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PALEOZOIC OSTRACODA: THEIR MORPHOLOGY, CLASSIFICATION AND OCCURRENCE[1]

BY

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General Morphology

The minute bivalved crustacea known as Ostracoda exist in countless numbers in both fresh and marine waters. Just as to-day, so in the past they were exceedingly prolific, certain rock strata being composed almost entirely of their shells and separated valves. The fossil forms moreover are very constant in the lobing, surface ornamentation, and other features of their shells, so that they have become most useful to the few who know them in identifying stratigraphic horizons. In order to increase the number of students of these organisms and thus to widen their application in stratigraphy, it was thought well to prepare the following account including their anatomical and shell structure. This seemed particularly appropriate at this time because of the fact that the greater part of the Silurian faunas of Maryland consists of ostracoda.

ANATOMICAL FEATURES

The ostracoda are small, generally minute crustacea with the entire body enclosed in a horny or calcareous carapace, the right and left sides of which are separate and articulated along the dorsal edge so as to form a bivalved shell. The body is indistinctly segmented and has seven pairs of appendages of which the first two are antennæ, which, like the others, are also adapted for creeping and swimming. These appendages together

[1] Published by permission of the Director of the U. S. Geological Survey and the Secretary of the Smithsonian Institution.

with the caudal extremity of the abdomen are protruded along the ventral margin of the carapace when the valves are opened.

Behind the first two pairs of appendages (antennules and antennæ) is a pair of mandibles, followed by two pairs of maxillæ and finally two pairs of slender legs. The abdomen is short and rudimentary and its extremity may consist of a single spinous plate or may be bifurcated. The details of the anatomy of the animal are shown in the accompanying text figure. With a single exception the fossil species preserve only the carapace valves (see Fig. 11-1) so that the anatomy of the animal is known almost entirely from living species.

A small median eye and two large lateral eyes are commonly developed, the position of the latter being indicated on the exterior of the valves of certain fossil species by a small "eye tubercle" or ocular spot. A distinct heart is not developed. Respiration occurs through a number of respiratory plates fastened to the mouth parts which by their motion keep up a stream of fresh water pouring between the valves. The alimentary and generative organs are generally well developed. Small animals and decaying vegetable matter form their food for the most part.

SHELL CHARACTERS

The valves are closed by a subcentral adductor muscle, the attachment of which is marked on their inner sides by a tubercle, pit, or a number of small spots. The shell is compact in structure, commonly from 0.5 mm. to 4 mm. in length, although in certain doubtful Paleozoic forms (Leperditiidæ) sometimes exceeding 25 mm. The outer surface may be smooth and glossy, or granulose, pitted, reticulose, striate, hirsute, or otherwise marked, the effect being often quite ornamental. The two valves may be of equal size (Primitiidæ) or more or less unequal with either the right or left valve overlapping at the ventral border only (*Leperditia*) or at the dorsal border as well (*Bairdia*), or in some cases overlapping all round (*Cytherella*).

Among the fossil forms, particularly those of Paleozoic ages, the valves are commonly lobed or sulcate or nodose, and variations in the number, position and relation of these surface characters are regarded as important

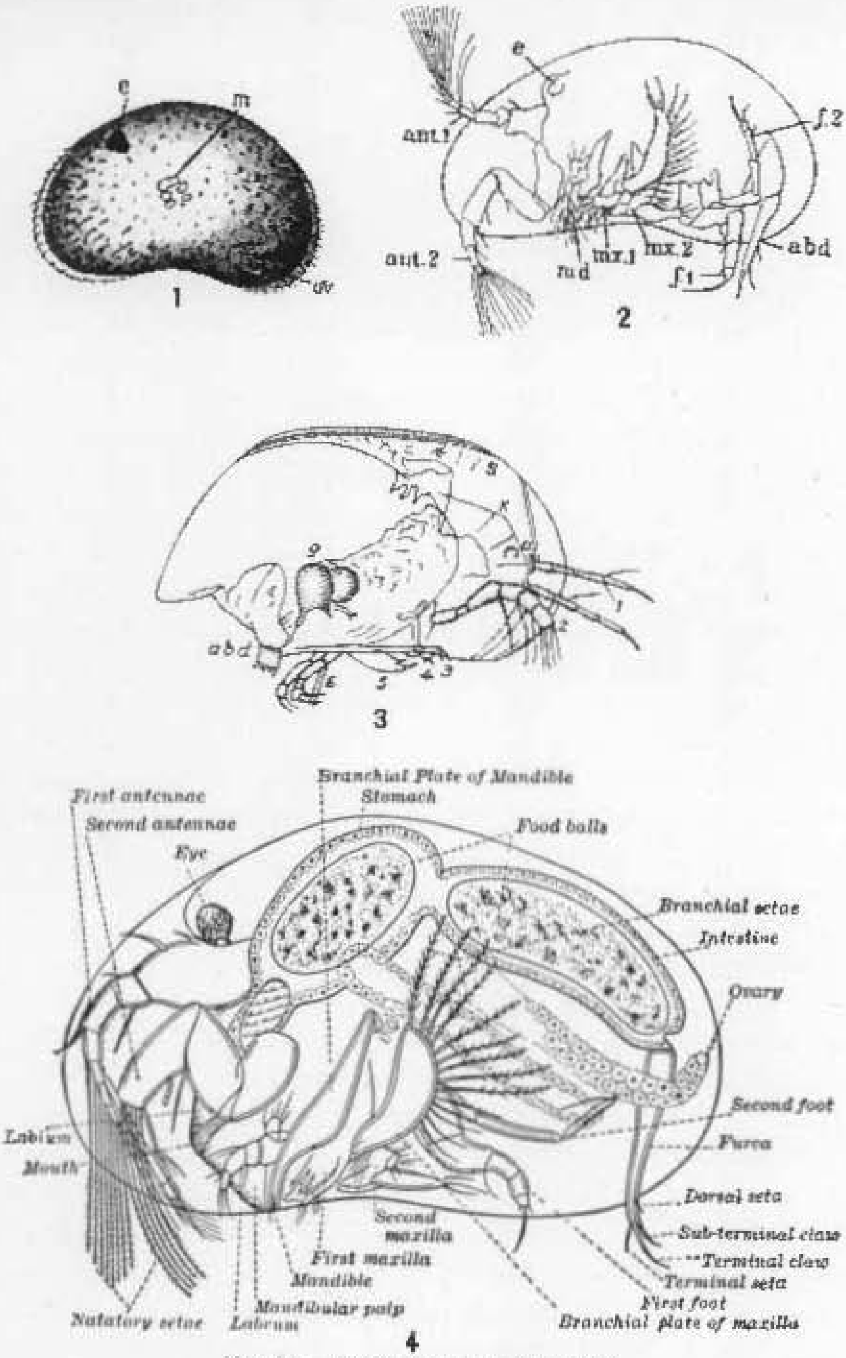

FIG. 11.—ANATOMY OF THE OSTRACODA.

1. Left side of the translucent shell of a recent species of *Cypris*, magnified, showing eye spot (e), the position of the ovary (ov) and adductor muscle scars (m).
2. Sketch showing anatomy of the same species: median eye (e), abdomen (abd), antennule (ant. 1), antenna (ant. 2), thoracic feet (f. 1, f. 2), maxillæ (mx. 1, mx. 2), mandible (md) (figs. 1, 2, after Gerstaecker).
3. Fossil ostracod (*Palaeocypris edwardsi*, Carboniferous of France) preserving the internal structures which are silicified. Shell (s), incomplete behind, abdomen (abd), genital regions (g), antennule (1), antenna (2), mandible (3), premaxillæ (4), maxillæ (5), thoracic appendages (6) (after Brongniart).
4. Detailed anatomy of the recent species *Cypris virens* Jurine (after Vavra). The ends of the adductor muscle are seen in the middle of the figure.

by the paleontologist in segregating the seemingly endless number of species into genera and families. The student of the living depends for his taxonomic criteria almost entirely upon the characters of the soft parts of the animals which are almost never preserved in the fossil state. However, as the lobing of the valves in the fossil forms is developed in similar manner and often even more distinctly on their inner sides than on their exterior surfaces it is evident that the varied lobing and sulcation of the valves and the presence of large protuberances or nodes on the exterior can be nothing else but external manifestations of and conforming to internal anatomical features of the animals themselves. Though it may be, as a rule, impossible to interpret the meaning of these shell characters we may nevertheless appreciate and establish their respective values as taxonomic criteria by noting the relative persistence of each particular feature both severally and in combination with other characters. If the same peculiarity is recognized in a number of otherwise similar yet clearly distinguishable species then we may reasonably infer that it represents some anatomical character of sufficient importance to the animal to require its maintenance and continued development through one or more diverging or parallel lines of genetically allied species. Obviously, too, the relative importance of any single character or any combination of characters is in proportion to its persistence in nature. It follows also that the taxonomic importance of a character is determined not so much by extravagance in development as by its persistence.

Regarding the lobing of the carapace, particularly as developed in Beyrichiidæ and Zygobolbidæ, it may very well be explained as an external manifestation of the segmentation of the animal itself. In the living species the body usually is indistinctly segmented and the abdomen short. But it does not follow that the segmentation in the Paleozoic Beyrichiacea was similarly indistinct or that their abdomen was equally short. On the contrary, if the Ostracoda were evolved, as seems most probable, out of preceding Branchiopoda the chances strongly favor the assumption that in the Beyrichiacea the segmentation of the body was more distinct and the abdomen longer than in recent Ostracoda. At any rate the definite information concerning these parts in the Cambrian Branchiopoda which we owe to the researches of Walcott[1] leaves no doubt regarding the clearness and generally larger number of their segments.

The exceeding persistence of the posterior lobe and the fact that this lobe often is prolonged by curving anteriorly across more or less of the ventral slope of the valves suggests that it received the infolded thorax and abdomen when the animal retreated to and closed the valves of its shell. If this suggestion is well founded, then we get some idea of the length of the thorax and abdomen from the degree in which the posterior lobe is prolonged along the ventral side. They would have been long, for instance, in such Ordovician genera as *Drepanella, Ceratopsis* and *Tetradella,* and relatively short in *Beyrichia* and most of the Zygobolbidæ. This suggestion also gives a plausible explanation of the purpose of the otherwise unexplained submarginal ridge which so often, notably in *Paræchmina* and *Drepanella* dies out on the anterior slope.

Under the law of determining values by relative persistence certain other features of the shell that are less obviously connected with anatomical characters of the animals and which occur mainly among Paleozoic representatives of the class must also be counted as important. We refer here particularly to the false borders which commonly project beyond and hide the true contact edges of the valves. Sometimes, as in the Eurychilininæ, these form frill-like extensions of such great width that it seems impossible that the appendages of the animal could have been protruded beyond their outer edges. Often these frills are developed best or only on the posterior half or two-thirds of the valves and sometimes the concave area beneath them is broken up into loculi. Their purpose is doubtful, the only plausible explanation being that they served for the temporary lodgment and protection of broods of young.

As only the shell of the Ostracoda is found fossil, and since the major classification, as determined from living forms, is based principally upon characters presented by the appendages, the relations of fossil to recent forms is necessarily more or less uncertain and in many instances probably must remain undeterminable.

[1] Walcott, C. D., Middle Cambrian Branchiopoda, Malacostraca, Trilobita and Merostomata, Smithsonian Miscellaneous Collections, 1912, vol. lvii, no. 6.

Most commonly the outline of the carapace is ovate or reniform, and it is always so when the valves overlap on the dorsal side. In many cases, however, either and rarely both ends may be pointed or drawn out in the form of a beak; and when the dorsum is straight, the ends usually join it angularly, the sharper of the two being the anterior. Although usually convex, the ventral margin is sometimes straight or gently concave. In fossil forms it is sometimes impossible to distinguish between the anterior and posterior extremities of the shell but as a rule the posterior half even though of equal or less height than the anterior is somewhat the thicker or blunter in dorsal views. Frequently in certain Middle Paleozoic genera a brood pouch is developed, thus clearly marking the posterior end. The hinge-line may be straight or arcuate, the hinge itself being generally simple, although among the Cytheridæ hinge teeth and corresponding sockets are often developed. Except in the large Leperditiidæ, which may be Phyllopoda rather than Ostracoda, the exterior of the valves only very rarely gives any definite indication of either the small median or the two large lateral eyes that are found in many of the living species.

REPRODUCTION

The sexes in the ostracoda are distinct but usually in the recent species the shells of both sexes are of the same size and shape. In some, however, for example, *Candona*, the males are larger and of different shape while in the well-known *Cypris* the females are the larger. Both the male and female sexual organs are of rather complex structure and variations in their form are regarded by systematists as valuable specific distinctions. Propagation is both by fertilized eggs and by unfertilized eggs or parthenogenesis. In the latter case a number of parthenogenetic generations may be preceded by a sexual one. Again in some species, even after long search, males have never been discovered. These various methods of propagation, namely, always sexual, temporarily parthenogenetic and always parthenogenetic, have been used as distinctions of generic value.

The eggs are covered with limy shells varying in color with the species from white to orange red and dark green. They are laid in characteristic ways, some singly, others in packets on the leaves of water plants and others again in regular rows. Bottom forms crawl to the roots of water plants and then to the leaves where they deposit their eggs and fasten them with threads, having previously scraped off a suitable place with their antennæ. The eggs have great vitality, for those in samples of dried mud after 30 years' time have been hatched. Indeed one student, G. O. Sars, has described many new species of ostracods which he raised from the eggs contained in dried mud sent him from distant countries. The eggs hatch into larval forms, nauplii, which differ greatly from the mature stages into which they pass after many moltings.

So far the rocks have revealed no trace of larval forms of Ostracoda. Indeed the possibility that such may yet be found seems quite hopeless when we consider the altogether unusual conditions, referring especially to the suddenness and permanence of their original burial, that would be required to insure the preservation of such delicate and readily decaying organisms. But the fossil forms are not entirely uncommunicative on so important a factor of reproduction as sex discrimination. There is at least one large group of fossil Ostracoda, in fact it is the most important of the Paleozoic representatives of the class, namely, the Beyrichiacea, in which the individuals of species of many genera are separable by most conspicuous differences, into two kinds that can scarcely indicate anything other than fertilized females on the one hand and males and probably also unproductive females, on the other. In its simplest expression, as in the strongly convex carapaces of *Welleria* and *Plethobolbina*, the difference between the shells of the two sexes consists merely of the slightly greater obesity of the post-ventral half of the individuals that we are designating as females. In its most specialized development, as in the relatively emaciated carapaces of *Beyrichia*, the difference is much more conspicuous, the slight swelling of the surface being represented in these by a large semiovate or subglobular pouch which covers most of the post-ventral quarter of each valve. Between these two extremes the many genera in which such differentiation of the sexes is known, the brood pouch as we call it, affords a great variety of intermediate forms. In others again, especially in the genus *Mastigobolbina*, the brood pouch is extremely large and capacious, covering the posterior two-fifths of the valves. In others again, as in *Mesomphalus*, it forms a long sausage-shaped swelling covering most of the ventral slope. Finally, in the genus *Zygosella*, it forms a narrow curved extra lobe or rounded ridge close to and paralleling the posterior edge.

As a rule these pouches communicate directly with the inner cavity of the shell by means of a large opening just within the contact edges of the valves. As a rule, again, though their bases commonly spread to or beyond the outer edge of the border, their greater part lies on the convex part of the valves within the border. However, in a few Ordovician types, notably *Eurychilina ventrosa*, there is a similar swelling with probably related functions, that is entirely confined to the border and which does not connect directly with the inner cavity of the shell. Another peculiar and entirely external development of the pouch occurs in *Primitiopsis* in which it forms a large simple, externally smooth and obscurely off-set, internally concave addition to one end of each valve. What may prove to be a transition from these external cavities toward the usual internally opening pouches is found in the Baltic Ordovician *Chilobolbina dentifera* Bonnema. In this species the inner third of the pouch lies on the ventral slope of the valve proper. Unfortunately it is not known whether it opens on the inner or outer side of the contact edge.

It has been suggested that these pouches are abnormal, in fact, pathological swellings. But it is inconceivable that anything abnormal or of pathological origin could possibly have been developed with the constancy of form and position that pertains to these pouches. One would expect to find more or less of unrelated irregularities in form, size, position, and surface marking in any abnormal structure. On the contrary, comparison of many hundreds of these female examples, amounting in some instances to more than two hundred of the pouched individuals of the same species, has resulted in absolute failure to discover any such irregularities in the development of the pouches. Indeed, no specific feature is more accurately reproduced in the individuals of a particular species than is the particular form of brood pouch which helps in characterizing it.

DISTRIBUTION

Like all other organisms the distribution of the ostracoda is influenced by the conditions under which they must live, but as a class they are perhaps less sensitive to change in environment than most other classes of animals. Direct light accelerates all their life processes so that the free swimming forms are almost indicative of well lighted areas. Again the forms less able to swim spend most of their existence in the slimy debris and ooze of the bottom. Some forms exist indefinitely in waters that have become quite foul, as in sewers, others live in sulphur water and in hot springs. But practically no species are found in pure cold spring water or well water. Such facts suggest that the ostracoda thrive very well under conditions that would be decidedly unfavorable for the existence of most other kinds of invertebrates. They not only could live under conditions that would usually be regarded as unfavorable, but on account of the minuteness and lightness of the shells these were swept along by waves and currents to places where they did not live; all of which tends to enhance their value as guide fossils. Accordingly we find their remains in all kinds of sedimentary rocks, with little difference as to abundance or kind, whether the rock is a sandstone, a shale or a pure limestone.

