Panton Village (x 1).

3. *Dinorthis pectinella* (Conrad). Brachial valve showing large size of the shell and the nature of the well-developed costae. Common in Glens Falls limestone. Glens Falls limestone, shore of Lake Champlain about 0.9 mile north of Arnold Bay, Panton (x 1).

4. *Doleroides ottawanus* Wilson. Brachial valve, showing broadly elliptical outline of the shell and the numerous straight costae. Brachial valve with a low fold, pedicle valve with a low sulcus. Shell relatively thin, both valves being convex but with pedicle valve being the less convex. Common form in the lower part of Glens Falls limestone, but ranges throughout the formation. Glens Falls limestone, south of mouth of Hospital Creek, Addison (x 2).

5. *Doleroides ottawanus* Wilson. Pedicle valve showing the shallow sulcus. Exfoliated specimen from same locality as for Fig. 4 (x 2).

6. *Lingulella quadrata* (Eichwald). Portion of shell showing the characteristic groove that runs from near the center to the beak. This species is the largest known from the rocks of the Champlain Valley. The shell is marked by longitudinal striations and by its broadly oval shape as well as by its size. Essex Ferry landing, Charlotte (x 1).

7. *Lingulella trentonensis* (Conrad). Moderately large shell with a groove running from near center to beak. Smaller and more ovate than *Lingulella quadrata.* Essex Ferry landing, Charlotte (x 1).

8. *Paucicrura rogata* (Sardeson). Several specimens showing both brachial (B) and pedicle (P) valves. Small shells with circular outline and low fold in pedicle valve and shallow sulcus in brachial valve; well-developed costae which may split; common fossil in the Glens Falls limestone; found also in the younger shales. Glens Falls limestone, same locality as for Fig. 4 (x 1.5).

9. *Parastrophina hemiplicata* (Hall). Pedicle valve. Shell elliptical in outline with major axis across width of shell. Shell smooth in posterior half, becoming costate in the anterior portion. Low fold develops in front portion of brachial valve and a sulcus forms in the pedicle valve. Found chiefly in the lower part of the Glens Falls limestone (x 1.4).

10. *Parastrophina hemiplicata* (Hall). Brachial valve (x 1.5).

11. *Platystrophia trentonensis* McEwan. Pedicle valve showing the pentagonal outline of the shell and the sulcus with three costae. Species small for the genus, and like other members of the genus has well developed subrounded costae extending from the hinge area forward. Glens Falls limestone, shore of Lake Champlain about 0.9 mile north of Arnold Bay (x 1.5).

12. *Platystrophia trentonensis* McEwan. Brachial valve showing the four costae on the fold. Same locality as for Fig. 11 (x 1.5).

13. *Reuschella edsoni* (Bassler). Pedicle valve. Rather large shells with pedicle valves which have a sharp fold; numerous fine to moderate costae; brachial valve with a shallow sulcus; common in Glens Falls limestones but found in younger formations also. Glens Falls limestone, west of road at foot of Buck Mountain, about 2.5 miles south of the center of Vergennes (x 1).

14. *Reuschella edsoni* (Bassler). Partially exfoliated brachial valve. From Glens Falls limestone, south of mouth of Hospital Creek, Addison (x 1.5).

15. *Reuschella edsoni* (Bassler). Internal mold of a brachial valve. Glens Falls limestone, shore of Lake Champlain about 0.35 mile north of Crane Point, Addison (x 1.5).

16. *Sowerbyella sericea* (Sowerby). Pedicle valve. Wide-hinged shell which has convex pedicle valve and concave brachial valve. Very fine costae with smaller costae in groups which are separated by slightly coarser costae. Glens Falls limestone, same locality as for Fig. 14 (x 1).

17. *Sowerbyella sericea* (Sowerby). Exfoliated pedicle valve. Glens Falls limestone, same locality as for Fig. 14 (x 1).

18. *Rhynchotrema increbescens* (Hall). Pedicle valve. Small costate shell which is triangular in outline with broadly rounded anterior corners; pedicle valve with sulcus containing three or four costae; brachial valve with low fold which has 3 costae. Found in the Orwell and Glens Falls limestones. Orwell limestone, 0.9 mile north of Panton Village (x 1.5).

19. *Rhynochotrema increbescens* (Hall). Brachial valve showing the low fold; different specimen from that shown in Fig. 18 but from the same locality (x 1.5).

20. *Modiodesma* sp. Internal impression of right valve. Shell elongated obliquely to the hinge line with the back part of the shell being much longer than the front part; it has less prominent umbos than shells which resemble it in other ways. The surface is marked by a series of concentric lines, some of which are better developed than others. Essex Ferry landing, Charlotte (x 1).

21. *Ambonychia* sp. Left valve. Equivalved with the valves being inequilateral; the posterior portion of the shell is almost wing-like. Surface ornamentation consists of fine striae radiating out from the beak area; striae crossed by concentric growth lines. May be found in the Glens Falls limestone (x 1).

22. *Ctenodonta* sp. Right valve. Small, equivalved shell which is more or less equilateral. Shell ornamentation consists of concentric growth lines. May be found in the Orwell and Glens Falls limestones (x 1).

23. *Ctenodonta levata* (Hall). Internal impression of the right valve. Glens Falls limestone, West Bridport (x 1.6).

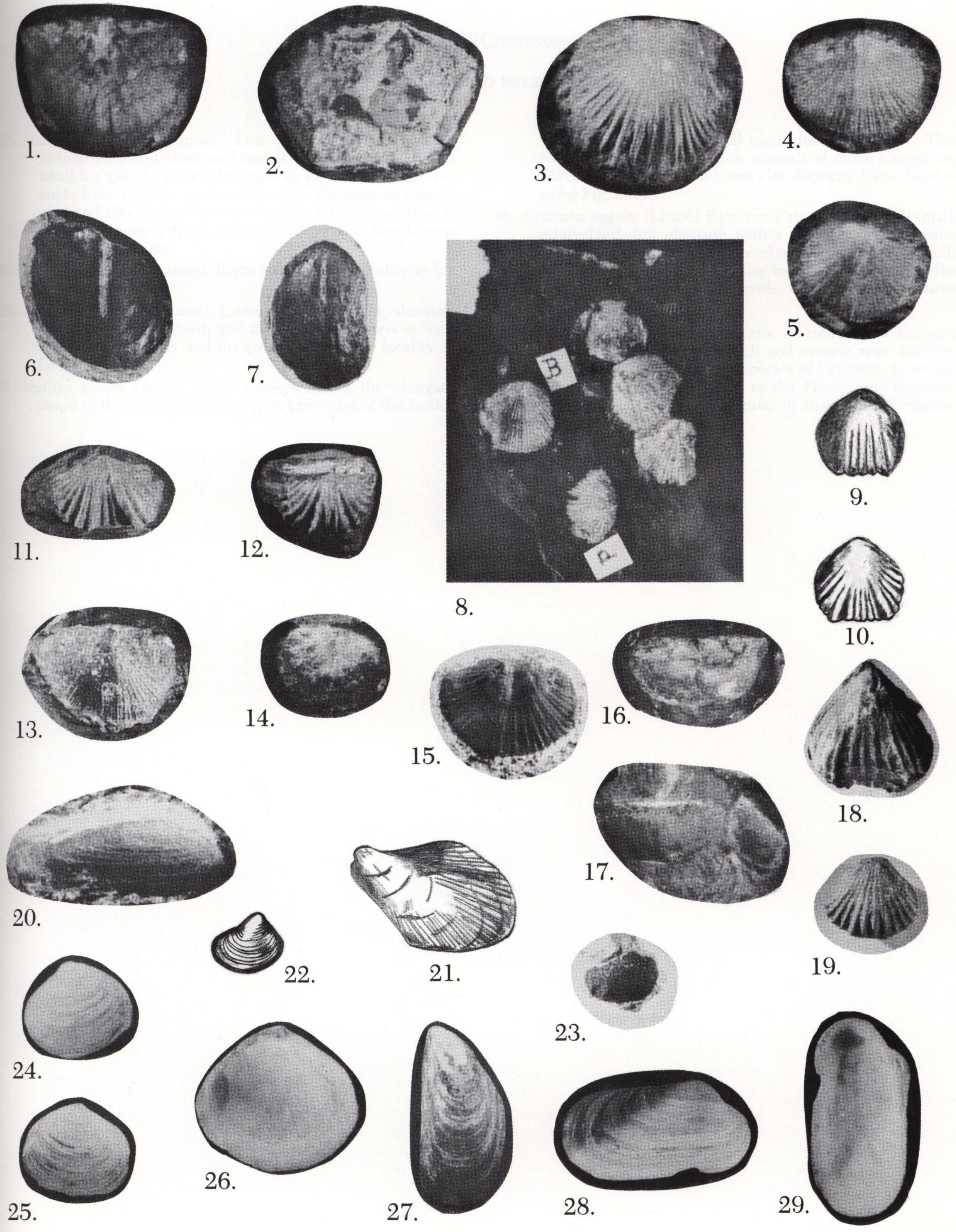


PLATE VII BRACHIOPODA AND PELECYPODA

PLATE VII (Continued)

BRACHIOPODA AND PELECYPODA

24. *Macoma balthica* (Linné). Left valve exterior showing general shape of shell and nature of growth lines. Shell small for genus; generally ovate in plan; faint ridge extends from beak to posterior margin. Pleistocene gravel, sand and clay deposits. Gravel quarry 0.6 mile northwest of Isle La Motte Village, Isle La Motte (x 1.5). Also known as *M. groenlandica.*
25. *Macoma balthica* (Linné). Right valve. Same locality as for Fig. 24 (x 1.5).
26. *Macoma balthica* (Linné). Interior of right valve, showing the small cardinal teeth and the adjacent sockets as well as the muscle scars and the pallial line. Same locality as for Fig. 24 (x 2).
27. *Mytilus edulis* Linné. Right valve showing the elongate shape of the shell and the terminal position of the beaks. The hinge has a few small teeth under the beaks. This form is one of the common mussels of today's seashore; Pleistocene gravel, sand, and clay deposits. Same locality as for Fig. 24 (x 1).
28. *Saxicava rugosa* (Linné). Exterior of right valve. Shell small, equivalved, but elongate with a general subrectangular plan. Beak near the anterior end of the shell. Young shells have a cardinal tooth, but the teeth are obsolete in the adult shells; Pleistocene gravels, sands, and clays. Same locality as for Fig. 24 (x 1).
29. *Saxicava rugosa* (Linné). Interior of right valve showing subrectangular shape of shell and muscle scar. Locality as for Fig. 24 (x 1). Another species of *Saxicava, S. arctica* (Linné) may also be found in the Pleistocene deposits. This form is more quadrangular in shape than *S. rugosa.*