The recent Ostracoda, including both the fresh water species and the marine forms, are world-wide in distribution. Not only are many of the species properly termed cosmopolitan, but they are also apparently unlimited bathymetrically. To-day we find them swimming at the surface or creeping over the bottom in great colonies, and after the death of the animal their shells are scattered far and wide, both on the land and in the water.

Many of us in our field work have no doubt come across small pools, sometimes a foot or less in diameter, swarming with fresh-water ostracods. In such instances, as evaporation proceeds, the pool will become a fairly solid mass of ostracods, and finally, when the water has disappeared entirely, their dead shells will be scattered by the winds as dust, sometimes to considerable distances. Fresh-water Ostracoda are therefore a factor in continental deposits. In the sea a similar wide dispersal, independent of the animal's life history, depends on the waves and currents, which bear the dead shells far from their habitat in life and scatter them broadcast, so that their final resting place may be in the shallow littoral deposits.

Most of the modern as well as ancient Ostracoda are of microscopic size, and for this reason, even though in individual development they probably exceed almost every other class, they must always remain an inconspicuous element of any fauna. Another and more serious difficulty, especially in the study of the fossil forms, lies in the simplicity of shell structure found in some of the families. Among the recent faunules, species and even genera, particularly of the smooth shelled families, are established on anatomical characters, the shell being practically disregarded. It is a fact that several distinct genera have shells with essentially the same outline and surface characters. The difficulty, if not impossibility, of distinguishing such genera among fossil forms is obvious. For example, *Bythocypris cylindrica*, an abundant fossil in practically all of the Middle and Upper Ordovician formations is closely differentiated from associated Cypridæ, yet the name possibly covers shells of a number of distinct species that were readily distinguishable by anatomical peculiarities. In fact so far as one can see, its shell is practically duplicated in outline and general structure by those of living species belonging to widely separated genera. For stratigraphic purposes, therefore, most of the Cypridæ have little value. However, this may be said only of these relatively characterless types.

The case is quite different with the much more characteristic Beyrichiacea, which comprise the bulk of the Paleozoic Ostracoda, and the Cytheracea which are so common in the Mesozoic and Cenozoic formations and in the seas of to-day. Nearly all of these are separable into finely drawn and precisely identifiable species and varieties of relatively short duration. When we add to these qualities the already mentioned facts concerning their ready adaptability to all kinds of environment and their exceeding abundance and wide geographic distribution the high value of these remains as guide fossils in stratigraphy is clearly apparent. Moreover because of their small size this value is particularly manifest in determining the age of beds passed through in drilling deep wells.

METHODS OF STUDY

As the fossil ostracoda occur in all kinds of rock ranging from unconsolidated sands or marls to dense hard limestone or sandstone, it is evident that the preparation of specimens for study varies with the matrix. Most of the Mesozoic and Cenozoic ostracoda occur in unconsolidated material from which, after washing away the clay, the specimens

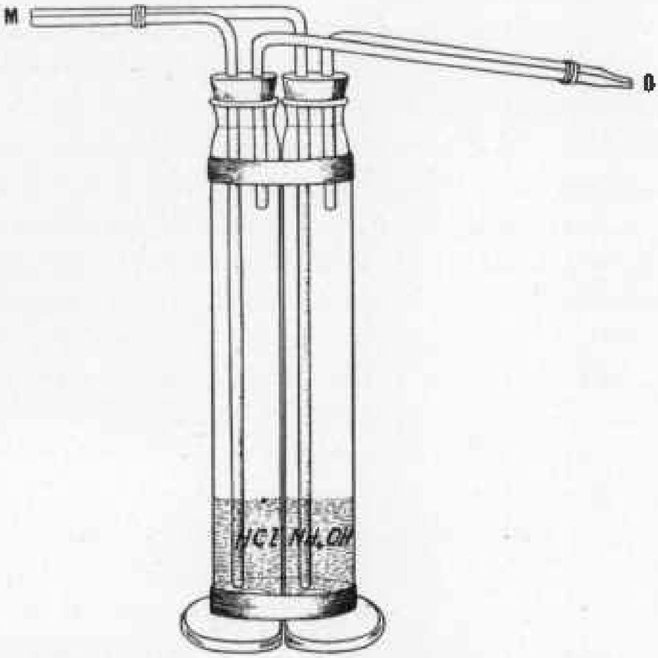

FIG. 12.—APPARATUS FOR WHITENING OBJECTS FOR STUDY.

Blowing through the mouthpiece (M) the fumes of hydrochloric acid (HCl) and ammonia (NH_4OH) unite at O and deposit a thin coating of white ammonium chloride upon the object held a few inches from this point.

are easily picked under a hand lens or binocular microscope. Samples of such rocks supposed to contain ostracoda should be allowed to soak in water for some hours. The material may then be agitated and the muddy water poured away. Continuing this process until the agitated water no longer becomes muddy the residual mass is set aside to dry. The debris when dried is then ready for assorting although passing it through several sieves of different mesh greatly facilitates the assorting of the contained fossils. The ostracoda in such debris may be concentrated at the surface to a considerable extent by gently tapping the containing vessel, because, being light and boat shaped, they have a tendency to rise to the surface.

The frequent occurrence in Paleozoic rocks of a thin seam of shale on top of a fossiliferous limestone bed affords an opportunity to secure the ostracoda as well as other fossils in greater abundance by washing quantities of the shale in the same manner as above described.

For species occurring in solid limestone the procedure is quite different. Specimens in hard clayey limestone may frequently be released from the matrix by the application of caustic potash in stick form and carefully washing and sifting the resulting muddy debris. Crystalline limestones preserve the ostracoda best of all, but here the preparation is more difficult because the rock must be broken to expose the specimen and the edges of the valves as well as the surface features must be carefully uncovered with a fine lithographic pick or needle. As the shell of the ostracoda is frequently very smooth or glossy, the specimens often pop out of the limestone when the latter is broken into small pieces. Such rock should be inclosed in a sack and pounded into comparatively small fragments with a wooden mallet. The resulting debris may then be washed and sifted for ostracoda as before.

In limestone in which upon weathering the fossils tend to become silicified, the ostracoda as well as other organisms may be freed by treatment with dilute hydrochloric acid and then picked out of the resulting debris.

Frequently, as in the sandstones and sandy shales of the Clinton group, the shell has been dissolved away, leaving only the interior and exterior mold of it. These molds often preserve details of structure and surface ornamentation that are but seldom so well shown on specimens in limestone that have been exposed by natural weathering. Very satisfactory replicas of either surface of the valve are procured by means of impressions made of guttapercha or some other plastic material.

The simplest way of preserving ostracoda that have been freed from the matrix is to mount them upon cardboard slips of sufficient size to receive the data concerning them but still small enough to be contained in glass vials.

The shells of many fossil ostracoda are of such a color that the details of the surface structure upon which the criteria for determination depend, are difficult to see and interpret. This is particularly true in the Silurian forms such as the numerous species of *Kloedenellidæ* whose black shells occur by the millions in certain strata. Again the glasslike shells of most of the recent and many fossil species are most difficult to study for the same reason. In all of these cases the surface outlines and markings are brought out in great clearness and perfection by whitening the specimens with a film of ammonium chloride. A simple apparatus for this purpose is shown in text Fig. 12. The hydrochloric acid and ammonia used should be of great strength for the best results, and small quantities only should be employed so that the bottles can be emptied and dried frequently as the reagents not only become weakened by the absorption of water but lose their strength in a day or two of use. The sublimate can be deposited upon the object in such a uniform thin film, varying according to its thickness from light blue to ivory white, that all the details of structure are reproduced perfectly and can be viewed even under the microscope without exhibiting any crystalline structure of the ammonium chloride. The white film can be removed by simply breathing upon the object so coated.

Orientation of the Valves

In the study of fossil Ostracoda the question as to which of the two ends of the carapace is the anterior is the most troublesome and the one on which students have differed most. Jones and other authors commonly followed the rule of regarding the thicker or blunter end as the posterior. In our experience Jones' rule proved much oftener true to nature than misleading. But there were too many exceptions so that it becomes necessary to seek other criteria which might prove less uncertain. Such other criteria were pointed out and discussed by us in an earlier revision of the Beyrichiidæ.[1] Thorough study of these together with all other

[1] Ulrich, E. O., and Bassler, R. S., Proc. U. S. Nat. Mus., vol. xxxv, p. 280, 1908.

Ostracods likely to throw any light on this vexing question resulted in the discovery of four other more or less helpful similarly trending and taken together probably decisive means of solving it. These criteria con-

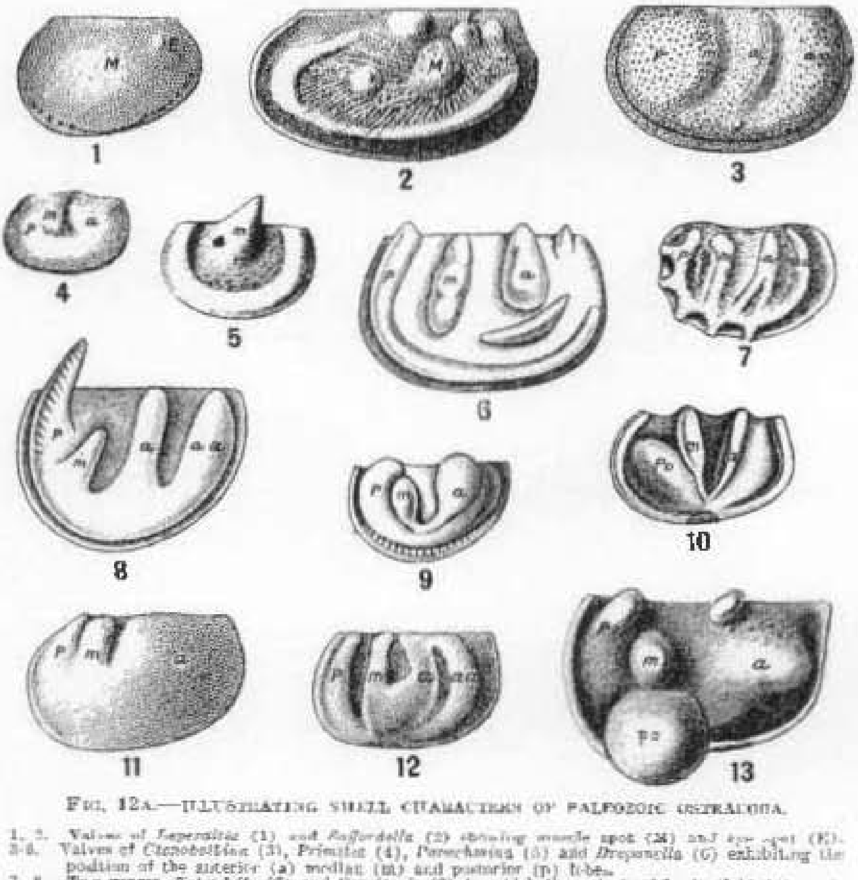

FIG. 12A.—ILLUSTRATING SHELL CHARACTERS OF PALEOZOIC OSTRACODA.

1, 2. Valves of *Leperditia* (1) and *[illegible]* (2) showing muscle spot (M) and eye-spot (E).
3-6. Valves of *Ctenobolbina* (3), *Primitia* (4), *Paraechmina* (5) and *Drepanella* (6) exhibiting the position of the anterior (a) median (m) and posterior (p) lobes.
7, 8. Two genera, *Tetradella* (7) and *Ceratopsis* (8) in which the anterior lobe is divided (a, aa).
9. Lobation in typical *Beyrichia*.
10. Right valve of female in *Zygobolba* showing brood pouch (po).
11, 12. *Kloedenella* (11) with lobation little developed and *Dizygopleura* (12), of the *Kloedenellidae* in which it reaches an extreme.
13. A Silurian species of *Beyrichia* with nodose development of lobes.

cerned (1) the relative width, position and direction of the median furrow or sulcus which was found to be wider than either the anterior or the posterior sulcus, to lie almost always more or less behind the mid-length of the valves and which when prolonged ventrally was found to curve more or less backward; (2) the correlation and identification of the median and posterior lobes, both of which lie behind the median sulcus and usually are distinctly separated by the posterior sulcus though occasionally completely confluent, as in *Ctenobolbina ciliata;* (3) the outline of the valves, particularly in straight-hinged forms, which commonly are more or less oblique and widest behind with a backward swing from the hinge, and which suggests a parallelogram rather than an oblong; (4) the location of the brood pouch which obviously should be associated with the posterior half of the carapace and in fact always lies at least for its greater part, behind the anterior lobe. Another criterion that often is useful rests on the previously suggested purpose of the ventral prolongation of the posterior lobe as a lodging space for the incurved abdomen when the animal retreated to the inside of the shell and closed its valves. If this suggestion is based on fact then it follows obviously that the more persistent end of the submarginal ridge must be posterior and the other end, which may die out at any point between the middle of the ventral side and the antero-dorsal angle, must be directed toward the front. The various features here discussed are illustrated on the accompanying text figure (Fig. 12a).

Criteria in Classifying Fossil Ostracoda

The criteria employed in the study and separation of species of fossil ostracoda refer entirely to the shell. They may be classified under the following headings.

1. Differences in size, outline, convexity of valves and location of greatest thickness. Such distinctions vary greatly in value being used in discriminating varieties, species, genera and families, the values depending on relative persistence of occurrence.

2. Nature of hinge. It is essential to observe whether the hinge is straight, the two valves fitting evenly, or whether articulation is by overlap of the more or less rounded dorsal edge of one or the other.

3. Modification of the hinge. Modifications such as internal denticles (Cytheridæ) or external interlocking processes (Klœdenellidæ) are important and should be carefully noted.

4. Overlap of edges. Studying entire carapaces, it should be observed whether the valves are unequal or equal and when unequal which valve overlaps the other and whether the overlap is mainly or wholly confined to the dorsal edge which is rather rare, to the ventral side a more common occurrence, or takes in the entire circumference, one valve being set into the other. Such modifications are usually considered of generic and family importance.

5. Surface characters of valves. Here it should be observed whether the valves are simple, smoothly convex, or develop terminal spines or a border at the contact edge or a false border which overhangs the contact edges. The false border may be simple or developed into a broad, radially lined frill. This frill may be a simple flat plate or may be convexly bowed to form a marginal chamber beneath it, or it may be modified in various other ways.

6. Lobation of valves. Good generic characters are found in the lobation of the valve. In the simplest forms there is a small subcentral depression or pit (probably always indicating the attachment of the adductor muscles) which may be prolonged slit-like as a sulcus to the dorsal edge or extended toward the ventral margin. In other forms there is a node on either side of the pit which may be modified into long lobes. The lobe posterior to the median sulcus is designated the median lobe. This may be defined on its posterior side by another sulcus thus separating a posterior lobe. Anterior to the median sulcus is the anterior lobe which is often again divided by another sulcus. These three lobes are present in one form or another in practically all of the Beyrichiacea and variations in their development always afford good specific characters and often distinguish genera. Any or all these lobes may be prolonged into spines dorsally. The confluence of the lobes or their immersion in the general surface by an increase in convexity of the valves or their breaking up into smaller nodes or ridges are all to be noted and are of varying importance. Excellent examples of these features occur in the Klœdenellidæ and Beyrichiidæ.[1]

[1] Ulrich, E. O., and Bassler, R. S., Revision of the Beyrichiidae, Proc. U. S. Nat. Mus., vol. xxxv, pp. 277-340, 1908.

7. Surface ornamentation. As a rule reticulation and other forms of surface ornament of the valves are not of generic importance but are always useful in specific determinations. Crest-like ribs traversing the surface irrespective of the lobes, or crowning them, as in *Steusloffia, Mastigobolbina* and *Strepula,* are commonly regarded as of higher value.

8. Sex characters. The presence or absence of a separate pouch-like swelling regarded as a brood chamber for the development and protection of the larvæ in many of the Beyrichiacea is regarded as a generic character.

STRATIGRAPHIC OCCURRENCE, ORIGIN AND CENTERS OF DEVELOPMENT AND DISTRIBUTION

Many species supposed to be Ostracoda have been described from Cambrian rocks, but recent unpublished studies show that all of these are bivalved Branchiopoda and possibly true Conchostraca. The oldest of the forms still retained in the Ostracoda are members of the family Leperditiidæ which also may have to be removed to some other order. However, as the Leperditiidæ are the only known group of Eucrustacea from which the true Ostracoda might have been derived the most logical course provisionally is to leave them as hitherto, namely, the first family of the superorder Ostracoda.

Accordingly, beginning with the Leperditiidæ the Ostracoda make their first appearance in the Middle to Upper Canadian rocks of America in which apparently nearly typical species of *Isochilina* have been found in the south central states of Tennessee, Missouri, Arkansas and Oklahoma, and in the Champlain Valley of the northern Appalachian region. The faunas with which these occur, likewise the regions in which they have been found, suggest that they originated in the south and middle Atlantic and invaded the American continental seas of the time from those directions. So far none have been found in Pacific or European deposits of Canadian age. During the Ordovician the Leperditiidæ increased in importance and extended their range in east, north and west directions while holding their own in the south. But following the Trenton they seem to have become extinct in the southern waters, no Leperditiidæ being known in any later Ordovician or Silurian fauna concerning which anything like certainty prevails regarding its southern origin. In the northern Atlantic and Polar regions, on the contrary, the genus *Leperditia* attained its maximum development both as to size and abundance of individuals and species. This greatest development preceded only a relatively short time the final extinction of the family in the early Devonian.