PLATE VIII

GASTROPODA AND PELECYPODA

1. *Ecculiomphalus volutatus* Whitfield. Steinkern; view of upper surface showing coiling pattern. The loosely coiled earlier whorls are obscured by matrix. Cassin formation, Fort Cassin, Ferrisburg (x 1).
2. *Ecculiomphalus volutatus* Whitfield. Apertural view of specimen shown in Fig. 1. Note rather sharp ridge on the upper left side of the aperture, the upper side of the shell. The shell is coiled in one plane, gradually expanding toward the aperture. Same locality as for Fig. 1 (x 1).
3. *Calaurops lituiformis* Whitfield. View of upper surface. Early whorls are disc-like, being in contact; the last whorl separates from the earlier formed ones and extends more or less straight. Cassin formation, west shore Fort Cassin, Ferrisburg (x 0.8).
4. *Hormotoma obelisca* (Whitfield). Apertural view. High-spired shell with rounded whorls and relatively deep sutures between whorls; selenizone not prominent. Cassin formation, Thorp Point, about 200 yards south of road to Thompsons Point, Charlotte (x 1.5).
5. *Lophospira cassina* Whitfield. Low-spired shell with well-defined shoulders and gradually expanding profile; turbinate. The last or body whorl is missing from this specimen which is a steinkern. Cassin formation, about 3.5 miles south-southwest of Vergennes (x 1).
6. *Maclurites affinis* Billings. Basal view of a steinkern, showing the flat base and the nature of the coiling as seen from the bottom of the shell. Whorls are in contact. This is a relatively small member of this genus. Cassin formation, Fort Cassin, Ferrisburg. The specimen is in the Middlebury College collections (x 1).
7. *Maclurites affinis* Billings. Apertural view of the specimen shown in Fig. 6 showing the relatively low spire of this form and the characteristic shape of the aperture. Locality and formation as for Fig. 6 (x 1).
8. *Maclurites* sp. Apertural view of a small specimen of this genus with a more or less square-shaped aperture. Locality and horizon as for Fig. 4 (x 1.5).
9. *Maclurites acuminata* Billings. Apertural view showing the relatively high spire of this form. The outside part of the last whorl has been removed from the steinkern, and thus the angulations which characterize this species are not seen in this figure. Horizon and locality same as for Fig. 4 (x 1).
10. *Plethospira cassina* (Whitfield). Moderately high-spired shell with moderately wide apical angle and with deep sutures between the whorls. Selenizone about midway between sutures shows as faint ridge on the steinkern. Cassin formation, Fort Cassin, Ferrisburg (x 0.75). Specimen in University of Vermont collections.
11. *Rhombella? etna* (Billings). Steinkern. Shell with low spire and widening rapidly to give low conical appearance. Base flat; sutures shallow; selenizone appearing on steinkern as flattening of whorl near its base. Described as *Pleurotomaria* by Billings. Cassin formation, Fort Cassin, Ferrisburg (x 0.75). Specimen in University of Vermont collections.
12. *"Trybidium" simplex* Whitfield. Side view of steinkern. Shell ovate in plan and with almost vertical anterior (?) margin. Affinities not definitely known. Cassin limestone, Fort Cassin, Ferrisburg (x 1). Specimen in University of Vermont collections.
13. *Ophileta* sp. Top view of partial steinkern showing nature of whorls and general low spire. Basal sandy unit of Cutting formation, Cedar Island, Charlotte (x 1.2).
14. *Ophileta complanata* Vanuxem. Oblique top view to show nature of low spire and cross-sectional shape of aperture. May be found in Cassin limestone and perhaps some of the older Beekmantown formations (x 1).
15. *Raphistoma compressum* Whitfield. Oblique apertural view of a steinkern to show the low, almost flat spire and the umbilicus. Whorls outlined by faint white lines in upper part of the shell. Body whorl and aperture broken away. Cassin formation, Thorp Point, about 200 yards south of Thompsons Point road, Charlotte (x 1). See Fig. 24 also.
16. *Hormotoma confusa* (Whitfield). Small, high-spired shell with small apical angle. Maximum curvature of whorl in lower one-third. Occurs mostly as steinkerns. Cassin formation (x 1).
17. *Lecanospira compacta* (Salter). Oblique top view, showing the umbilicus and the shape of the shell cross-section. This form and *Ophileta complanata* have often been confused. The umbilicus of *Ophileta* is at the base of the shell when it is oriented so that any cone placed within the umbilicus would have its apex up when the aperture of the shell is on the viewer's right; *Lecanospira* coils so that a cone placed in its umbilicus would point down when the aperture of the shell is oriented on the viewer's right. Compare with Fig. 14. Found in the Cassin limestone (x 1).
18. *Plethospira arenaria* (Billings). Apertural view of a steinkern. Moderately high-spired shell with moderately wide apical angle and with deep sutures. Selenizone about midway between sutures shows as faint ridge on the steinkern. Whorls somewhat more rotund than those of *Plethospira cassina* (Fig. 10). Cassin formation, Fort Cassin, Ferrisburg (x 0.75). Specimen in the University of Vermont collections.
19. *Plethospira arenaria* (Billings). Another view of the specimen shown in Fig. 18 (x 0.75).
20. *Yoldia arctica* (Linné). Exterior of a left valve; shell subovate in outline; numerous small teeth in hinge area. Pleistocene gravels, sands, and clays; Reynolds Point, Isle La Motte (x 1).
21. *Mya arenaria* (Linné). Exterior of a right valve. Oval-shaped shell with beak near the center; shell rounded in front and somewhat sharper in the posterior portion; teeth lacking. Ornamentation consists of growth lines. Pleistocene gravels and sands. Reynolds Point, Isle La Motte (x 0.75).
22. *Mya arenaria* (Linné). Exterior of left valve; locality same as for Fig. 21 (x 0.75).
23. *Mya arenaria* (Linné). Interior of left valve showing faintly beneath the beak the spoon-shaped projection which is part of the system for holding the two valves together. Also the adductor muscle scars and the pallial line may be seen. Locality same as for Fig. 21 (x 0.75).
24. *Raphistoma compressum* Whitfield. Apertural view showing the low spire of the shell and the angulation on the outer margin of the body whorl (x 1).

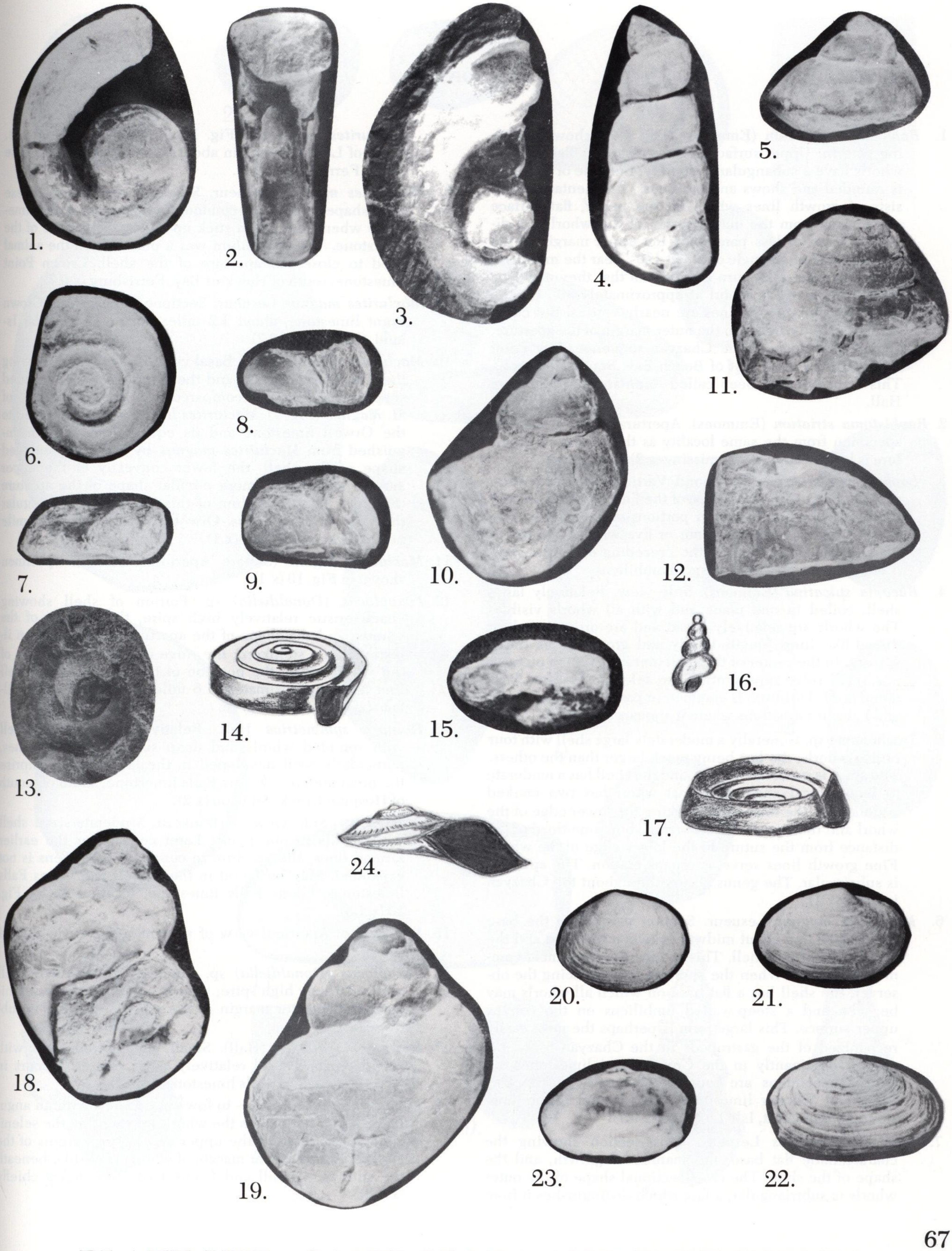


PLATE VIII GASTROPODA AND PELECYPODA

PLATE IX

GASTROPODA

1. *Raphistoma striatum* (Emmons). Top view showing coiling pattern. Upper surface of shell is nearly flat and the whorls have a subangular periphery; the base of the shell is rounded and shows an umbilicus. Ornamentation consists of growth lines which on the upper, flat surface curve away from the outer margin of the whorl in a direction more or less parallel to the upper margin of the aperture and at an angle of about 120°; near the middle of the surface the lines turn abruptly so that they meet the inner margin of the whorl at approximately 90°. On the last whorl the growth lines are nearly vertical but curve approximately parallel to the outer margin of the aperture. Common throughout the Chazyan sequence. Day Point formation, 0.7 mile east of Beech Bay, South Hero (x 2). This form has also been called ***Raphistoma stamineum*** Hall.
2. *Raphistoma striatum* (Emmons). Apertural view of another specimen from the same locality as that of Fig. 1. Aperture is broken and largely missing (x 2).
3. *Lophospira rectistriatus* Raymond. Vertical view of a portion of a whorl showing the nature of the fine growth lines and the angulations on the outer portions of the whorls. The complete shell consists of four or five whorls, the last of which is much larger than the preceding ones; the shell is of medium size and has a small umbilicus.
4. *Bucania sulcatina* (Emmons). Side view. Relatively large shell, coiled in one plane and with all whorls visible. The whorls are relatively broad and are ornamented by thread-like lines longitudinally and growth lines transversely. In the center of the shell (outer margin in picture) is a small ridge representing the selenizone. After Raymond (x 1). This form is common in parts of the Day Point and Valcour formations where it appears as sections.
5. *Trochonema* sp. Generally a moderately large shell with four or five whorls, the last being much larger than the others. The spire is moderate to low, and the shell has a moderate to large apical angle. The last whorl has two marked angulations, the lower one marking the lower edge of the whorl and the upper one occurring about one-third of the distance from the suture to the lower edge of the whorl. Fine growth lines serve as ornamentation. The aperture is subcircular. The genus occurs throughout the Chazyan interval (x 1).
6. *Maclurites magnus* Lesueur. Section parallel to the base of the shell and about midway between the base and the upper part of the shell. This is how the form most commonly appears. When the aperture is held facing the observer, the shell has a flat base on which all whorls may be seen and a steep-walled umbilicus on the convex upper surface. This large form is perhaps the most easily recognized of the gastropods in the Chazyan rocks, occurring dominantly in the Crown Point limestones, although specimens are found occasionally in the Day Point and Valcour limestones also. Crown Point limestone, Jordan Point, Isle La Motte (x 0.7).
7. *Maclurites magnus* Lesueur. Cross-section showing the characteristic flat base, the manner of growth, and the shape of the shell. The cross-sectional shape of the outer whorls is subtriangular, a fact which distinguishes it from *Maclurites logani* (see Fig. 11). Crown Point limestone, shore of Lake Champlain about 0.35 mile south of Grosse Point, Ferrisburg (x 0.7).
8. *Maclurites magnus* Lesueur. Silicified operculum. These horn-shaped fossils are common in the Crown Point limestone where they often stick up above the surface of the limestone. The operculum was a plate which the animal used to close the aperture of the shell. Crown Point limestone, south of Hawkins Bay, Ferrisburg (x 0.7).
9. *Maclurites magnus* Lesueur. Sectioned operculum. Crown Point limestone, about 1.2 miles northeast of Cedar Island, Charlotte (x 0.7).
10. *Maclurites logani* (Salter). Basal view of a steinkern showing the whorls of the shell and the somewhat more rounded shape of the shell as compared with the shell shape of *M. magnus* (Fig. 7). *Maclurites logani* seems restricted to the Orwell limestone and its equivalents. It is distinguished from *Maclurites magnus* by the more rounded shape of the shell, the lower convexity of the upper surface and by the more circular shape of the aperture (Fig. 11). The operculum of this species is less angular than that of *M. magnus*. Orwell limestone about a mile north of Panton Village (x 1).
11. *Maclurites logani* (Salter). Apertural view of specimen shown in Fig. 10 (x 1).
12. *Loxoplocus (Donaldiella)* sp. Portion of shell showing characteristic relatively high spire, the contact of the whorls, and the shape of the aperture. The specimen illustrated is a steinkern; the ridge on the outer margin of the whorl marks the position of the selenizone. Orwell limestone, approximately 1.6 miles north of Panton Village (x 1). See also Fig. 16.
13. *Holopea symmetrica* Hall. Relatively low-spired shell with rounded whorls and deep sutures. Growth lines, particularly well developed in the last whorl, comprise the ornamentation. Glens Falls limestone, south of mouth of Hospital Creek, Addison (x 2).
14. *Sinuites* sp. Side view of steinkern. Moderate-sized shell which coils in one plane. Later coils cover the earlier formed ones; the aperture in complete specimens is not expanded. May be found in the Orwell and Glens Falls limestones. Glens Falls limestone, location as for Fig. 13 (x 1.5).
15. *Sinuites* sp. Apertural view of specimen shown in Fig. 14 (x 1.5).
16. *Loxoplocus (Donaldiella)* sp. Moderate to smallish shell with relatively high spire; whorls in contact and a selenizone at the outer margin of the whorl. Aperture is subovate (x 1.5).
17. *Hormotoma gracilis* (Hall). Small, high-spired shell with rounded whorls and relatively deep sutures. Occurs in Orwell and Glens Falls limestones (x 1.5).
18. *Lophospira* sp. Moderate- to low-spired shell with an angulation about midway in the whorl representing the selenizone; angulations at the upper and lower margins of the last whorl also; upper margin of whorls shelf-like beneath the sutures; Orwell and Glens Falls limestones chiefly (x 1.5).

PLATE IX GASTROPODA

PLATE IX (Continued)

GASTROPODA

19. *Loxobucania punctifrons* (Emmons). Small to moderate shell which gradually expands as it coils; coiling in one plane and last coil covering the umbilici. The aperture does not expand abruptly. Steinkern shown in the illustration does not have the pits which give the species its name. Glens Falls limestone, Larrabees Point, Shoreham (x 1). Specimen in University of Vermont collections.

20. *Loxobucania punctifrons* (Emmons). Apertural view of another specimen from the same locality as the one illustrated in Fig. 19 (x 1.5).

21. *Phragmolites compressus* Conrad. Moderately large shell which is coiled in one plane. Fluting of apertural lip gives rise to crenulated growth lines; ridge with selenizone on outside of whorl (x 1).

PLATE X

CEPHALOPODA

1. *Cassinoceras explanator* (Whitfield). Large shell, expanding rapidly, and oval in cross-section. Lower part of the shell is almost straight while the dorsal portion is convex. Septa are closely spaced, and the siphuncle is located close to the lower part of the shell. Specimen shown is a steinkern with the outer shell removed, but showing the septa and the filled camerae; view is from the right side of the shell. Cassin limestone, Fort Cassin, Ferrisburg (x 0.7). Specimen is in the University of Vermont collections.
2. *Centrotarphyceras seelyi* (Whitfield). Side view of a steinkern showing the open coiling and the general rounded shape of the shell which is flattened slightly on the outer circumference. The shell is coiled in one plane, being discoidal, and it expands gradually. The sutures are nearly straight and may be seen in the lower portion of the picture. The siphuncle is located slightly to the outside of the center of the cross-section; that is, slightly towards the ventral side. Cassin limestone, Fort Cassin, Ferrisburg (x 0.75). Specimen is in the University of Vermont collections.
3. *Centrotarphyceras seelyi* (Whitfield). Apertural view of the specimen shown in Fig. 2 showing flattening of the shell and central position of the siphuncle (seen as faint dark spot) (x 0.6). See also Fig. 13.
4. *Proterocameroceras brainerdi* (Whitfield). Moderate- to large-sized straight shell which expands gradually toward the aperture and is broadly elliptical in cross-section. Septa closely spaced, and sutures mostly straight but with slight sinuosity. Siphuncle is located near the bottom of the shell. Front one-third without septa is the living chamber. Specimen illustrated is a steinkern viewed from the dorsal side. Cassin limestone, Fort Cassin, Ferrisburg (x 0.5). Specimen is in the University of Vermont collections.
5. *Cyclostomiceras cassinense* (Whitfield). Dorsal view of a steinkern showing the short nature of the shell and the accompanying rapid expansion of the shell in the anterior portion; shell broadly elliptical in cross-section; sutures straight, crossing the axis of the shell at about right angles; siphuncle near the ventral margin. Locality and horizon as for Fig. 4 (x 0.5). Specimen is in the University of Vermont collections.
6. *Rudolfoceras cornu-oryx* (Whitfield). Shell small, almost straight-shelled, and expanding moderately rapidly toward the aperture; with a circular cross-section. Internal fillings have prominent annulations which are spaced about a third of the shell diameter; annulations not so prominent on the exterior of the shell. Sutures are straight and cross the shell axis at about right angles, but are slightly sinuous and are closely spaced. The siphuncle is located in the ventral one-half of the shell and is small. Cassin limestone, about 100 yards inland from south end of Thorp Point, Charlotte (x 1).
7. *Eurystomites kellogi* (Whitfield). Steinkern of the living chamber. Cassin limestone, Thorp Point, 200 yards south of Thompsons Point road, Charlotte (x 0.7).
8. *Eurystomites kellogi* (Whitfield). Complete shell; lateral view; large shell of approximately four and a half volutions; flattened slightly on outer edge; general ovate cross-section; siphuncle located near the outer margin of the shell; sutures at about right angles to the axis of the shell and slightly sinuous; no surface ornamentation. From Ulrich, Foerste, Miller, and Furnish (1942) and used with the permission of the Geological Society of America. Cassin limestone, Fort Cassin, Ferrisburg (x 0.33).
9. *Tarphyceras perkinsi* (Whitfield). Side view of a slightly crushed specimen. Discoidal, coiling in one plane, simple sutures which cross the axis of the shell at about right angles. Ornamentation consists of rounded ribs. Siphuncle is located near the ventral (outside) margin of the shell and is small. This form and *Centrotarphyceras* may be confused, but the position of the siphuncle is the primary distinguishing feature. From Ulrich, *et al.*, (1942) and published with the permission of the Geological Society of America. Cassin limestone, Fort Cassin, Ferrisburg (x 0.65).
10. *Tarphyceras perkinsi* (Whitfield). View in the plane of coiling. Same specimen as Fig. 9 (x 0.65).
11. *Valcouroceras tenuiseptum* (Hall). Relatively large, cylindrical, expanding gradually; septa closely spaced and straight, intersecting the axis of the cone at right angles; cross-section circular. Detailed identification depends upon study of structures associated with the siphuncle as species with similar external appearance may be found in the same rocks; left lateral view. Chazyan interval, Isle La Motte (probably Valcour) (x 0.6). This form has been known for a long time as *Cameroceras tenuiseptum*, but work of Flower (1955) indicates that it belongs in *Valcouroceras*. Specimen in the University of Vermont collections.
12. *Valcouroceras tenuiseptum* (Hall). Vertical section of specimen shown in Fig. 11 showing the septa and the ventral position of the siphuncle. Ventral side is to the left (x 0.6).
13. *Centrotarphyceras seelyi* (Whitfield). Cross-section of a shell showing the nearly central position of the siphuncle and the manner in which the whorls are impressed upon one another (x 0.5).