The oldest of the smaller true Ostracoda are found in the lower Ordovician rocks of the Chazyan series. They include Aparchitidæ—which probably were directly derived out of Leperditiidæ and attained their maximum development in the Ordovician—and a great number of primitive Beyrichiacea. The Aparchitidæ are most abundant in the Stones River and Black River faunas that invaded from the south, are entirely absent in the succeeding southern Ordovician and Silurian, but reappear in modest numbers in the Onondaga Devonian and certain late Mississippian faunas. The family is not represented in the Chazyan faunas of the middle and northern Appalachians, but in the late Black River its most typical representatives had spread to the Polar seas from which it invaded to Minnesota with the Decorah fauna. During the Silurian the Aparchitidæ seem to have been confined to the north Atlantic, leaving a few representatives in the Appalachian and St. Lawrence faunas of that time and more of them in the Wenlock of England and the Gotlandian of Sweden.

The Beyrichiacea are already strongly represented in the early Chazyan deposits, especially in those of the southern Appalachian region and in the Simpson formation of central Oklahoma, by various types of the relatively simple Primitiidæ and Eurychilininæ. Though probably originating in the south Atlantic these soon attained cosmopolitan distribution, being found in lower and middle Ordovician deposits in Nevada, the Mississippi Valley, the Appalachian region from Alabama to Canada, Great Britain, the Baltic provinces and other regions. Some of the later more specialized genera of the family apparently were of relatively short duration and limited in geographic distribution. For instance, the late Ordovician *Jonesella* seems to have been confined to southern faunas of Eden age; *Dicranella* and *Dilobella* to northern invasions of late Black River and Trenton ages; and *Primitiopsis* to the Silurian of the Baltic region. The extraordinary horned genus *Aechmina*, although first described from Silurian species found in England and the Island of Gotland, began much earlier in America where we find an incipient species in the lower Ordovician, a typical representative in the upper Ordovician, and at least one Silurian and one early Devonian species. The closely related *Paraechmina*, on the contrary, though also a middle Atlantic type is unknown in Europe, but widely distributed and represented by many species in eastern America.

The Beyrichiidæ also seem to have originated in the south during the Ordovician though they delayed their advent to the middle Ordovician. The Ordovician genera of the family differ from their Silurian descendants in having the anterior lobe divided, making them quadrilobate instead of trilobate, also in lacking the brood pouch which generally distinguishes the female in the Silurian genera. It is interesting to note that in the decadence of the family, which became largely extinct in the Devonian and entirely so in the Mississippian, at least one of the genera (*Hollina*) reverts to the primitive quadrilobate stage. Others are so much like middle Ordovician species of *Ctenobolbina* and *Ceratopsis* that one is left in doubt whether they should be regarded as survivors or as reversionary new developments. Ordovician Beyrichiidæ occur somewhat sparingly in northwestern Europe but the more prominent of the American genera, particularly those associated with distinctively southern faunas, are unknown there. Directly the opposite is true of the Silurian Beyrichiidæ. These are exceedingly abundant and varied in structure in northwestern Europe but exceedingly rare in American Silurian faunas that invaded from the south. Even more unexpected is the fact that they are wanting also in the northern Silurian faunas. But all ostracoda are practically wanting in the Silurian of interior America except in those faunas that are definitely known to have invaded from the Atlantic side.

The Silurian Atlantic invasions gave us the exceedingly prolific ostracod faunas of the Appalachian region which are described in this volume. So far as known it was only during the closing stages of the Clinton that these Atlantic invasions extended westward into interior areas that commonly were subjected to alternating northern and southern invasions.

The most important if not the only well-established instances of such westward extensions are (1) the commingling of distinctively Atlantic ostracods like *Dizygopleura* and *Paraechmina* with normally southern types of bryozoa and other classes of fossils in the Rochester shale of western New York; (2) the extension of the fauna of the *Mastigobolbina typus* zone of the upper Clinton in uncontaminated condition from southwestern Virginia across Kentucky into southern Ohio where it is confined to a definitely limited formation known as the Alger formation; and (3) the similar extension of the *Drepanellina clarki* fauna at the top of the Clinton to the same part of southern Ohio. As the concerned faunal zone is wanting in Virginia, the latter invasion of Ohio must have followed a different path. Evidently it turned more directly westward from Pennsylvania or Maryland. Another interesting feature concerning it is the fact that whereas the *Drepanellina* fauna occurs in a shale formation with few to many thin layers of pure limestone in Maryland and Pennsylvania, in Ohio, on the contrary, it is found in a slightly cherty dolomite known as the Bisher member of the West Union formation.

Like the typical Silurian Beyrichiidæ so also the Zygobolbidæ, the Kirkbyidæ and the Klœdenellidæ of the same period, are almost entirely confined to faunas that must have invaded America from the north middle Atlantic. Many of the genera of these families are suggested or represented by primitive types in the southern lower and middle Ordovician faunas but only *Drepanella*, which is prominently considered as a probable ancestor of the Zygobolbidæ, appears in any post-Ordovician southern fauna. After a long absence from southern faunas, lasting through the upper Black River, Trenton, Eden and Maysville ages, this genus reappears with a single well-marked species in the lower Richmond of Ohio. The same species occurs also in the lower part of the red Juniata and Sequatchie formations in southwestern Virginia and Tennessee, and in red beds of the age of the Queenston shale near Toronto, Canada. So far as known there is no reason to doubt the essential contemporaneity of these widely separated occurrences.

The Cypridacea began in the lower or middle Ordovician and have lived on to the present. They seem also to have attained cosmopolitan distribution early in their history. They may therefore be expected in almost any fossiliferous bed, but on account of their simple, relatively characterless shells we often find it difficult to reach entirely satisfactory decision as to their specific and generic relations. The Cypridacea probably originated in southern seas by development out of *Aparchites*. In some of the lower and middle Ordovician species of that genus there is a tendency to a rounding of the dorsal edge and it seems but a step from these to forms in which the hingement is made by dorsal overlap of the valves. Besides the oldest of the latter forms are relatively short and thus are more nearly comparable in outline to average Aparchitidæ. Finally, so far as known, the Aparchitidæ preceded the Cypridacea.

Living genera of other families have been identified, mainly by Jones, in Paleozoic formations. Notable among these is *Cytherella*, *Cypridina* and *Xestoleberis*.

In all of these cases the plain shells of the Paleozoic species certainly resemble their supposed living relatives, but when there is nothing in the intervening system at all like either, some doubt as to the generic identity of the Silurian or later Paleozoic species and the living types of the genera seems pardonable.

That unquestionable Cytheracea occurred already in Paleozoic faunas is not unlikely. It is probable, if only for the reason that this superfamily is so well represented in Mesozoic and Cenozoic faunas that one cannot well escape the conviction that the Mesozoic forms were descendants of a previously well-established tribe. In any event there are a few, mostly undescribed, middle Devonian species and others in the Mississippian and Pennsylvanian that fit but poorly in the Kirkbyidæ and clearly foreshadow the Cytheracea. According to present information and referring only to described species the Cytheracea were derived out of relatively simple Kirkbyidæ, like *Youngiella*, and these out of some simple primitian stock like *Primitiella*.

From preceding statements certain generalized conclusions may be drawn. In the first place it seems reasonably certain that the Ostracoda originated in southern seas by development through early Leperditiidæ out of bivalved Branchiopoda. Next, that in the middle and later stages of the Ordovician a great expansion of the superorder both as regards variety of expression and geographic distribution occurred, all of the main Paleozoic families being introduced in this period. Third, during the middle Ordovician there seems to have been a decided shifting of the Ostracoda from the southern seas to the northern. This was accompanied by considerable changes in type. Thus while the Ostracoda of the Stones River and early Black River faunas, which are of southern origin, consist mainly of Leperditiidæ, Aparchitidæ and Eurychilininæ, the next succeeding late middle and upper Ordovician deposits in the Baltic region of Europe and in the northern areas of North America, which came in from the Arctic and north Atlantic sides, contain only few of these but instead a larger development of primitive types of Beyrichiacea. Further, all types of Ostracoda save the Leperditidæ and the already cosmopolitan genus *Eurychilina* are rare in the rocks of Trenton age in the Mississippi and Appalachian valleys. But the succeeding lithologically similar Cincinnatian deposits in the Ohio valley lack all Leperditiidæ and Eurychilininæ and almost all Aparchitidæ, whereas they show a great addition of species closely akin to the late Black River forms that are found in America north of Missouri and in the Baltic region of Europe.

In passing from the Ordovician to the Silurian the Beyrichiacea manifested also a striking structural or rather sexual change. Brood pouches were only very rarely developed in Ordovician genera and the few Ordovician instances of anything comparable to those pouches are confined to species of *Eurychilina*. However, in the Silurian representatives of the superfamily brood pouches are generally developed in what we take to be fertilized females of nearly all the Beyrichiidæ and Zygobolbidæ. The pouch was adopted at this time also by all of the surviving Eurychilininæ and occurs even in a few of the Primitiidæ, notably in the new Bollia-like genus *Bolbibollia*. In fact, the common occurrence of pouched Beyrichiacea may be accepted as a reasonably positive indication of the Silurian age of Ostracoda so provided. A clearly recognizable brood pouch is retained by only a few of the Devonian Beyrichiidæ, particularly *Treposella*, and seems to have been abandoned by all other ostracods of this and subsequent periods.

The almost total absence of Ostracoda save *Leperditia* in the North America Silurian faunas that invaded from the north and the south in contrast to their extraordinary abundance in north middle Atlantic faunas suggests a fourth conclusion, namely, that the exclusion of the ostracoda from the Gulf of Mexico in the south and the Arctic sea in the north could have been brought about only by the development of physical barriers which prevented free communication with the middle Atlantic. And this barrier lasted with but a single known and very brief interval until the Onondaga invasion from the south.

In the Devonian period the general aspect of the Ostracoda changes markedly. True Leperditiidæ have practically disappeared, only a few stragglers occurring in the lower beds of the Helderbergian. The Beyrichiidæ have evolved into new generic groups with a quite different aspect. The hitherto poorly represented genera, like *Kirkbya, Octonaria, Thlipsura*, etc., now make up a considerable portion of the total number. It appears that the area of development and dispersal was again shifted back to south and middle Atlantic waters. The general aspect of this ostracod fauna was not materially changed until the close of the Mississippian. In abundance and variety American Devonian ostracods are in contrast with those of Europe because the latter are so poorly developed.

Except as sporadic occurrences the Ostracoda are abundant in the Mississippian only in a thin zone near the top of the Kinderhook stage and in the Golconda and Glen Dean formations of the Chester series. In the Pennsylvanian a number of types not hitherto seen are introduced, the notched Cypridinoids, primitive Cytheriidæ, and numerous Cythereloids. At this time also a host of fresh-water forms are introduced—the first known. By this time the marine Ostracoda have become so cosmopolitan that the locus of their development can no longer be traced. In succeeding time the fresh-water forms become more and more abundant. They are frequently found in the Red Beds of the West, and layers are often almost made up of them in the land deposits of the Cretaceous and Tertiary. Although a few can be determined as land forms, many others are so similar to the marine Cypridæ that on their own evidence it would be almost impossible to decide that they are actually land forms and not marine.

The marine Cretaceous and Tertiary ostracods consist almost entirely of Cytheracea and Cypridæ and the general aspect of these is very similar in the two systems, the differences being only specific. A large number of these has been described from European deposits of these ages, particularly from the Paris basin of France and southern England and the Vienna basin of central Europe. Some of the American Tertiary marine representatives have been described in the Maryland reports but many others from the southern Coastal Plain remain to be described. However, the host of Cretaceous species known from American deposits are wholly untouched.

Similarly little difference can be detected between Tertiary ostracods and their modern descendants, although on account of the facilities for studying the anatomy of the soft parts it has been possible to distinguish many genera among the living forms that cannot be certainly determined among the fossil forms.

CLASSIFICATION AND DIAGNOSIS OF PALEOZOIC OSTRACODS

Family LEPERDITIIDAE Jones (restricted)

Extinct, thick-shelled ostracoda of considerable size (5-30 mm.); shell smooth and glossy, of very compact structure; valves more or less unequal, one overlapping the other on the ventral side, usually with eye tubercle, otherwise smooth or with two or three low nodes in the antero-dorsal quarter; muscle spot reticulate, flat or elevated; hinge line straight; anterior and posterior ends obliquely truncated or rounded and neither gaping nor excised. (Fig. 13.)

Genus LEPERDITIA Rouault

Shell suboblong with an oblique backward swing, usually large, commonly exceeding 8 mm. in length. Ventral edge thick, formed by the overlap of the right valve. Valves strongly unequal, the right the larger and widely overlapping the ventral edge of the left; hinge simple. A small tubercle or "eye-spot" is generally present on the antero-dorsal fourth while a large rounded subcentrally situated muscular imprint is a well marked feature of the interior and sometimes distinguishable even on the exterior.

Genotype.—*Leperditia brittanica* Rouault. Canadian, early Devonian.

Genus ISOCHILINA Jones

Like Leperditia except that exteriorly the valves do not overlap but seem to be equal in every respect. In reality within the left valve there is

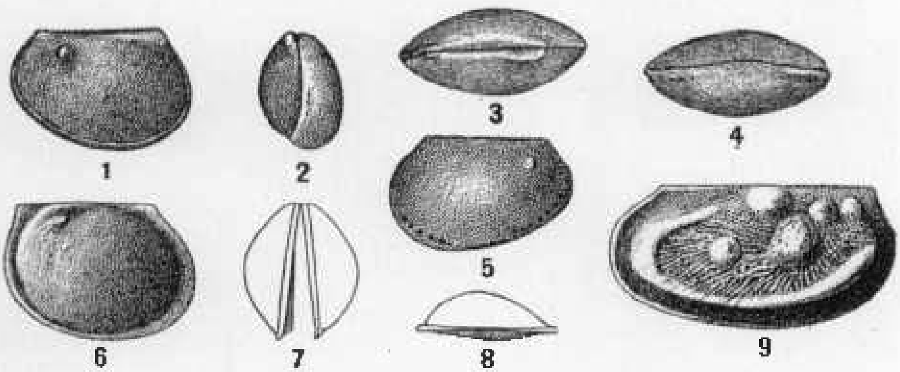

FIG. 13.—ILLUSTRATING THE FAMILY LEPERDITIIDÆ.

1-5. *Leperditia* Rouault. 1. Left side of an entire carapace of *Leperditia jubilitae* Conrad, × 2, illustrating the large size, the eye spot and the characteristic overlapping ventral edge of the larger right valve. 2-4. Posterior, dorsal and ventral edge views of the same specimen. 5. Cast of the interior of the right valve, × 2, showing impression of two sets of internal papillæ along the ventral margin. Their purpose is to prevent undue overlapping of the valves. Ordovician (Black River) limestone of Minnesota.
6-8. *Isochilina* Jones. 6. Left valve of *Isochilina jonesi* Wetherby, × 1.3, showing eye spot, large size and other resemblances to *Leperditia* but differing in that the two valves are nearly equal. 7. End view of two valves, separated so as to show the overlap. 8. Ventral edge view of left valve, natural size, showing sloping area which is overlapped by the right valve. Ordovician (Trenton) limestone, Harrodsburg, Kentucky.
9. *Saffordella* new genus. Complete example of left valve of genotype *Saffordella muralis* n. sp. Mohawkian (Catheys limestone) Nashville, Tenn.

a sloping area that is overlapped by a corresponding bevelled edge of the right valve. Surface sometimes lobulate or nodose.

Genotype.—*Isochilina ottawa* Jones. Ordovician, Silurian.

Genus SAFFORDELLA new genus

Similar to Isochilina except that the surface is more nodose and has a long curved submarginal ridge.

Genotype.—*Saffordella muralis* n. sp. Mohawkian (Catheys) limestone, Nashville, Tenn.

Family APARCHITIDAE new family

Simple, unsulcated, smooth ostracoda usually larger than the average size (2 to 3 mm.) with straight hinge line and thickened, often channelled, free edges, the edge of one valve sometimes slightly overlapping the other ventrally. Dorsal region often protruding over the hinge line. (Fig. 14.)

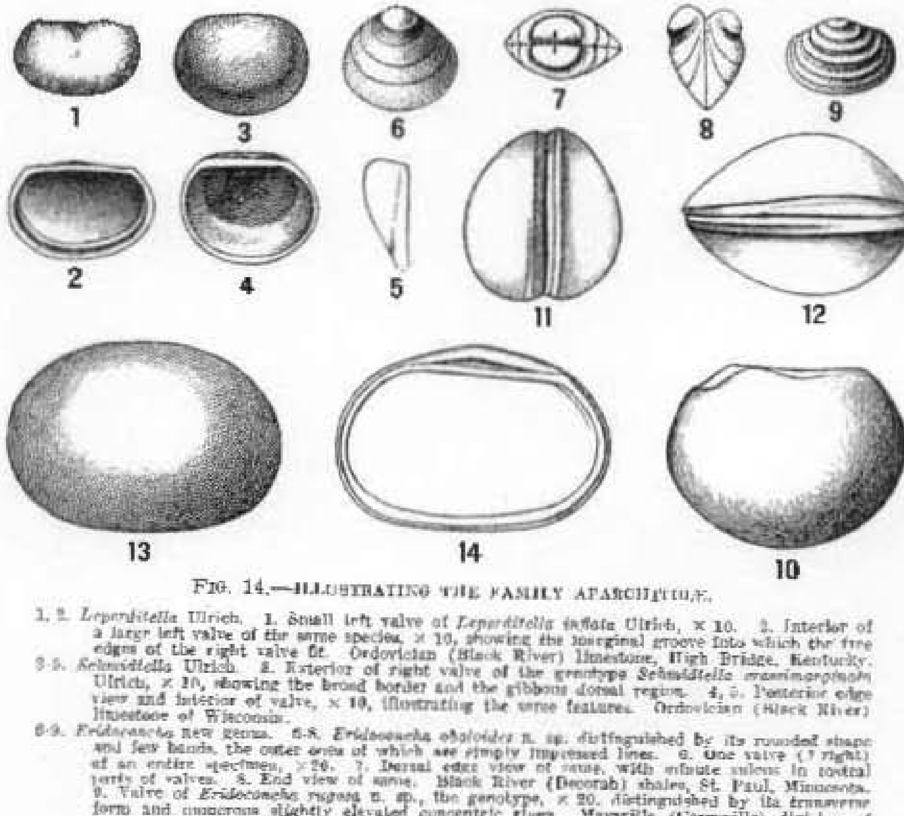

FIG. 14.—ILLUSTRATING THE FAMILY APARCHITIDAE.

1, 2. *Leperditella* Ulrich. 1. Small left valve of *Leperditella inflata* Ulrich, × 10. 2. Interior of a large left valve of the same species, × 10, showing the marginal groove into which the free edges of the right valve fit. Ordovician (Black River) limestone, High Bridge, Kentucky.
3-5. *Schmidtella* Ulrich. 3. Exterior of right valve of the genotype *Schmidtella crassimarginata* Ulrich, × 10, showing the broad border and the gibbous dorsal region. 4, 5. Posterior edge view and interior of valve, × 10, illustrating the same features. Ordovician (Black River) limestone of Wisconsin.
6-9. *Eridoconcha* new genus. 6-8. *Eridoconcha obolloides* n. sp. distinguished by its rounded shape and few bands, the outer ones of which are simply impressed lines. 6. One valve (? right) of an entire specimen, × 20. 7. Dorsal edge view of same, with minute sulcus in central parts of valves. 8. End view of same. Black River (Decorah) shales, St. Paul, Minnesota. 9. Valve of *Eridoconcha rugosa* n. sp., the genotype, × 20, distinguished by its transverse form and numerous slightly elevated concentric rings. Maysville (Corryville) division of the Ordovician at Cincinnati, Ohio.
10-12. *Aparchites* Jones. 10. Exterior of valve, × 10. 11, 12. Anterior end and ventral views of an entire example of the genotype *Aparchites whiteavesi* Jones, × 10, showing valves with thickened edge but not overlapping. Ordovician (Trenton) of Manitoba.
13, 14. *Paraparchites* Ulrich and Bassler. 9. Exterior of valve, × 20, of the genotype *Paraparchites humerosus* Ulrich and Bassler. 10. Interior of right valve, × 20, showing a linear socket for reception of edges of opposite valve. Upper Carboniferous of Kansas.

Genus APARCHITES Jones

Shell not exceeding 3 mm. in length, equivalved, subovate or oblong; hinge straight, ventral edge thickened, often bevelled or channelled; surface convex, mostly in the ventral half, smooth.

Genotype.—*Aparchites whiteavesi* Jones. Ordovician, Silurian.

Genus LEPERDITELLA Ulrich

Similar to Aparchites but the left valve is larger and has a groove within its ventral border into which the simple edge of the right valve is received. A more or less obscure broad depression is generally present in the central part of the dorsal half. Length 1 to 3 mm.

Genotype.—Leperditia inflata Ulrich. Ordovician, ? Silurian.

Genus SCHMIDTELLA Ulrich

Unsulcated shells, 2 mm. or less in length, short, subovate, broadly umbonate, most convex in the dorsal region and pinched in ventral slope; right valve overlapping the left along the ventral margin.

Genotype.—Schmidtella crassimarginata Ulrich. Ordovician, Silurian.

Genus ERIDOCONCHA new genus

Small, apparently unequivalved carapaces with concentric, simple or rugose bands or rows of punctæ, resembling an equilateral pelecypod or a brachiopod in shape and markings.

Genotype.—Eridoconcha rugosa n. sp. Ordovician, Silurian.

Superfamily BEYRICHIACEA

Family PRIMITIIDAE new family

Relatively simple Beyrichiacea with undefined to well defined median sulcus or simple submedian pit. (Fig. 15.)

Genus PRIMITIELLA Ulrich

Small straight-backed, equivalved shells with a broad undefined median depression mainly in the dorsal half of the valves and with narrow border.

Genotype.—Primitiella constricta Ulrich. Ordovician, Devonian.

Genus HAPLOPRIMITIA new genus

Distinguished from Primitia by the absence of a border along the free edge of valves and occurrence of a simple slit-like furrow in the dorsal half.

Genotype.—Haploprimitia (Primitia) minutissima Ulrich. Ordovician, Devonian.

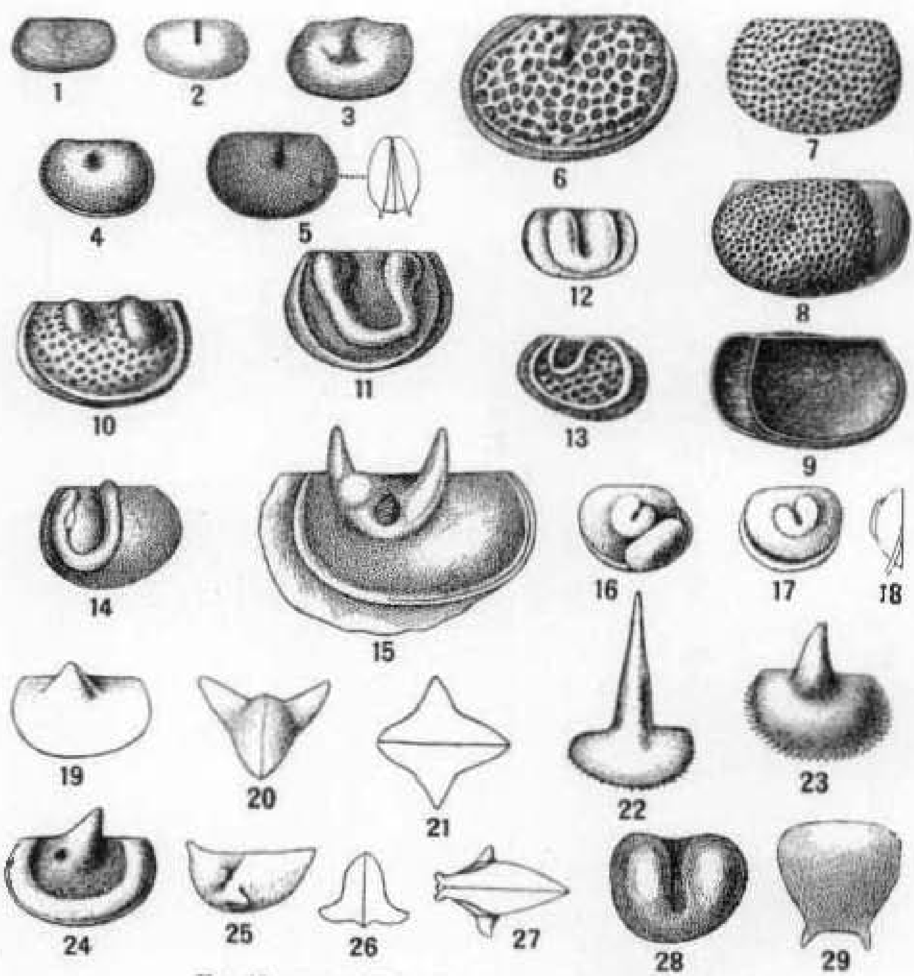

FIG. 15.—ILLUSTRATING THE FAMILY PRIMITIIDÆ.

1. *Primitiella* Ulrich. Right valve, of *Primitiella constricta* Ulrich, × 20, showing the characteristic broad undefined mesial depression. Black River (Decorah) shales, Minneapolis, Minn.
2. *Haploprimitia* new genus. Left valve of *Haploprimitia* (*Primitia*) *minutissima* Ulrich, × 40, illustrating absence of border and occurrence of simple slitlike furrow in dorsal half. Black River (Decorah) shales, Fountain, Minn.
3. *Primitia* Jones and Holl. Right valve, × 20, of *Primitia cincinnatiensis* Miller, a typical species of the genus with the low node indicated on the posterior side of the curved sulcus. Early Silurian (Richmond) shales of southwestern Ohio.
4. *Laccoprimitia* new genus. Left valve, × 20, of *Laccoprimitia* (*Primitia*) *centralis* Ulrich showing the characteristic single, simple, subcircular pit a little above the midheight, and the border. Ordovician (Trenton) limestone, West Covington, Kentucky.
5. *Euprimitia* new genus. Right valve of the type species, *Euprimitia* (*Primitia*) *sanctipauli* Ulrich, × 20, and end view of entire carapace, exhibiting the simple sulcus, the double border and the reticulate ornament. Ordovician (Black River) shales, St. Paul, Minn.
6. *Halliella* Ulrich. Right valve, × 20, of *Halliella retifera* Ulrich, the genotype illustrating the coarsely reticulate surface, the broad sulcus and the thick border. Devonian (Onondaga) limestone, Falls of the Ohio.
7-9. *Primitiopsis* Jones. Three views of the genotype *Primitiopsis planifrons* Jones, × 20. 7. Male left valve, × 25. 8, 9. Exterior and interior views of the female left valve, × 20, showing form and position of brood pouch. Silurian, Island of Gotland.
10. *Ulrichia* Jones. Left valve, × 30, of *Ulrichia conradi* Jones, showing a well-developed node on each side of a scarcely visible sulcus. Middle Devonian shales, Thedford, Ontario.
11, 12. *Bollia* Jones and Holl. 11. Right valve, × 20, of *Bollia bicollina* Jones and Holl showing the ventral loop and the marginal ridge. Silurian at Wenlock, England. 12. Right valve of *Bollia ungula* Jones, × 20, showing a different expression of the genus. Devonian of Western Maryland.
13. *Placentula* Jones and Holl. Valve, enlarged, of *Placentula excavata* Jones and Holl, illustrating resemblance to *Bollia* but the loop is smaller in front of the rudder. Silurian of England.
14. *Jonesella* Ulrich. Right valve, × 18, of *Jonesella crepidiformis* Ulrich, with characteristic curved ridge on the posterior portion. Ordovician (Eden) shales at Cincinnati, Ohio.
15. *Dicranella* Ulrich. Right valve, × 20, of *Dicranella bicornis* Ulrich. Ordovician (Black River) shales, Minneapolis, Minn.
16-18. *Bolbibollia* new genus. Views of the genotype *Bolbibollia labrosa* n. sp., × 20. 16. Left valve of female form showing the brood pouch. 17, 18. Right valve of male and edge view of same. In this species the yokelike loop is small and low and its axis is oblique to the hinge line. The cardinal angles are very obtuse and a thick false border occurs around the ventral half. Silurian (Anticostian-Jupiter River), Jumpers, Island of Anticosti.
19-23. *Aechmina* Jones and Holl. 19-21. Lateral, end and ventral views, × 20, of *Aechmina richmondensis* n. sp., closely allied to *Aechmina bovina* Jones but longer and lacks the small spines on the ventral edge of valves. Early Silurian (Richmond-Elkhorn) Richmond, Indiana. 22. Left valve, × 20, of *Aechmina cuspidata* Jones and Hall, showing the extraordinary development of the spine. Devonian (Helderbergian) limestone of Western Maryland. 23. Left valve of the genotype *Aechmina bovina* Jones, × 30, with marginal row of spines well developed. Silurian (Wenlock) England.
24. *Paraechmina* new genus. Right valve, × 20, of *Paraechmina* (*Aechmina*) *spinosa* Hall, the genotype, illustrating the characteristic ridge along the free edge, the spine and the pit near its base. Silurian (Rochester shale) Lockport, N. Y.
25-27. *Acronotella* new genus. Lateral, end and ventral views of the genotype *Acronotella shideleri* n. sp., × 20. Early Silurian (Richmond-Elkhorn) Richmond, Ind.
28. *Dilobella* Ulrich. Valve, × 20, of *Dilobella typa* Ulrich, illustrating the two large subequal lobes separated by a deep subcentral sulcus. Ordovician (Black River) shales, St. Paul, Minn.
29. *Bursulella* Jones. Valve of *Bursulella triangularis* Jones, × 20. Silurian, Island of Gotland.

Genus PRIMITIA Jones and Holl

Distinguished from Primitiella by having a well-marked subcentral, usually curved sulcus with undefined swellings or low nodes on one or both sides of it instead of an undefined depression. As a rule also the valves are shorter, the outline being generally more ovate.

Genotype.—Primitia mundula Jones. Ordovician, Permian.

Genus LACCOPRIMITIA new genus

Valves with a border along the free edge, a single, simple subcircular pit a little above the mid-height and without surface nodes. Otherwise as in Primitia.

Genotype.—Laccoprimitia (*Primitia*) *centralis* Ulrich. Ordovician, Carboniferous.

Genus EUPRIMITIA new genus

Like typical Primitia except that the carapace has a simple sulcus, reticulate ornamentation and an elevated false border around the free edge of the valve, making a bicanaliculate edge in the entire closed carapace.

Genotype.—Euprimitia (*Primitia*) *sanctipauli* Ulrich. Ordovician, Silurian.

Genus HALLIELLA Ulrich

Like Euprimitia but with broader sulcus and very coarsely reticulate surface which rises to greatest height in antero-dorsal quarter. Thick double border.

Genotype.—Halliella retifera Ulrich. Ordovician, Devonian.

Genus PRIMITIOPSIS Jones

Oblong, strongly convex, borderless shells with a sharply defined but small, deep, subcentral pit and reticular ornament. In the female a rather wide internally concave and distinctly smooth area along the posterior side represents the brood pouch. Female, therefore, much longer than the male.

Genotype.—Primitiopsis planifrons Jones. Silurian, Devonian.

Genus ULRICHIA Jones

Differs from Primitia by having a sharply defined node on each side of the sulcus, which in this case is scarcely impressed. Occasionally other nodes are present on the ventral half of the surface.

Genotype.—Ulrichia conradi Jones. Ordovician, Devonian.

Genus BOLLIA Jones and Holl

Distinguished by a centrally situated loop-like or horseshoe-shaped ridge, the free upper extremities of which are often bulbous; a more or less complete marginal ridge may be present or wanting.

Genotype.—Bollia uniflexa Jones and Holl. Ordovician, Carboniferous.

Genus PLACENTULA Jones and Holl

Probably related to Bollia but differing in having the " loop " generally in front of the center and close to the dorsal margin. As a rule a rim-like ridge parallels the outer border of the valves.

Genotype.—Placentula excavata Jones and Holl. Ordovician, Silurian.

Genus JONESELLA Ulrich

Small oblong or subovate borderless ostracoda distinguished by a horseshoe or L-shaped ridge on the posterior two-thirds.

Genotype.—Jonesella crepidiformis Ulrich. Ordovician, Silurian.

Genus DICRANELLA Ulrich

Distinguished from Ulrichia in having one or both nodes developed into long, horn-like, diverging prominences and usually with a broad frill-like border along the free edge of valves.

Genotype.—Dicranella bicornis Ulrich. Ordovician.

Genus BOLBIBOLLIA new genus

Like Bollia but males and females distinct, the latter with brood pouch.

Genotype.—Bolbibollia labrosa n. sp. Early Silurian.

Genus AECHMINA Jones and Holl

Straight hinged, simply convex ostracoda without pit or sulcus and lobation confined to a single, sometimes enormously developed horn-like process.

Genotype.—Aechmina bovina Jones and Holl. Ordovician, Devonian.

Genus PARAECHMINA new genus

Differs from Aechmina in having a well defined ridge-like elevation along the free edge of the valve and in the development of a pit on the posterior side of the base of the spine.

Genotype.—Paraechmina (Aechmina) spinosa Hall. Silurian, Devonian.

Genus ACRONOTELLA new genus

Simple, unbordered ostracoda with long hinge and produced dorsal extremities, crossed obliquely by a sharp sulcus dividing the larger, evenly convex anterior part from the smaller more compressed posterior side. A low node just beneath the middle of the sulcus and beneath this and close to the ventral edge, a thick spine.

Genotype.—Acronotella shideleri n. sp. Early Silurian.

Genus DILOBELLA Ulrich

Subovate or somewhat reniform bilobed shells; lobes very large, subequal and almost completely separated by a deep subcentral vertical or oblique sulcus.

Genotype.—Dilobella typa Ulrich. Ordovician.

Genus BURSULELLA Jones

Small bivalved carapaces (possibly not ostracodal) with more or less triangular equilateral valves which have one or more horn-like projections on the ventral edge of each valve.

Genotype.—Bursulella triangularis Jones. Silurian.

Subfamily EURYCHILININAE new subfamily

Large Primitiidæ with a broad frill along the free edge of the valves. (Fig. 16.)