PLATE X CEPHALOPODA

PLATE XI

CEPHALOPODA

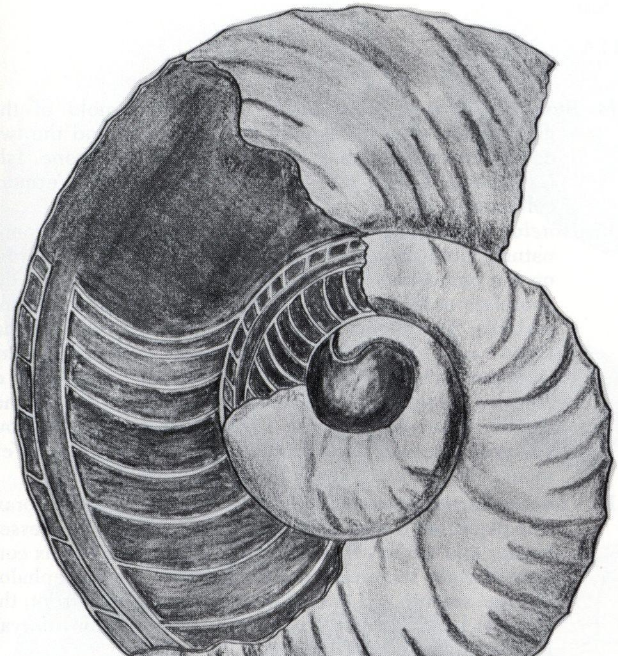
1. Cf. *Stereospyroceras* sp. This is one of the prominently annulated, more or less straight-shelled cephalopods to which the name *"Spyroceras clintoni"* has been applied in the past. The shell is relatively small in diameter compared to its length and expands at a moderate rate. The annulations are to be seen in the posterior portion of the shell while the close-spaced septa can be seen in the anterior portion of the shell. Crown Point limestones, "reefy zone" about 1.5 miles south of Isle La Motte Village, Isle La Motte (x 0.7).
2. *Stereospyroceras clintoni* (Hall). Shell is long and slender, curving slightly, and with prominent annulations. The siphuncle is in small segments and has irregular annular deposits; there are also deposits in the camerae. Chazyan rocks (x 0.5). Modified after Ruedemann (1906).
3. *Stereospyroceras champlainensis* Flower. Polished section oblique to a vertical plane from the dorsal (upper) to the ventral (lower) side of the shell. In cross-section the shell is about circular, being slightly wider than high. The siphuncle is closer to the ventral side of the shell than the dorsal, and its segments are slightly expanded. Annuli and faint longitudinal lines mark the shell. From Crown Point limestones near Vergennes (x 0.75). From Flower (1955b).
4. *Endoceras? lamottense* Ulrich *et al.* Side view of an internal mold. Moderately large shell characterized by a broadly elliptical cross-section and gradual expansion toward the front of the shell. Sutures are essentially straight. The siphuncle is large, circular in cross-section and is located near the ventral wall of the shell. According to Flower (1955a, p. 343) this form is very similar to the form described by Ruedemann (1906) as *Vaginoceras oppletum.* From Ulrich, Foerste, Miller, and Unklesbay (1944) and published with the permission of the Geological Society of America. Probably Valcour formation, Isle La Motte (x 0.7).
5. *"Vaginoceras" oppletum* Ruedemann. Large, closely septate, straight-shelled cephalopod whose septa cross the shell at about right angles to the axis. The cross-section is slightly flattened in a ventral-dorsal direction. The shell surface is essentially smooth. Evidence from structures associated with the siphuncle indicates that this form does not belong in the genus *Vaginoceras,* although its relationships are not clear (Flower, 1955a); hence the generic name is placed in quotation marks. Specimen illustrated shows the cross-sectional shape as seen in an oblique section and the position of the siphuncle. A natural, approximately vertical section crossing the axis of the shell; from the Crown Point limestone on the east side of the "reefy horizon" about 1.5 miles south of Isle La Motte Village (x 0.4).
6. *Vaningenoceras* sp. This genus is based upon siphuncles only (Flower, 1958, p. 445). Long tapering siphuncle which is essentially circular in cross-section, but flattened slightly ventrally and rounded dorsally. The siphuncle is constructed of a series of cones placed one inside another (endocones). Crown Point limestone, shore of Lake Champlain, 0.35 mile south of Grosse Point, Ferrisburg (x 0.4).
7. *Proteoceras perkinsi* (Ruedemann). Vertical longitudinal section of the type specimen. Sutures are straight and cross the axis of the shell at about right angles, but curve slightly toward the apex of the shell; the shell is curved, the concave side presumably being the lower or ventral side. Siphuncle segments expand so that their width is about equal to their length, and the siphuncle is located near the convex side of the shell. Type specimen from either the Crown Point or the Valcour limestones of Isle La Motte and deposited in the University of Vermont collections (x 1.5). From Flower (1955b).
8. *Proteoceras pulchrum* Flower. Section through siphuncle viewed from dorsal (upper) side of the shell. Shell straight, relatively rapidly expanding and unmarked on the surface by any features except very faint growth lines. The septa are gently curving and moderately spaced; siphuncle segments somewhat bulbous, attaining their maximum diameter toward the front and tapering more gently toward the apex of the shell. Various deposits in the siphuncle and the camerae relate this form to *P. perkinsi.* Crown Point limestones, 1.5 miles northwest of Vergennes (x 0.75). From Flower (1955b).
9. *Murrayoceras primum* Flower. Horizontal longitudinal section of type specimen, viewed from the dorsal side; shows the siphuncle and the cameral deposits. Shell straight, expanding gradually, with straight sutures which cross the axis of the shell at approximately right angles and which are relatively closely spaced. The siphuncle is large, located near the ventral margin of the shell, and is tubular in shape. Day Point formation, approximately 0.7 mile east of Beech Bay, South Hero (x 2). From Flower (1955b).
10. *Murrayoceras?* sp. Straight shell with relatively large siphuncle which is tubular. The illustration shows secondary calcite filling parts of the camerae and the siphuncle, part of which can be made out faintly in the front two camerae. Orwell limestone, Wings Point, Charlotte (x 1.5).
11. *Avilionella multicameratum* (Ruedemann). Coiled shell of three volutions; oval cross-section; small siphuncle is located near the outer margin of the shell. Ornamentation consists of faint growth lines. Septa are closely spaced and slightly concave. Specimen illustrated is apparently from the Valcour limestone of Isle La Motte (x 0.75). Specimen is in the University of Vermont collections.

PLATE XI CEPHALOPODA

PLATE XII

CEPHALOPODA

1. *Plectoceras jason* (Billings). Moderate-sized shell, coiled in one plane; three or four volutions; cross-section subcircular with the outer part being somewhat flattened; septa are closely spaced and shallowly saucer-shaped; on the outer margin there is a bend in the suture, convex toward the aperture. The siphuncle is moderately large and tubular and located in the outer one-quarter of the shell. Rounded ridges ornament the outer shell, crossing it obliquely. Found in the Crown Point limestones chiefly (x 0.8). Modified from Ruedemann (1906).
2. *Sigmorthoceras vagum* (Ruedemann). Shell very slender and irregularly bending and with a circular cross-section. Septa are very convex, and the sutures cross the shell at about right angles. The siphuncle is located along the axis of the shell and expands to a moderate depth into the camerae. Found in Chazyan rocks (x 1). Modified from Ruedemann (1906).
3. *Nanno* sp. Shell expands rapidly in the form of a cone for the first one-third and then maintains a more or less constant diameter until the front one-third where it contracts slightly; subcircular in cross-section. The siphuncle is bulbous in the posterior part of the shell before the first septa, and it is located beneath the axis of the shell (toward the ventral side); siphuncle commonly filled with coarse calcite. Septa deeply concave, meeting the siphuncle at about 70 degrees, and closely spaced. Specimen illustrated is a natural section weathered along a nearly vertical plane from the dorsal to the ventral (right to left in the illustration) side of the shell. Crown Point limestone, approximately 0.35 mile south of Grosse Point, Ferrisburg (x 0.8).
4. *Murrayoceras multicameratum* (Hall). Portion of the relatively long, slender cone of this species which has also been known as *Michelinoceras? multicameratum* (Hall). Closely spaced septa which are only moderately concave; siphuncle relatively large in comparison with the shell size. Orwell limestone, east slope of hill approximately 1.1 miles south of the mouth of Otter Creek, Ferrisburg (x 1.5).
5. *Stereospyroceras* sp. Moderately large shell of this genus showing annulated nature of the exterior, the curvature of the septa and the expansion of the siphuncle in the camerae. View is looking down on the convex side of the slight curve in the shell (ventral side). Crown Point limestone, west face ridge, approximately 1.9 miles west of the railway bridge across Little Otter Creek, Ferrisburg (x 0.7).
6. *Endoceras proteiforme* Hall. Large shell, attaining a length of as much as ten or twelve feet; has a large siphuncle which is located in the lower portion of the shell. Septa closely spaced and relatively straight; sutures straight. This form occurs mostly as internal molds such as illustrated here. Essex Ferry landing, Charlotte (x 0.3).
7. *"Spyroceras" bilineatum* (Hall). Relatively small shell crossed by rounded annulations and marked by longitudinal striae which are very fine and closely spaced; every other striation is slightly more elevated than the ones adjacent to it. May be found in the Orwell and Glens Falls limestones (x 1). Modified from Hall (1847).