Genus EURYCHILINA Ulrich

Oblong or semielliptical, long-hinged shells having a subcentral Primitian sulcus, the posterior edge of which is often raised into a small rounded node; free margins provided with a wide, usually radiately plicated, frill-

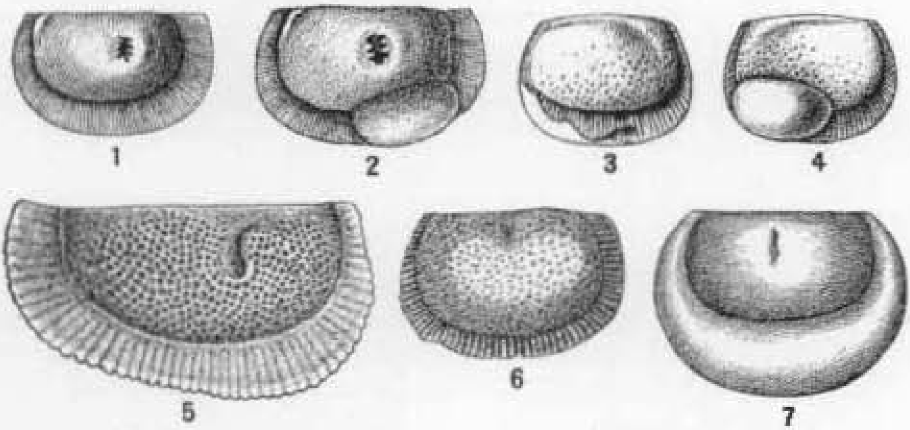

FIG. 16.—ILLUSTRATING THE SUBFAMILY EURYCHILININÆ.

1, 2. *Chilobolbina* new genus. Left valve, × 15 of the genotype *Chilobolbina* (*Primitia*) *dentifera* Bonnema, showing the male and female forms respectively. Ordovician (Kuckers formation), Kuckers, Esthonia.
3, 4. *Apatobolbina* new genus. 3. Male valve, × 12 of the genotype *Apatobolbina granifera* n. sp. showing convex surface without sulcus. 4. Right valve of female form, × 12, illustrating character of brood pouch. Upper Clinton (*Mastigobolbina typus* zone) near Hollidaysburg, Pa.
5. *Eurychilina* Ulrich. Left valve, × 26, of the genotype *Eurychilina reticulata* Ulrich, illustrating the sulcus and node on the valve and the wide frill-like border. Ordovician (Black River-Decorah shales), Fillmore Co., Minn.
6. *Apatochilina* new genus. Left valve of the genotype *Apatochilina* (*Eurychilina*) *obesa* Ulrich, × 15, with sulcus and node wanting. Ordovician (Black River-Lowville limestone), High Bridge, Kentucky.
7. *Calochilina* new genus. Right valve of the genotype *Calochilina* (*Eurychilina*) *æqualis* Ulrich, × 15, with simple sulcus developed. Ordovician (Stones River-Lebanon limestone), High Bridge, Kentucky.

like border curved on its under side so as to form a concave area around the true contact edges of the valves.

Genotype.—*Eurychilina reticulata* Ulrich. Ordovician, early Silurian.

Genus COELOCHILINA new genus

Carapace similar to Eurychilina but with only a simple sulcus and lacking the node.

Genotype.—*Calochilina* (*Eurychilina*) *æqualis* Ulrich. Ordovician.

Genus CHILOBOLBINA new genus

Like Cœlochilina in many respects but a long ovate brood pouch is developed in the posterior three-fifths of the ventral part of the frill.

Genotype.—Chilobolbina (Primitia) dentifera Bonnema. Ordovician, Silurian.

Genus APATOCHILINA new genus

Similar to Eurychilina but the node is missing, the border is not incurved, and the sulcus is represented by a dorsal undefined depression, the surface of the valves being more evenly convex.

Genotype.—Apatochilina (Eurychilina) obesa Ulrich. Ordovician.

Genus APATOBOLBINA new genus

Like Apatochilina but an oval brood pouch is developed in the female on the postventral half of the frill and on a part of the adjacent convex area.

Genotype.—Apatobolbina granifera n. sp. Silurian.

Family ZYGOBOLBIDAE new family

Beyrichiacea with lobate valves; lobes two, three, or four in number, the posterior the most unstable, the anterior lobe divided in the quadrilobate genera, the anterior and median ones commonly broadly or narrowly confluent below. Brood pouch present as an added lobe or undefined swelling along the posterior edge or on the post-ventral slope. (Fig. 17.)

Subfamily ZYGOBOLBINAE new subfamily

Carapace having an emaciated appearance with narrow lobes and wide sulci, the posterior lobe weak and commonly obsolete, the anterior and median lobes uniting below to form a thin U-shaped ridge.

Genus ZYGOBOLBA new genus

Zygobolbinæ with posterior lobe present but weak and the brood pouch a well defined, acuminate-ovate swelling on the outer two-thirds of the post-ventral quarter.

Genotype.—Zygobolba (Beyrichia) decora Billings. Clinton.

Genus ZYGOBOLBINA new genus

Like Zygobolba but larger, the posterior lobe usually nearly or quite obsolete, and the brood pouch of the female unequally bilobed.

Genotype.—Zygobolbina conradi n. sp. Clinton.

Genus ZYGOSELLA new genus

Similar to Zygobolba but the brood pouch is a narrow ridge-like elevation paralleling the posterior border.

Genotype.—Zygosella vallata n. sp. Clinton.

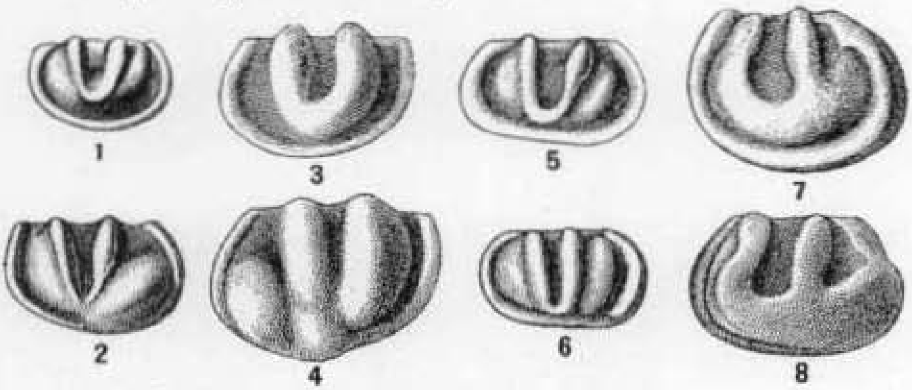

FIG. 17.—ILLUSTRATING THE FAMILY ZYGOBOLBIDÆ.

1, 2. *Zygobolba* new genus. 1. Male left valve, × 8 of the genotype *Zygobolba* (*Beyrichia*) *decora* Billings, illustrating development of lobes. 2. Left valve, female of the same species, × 8, showing the ovate brood pouch in the post ventral quarter. Silurian (Jupiter River formation), Island of Anticosti.
3, 4. *Zygobolbina* new genus. Right valves of male and female forms, of genotype, × 8, *Zygobolbina conradi* n. sp., the latter illustrating the unequally bilobed brood pouch. Middle Clinton (Mastigobolbina lata zone), Armuchee, Ga.
5, 6. *Zygosella* new genus. Left valve, male, of the genotype *Zygosella vallata* n. sp., × 8, from the Upper Clinton (Mastigobolbina typus zone) 7 miles east of Great Cacapon, West Virginia. 6. Left valve, female, × 8, of *Zygosella* [illegible] n. sp., exhibiting the narrow ridge-like brood pouch paralleling the posterior border. Upper Clinton (Mastigobolbina typus zone), North of Williamsville, Virginia.
7, 8. *Bonnemaia* new genus. Left valves, male, × 8, and female, × 8, of *Bonnemaia rudis* n. sp. Upper Clinton (Bonnemaia rudis zone), Powell Mountain, 5 miles N. W. Sneedville, Tennessee.

Genus BONNEMAIA new genus

Very large Zygobolbinæ with median sulcus short and the U-shaped lobe thick, its posterior limb often divided in its upper half by a short posterior sulcus and the anterior lobe usually crowned with a sigmoidally-curved angular crest. Brood pouch large, indefinitely outlined on the inner side, situated as in Zygobolba, in the post-ventral quarter.

Genotype.—Bonnemaia celsa n. sp. Clinton.

Subfamily KLOEDENINAE new subfamily

Ventrally rather obese with relatively short narrow sulci and more or less confluent lobes, the posterior lobe usually large and thick. (Fig. 18.)

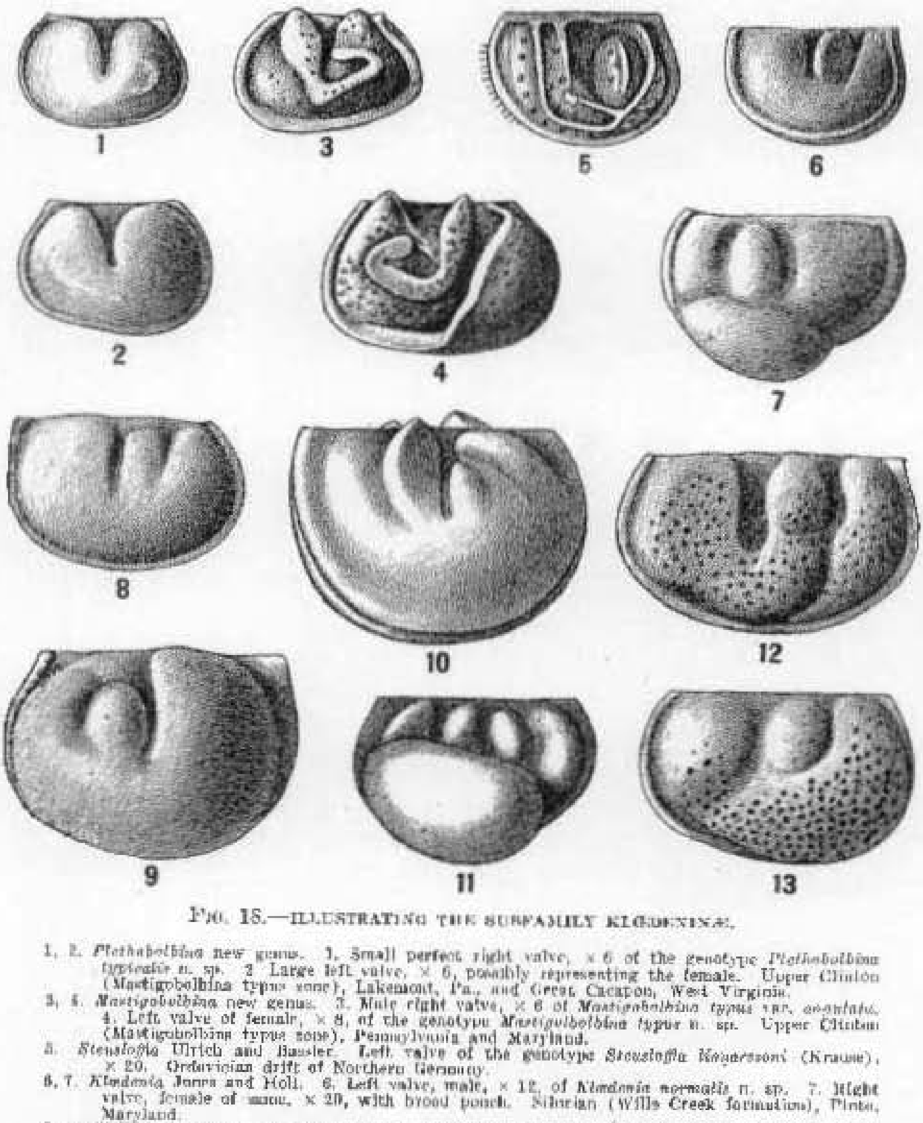

FIG. 18.—ILLUSTRATING THE SUBFAMILY KLOEDENINAE.

1, 2. *Plethobolbina* new genus. 1, Small perfect right valve, × 6 of the genotype *Plethobolbina typicalis* n. sp. 2 Large left valve, × 6, possibly representing the female. Upper Clinton (Mastigobolbina typus zone), Lakemont, Pa., and Great Cacapon, West Virginia.
3, 4. *Mastigobolbina* new genus. 3. Male right valve, × 6 of *Mastigobolbina typus* var. *angulata*. 4. Left valve of female, × 8, of the genotype *Mastigobolbina typus* n. sp. Upper Clinton (Mastigobolbina typus zone), Pennsylvania and Maryland.
5. *Steusloffia* Ulrich and Bassler. Left valve of the genotype *Steusloffia Linnarssoni* (Krause), × 20. Ordovician drift of Northern Germany.
6, 7. *Kloedenia* Jones and Holl. 6. Left valve, male, × 12, of *Kloedenia normalis* n. sp. 7. Right valve, female of same, × 20, with brood pouch. Silurian (Wills Creek formation), Pinto, Maryland.
8, 9. *Welleria* new genus. Left valve male and right valve female, × 12 of the genotype *Welleria obliqua* n. sp. Silurian (Tonoloway limestone) Western Maryland.
10, 11. *Kyammodes* Jones. 10. Valve of male, magnified, of *Kyammodes whidbornei* Jones, the genotype from the Devonian of Devonshire, England. 11. Right valve, female, × 10, of *Kyammodes* (*Kloedenia*) *kiesowi* (Krause) from the Silurian drift of northern Germany.
12, 13. *Zygobeyrichia* Ulrich. Male and female left valves, × 12, of *Zygobeyrichia ventripunctata* n. sp. Silurian (Tonoloway limestone), Keyser, West Virginia.

Genus PLETHOBOLBINA new genus

Carapace large, obese, primitian in aspect, the lobes submerged with only the median sulcus remaining; curved crest on anterior lobe barely indicated. Females differing only in slightly greater fullness of post-ventral part.

Genotype.—Plethobolbina typicalis n. sp. Clinton.

Genus MASTIGOBOLBINA new genus

Large trilobate Klœdeninæ with a narrow posterior lobe, a much larger and irregularly-shaped anterior lobe and a pyriform median lobe, the latter tapering below and passing into a whiplash-like raised extension that turns obliquely forward and upward and then backward again across the anterior lobe. Brood pouch large, posterior in position, covering summit of posterior lobe, its inner side sharply defined by the posterior sulcus.

Genotype.—Mastigobolbina typus n. sp. Clinton.

Genus KLŒDENIA Jones and Holl

Obese carapaces like Plethobolbina and approaching the simple forms of Mastigobolbina in having both median and posterior sulci and the median lobe partly separated as a rounded or subovate node; sulci short, confined to the dorsal half. Brood pouch well developed, large and rather distinctly outlined, projecting beyond the ventral edge and most of it behind the midlength of valves.

Genotype.—Klœdenia wilckensiana Jones. Silurian, Devonian.

Genus WELLERIA new genus

Similar to Klœdenia but the brood pouch forms a low broad inwardly undefined, swelling affecting the ventral half or two-thirds of the valves and projecting slightly beyond the edge.

Genotype.—Welleria obliqua n. sp. Late Silurian.

Genus KYAMMODES Jones

Similar to Welleria but having two additional short sulci produced by incipient division of the anterior and posterior lobes. Brood pouch strongly convex, sharply defined, very large, covering nearly half the valve and projecting beyond the border.

Genotype.—Kyammodes whidbornei Jones. Late Silurian, Devonian.

Genus ZYGOBEYRICHIA Ulrich

Like Klœdenia except that the sulci are larger and the posterior one extends to the ventral border, leaving the anterior and median lobes yoked together. The brood pouch also is undefined on its inner side and larger.

Genotype.—Zygobeyrichia apicalis Ulrich. Silurian, Devonian.

Genus STEUSLOFFIA Ulrich and Bassler

Valves similar to Klœdenia and Beyrichia but traversed by thin elevated crest-like ridges.

Genotype.—Steusloffia (Beyrichia) linnarssoni Krause. Ordovician.

Subfamily DREPANELLINAE new subfamily

Typically quadrilobate, the anterior lobe divided or broken up into lobes or nodes, the median lobe isolated, the posterior lobe narrow and prolonged as a sickle-shaped ridge around the ventral side; rarely the posterior lobe is completely submerged and the other two lobes reduced to small rounded subcentral nodes. Brood pouch elongate, confined to ventral side. (Fig. 19.)

Genus DREPANELLA Ulrich

Depressed convex, suboblong valves with a more or less complete, often sickle-shaped, sharply elevated marginal ridge, within which the surface exhibits two or more usually isolated nodes; ventral edge thick; brood pouch unknown, probably wanting.

Genotype.—Drepanella crassinoda Ulrich. Ordovician, early Silurian.

Genus DREPANELLINA new genus

Similar to Drepanella but the female is provided with a brood pouch that appears as an indefinite swelling over the ventrally confluent ridges.

Genotype.—Drepanellina clarki n. sp. Middle Silurian.

Genus SCOFIELDIA Ulrich and Bassler

Like Drepanella but with median lobe small and located near middle of dorsal edge, and the anterior and posterior lobes symmetrically arranged and irregularly triangular in form; near the ventral edge a thick, sharply elevated bar-like ridge.

Genotype.—*Scofieldia* (*Drepanella*) *bilateralis* Ulrich. Ordovician.

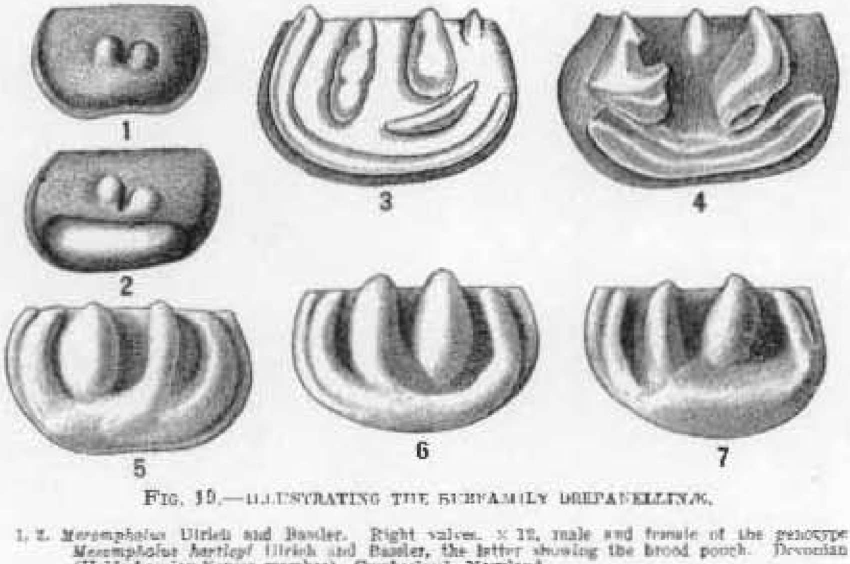

FIG. 19.—ILLUSTRATING THE SUBFAMILY DREPANELLINÆ.

1, 2. *Mesomphalus* Ulrich and Bassler. Right valves, × 12, male and female of the genotype *Mesomphalus hartleyi* Ulrich and Bassler, the latter showing the brood pouch. Devonian (Helderbergian-Keyser member), Cumberland, Maryland.
3. *Drepanella* Ulrich. Right valve, × 12, of the genotype *Drepanella crassinoda* Ulrich. Ordovician (Black River-Lowville limestone), High Bridge, Kentucky.
4. *Scofieldia* Ulrich and Bassler. Right (?) valve, × 12, of *Scofieldia* (*Drepanella*) *bilateralis* Ulrich, the genotype. Ordovician (Black River-Decorah shale), St. Paul, Minn.
5-7. *Drepanellina* new genus. 5. Well-preserved right valve, male, × 8, of the genotype *Drepanellina clarki* n. sp. 6. Left valve, male, × 6, showing the resemblance to *Drepanella*. 7. Left valve, female, × 8, showing the ventral brood pouch. Upper Clinton (*Drepanellina clarki* zone), Cumberland, Maryland.

Genus MESOMPHALUS Ulrich and Bassler

Carapace obese, the posterior lobe completely submerged, the median and anterior lobes reduced to small, rounded, closely approximated subcentrally situated nodes separated by a short pit-like sulcus. Brood pouch sausage-shaped, uncommonly prominent and well defined, located on the ventral slope.

Genotype.—*Mesomphalus hartleyi* Ulrich and Bassler. Early Devonian.

Family BEYRICHIIDAE Jones (restricted)

Valves trilobate or quadrilobate, deeply sulcated; brood pouch when present, very prominent, subglobular or egg-shaped, on the ventral slope. (Fig. 20.)

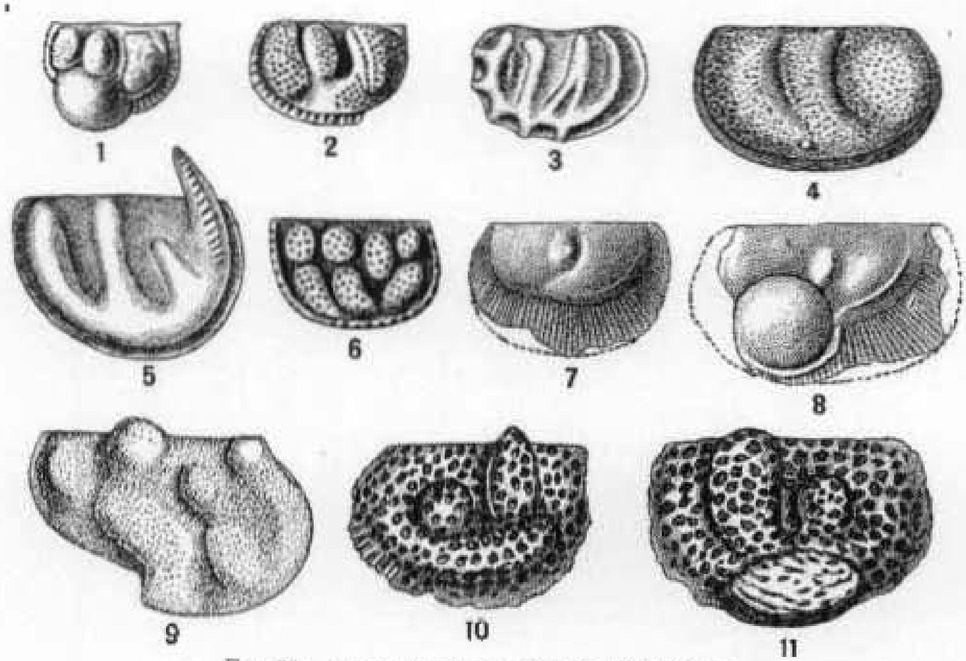

FIG. 20.—ILLUSTRATING THE FAMILY BEYRICHIIDÆ.

1, 2. *Beyrichia* McCoy. Female and male valves, × 12, of *Beyrichia veronica* n. sp., the former with the test in part removed. Upper Clinton (*Drepanellina clarki* zone), Western Maryland.
3. *Tetradella* Ulrich. Right valve of the genotype *Tetradella* (*Beyrichia*) *quadrilirata* Hall and Whitfield. Ordovician (Black River-Decorah shale), Minneapolis, Minn.
4. *Ctenobolbina* Ulrich. Left valve, × 15, of the genotype *Ctenobolbina ciliata* (Emmons). Ordovician (Cincinnatian-Eden shale), Cincinnati, Ohio.
5. *Ceratopsis* Ulrich. Left valve, × 20, of the genotype *Ceratopsis chambersi* (Miller). Ordovician (Black River-Decorah shale), St. Paul, Minn.
6. *Kiesowia* Ulrich and Bassler. Left valve, × 20, of the genotype *Kiesowia* (*Beyrichia*) *dissecta* Krause. Silurian drift of northern Germany.
7, 8. *Dibolbina* new genus. Right valves, × 20, male and female, of the genotype *Dibolbina cristata* n. sp., showing the surface characters, broad frill and in the latter, the hemispherical, posterior brood pouch. Silurian (Tonoloway limestone), Keyser, West Virginia.
9. *Hollina* Ulrich and Bassler. Left valve, × 20 of the genotype *Hollina* (*Ctenobolbina*) *insolens* Ulrich. Devonian (Onondaga limestone), Falls of the Ohio River.
10, 11. *Treposella* Ulrich and Bassler. 10. Right valve, male, × 20, of *Treposella* (*Beyrichia*) *lyoni* Ulrich. 11. Left valve, female, × 20, of the same species, with the brood pouch near middle of ventral edge. Devonian (Onondaga limestone), Falls of the Ohio River.

Genus BEYRICHIA McCoy

Distinctly trilobate, the middle lobe smallest, rounded and commonly isolated, the posterior longer but also detached. Brood pouch subglobular or ovate, more or less posterior in position.

Genotype.—Beyrichia kladeni McCoy. Silurian, Devonian.

Genus TETRADELLA Ulrich

Valves marked by four or less curved, vertical ridges ventrally united; one or both of the inner ridges sometimes duplex.

Genotype.—Tetradella (Beyrichia) quadrilirata Hall and Whitfield. Ordovician, early Silurian.

Genus CTENOBOLBINA Ulrich

Middle lobe more or less completely confluent with the posterior lobe, the composite lobe bulbous and sharply defined in front by a deep curved sulcus; the anterior lobe divided by an oblique furrow. Free edges with false border or frill.

Genotype.—Ctenobolbina (Beyrichia) ciliata Emmons. Ordovician, Devonian.

Genus CERATOPSIS Ulrich

Distinguished from Tetradella by the remarkable process which arises from the dorsal extremity of the posterior ridge. This may be straight and horn-like with one of the edges toothed, or expanded somewhat mushroom-like.

Genotype.—Ceratopsis (Beyrichia) oculifera Hall. Ordovician, Silurian.

Genus KIESOWIA Ulrich and Bassler

Like Tetradella except that the two anterior and the posterior lobes are each divided into two or three nodes.

Genotype.—Kiesowia (Beyrichia) dissecta Krause. Silurian.

Genus DIBOLBINA new genus

Widely frilled Beyrichiidæ with trilobation of surface much obscured, only the middle lobe being definitely developed. Brood pouch nearly hemispheric, mainly posterior in position.

Genotype.—Dibolbina cristata n. sp. Late Silurian.

Genus HOLLINA Ulrich and Bassler

Allied to Ctenobolbina but the posterior lobe is commonly broken up into three or four nodes of which the inner one is the most pronounced and most persistent; the middle lobe terminates dorsally in a large rounded node and the anterior lobe is reduced to a small node or is obsolete. Marginal frill confined chiefly to the posterior two-thirds. Brood pouch not developed.

Genotype.—Hollina (Ctenobolbina) insolens Ulrich. Devonian, Mississippian.

Genus TREPOSELLA Ulrich and Bassler

Like Beyrichia except that the posterior lobe is obsolete in the post dorsal quarter but well developed along the ventral side, the middle lobe is prominent and rounded and the anterior lobe is reduced to a vertically elongated node. Between the latter two is a definite pit. Brood pouch near middle of ventral edge instead of distinctly posterior.

Genotype.—Treposella (Beyrichia) lyoni Ulrich. Middle Devonian.

Family KLŒDENELLIDAE new family

Straight-hinged, more or less inequivalved small ostracoda, usually the right valve overlapping the left around the free edges and provided with a small process in the post-dorsal angle that fits into a corresponding depression in the opposite valve. Valves shallowly unisulcate to deeply quadrilobate with practically complete transition from the one extreme to the other. (Fig. 21.)

Genus EUKLŒDENELLA new genus

Surface of valves evenly convex or with only a median pit or sulcus and more rarely with a shallow depression in the ventral slope.

Genotype.—Euklœdenella umbilicata n. sp. Silurian.

Genus KLŒDENELLA Ulrich and Bassler (restricted)

Surface of valves with a median and a posterior sulcus both usually confined to the post-dorsal quarter; otherwise like Euklœdenella.

Genotype.—Klœdenella pennsylvanica Jones. Silurian, Devonian.

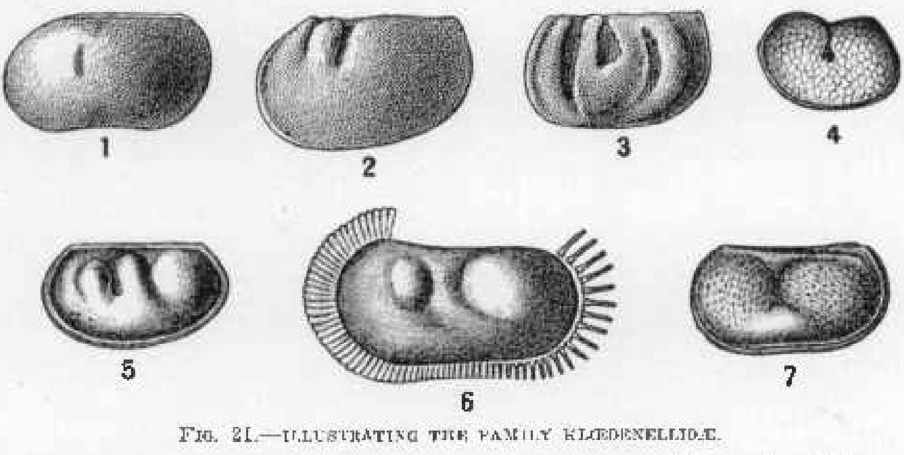

FIG. 21.—ILLUSTRATING THE FAMILY KLŒDENELLIDÆ.

1. *Euklœdenella* new genus. Right side of a complete carapace, × 10, of the genotype *Euklœdenella umbilicata* n. sp., illustrating obsolete lobation of valves. Silurian (Cayugan-McKenzie formation), Flintstone, Maryland.
2. *Klœdenella* Ulrich and Bassler. Right valve, × 20, of *Klœdenella obliqua* n. sp. exhibiting the characteristically short median and posterior sulci limited to the post dorsal quarter. Silurian (Cayugan-Tonoloway limestone). Cumberland, Maryland.
3. *Dizygopleura* new genus. Right valve of *Dizygopleura stossi* n. sp., × 20, showing the typical quadrilobate surface. Silurian (Cayugan-McKenzie formation), 1½ miles east of Great Cacapon, West Virginia.
4. *Kirkbyina* Ulrich and Bassler. Left valve, × 25, of the genotype *Kirkbyina (Beyrichiella) reticosa* Jones and Kirkby. Carboniferous of Great Britain.
5. *Jonesina* Ulrich and Bassler. Right valve, × 25, of the genotype *Jonesina (Beyrichia) fastigiata* Jones and Kirby. Carboniferous of Scotland.
6. *Beyrichiopsis* Jones and Kirkby. Apparently perfect, right valve, × 40, of the genotype *Beyrichiopsis fimbriata* Jones and Kirkby. Carboniferous of Scotland.
7. *Beyrichiella* Jones and Kirkby. Right valve, × 20, of the genotype *Beyrichiella cristata* Jones and Kirkby. Carboniferous of Scotland.

Genus DIZYGOPLEURA new genus

Distinguished from Klœdenella by the more or less distinct quadrilobation of the valves, the posterior sulcus being much longer, the median sulcus longer, and the anterior lobe more or less completely divided by another sulcus.

Genotype.—Dizygopleura swartzi n. sp. Silurian, Devonian.

Genus JONESINA Ulrich and Bassler

Like Klœdenella but the overlap of the valves is reversed, the left valve overlapping the right.

Genotype.—Jonesina (Beyrichia) fastigiata Jones and Kirkby. Carboniferous.

Genus KIRKBYINA Ulrich and Bassler

Carapace small, less than 1 mm. in length, rather short, subovate to subquadrate, ventricose, thickest anteriorly, with a simple primitian sulcus about the middle of the dorsal half. Valves unequal, the right slightly larger and overlapping the edges of the left.

Genotype.—Kirkbyina (Beyrichiella) reticosa Jones and Kirkby. Carboniferous.

Genus BEYRICHIELLA Jones and Kirkby

Carapace small, 1 mm. or less in length, elongate subquadrate, thickest anteriorly, with a rather broad median sulcus giving the shell a bilobed aspect; a low, transverse ridge in the ventral part cuts off the sulcus and unites the lower parts of the two lobes. Valves unequal, the edge of the smaller right valve being set into the overlapping ventral and end parts of the large left valve.

Genotype.—Beyrichiella cristata Jones and Kirkby. Carboniferous.

Genus BEYRICHIOPSIS Jones and Kirkby

Like Beyrichiella but lacking the transverse ridge and having a small rounded post-median lobe. A wide radiated marginal fringe is present.

Genotype.—Beyrichiopsis fimbriata Jones and Kirkby. Carboniferous.

Family KIRKBYIDAE Ulrich and Bassler

A most variable and probably unnatural association of equivalved genera of Beyrichiacea tending toward the Cytheracea. Typically with a distinct false border and a subcentral well defined pit and often with concentric or transverse more or less parallel ridges. (Fig. 22.)

Genus YOUNGIELLA Jones and Kirkby

Simple unadorned valve with long straight, internally denticulated hinge.

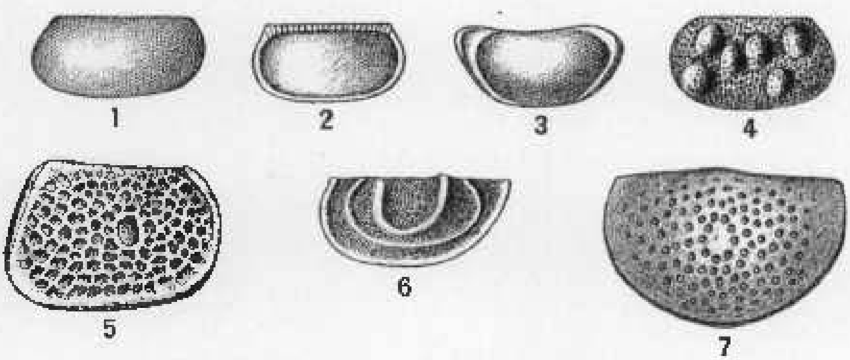

FIG. 22.—ILLUSTRATING THE FAMILY KIRKBYIDÆ.

1, 2. *Youngiella* Jones and Kirkby. Right (?) valve of the genotype *Youngiella* (*Youngia*) *rectidorsalis* Jones and Kirkby, × 50. 2. Interior of valve showing teeth along the hinge. Carboniferous of England.
3. *Moorea* Jones and Kirkby. Left valve of the genotype *Moorea obesa* Jones and Kirkby, magnified. Carboniferous of England.
4. *Mauryella* new genus. Left valve of the genotype *Mauryella mammillata* n. sp., × 20, showing the absence of a false border, and the presence of a subcentral pit, reticulate surface with six prominent rounded nodes. Mississippian (Kinderhook-Ridgetop shale), Mt. Pleasant, Maury County, Tennessee.
5. *Kirkbya* Jones. Right valve, × 20, of *Kirkbya subquadrata* Ulrich. Devonian (Onondaga limestone), Falls of the Ohio River.
6. *Strepula* Jones and Holl. Right valve of the genotype *Strepula concentrica* Jones and Holl, × 20, with the characteristic crest-like ridges. Silurian of England.
7. *Macronotella* Ulrich. Valve (right?), × 20, of the genotype *Macronotella scofieldi* Ulrich. Ordovician (Black River limestone), Cannon Falls, Minnesota.

Genotype.—*Youngiella* (*Youngia*) *rectidorsalis* Jones and Kirkby. Carboniferous.

Genus MOOREA Jones and Kirkby

Small, more or less oblong or ovate shells; valves compressed convex, the free edges bounded by a raised marginal ridge, sometimes wanting along the ventral side; inner region flat or gently convex, without nodes, sulcus or pit.