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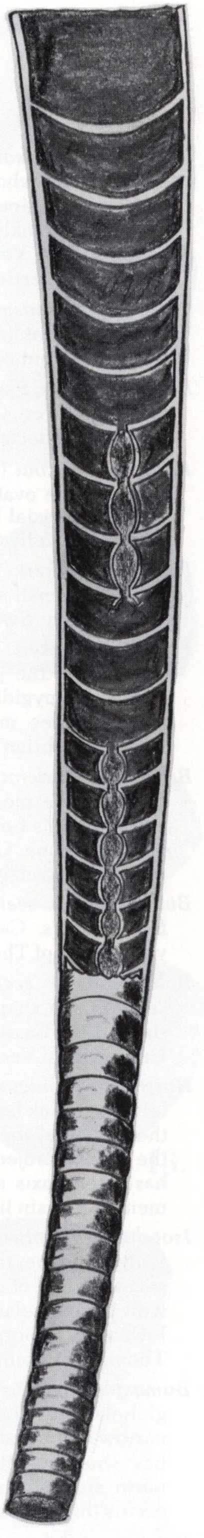

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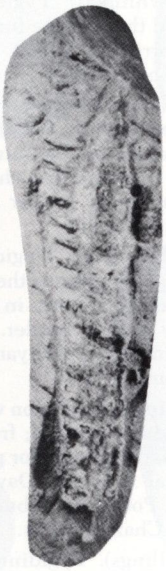

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PLATE XII CEPHALOPODA

PLATE XIII

TRILOBITA

1. *Olenellus thompsoni* (Hall). Plaster cast showing the oval shape of the whole animal and the globular shape of the glabella. Original specimen came from Parker Quarry, Georgia, Franklin County. Lower Cambrian beds of northwestern Vermont (x 0.8). Cast in the University of Vermont collections.
2. *Olenellus thompsoni* (Hall). Internal mold of a cephalon, Georgia, Franklin County (x 0.7). Specimen in the University of Vermont collections.
3. *Leiostegium* sp. Pygidium of a form that is common in some of the Lower Ordovician limestones of northwestern Vermont, especially north of Highgate (x 2).
4. *Kootenia marcoui* (Whitfield). Internal mold of a pygidium showing the ovate shape, the fusion of the pleural lobes, the narrow axial lobe, and the spines. Parker slate, Lower Cambrian. Kelly Quarry, Swanton (x 1).
5. *Pagetides parkeri* (Walcott). Impression of the pygidium of this very small species. Parker slate, Lower Cambrian. Kelly Quarry, Swanton (x 4).
6. *Pagetides parkeri* (Walcott). Cephalon without the free cheeks and the pygidium. Shell has only three thoracic segments; pygidium has a well-defined axial lobe; the pleural lobes may be relatively smooth or furrowed. Lower Cambrian (x 6).
7. *Bonniella desiderata* (Walcott). Internal mold of a pygidium showing the more or less straight edge of the posterior margin of this Lower Cambrian form; probably from Dunham dolostone, Georgia, Franklin County (x 2). Specimen is in the University of Vermont collections.
8. *Bolbocephalus seelyi* (Whitfield). Glabella and part of the fixed cheeks. Cassin limestone, Thorp Point, about 200 yards south of Thompsons Point road, Charlotte (x 1).
9. *Bolbocephalus seelyi* (Whitfield). Pygidium showing the semicircular shape and the oblique furrows. Cassin limestone, Fort Cassin, Ferrisburg (x 0.7). Specimen is in the University of Vermont collections.
10. *Hystricurus conicus* (Billings). Cephalon and pygidium. The left free cheek has been restored. Shows tapering glabella, the nature of the facial suture, the pustulate surface, and the spines projecting from the free cheek; the pygidium has a long axis and a narrow border and is clearly segmented. Cassin limestone (x 2).
11. *Isoteloides whitfieldi* (Raymond). Pygidium showing the long axial lobe, the segmentation of the lobe, and the faint segmentation of the fused segments in the pleural lobe, as well as the relatively narrow border. Cassin limestone, lower part, Thorp Point, about 200 yards south of road to Thompsons Point, Charlotte (x 1).
12. *Bumastus globosus* (Billings). Cephalon which has a general globular appearance and is smooth; free cheeks are very narrow and usually missing. Posterior portion of cephalon has short longitudinal grooves. Day Point formation, north side of Grosse Point, Ferrisburg (x 2). This form occurs throughout the Chazyan rocks.
13. *Bumastus globosus* (Billings). Pygidium and part of the thorax. The pygidium is smooth and subovate; the thorax consists of ten segments when complete and has a very wide axial lobe. Valcour or Crown Point limestone, Isle La Motte (x 1.6). Specimen illustrated is in the University of Vermont collections.
14. *Bumastus eratusi* (Raymond). An internal mold of the glabella showing its general circular shape and the two dorsal furrows. Valcour or Crown Point limestone, Isle La Motte (x 1). Specimen is in the University of Vermont collections.
15. *Isotelus platymarginatus* Raymond. Clay cast made from a natural mold showing the relatively wide concave border on the pygidium. The cephalon is large in respect to the complete animal, smooth and lacking in furrows on the glabella. The thorax consists of eight segments and has a wide axial lobe. The glabella and fixed cheeks are somewhat narrower than those of *Isotelus harrisi*. Specimens of *Isotelus platymarginatus* also tend to be somewhat smaller than specimens of *I. harrisi*. Found throughout Chazyan interval; impression is in the University of Vermont collections and came from Isle La Motte (x 1).
16. *Isotelus harrisi* Raymond. Pygidium and part of the thorax. The pygidium is rounded in plan with a slightly depressed border and an axis that is barely visible. The thorax consists of eight segments; the axial lobe is wide. Cephalon is large, smooth and has a flat border around the front; the glabella lacks furrows. Found through Chazyan interval; Isle La Motte (x 0.7).
17. *Isotelus harrisi* Raymond. Hypostome, a plate that lay in front of the mouth region on the underside of the animal. Valcour formation, Jordan Point, Isle La Motte (x 1).
18. *Eoharpes antiquatus* (Billings). Cephalon showing the semicircular shape and one of the spines (left) extending back from the juncture of the side of the cephalon and the posterior margin. The relatively long, thin glabella is distinctly outlined; the cephalon surface is pitted. A ring next to the posterior margin of the cephalon shows a median pustule. Occurs mostly in the Day Point formation but is also known from the Crown Point. Day Point formation, north side of Grosse Point, Ferrisburg (x 1).
19. *Pliomerops canadensis* (Billings). Thorax and pygidium. The thorax has 19 segments while the axis of the pygidium has 6 divisions. The axis of the thorax occupies about one-third its width, and the thorax tapers very little. Crown Point limestone, Isle La Motte (x 1). Specimen is in the University of Vermont collections.
20. *Pliomerops canadensis* (Billings). Two glabellas and parts of fixed cheeks. The glabella of this form is relatively wide and broadly rounded in front and is marked by three pairs of furrows. Wide spines on pygidium point posteriorly. Fixed cheeks are large and free cheeks are small. Crown Point limestone, Isle La Motte (x 1). Specimen is in the University of Vermont collections.
21. *Vogdesia bearsi* (Raymond). Pygidium, evenly convex, smooth, with the axis only very faintly suggested, and with a flattened border. Occurs mostly in the Crown Point limestone (x 1).
22. *Glaphurus pustulatus* (Walcott). Glabella and fixed cheeks showing the straight-edged shape of the glabella and the pustulate nature of the surface. Two grooves run longitudinally near either edge of the glabella and near its front intersect the anterior pair of glabellar furrows which make only small impressions on the surface of the glabella. This species occurs exclusively, so far as is known, in the "reefy horizons" of the Valcour. Valcour formation, Isle La Motte (x 2.5).