Genotype.—Moorea obesa and *M. tenuis* Jones and Kirkby. Ordovician, Carboniferous.

Genus KIRKBYA Jones

Distinguished from Moorea by the presence of a subcentral pit. Surface ornament usually reticulated.

Genotype.—Kirkbya permiana Jones. Silurian, Permian.

Genus MAURYELLA new genus

Like Kirkbya except that valves have no false border and the surface bears five or six strongly elevated rounded nodes arranged without special order.

Genotype.—Mauryella mammilata n. sp. Mississippian of Tennessee.

Genus STREPULA Jones and Holl

Suboblong shells, valves slightly convex without sulcus, traversed by two or more concentric or twisted, thin crest-like ridges.

Genotype.—Strepula concentrica Jones and Holl. Silurian, Devonian.

Genus MACRONOTELLA Ulrich

Shell semicircular or semiovate with a long, nearly straight hinge; valves equal, inflated centrodorsally, without ridges or sulcus but exhibiting a smooth, subcentral spot where the reticular ornament is omitted.

Genotype.—Macronotella scofieldi Ulrich. Ordovician.

Superfamily CYPRIDACEA

Family THLIPSURIDAE Jones

Reniform or ovate inequivalved shells less than 2 mm. in length, the margin of one valve overlapping that of the other more or less completely. Dorsal margin arcuate, ventral sometimes straight or even slightly sinuate;

surface with two or more definite pits. Determination of right and left valve arbitrarily made. (Fig. 23.)

Genus THLIPSURA Jones and Holl

Oval to reniform shells; each valve generally with three pits, one posterior and two in the anterior half; surface without ornament.

Genotype.—Thlipsura corpulenta Jones and Holl. Silurian, Devonian.

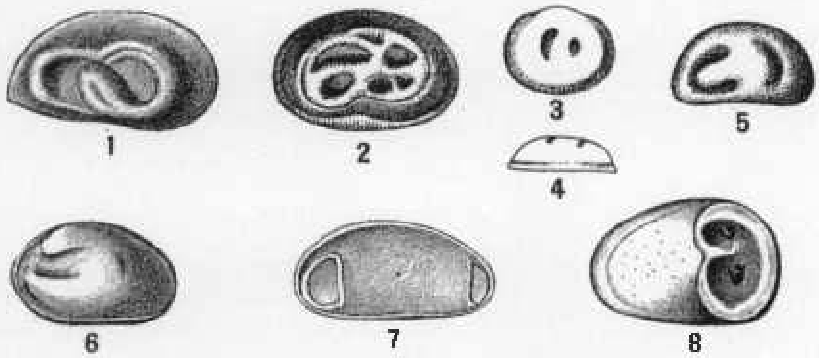

FIG. 23.—ILLUSTRATING THE FAMILY THLIPSURIDÆ.

1-4. *Octonaria* Jones. 1. Left valve of the genotype *Octonaria octoformis* Jones, × 20, showing the typical 8-shaped annular ridge. Silurian of England. 2. An American species of *Octonaria* (*O. ovata* Ulrich), × 20, in which the 8-shaped ridge is more modified. Devonian (Onondaga limestone), Falls of the Ohio. 3, 4. The overlapping valve and edge view of same, × 20, of a simple species, *Octonaria bicava* n. sp., distinguished by the two median cavities. The other valve lacks the slight dorsal angles. Cincinnatian (Southgate member of Eden shale), Covington, Kentucky.

5, 6. *Thlipsura* Jones and Holl. 5. Left valve of *Thlipsura v-scripta* var. *discreta* Jones, × 20, showing the characteristic three pits of *Thlipsura*, one posterior and two anterior. Silurian, Island of Gotland. 6. Left valve of the genotype *Thlipsura corpulenta* Jones and Holl, × 20. Silurian, Woolhope, England.

7. *Phreatura* Jones and Kirkby. Right valve of the genotype, *Phreatura concinna* Jones and Kirkby, × 50. The shallow semi-circular pit at each end and the compressed posterior end are characteristic. Carboniferous, Yoredale, England.

8. *Craterellina* Ulrich and Bassler. Right valve of the genotype *Craterellina robusta* Ulrich and Bassler, × 20, showing the characteristic anterior crater-like depression. Devonian (Oriskany formation), Cash Valley, Maryland.

Genus OCTONARIA Jones

Similar to Thlipsura but distinguished by having the surface of the valves raised into a thin spiral or ring-like ridge which in the more typical forms resembles the figure 8.

Genotype.—Octonaria octoformis Jones. Ordovician, Devonian.

Genus PHREATURA Jones and Kirkby

Distinguished from Thlipsura by the strong compression of the posterior end of the shell; this end is further marked by a shallow though clearly outlined, semicircular pit; a similar though smaller pit at the anterior extremity.

Genotype.—*Phreatura concinna* Jones and Kirkby. Carboniferous.

Genus CRATERELLINA Ulrich and Bassler

Valves similar to Octonaria and Thlipsura but the anterior half or third is marked by a crater-like depression bordered by an elevated rim.

Genotype.—*Craterellina robusta* Ulrich and Bassler. Devonian.

Family BEECHERELLIDAE Ulrich

Small inequivalved, ovate, subtriangular or boat-shaped ostracoda having the posterior end of one or both valves drawn out into a spine. (Fig. 24.)

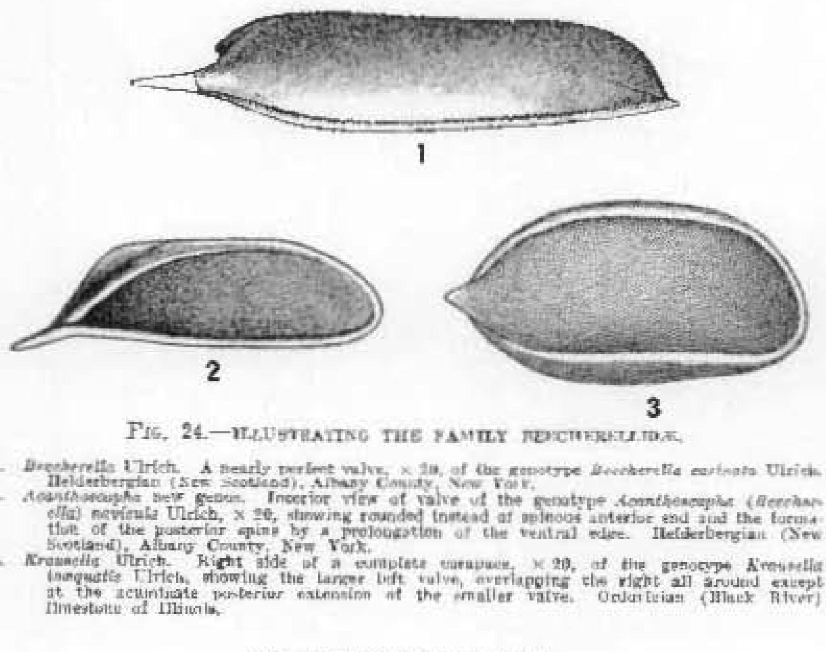

FIG. 24.—ILLUSTRATING THE FAMILY BEECHERELLIDÆ.

1. *Beecherella* Ulrich. A nearly perfect valve, × 20, of the genotype *Beecherella carinata* Ulrich. Helderbergian (New Scotland), Albany County, New York.
2. *Acanthoscapha* new genus. Interior view of valve of the genotype *Acanthoscapha* (*Beecherella*) *navicula* Ulrich, × 20, showing rounded instead of spinous anterior end and the formation of the posterior spine by a prolongation of the ventral edge. Helderbergian (New Scotland), Albany County, New York.
3. *Kraussella* Ulrich. Right side of a complete carapace, × 20, of the genotype *Kraussella inaequalis* Ulrich, showing the larger left valve, overlapping the right all around except at the acuminate posterior extension of the smaller valve. Ordovician (Black River) limestone of Illinois.

Genus BEECHERELLA Ulrich

Shell elongate, boat-shaped, triangular in cross section, the ventrum being flat and carinated on its outer edges; ventral carinæ prolonged at each end into spines, the anterior one short and small, the posterior much larger; hinge apparently simple while the ventral edge of the right valve seems to overlap the left sharply.

Genotype and Only Species.—*Beecherella carinata* Ulrich. Lower Devonian.

Genus ACANTHOSCAPHA new genus

Similar to Beecherella but the anterior end is spineless and rounded in outline while the posterior spine is formed by a prolongation of the ventral edge instead of the outer carina which may be wanting entirely. Within the posterodorsal region the true contact edge is set some distance within the outer edge of the valves.

Genotype.—*Acanthoscapha* (*Beecherella*) *navicula* Ulrich. Lower Devonian.

Genus KRAUSELLA Ulrich

Similar to Beecherella except that the valves are more unequal, the left overlapping the right both dorsally and ventrally while but a single spine occurs, this being a prolongation of the posterior extremity of the smaller (right) valve.

Genotype.—*Krausella inæqualis* Ulrich. Ordovician, Silurian.

Family BAIRDIIDAE new family

Minute, mostly reniform or elongate ovate, corneo-calcareous shells with thin, more or less unequal valves, one overlapping the other either ventrally or dorsally, or both.

This new family is instituted for the genera Bairdia McCoy, Bythocypris Brady, Pontocypris Sars, and Macrocypris Brady, the latter three based upon recent species. It is possible that future studies will show the Paleozoic representatives of these three genera to be distinct from their modern genotypes, but in any event these four genera are thought to be different from the fresh-water Cypridæ to which they have hitherto been referred. (Fig. 25.)

Genus BAIRDIA McCoy

Shell subtriangular or rhomboidal, with the greatest height near the middle, inequivalved, narrowly rounded anteriorly and more or less acuminate posteriorly, generally smooth; dorsal margin more or less strongly convex; hingement formed by strong overlap of the left valve over the right.

Genotype.—*Bairdia curta* McCoy, a Carboniferous species. Range Silurian to Recent, particularly abundant in the Carboniferous.

Genus BYTHOCYPRIS Brady

Shell smooth, reniform, ovate or elliptical; left valve larger than the right overlapping it usually on both the dorsal and ventral margins;

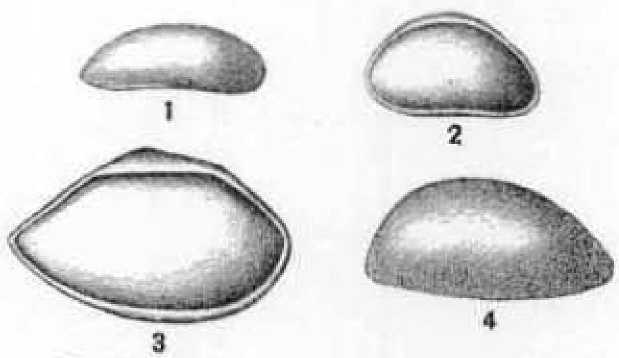

FIG. 25.—ILLUSTRATING THE FAMILY BAIRDIIDÆ.

1. *Macrocypris* Brady. Left valve of *Macrocypris siluri* Jones, × 15, showing elongate shape and acuminate posterior end. Silurian, Island of Gotland.
2. *Bythocypris* Brady. Complete carapace of *Bythocypris phillipsiana* Jones and Holl, magnified, illustrating form of shell and overlap of valves. Silurian of England.
3. *Bairdia* McCoy. Complete carapace of a typical Carboniferous species *Bairdia beedei* Ulrich and Bassler, × 30. Carboniferous of Kansas.
4. *Pontocypris* Sars. Valve of *Pontocypris mawii* Jones, × 30. Silurian, Island of Gotland.

dorsal margin convex, the ventral edge straighter, sometimes slightly concave.

Genotype.—*Bythocypris reniformis* Brady, a recent species. Range Ordovician to Recent.

Genus PONTOCYPRIS Sars

Similar to Bythocypris except that the shell is very delicate and the hinge simple without overlap.

Genotype.—*Pontocypris serrulata* Sars, a recent species. Range Silurian to Recent.

Genus MACROCYPRIS Brady

Similar to Bythocypris but as a rule more elongate, posteriorly more acuminate and with the right instead of the left valve the larger; inner side of valves with a thin plate along the anterior ventral and posterior edges.

Genotype.—*Macrocypris minna* Baird, a recent species. Range Ordovician to Recent.

Family CYPRIDAE Zenker[1]

Palæocypris Brongniart, Cypris Müller, Cypridea Bosquet, Aglaia Brady, Argillœcia Sars, Cypridopsis Brady, Potamocypris Brady, Paracypris Sars, Notodromus Sars, Candona Baird.

Family CYTHERELLIDAE Sars

*Cytherella Jones, *Cytherellina Jones and Holl, *Pachydomella Ulrich, Bosquetia Brady.

Family ENTOMIDAE Jones

*Entomis Jones, *Entomidella Jones, *Elpe Barrande.

Family CYPRIDINIDAE Sars

*Cypridina Milne Edwards, *Cypridinella Jones, Kirkby, and Brady; Cypridellina J. K. and B., *Cypridella DeKoninck, *Cyprella DeKoninck, *Sulcuna J. K. and B., *Rhombina J. K. and B., *Cyprosis Jones, *Cyprosina Jones, Bradycinetus Sars, Philomedes Lilljeborg, Eurypylus Brady, Asterope Fischer.

Family ENTOMOCONCHIDAE Ulrich

Entomoconchus McCoy, *Offa J. K. and B.

Family POLYCOPIDAE Sars

Polycope Sars.

[1] To complete the classification of the ostracoda we list only the following families, their study not having been undertaken at the present time. Genera marked * are Paleozoic or have Paleozoic representatives.

Family DARWINULIDAE Jones

Darwinula Jones.

Family BARYCHILINIDAE Ulrich

*Barychilina Ulrich.

Superfamily CYTHERACEA

Family CYTHERIDAE Zenker

Cythere Müller, Cythereis Jones, Cytheridea Bosquet, Cytherideis Jones, *Carbonia Jones, Cytheropteron Sars, Xestoleberis Sars, Pseudocythere Sars, Krithe Brady, Crosskey and Robertson; Eucythere Brady, Cytherura Sars, Sclerochilus Sars, Kiphichilus Sars, Limnicythere Brady, Sarsiella Brady, and Paradoxostoma Fischer.

OSTRACOD ZONES OF THE SILURIAN

INTRODUCTION

Although the Ostracoda, despite their usual minuteness, are interesting for themselves, the dominating purpose of their intensive investigation, mainly for the present work, lay in the hope that they might throw some very much needed light on Silurian stratigraphic problems.

Prior to 1916, study of other classes of fossils by the senior author, in connection with extensive field investigations of the beds containing them, had shown very clearly that a large part of the deposits in the Appalachian region—especially in its southern half—which had been classed as of the age of the Clinton were in fact older. Most of these pre-Clinton beds were shown to be of late Medinan age, others of early Medinan or Richmond and some of them even so old as late Ordovician—that is, Maysville and Eden.

In Alabama and Georgia it was found that whereas the supposed Clinton, or Rockwood, as it was more commonly called, actually is mainly made up of beds corresponding in age to the Clinton at the typical locality in New York, its basal part locally included also a band of similar iron-bearing strata that is of the age of the Brassfield of Kentucky and Ohio, which corresponds to the upper part of the Upper Medina in New York and the Cataract formation in Ontario. Its top, on the other hand, locally comprises beds that were regarded as Upper Clinton, and possibly as young as the Rochester shale. In Alabama, then, the sequence of Clinton deposits seemed essentially the same as at Clinton, N. Y., where the formation likewise was thought to include a considerable thickness of deposits of Rochester age. However, at least one important difference was recognized, namely, the Alabama Clinton does not include beds corresponding to those which come to the surface and make up the lower part of the formation in the area between the towns of Clinton and Utica in New York. The missing beds are the ones that contain the wealth of ostracod forms that up to the present time have been loosely referred to *Beyrichia lata*. Although Ostracoda were found in the shaly beds above the oölitic iron ore at Clinton, N. Y., none of them seemed strictly the same as those which are so exceedingly abundant in the mentioned more sandy lower beds in the town of New Hartford and at other nearby places in New York, and which are found hardly less abundant to the southward in the Clinton rocks of central Pennsylvania, Maryland, and Virginia. Very disappointing, too, was the fact that none of the New Hartford Ostracoda—now known to belong in the Mastigobolbina lata zone—nor indeed any kind of Ostracoda had ever been listed or, so far as known, ever been found in the Clinton section beneath the Rochester shale in the valley of Genesee River. Perhaps even more disturbing was the known occurrence of the New Hartford species in northwestern Georgia when the data in hand indicated the entire absence of the Clinton in the Appalachian valley region between the Georgia locality and the northern boundary of Tennessee.

How were these seeming inconsistencies and anomalies in faunal distribution to be explained? Were they to be ascribed to local variations in the composition of faunas, or to vertical shifting of species and faunas in migration, or to actual local absence of the beds themselves? The other classes of fossils helped very little in solving these questions, mainly perhaps because they were few in number, poorly preserved and too often wanting entirely where their need was greatest. Under the circumstances, the obvious primary essential was to enter the field with the data in hand and try to establish by careful collecting in the longest and best exposed sections the true sequence of the fossiliferous zones. Work to this end was planned and carried out by devoting parts of each of the past six seasons to the study of new and previously visited sections in New York, Pennsylvania, Maryland, Virginia, Georgia, and Alabama, and the collections from all of these places were prepared and minutely scrutinized. Incidentally, fine collections of Ostracoda were procured from localities and beds in New York and elsewhere that had previously been thought to be without them. As a result most of the perplexities have been cleared so that we can now present conclusions with a reasonable degree of confidence. However, most of the stratigraphic details are reserved for a special work on the Medina and Clinton formations in eastern North America. Here only such parts will be given as may be required to fix the Clinton correlations.