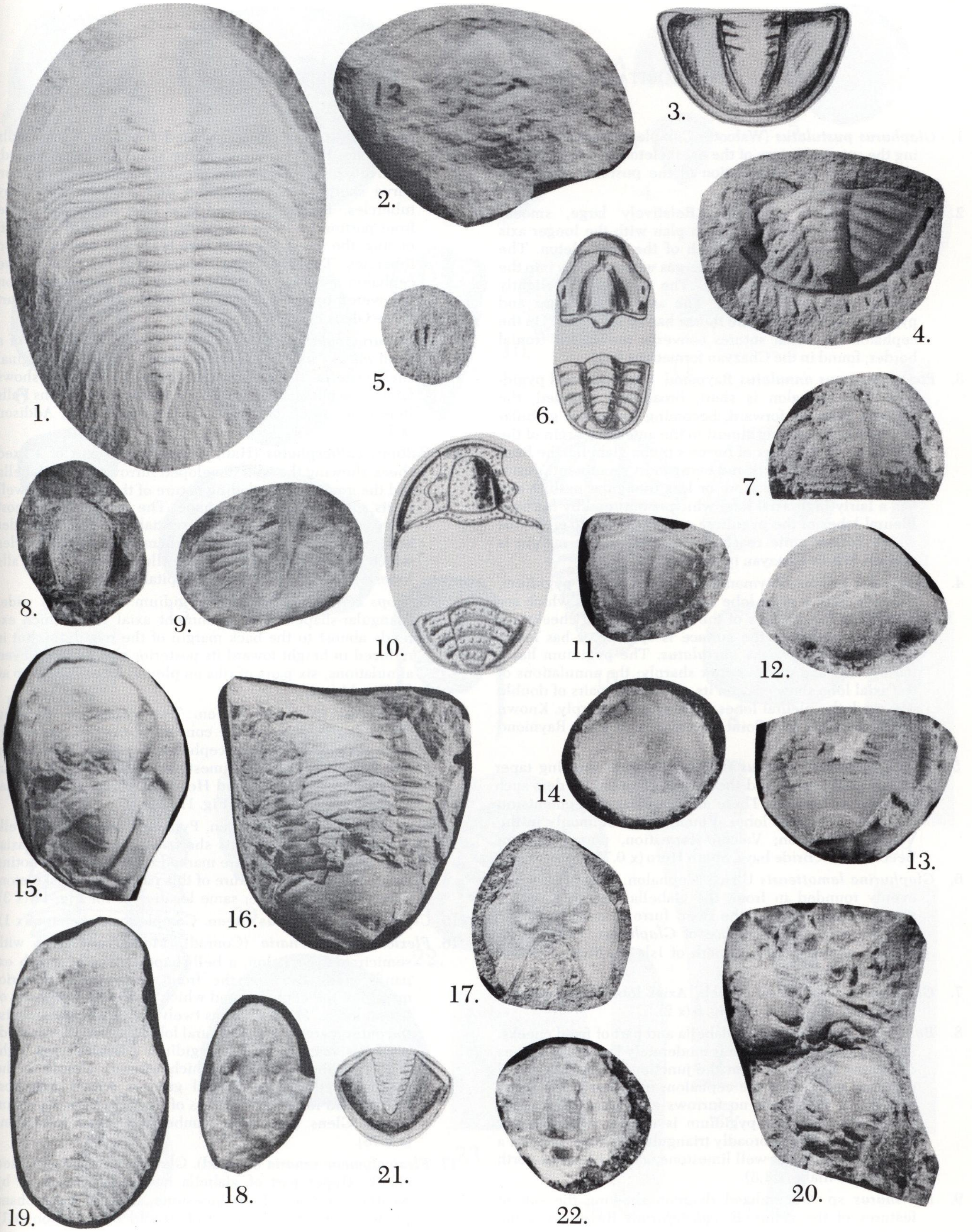


PLATE XIII TRILOBITA

PLATE XIV

TRILOBITA, ECHINODERMATA, AND GRAPTOLITHINA

1. ***Glaphurus pustulatus*** **(Walcott). Complete specimen showing the spinose nature of the exoskeleton, the shape of the glabella and the distribution of the pustules. Found in Valcour formation (x 1.5).**
2. ***Illaenus bayfieldi*** **(Billings). Relatively large, smooth cephalon which is elliptical in plan with the longer axis being transverse to the length of the exoskeleton. The axial region of the cephalon merges without a line into the frontal part of the cephalon. The pygidium is slightly smaller than the cephalon. The axis of the thorax and pygidium is wide, and the thorax has 10 segments. On the cephalon the facial sutures converge toward the frontal border; found in the Chazyan formations (x 1).**
3. ***Pterygometopus annulatus*** Raymond. Cephalon and pygidium. The cephalon is short, broad and rounded; the glabella expands forward, becoming somewhat globular in shape and reaching almost to the anterior margin of the cephalon. Three pairs of furrows in the glabella, the front one sloping posteriorly and being most prominent; pustulate. Pygidium has a more or less triangular outline and has a fairly high axial lobe which is outlined by furrows. Pleural lobes of the pygidium marked by six to eight ribs which do not quite reach to the margin; the margin is smooth. Whole Chazyan interval (x 1.4).
4. *Cybeloides primus* (Raymond). A. Cephalon; B. pygidium. Glabella with a main lobe and two side lobes which are formed by the furrows of the glabella. Fixed cheeks are very convex; while the surface is spinose, it has fewer spines than *Glaphurus pustulatus*. The pygidium has a narrow axis and tapers rather sharply; the annulations of the axial lobe show only on its sides. Four pairs of double ribs mark the pleural lobes, turning back sharply. Known mostly from the Day Point formation (x 2). From Raymond (1910).
5. *"Onchometopus" obtusus* (Hall). Pygidium showing taper of the axial region and the lack of flattened borders such as occur in *Isotelus*. There are no traces of segments on the axial or pleural lobes. Found most commonly in the Valcour formation; Valcour formation, point between Beech and McBride bays, South Hero (x 0.75).
6. *Glaphurina lamottensis* Ulrich. Cephalon, wider than long, evenly rounded in front, the glabella extending to the anterior margin; lacks the deep furrows in the glabella and the spinose appearance of *Glaphurus*. Valcour formation, about 1.1 miles south of Isle La Motte Village, Isle La Motte (x 2).
7. *Glaphurina lamottensis* Ulrich. Axial lobe and a pleural lobe. Same locality as for Fig. 6 (x 2).
8. *Bathyurus spiniger* (Hall). Glabella and part of fixed cheeks. The cephalon of this form is moderately large with spines extending backward from the junction of the lateral and posterior margins of the cephalon; free cheeks are large; glabella is high with no furrows and ornamented with small tubercles; the pygidium is convex with three or four pairs of ribs, is broadly triangular in shape, and has a prominent spine. Orwell limestone, about 1.9 miles north of Panton Village (x 1.3).
9. *Encrinurus* sp. Generalized diagram showing the salient features of the genus. *E. cybeleformis* Raymond is the form that is most often reported from the Glens Falls limestone; the pygidium has the shape of a short-based, relatively high triangle. The pleural lobes of the pygidium curve sharply to the posterior and are not marked by tubercles. The well-defined axial lobe is marked in the front portion by three segments; after the third segment, or ring, the top of the axial lobe is smooth except for two tubercles. The glabella widens toward the front of the cephalon and extends to its border; the whole cephalon is covered by tubercles. Found mostly in the lower part of the Glens Falls limestone (x 1).
10. *Encrinurus cybeleformis* Raymond. Glabella and part of a fixed cheek; internal mold, although part of the original shell material remains on the edges. The picture shows faintly the pustulate nature of the exoskeleton. Glens Falls limestone, south of mouth of Hospital Creek, Addison (x 1.5).
11. *Calliops callicephalus* (Hall). Glabella and part of a fixed cheek showing the well developed furrows in the glabella and the gradually expanding nature of the glabella as well as its somewhat rounded shape. The cephalon is almost twice as wide as long with essentially no frontal border and with wide lateral borders; ornamented with tubercles which can be seen faintly in the illustration. Glens Falls limestone, south of mouth of Hospital Creek (x 2).
12. *Calliops callicephalus* (Hall). Pygidium. Moderately wide, triangular-shaped with prominent axial lobe which extends almost to the back margin of the pygidium, but is reduced in height toward its posterior end; ten or eleven annulations; six pairs of ribs on pleural lobes. Location as for Fig. 11 (x 2).
13. *Cryptolithus tesselatus* Green. Two cephalons showing the high glabellas and the concentric rows of pits which lie in the outer part of the cephalon. Common in the upper part of the Glens Falls limestone, and may be found in the overlying Cumberland Head and Stony Point formations also. Location as for Fig. 11 (x 1).
14. *Cryptolithus tesselatus* Green. Pygidium showing the well-defined axial lobe and its short, wide nature. The axial lobe and pleural lobes are marked by faint lines denoting the once-segmented nature of this part of the exoskeleton. Glens Falls limestone; same location as for Fig. 11 (x 3).
15. *Cryptolithus tesselatus* Green. Complete exoskeleton (x 1).
16. *Flexicalymene senaria* (Conrad). Moderately large with semicircular cephalon, a bell-shaped glabella which expands gradually from the front towards the posterior margin of the cephalon and which is marked by 3 pairs of lateral lobes. The thorax has twelve or thirteen segments; the outer margins of the pleural lobes are bent downward; posterior margin of the pygidium essentially at right angles to the axial lobe which extends almost to the margin; well-defined pleural grooves which arch posteriorly and reach the margins of the pygidium. Common in the Glens Falls and Cumberland Head formations (x 0.75).
17. *Flexicalymene senaria* (Conrad). Glabella and part of a fixed cheek. Upper part of glabella has been planed off by weathering. Glens Falls limestone, shore of Lake Champlain about 0.8 mile north of Arnold Bay, Panton (x 1).

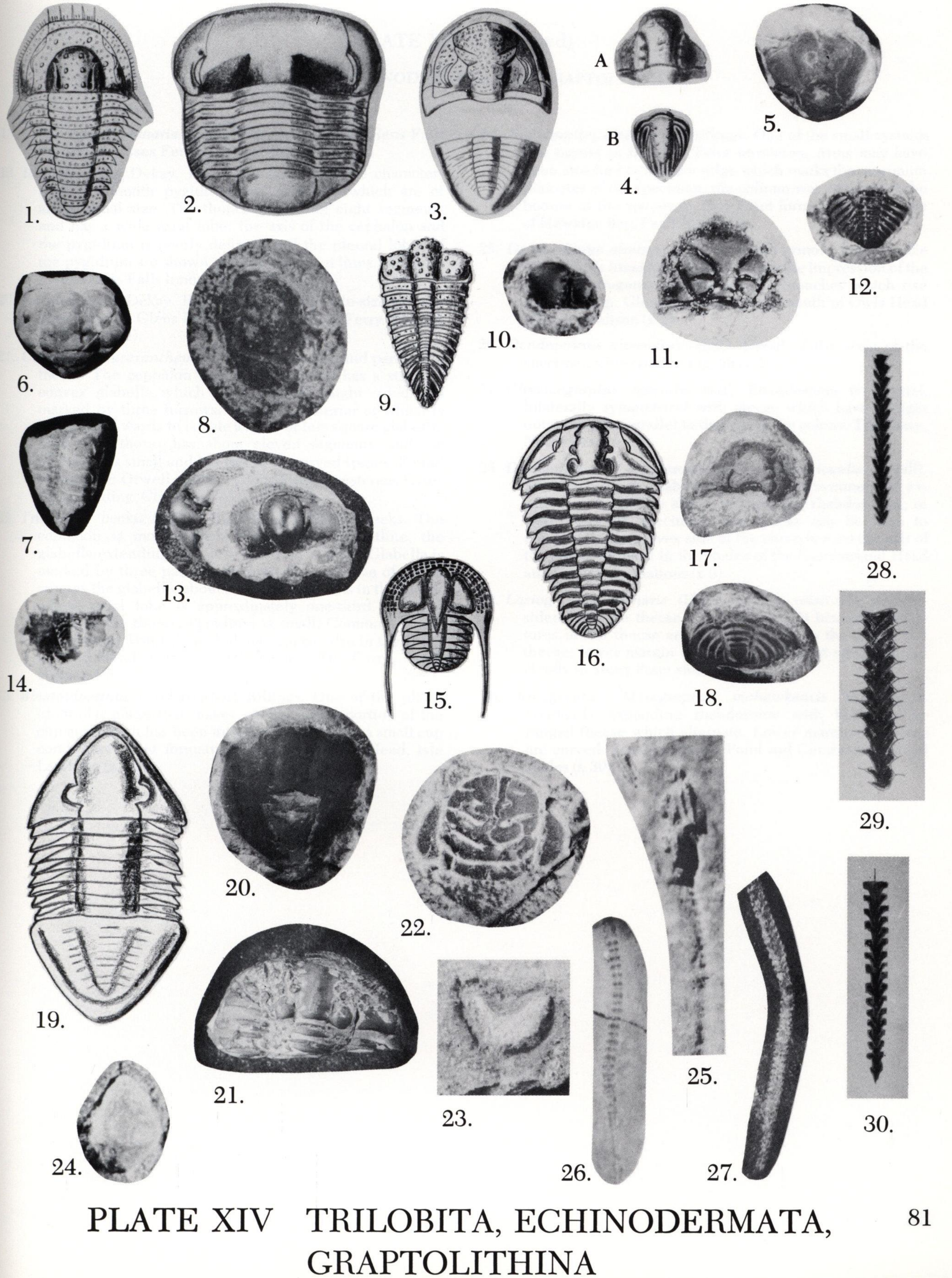


PLATE XIV TRILOBITA, ECHINODERMATA, GRAPTOLITHINA

PLATE XIV (Continued)

TRILOBITA, ECHINODERMATA, AND GRAPTOLITHINA

18. *Flexicalymene senaria* (Conrad). Pygidium from Glens Falls limestone, Essex Ferry landing, Charlotte (x 1).

19. *Isotelus gigas* Dekay. Relatively large trilobite characterized by smooth pygidium and cephalon which are of about equal size. The thorax consists of eight segments and has a wide axial lobe; the axis of the cephalon and the pygidium is poorly defined, and the pleural lobes of the pygidium are shown only by very faint lines. Common in the Glens Falls limestone (x 0.7).

20. *Isotelus gigas* Dekay. Pygidium of a moderate-sized specimen from the Glens Falls limestone. Essex Ferry landing, Charlotte (x 1).

21. *Ceraurus pleurexanthemus* Green. Cephalon and part of the thorax. The cephalon is semicircular and has a strongly convex glabella which is relatively straight sided and marked by three furrows, the most posterior of which is turned backwards to isolate a more or less square glabellar lobe. The thorax has about eleven segments, and the pygidium is small and has two long, curved spines. Found in both the Orwell and the Glens Falls limestones. Essex Ferry landing, Charlotte (x 1).

22. *Triarthrus beckii* Green. Glabella and fixed cheeks. The cephalon is more or less semicircular in outline, the glabella extending almost to the front margin. Glabella is marked by three pairs of furrows, the back one of which crosses the glabella; about fourteen segments in the thorax whose axial lobe is approximately one-third the total width of the thorax. Pygidium is small. Common locally in the Stony Point shale, but may appear also in the Cumberland Head. Stony Point formation, The Carry, North Hero (x 1.5).

23. *Blastoidocrinus carchariadens* Billings. One of the plates (deltoidal plate) that makes up the upper portion of the cup and which has been mistaken by some for a small cup coral. Day Point formation, upper part, The Head, Isle La Motte (x 0.8).

24. *Bolboporites americanus* Billings. One of the small cystoids that occurs in the Day Point formation. Arms may have been attached to the low ridge which marks the maximum diameter of the specimen; the column was attached at the bottom of the specimen. Day Point formation, south side of Hawkins Bay, Ferrisburg (x 3).

25. *Dendrocrinus alternatus* (Hall). Small crinoid found in the Glens Falls limestone. Figure shows the impression of the stem and fragments of the slender branches which rise from the cup. Glens Falls limestone, south of Owls Head Harbor, Addison (x 2).

26. *Dendrocrinus alternatus* (Hall). Detail of the stem of the specimen illustrated in Fig. 25 (x 2).

27. *Climacograptus typicalis* Hall. Rhabdosome is biserial, bilaterally symmetrical with thecae which have straight outer margins parallel to the axis of the colony. The Carry, North Hero (x 1.5).

28. *Diplograptus (Amplexograptus) amplexicaulis* (Hall). Straight biserial, rhabdosome, which is symmetrical except that the thecae alternate along the rhabdosomes; in well-preserved specimens the thecae can be seen to curve with the convex side of the curve toward the axis of the colony. Found in the shales of the Cumberland Head and younger formations (x 3).

29. *Lasiograptus eucharis* (Hall). Colony relatively straight-sided with the thecae arranged along it biserially; apertures of the thecae are at right angles to the axis of the thecae; lower margin of aperture has short spine. Found chiefly in Stony Point shales (x 3).

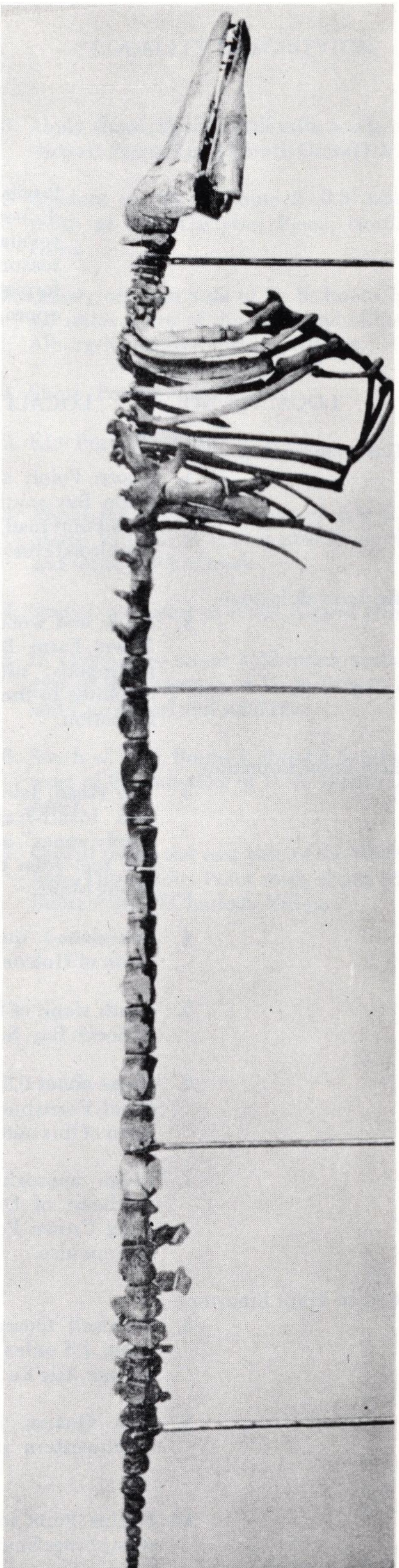
30. *Diplograptus (Mesograptus) mohawkensis* Ruedemann. Gradually expanding rhabdosome with biserially arranged thecae which alternate. Lower margins of thecae are curved. Found in Stony Point and Cumberland Head shales (x 30).

PLATE XV

ALGAE, GASTROPODA, AND WHALE

1. ***Maclurites magnus*** Lesueur. Section parallel to the base in a black "marble" slab from one of the Isle La Motte quarries. Specimen in the University of Vermont collections (x 0.5).
2. ***Delphinapterus vermontanus*** (Thompson). Picture of the skeleton of the Charlotte whale as it is mounted in the State Museum in Montpelier. From Perkins (1908) (x 1/15).
3. ***Stromatocerium***—algal "reefy zone" in the Day Point formation. 3700 feet N. 20° W. of Reynolds Point, Isle La Motte. Hammer gives scale.
4. ***"Stromatocerium" lamottense*** Seely. Close-up of one of the large colonies; Goodsell Quarry, Isle La Motte. Hammer gives scale.

1.



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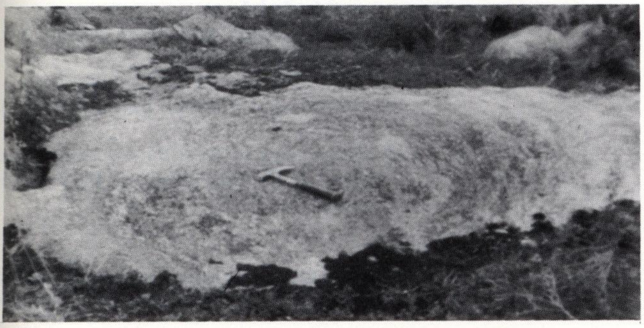

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4.

PLATE XV ALGAE, GASTROPODA, AND WHALE

PLATE XVI

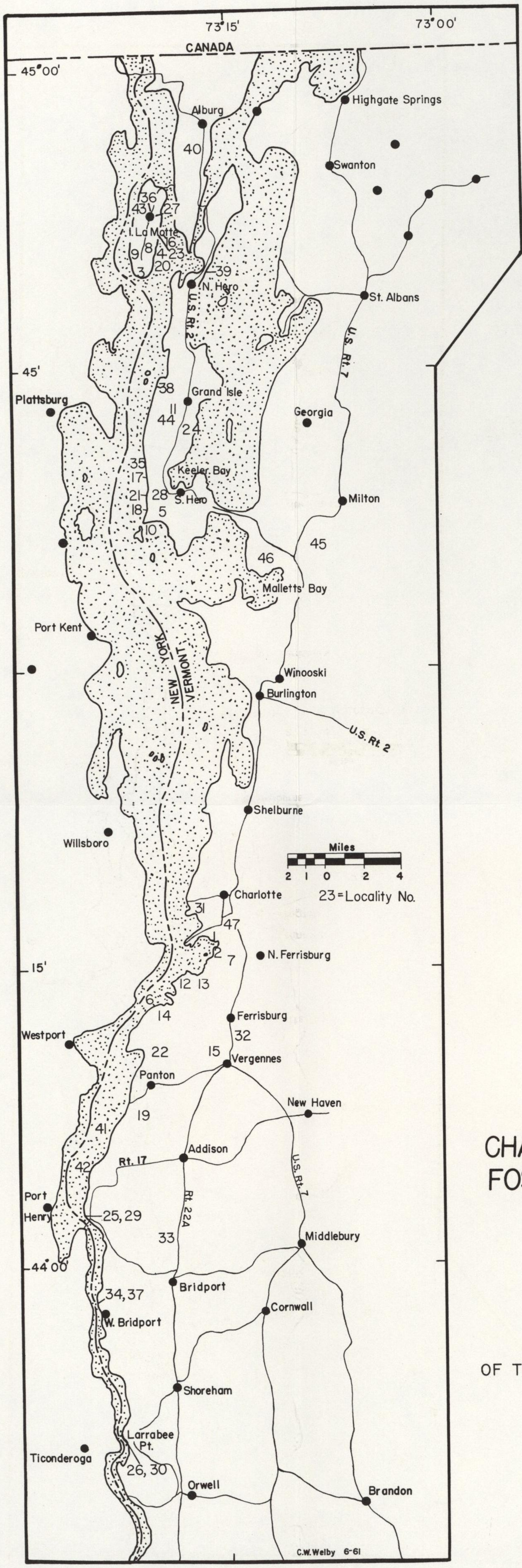
LOCALITY LIST

Given below and shown on Plate XVI are localities where fossils may be found in the Champlain Basin. These localities do not represent all the places that fossils may be found in the several formations, but they are localities where fossils occur in reasonable abundance. The arrangement within the list is by formation. For details of each locality you should consult the appropriate Vermont Geological Survey bulletin.

LOCALITY NO.	LOCALITY DESCRIPTION
Cassin formation	
1.	Thorp Point; small point into Town Farm Bay south of Charlotte-Thompsons Point road, about a half mile west of railroad crossing, Charlotte.
Bridport dolostone	
2.	Shore and woods east of Dean Island, Town Farm Bay, Ferrisburg. Small gastropods, ostracods, and possibly trilobites in the thin limestones of the formation.
Day Point formation	
3.	The Head, Isle La Motte; sandstones and fossil-fragmental limestones; "reefy zones" occur in the fields about 500 feet from the edge of the south-facing bluffs.
4.	Abandoned quarry about 400 yards south of Holcomb Point, Isle La Motte.
5.	South slope of hill about 0.5 mile east of Beech Bay, South Hero.
6.	Shore about 0.5 mile south of Summer Point, Ferrisburg, and inland continuation of this outcrop.
7.	Ridge approximately 0.8 mile east-northeast of Dean Island. The overlying Crown Point outcrops are fossiliferous also.
Crown Point limestone	
8.	Goodsell Quarry and adjacent areas about 1.5 miles south of Isle La Motte Village, Isle La Motte.
9.	Fisk Quarry, north of Fleury Bay, southwestern part of Isle La Motte.
10.	Phelps Point to Jackson Point, southwest corner South Hero.
11.	About 0.7 mile southeast of Pearl railroad crossing in Grand Isle. Sponges are particularly abundant here.
12.	Woods and shore west of Kingsland Bay, Ferrisburg.
13.	Woods and fields south of Hawkins Bay, Ferrisburg.
14.	Fields south of Summer Point, Ferrisburg.
15.	Hill about 0.5 mile N. 10° W. of the dam across Otter Creek, Vergennes.
Valcour formation	
16.	West side of Jordan Point, Isle La Motte.
17.	Rockwell Bay and shore south of it, South Hero.
18.	North shore of Beech Bay, South Hero.
19.	Ridge west of West Panton School and about 0.75 mile south of Panton Village.
Orwell – Isle La Motte	
20.	Hill Quarry, shore, east-southeast of Isle La Motte Village, Isle La Motte.
21.	Shore north and south of Sawyer Bay, South Hero.
22.	Ridge about a mile north of Panton Village.
Glens Falls limestone – Larrabee member	
23.	Fields northwest of Jordan Bay, Isle La Motte.
24.	Fields approximately 0.7 mile west of Cooper Bay, South Hero.
25.	South edge of Crane Point, Addison.
26.	Larrabee Point, Shoreham.
Glens Falls limestone – Shoreham member	
27.	Fields about 0.4 mile east of Isle La Motte Village, Isle La Motte.

LOCALITY NO.	LOCALITY DESCRIPTION
	28. Fields 0.4 mile east of Sawyer Bay, South Hero; also along the shore north of McBride Bay.
	29. South and west shore of Crane Point, Addison.
	30. Larrabee Point, Shoreham.
	31. North shore and fields to the north of McNeil Cove, Charlotte (Essex Ferry landing).
	32. Hill about 0.7 mile south of Little Otter Creek bridge on U. S. Route 7, Ferrisburg.
	33. Roadcut on west side of Route 22A, about 0.7 mile north of Addison-Bridport townline.
	34. Shore, West Bridport.
Cumberland Head formation	35. Shore, approximately 0.4 mile north of Rockwell Bay, South Hero.
	36. North edge of Isle La Motte Village, Isle La Motte.
	37. Shore, northwest of West Bridport.

LOCALITY NO.	LOCALITY DESCRIPTION
Stony Point shale	38. Along shore, about a half mile south of Nichols Point (Long Point), Grand Isle.
	39. Roadcut on U. S. Route 2, 0.5 mile south of The Carrying Place, North Hero.
	40. Quarry on west side of U. S. Route 2, 3.3 miles north of the west end of the Alburg-North Hero bridge, Alburg.
	41. Shore, Potash Point, Panton.
	42. Elm Point, Addison.
Pleistocene	43. About 0.5 mile northwest of Isle La Motte Village, in gravel pits on north and south sides of road.
	44. Gravel pits west of Pearl, Grand Isle.
	45. In Colchester about 1.25 miles northeast of the junction of U. S. Routes 2 and 7, in gravel and sand pits.
	46. South of U. S. Route 2, about 2.5 miles west of the junction of U. S. Routes 2 and 7.
	47. Gravel pit on the east side of the Charlotte-Thompsons Point road, about 1.5 miles south of Charlotte Village.



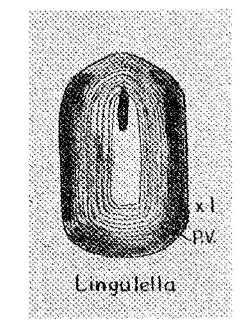
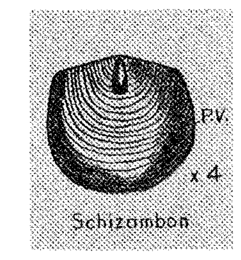
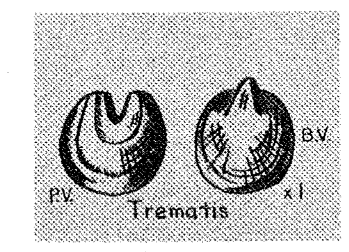
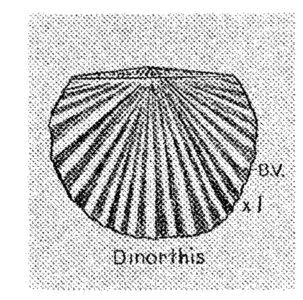
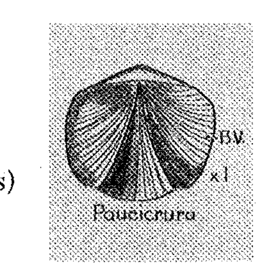
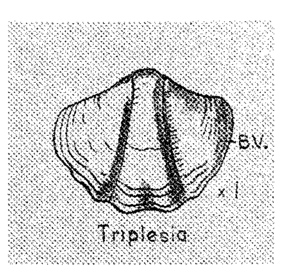
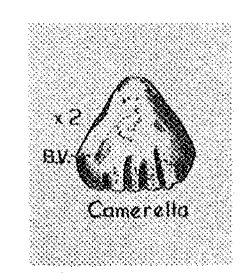
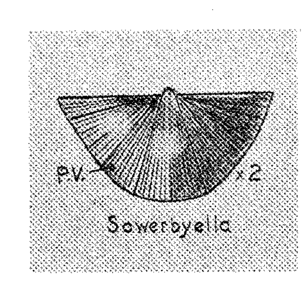
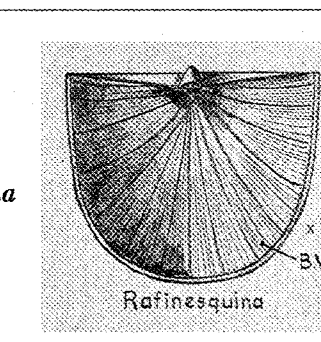
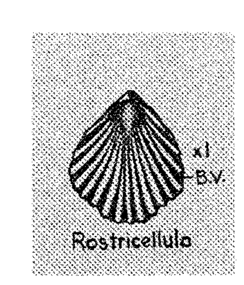
CHAMPLAIN BASIN FOSSIL LOCALITIES

PLATE XVI

PALEONTOLOGY
OF THE CHAMPLAIN BASIN IN
VERMONT

C.W. Welby

TABLE 2 BRACHIOPOD SUPERFAMILIES

Superfamily	Prominent Shell Characteristics				Age Range	Illustration
	Outline and Size	Surface Ornamentation, Costae, Sulcus, etc.	Relative Convexity of the Valves	Hinge and Interarea Structures		(P.V. = Pedicle Valve; B. V. = Brachial Valve)
INARTICULATA Lingulacea	Elongate, tongue-shaped to subtriangular	Smooth except for growth lines concentric about the beak region; pedicle grooves occasionally appear as slight depression on shell	Approximately equal with the larger pedicle valve slightly more convex	Short hinge area under beak	Cambrian to Recent	*Lingulella* 
Siphonotretacea	Circular or elliptical or both	Growth lines	Overall conical form with pedicle opening at apex or in front; pedicle valve higher cone and larger than brachial valve; apex of cone is near posterior margin of valve	Interarea inclined at an obtuse angle to the plane between valves; pedicle opening in front of apex of pedicle valve	Cambrian to Ordovician	*Schizambon* 
Discinacea	Circular or elliptical	Growth lines and small pits	Both valves low to moderate conical or discoidal	Pedicle opening is modified slit indenting posterior margin of the pedicle valve located behind the apex of the cone	Ordovician to Recent	*Trematis* 
ARTICULATA Orthacea	Rounded to semielliptical and to subquadrate	Costae radiating from beak area; many forms with sulcus and fold; impunctate shells	Valves of most shells equally convex; a few with concave brachial valve and others with brachial valve more convex	Maximum width of shell commonly at hinge line; relatively short hinge lines where shell is circular in outline; distinct interarea on both valves	Cambrian to Devonian	*Dinorthis* 
Dalmanellacea	Rounded to semielliptical; maximum width is anterior of hinge	Fine radiating costae; general appearance like that of Orthacea; shell punctate	Approximately equal convexity; shell moderately thick and with moderate convexity	Distinct interarea on both valves; pedicle opening generally uncovered	Ordovician to Permian	*Paucicrura* (*Resserella* of authors) 
Triplesiacea	Rounded	Smooth shells to plicated ones with distinct fold and sulcus; impunctate	Approximately equal convexity; shell moderately thick and with moderate convexity	Short hinge line with small interarea; minute pedicle opening	Ordovician to Silurian	*Triplesia* 
Syntrophiacea	Suboval to subrectangular with posterior margin sloping at various angles; maximum width approximately 1/3 to 1/2 the distance from beak to anterior margin; broadly rounded; in most forms shell is wider than long	Shells generally smooth but often have strongly developed fold or plication on pedicle valve and corresponding sulcus on brachial valve; impunctate	Approximately equal	Small interareas behind a short hinge line	Cambrian to Devonian	*Camerella* 
Plectambonitacea	Subrectangular with greatest width at hinge line; width greater than length	Fine radiating costae and faint growth lines; pseudopunctate	Approximately equal low convexity to forms with concave brachial valve and convex pedicle valve; shell relatively flat and thin	Well-developed, narrow interarea on pedicle valve	Ordovician to Devonian	*Sowerbyella* 
Strophomenacea	Subrectangular to almost subtriangular; shell generally larger and more nearly equant in width and length than is the case with the Plectambonitacea	Generally fine radiating costae; growth lines faintly discernible; some forms with highly wrinkled or rugose growth lines; shell pseudopunctate	Shell flat and with concave brachial valve and convex pedicle valve; or may have obverse; some forms with concave to convex relation in early growth stages but with reversal to convex-concave relation in maturity	Well-developed interarea on pedicle valve, but the interarea is narrow; small pedicle opening, if present	Ordovician to Recent	*Rafinesquina* 
Rhynchonellacea	Subtriangular; small to medium-sized	Shells costate and some forms show moderately to well defined sulcus and fold; shell impunctate	Approximately same convexity; shell relatively thick, globose in appearance	Short hinge line, pedicle beak generally pointed; interarea lacking generally	Ordovician to Recent	*Rostricellula* 
Atrypacea	Subtriangular to subquadrate, rounded outline; widest part between 1/3 and 2/3 of distance from beak to anterior margin with anterior part broadly rounded in some forms; shells of Ordovician genera small	Medium-sized costae (some forms smooth) radiating from beak area; small fold and sulcus form near anterior edge; shell impunctate	Valves moderately and about evenly convex; shell moderately thick for overall size of shell	Short hinge line and very small interarea on pedicle valve	Ordovician to Mississippian	*Zygospira*