THE CLINTON GROUP

Under the term Clinton group is embraced all the beds in New York lying between the base of the Arthophycus bearing basal sandstone, generally known as the "Gray Band," and the top of the Rochester shale. It constitutes the lower group of the Niagaran series, the upper group being the Lockport group of which the Guelph dolomite is the top member or formation. The Clinton group in New York is divisible into three main parts, having the rank of formations, which for present purposes may be conveniently designated as Lower Clinton, Middle Clinton, and Upper Clinton.[1] Each of these three Clinton formations, except perhaps the middle one, is again divisible into two or more lithological members for most of which names have been proposed by Hartnagel[2] and more recently

[1] More formal locality names will be proposed for these formations in a work on the Silurian formations in New York, in the preparation of which the senior author of the present memoir is cooperating with Dr. Rudolph Ruedemann and Mr. C. A. Hartnagel.

[2] Hartnagel, C. A., 1907, Geologic map of the Rochester quadrangle.

by Chadwick.[1] The three major divisions of the Clinton are distinguished by strongly marked faunal differences which are maintained and clearly recognizable from New York to Alabama. They differ also very decidedly in geographic distribution.

Clinton Section at Rochester, N. Y.

In order that the character and relations of the subdivisions of the Clinton in New York may be clearly understood it is thought essential to give at least two local sections in considerable detail. The first of these describes the beds as exposed in the gorge of Genesee River at Rochester. The other section, which is at Clinton, the type locality, is postponed to later pages that deal particularly with the Upper Clinton division in New York. Both of these sections are taken from notes made by the senior author in 1913.

SECTION OF THE CLINTON GROUP AT ROCHESTER, N. Y.

	Feet
Niagaran series	
Lockport group	
Ordinary Lockport dolomite with the hydraulic De Cew limestone member at base and resting unconformably on the Rochester. Section incomplete at top, present about	125

[1] Chadwick, G. H., 1918, Stratigraphy of New York Clinton, Bull. Geol. Soc. Am., 29, pp. 327-368. This work by Chadwick, despite the obvious fact that it is based more on the literature than upon independent field investigation, is an important contribution to the subject. It departs in many respects widely and in part properly from preceding conceptions, but is still unduly influenced by the old belief in the eustatic nature of the emergences and submergences of the land areas. It fails particularly in disregarding the probability of differential factors in the movement of the lithosphere at times of sea withdrawal and readvance and which would have produced unequal warping of the surface and corresponding irregularities in the migration of the strandline. Besides, the author did not know that the fossils, especially the Ostracoda, of some of the beds correlated by him are in fact definitely indicative of distinct zones whose stratigraphic relations have been established. In view of these facts it is not surprising that Chadwick made the mistake of correlating two entirely distinct Lower Clinton ostracod zones with the Middle Clinton Mastigobolbina lata zone, and following this correlates Upper Clinton beds in Herkimer County with Lower Clinton beds at Rochester. For these and other reasons Chadwick's new nomenclature of the Clinton rocks in New York, while correcting some real errors in preceding practice, nevertheless complicates the subject greatly and introduces new perplexities.

Clinton group

Upper Clinton

Rochester shale

	Feet
Interbedded limestone and shale, highly fossiliferous...	85

Irondequoit limestone

Thin limestone interbedded with considerable shale in lower half, the shale becoming less in upper half. At top often with reefy elevations that project into the otherwise even base of the Rochester shale, which followed without time break........................	18

The faunas of the Irondequoit limestone and the Rochester shale are much alike and both of predominantly southern origin. However, species and genera of Atlantic origin, particularly Ostracoda, occur in both.

Williamson shale

Shale, dark colored, with *Monograptus clintonensis* and *Hastrites venosus*	5

Stratigraphic break (Middle Clinton and Wolcott limestone and Sodus shale of Lower Clinton and lower part of Williamson shale missing).

Lower Clinton

"Bear Creek shale"

Shale, olive above purple below, with intercalated layers of "pearly" limestone, full of *Anoplotheca* (*Coelospira*) *hemispherica* and Ostracoda of the genus Zygobolba which is here represented by five species, all of which are characteristic of the *Z. anticostiensis* zone........	18

Upper "Reynales limestone"

Limestone, the middle and upper parts magnesian, the lower 15 inches nearly pure and full of *Pentamerus oblongus*. Upper 8-12 inches with shells of a species of Brachioprion very abundant, the middle part with fewer fossils	4-5
Limestone, magnesian, bluish, sparingly fossiliferous, the lower third with chert. Fossils essentially as in underlying layer	7-8
Limestone, thin bedded, the top inch or two very fossiliferous, with *Camarotoechia* sp., *Anoplotheca hemispherica*, *Stricklandinia canadensis* and a few undetermined Bryozoa	0.6
Limestone, magnesian, the upper half (8 inches) with chert and carrying on its uneven top surface the same kinds of shells as in overlying layer; beneath this two 4-inch layers without chert and nearly unfossiliferous.	1.3
Shale and two or three layers of magnesian limestone, 17-24 inches	2

	Feet
Typical "Reynales limestone"	
Furnaceville iron ore, 6-11 inches thick, two broadly wave-marked, the ripples striking N. 15° E. and 30 to 50 inches from crest to crest. Upper surface with a Chondrites-like fucoid, the branches about one-sixteenth inch wide and dividing mainly in pinnate manner. The bed itself is largely made up of broken organic remains and quartz grains all coated with iron. The fossils so far as determined are of species occurring in the underlying limestone....................	1
Thin limestones and shale, the limestone layers becoming thinner and farther separated downward so that the bed grades without break into the underlying shale. About 2 feet 8 inches beneath the top a limy layer with black (? phosphatic) pebbles and minute gastropods (Cyclora and Microceras). The upper half of bed contains a fair representation of the *Hyattidina congesta* or typical Reynales Basin fauna............	3-4
Maplewood shale	
Shale, soft, green, unfossiliferous, the base sharply defined from the underlying sandstone.................	14-21
Thorold sandstone ("Gray band")	
Massive, hard, impure, light gray sandstone, with a small form of *Dædalus archimedes*.......................	3-5
Age uncertain (? Late Medinan)[1]	
Sandstone, muddy, red, partly thick-bedded, mottled with shale pebbles, and containing both the larger and smaller forms of *Dædalus archimedes*................	12-14
Sandstone wedge, its upper part with *Arthrophycus alleghaniense*, its lower part showing "pillow structure" and containing *Dædalus archimedes*.................	1-7

[1] The age of the four beds of sandstone beneath the Thorold sandstone in this section is in doubt. Hitherto they, together with the Thorold, have been referred without reservation to the Medina. But this assignment was made mainly on the mistaken belief that *Arthrophycus alleghaniense* is confined to rocks of that age. On the contrary most, if not all, of the occurrences of this peculiar fossil are in younger beds than those at Medina and Lockport that contain the typical marine fauna of the Upper Medina. The Arthrophycus and Dædalus borings seem never to occur in association with the unquestioned marine shells. They are always found above the shells. Still this fact does not establish that all of these borings are of subsequent time. Some of them may yet prove to be contemporaries of the Upper Medina marine fossils. The animals that made the borings probably lived in the muddy sands of beaches on bodies of fresh and brackish waters. Being therefore essentially land, or rather nonmarine, animals the withdrawal of the epicontinental seas obviously had a less unfavorable effect on the continuity of their existence than on the

		Feet
	Sandstone, rather regularly thin-bedded, red, with occasional thin shale partings; contains *Dædalus archimedes* and in its upper half casts of Arthrophycus-like borings, but these lack the characteristic annulations.	20
	Basal sandstone, heavy bedded, reddish or chocolate colored, quartzose, conglomeratic; pebbles consist of quartz, chert, sandstone, clay, red shale, ranging in size from very small to 6 inches. Base unconformable.	4-10
Medinan		
(Upper Medina wanting?)		
Queenston shale, exposed		40

The Lower Clinton in New York

In western New York the Lower Clinton begins with the Thorold sandstone ("Gray Band") which hitherto has been generally regarded as the highest zone of the Medina. In fact, however, it really constitutes either the top member or the whole of the more or less coarsely clastic initial deposit of the Clinton over the eroded and unconformable top of the underlying formation. At Niagara Falls it rests on mostly red sandstones that may be safely correlated with the closing marine stage of the Medinan series. Between Lockport and Rochester it lies on various older sandstones of the Upper Medina. East of Rochester the surface on which the Arthrophycus zone rests drops more and more in the section until at or to the east of Utica it lies on the Ordovician Frankfort shale. In the meantime, too, the Arthophycus zone has risen, first to the base of the

strictly marine organisms which were exterminated at least locally on the withdrawal of their natural habitat. For the same reason, too, these sand burrowing animals could very well appear not only in the initial advancing beach deposits which range through the Lower and Middle into even Upper Clinton ages, but they might also have been living and taking advantage of conditions favoring their existence that are easily conceivable as having occurred during the shallowing and filling of the preceding late Medina sea. Accordingly then these questioned sandstones in the Rochester section may very well be interpreted as late Medina beach deposits that were seldom if ever before Clinton time sufficiently submerged to permit the existence here of the marine fauna of the time. Under this conception, too, *Arthrophycus alleghaniense*, and for the earlier parts of the concerned time also *Dædalus archimedes*, lose their commonly assumed indexical value as late Medinan guide fossils and become remains of land organisms that persisted to at least the closing stage of the Clinton.

Middle Clinton and finally to the base of the Upper Clinton. To make the case plainer we may add that the Arthophycus zone is the tangential base of the Clinton, passing on the west into the Gray Band and then into the essentially equivalent Thorold sandstone and on the east into the typical Oneida conglomerate. The greater the stratigraphic break at its base—with due regard, however, to the nearness of the compared localities to respectively the eastern, northern, and northwestern shores of the composite Clinton sea and also the probable relief and nature of the adjacent contributing lands—the thicker and usually the coarser is this clastic basal deposit.

The next oldest bed of the Clinton as developed in New York is a green unfossiliferous shale, best displayed in the section at Rochester where it is 21 feet in thickness. This bed was formerly called Sodus shale, but Chadwick, having shown that the Sodus shale at the type locality is a younger bed, has proposed to designate it by the new name Maplewood shale. In our opinion this shale pinches out somewhere between Lakeport and Verona and does not, as Chadwick thinks, reappear in greater thickness to the east of Verona. The obvious error in the latter view is that it postulates the almost inconceivable condition of absence of the Lower Clinton Maplewood shale in the thickest known development of the Clinton under Lockport and recognizes its presence in even greater volume in the shallower section under Clinton. In other words, it recognizes the presence of a shale formation on the opposite rising flanks of a basin and has it wanting in the deeper middle part.

Above the Maplewood shale, in the section at Rochester, is a tripartite limestone about 18 feet thick. The lower 4 feet, which contains a representative of the Furnaceville iron ore seam, is definitely recognized by its fossils in all exposures of this horizon to the west as far as Hamilton, Ontario. Eastward from Rochester the limestone part of this lower member passes into and is soon completely replaced by the expanding Furnaceville ore bed. The latter continues on to the vicinity of Martville, beyond which it either pinches out or passes into shale. The upper 5 feet contain some nearly pure limestone layers and these are filled with a form of *Pentamerus oblongus*. This large shell is wanting to the west of Rochester, and it seems probable the layers that contain it there are not represented in the sections at Lockport and Niagara Falls. To the east of Rochester the Pentamerus continues in the section for some 40 or 50 miles but is unknown beyond the town of Wolcott. The middle member is the more highly magnesian and the most persistent of the three zones. However, it appears to be generally wanting in the outcrops of the formation between Lockport and Albion, in which stretch, as at Reynales Basin, near Gasport, and at Mellina, only the lower member has been observed. Apparently it attains its maximum thickness of 11 feet at Rochester, is 9 or 10 feet thick at Niagara Falls, and in the opposite direction pinches out entirely at some place beyond Lakeport. The bed is everywhere only sparingly fossiliferous and so far as known contains only one species that is particularly characteristic of it. This is the *Stricklandinia canadensis*. Besides this the bed is notable for the first appearance of *Anoplotheca hemispherica*, which was found with the Stricklandinia in the shaly lower part at Rochester.

This tripartite limestone was identified by Hall and later by Hartnagel with the Wolcott limestone, mainly because both contain *Pentamerus oblongus*. But, as is well known now, the typical Wolcott limestone is a higher bed which does not extend westward to Rochester. Chadwick therefore proposes the name Reynales limestone for it.[1] The lower member contains a considerable and for the most part highly characteristic fauna, differing rather widely from that of the typical Wolcott and reminding, particularly in its bryozoan elements, rather more of certain Brassfield and Cataract faunas than of succeeding Clinton faunas.

[1] In proposing the term Reynales limestone Chadwick recognizes the fact that one "must go to Lockport or the Rochester gorge for the typical section. As only the lower member is present at Reynales Basin the question is raised whether it is either wise or permissible to employ this term for the whole formation rather than for the lower member alone. Some special designation is desirable for the lower member. It is easily distinguished by its fauna and as most of its known fossils were originally collected in the vicinity of Reynales Basin it seems eminently proper to restrict this name to the beds occurring at Reynales instead of using it in the broader sense advocated by Chadwick. Pending the selection of a more appropriate name for the formation as a whole "Reynales limestone" is adopted provisionally.

THE BEAR CREEK AND SODUS SHALES.—The main difficulties in the interpretation of the New York Clinton sections come in above the Reynales limestone. In the section at Rochester this limestone is succeeded by an 18-foot bed of purple and olive shale with thin plates of fossiliferous pearly limestone. The pearly lustre is owing mainly to the shells of *Anoplotheca hemispherica* (Hall, Murchison?), which are exceedingly abundant. With these and also in the shale itself often occur a number of fairly characteristic Pelecypoda, *Phacopidella trisulcata*, and well-preserved valves of Ostracoda of which the most important are five species of the genus Zygobolba. Because of their bearing on correlations with formations in the Island of Anticosti and with Clinton zones in Maryland and Virginia discussion of these Ostracoda and the species of Anoplotheca, both of which are characteristic of this zone and widely distributed, is deferred to the chapter on correlation.

This particular bed of shale has received no name that is strictly applicable to it unless it be Chadwick's term Bear Creek shale. Hartnagel included it with the overlying dark graptolitiferous shale in his Williamson shale. But the true Williamson shale overlies the true Wolcott limestone which is absent in the Rochester section. Moreover, the Wolcott is underlain by another shale, the true Sodus, which also is younger than the shale at Rochester here under discussion and like the Wolcott limestone is wanting there. Evidently, then, there must be a stratigraphic break in the Rochester section between the dark, true Williamson and the underlying olive and purple shale here referred to. Chadwick, on the other hand, unites it with the similar Sodus shale which, as will be shown presently, contains a younger and quite different fauna. Chadwick's Bear Creek shale—which he says lies "just *beneath* the Furnaceville ore," but which according to Hartnagel lies not only over that ore but also over the Reynales limestone that separates the two—contains the pelecypod fauna that occurs in this shale at Rochester and probably in the same bed. In the absence of an unquestionable geographic name the bed is herein designated the *Zygobolba anticostiensis* zone.

As shown in the section and mentioned in the preceding paragraph, the *Z. anticostiensis* zone is succeeded at Rochester by 5 or 6 feet of dark shale containing an abundance of *Monograptus clintonensis*. The hiatus between these two shales is occupied in the vicinities of Sodus and Wolcott by (1) a thin limestone followed by a few inches of iron ore (Sterling Station iron ore of Chadwick), (2) 55 feet or more of Sodus shale, (3) Upper Pentamerus or typical Wolcott limestone, 22 feet, and (4) the Wolcott Furnace ore bed. These four lenses constitute the remaining upper members of the Lower Clinton. The Williamson shale which rests on the Wolcott Furnace ore bed in Wayne County is regarded as the basal member of the Upper Clinton. Wedging in from the east between the base of the Upper Clinton and the top of the eastwardly attenuating Lower Clinton is a lenticular mass that we are calling Middle Clinton. East of Clinton this intervening mass lies for a time at the base of the Clinton but its eastern edge is finally overlapped by the Upper Clinton so that in the eastern part of Herkimer County the latter, together with the initial deposit of Oneida conglomerate, constitutes the whole of the Clinton group as there developed.

Regarding the thin limestone and ore at Sterling Station little is known beyond the fact that it lies between the *Z. anticostiensis* zone (Bear Creek shale) and the overlying Sodus shale. We may add that it probably represents the sedimentary record of the retreat of the sea in which the *Z. anticostiensis* zone was deposited.

The succeeding Sodus shale, like the *Z. anticostiensis* zone at Rochester, consists mainly of purple shale with thin layers of highly fossiliferous pearly limestone. The general aspect of the faunas of these two shale beds also is much the same. However, on critical comparison, the simulating fossils prove in most cases to be distinguishable. There are two species of Anoplotheca in the Sodus, one with a short hinge and rounded outline, the other long-hinged like *A. hemispherica*; but neither is strictly the same as the one found at Rochester. The Ostracoda also are different, the differences being notable particularly in the lobate forms of the genus Zygobolba of which four species are recognized. Because of the immediate need of evidence showing the distinctness of these two purple shales we may anticipate matters to be discussed in the correlation chapter by saying that the four species of Zygobolba in the typical Sodus shale are found also on the Island of Anticosti where they occur only in the Jupiter River formation. On the other hand, the five species of Zygobolba which are found in the shale at Rochester clearly represent a lower zone in the Anticosti section, four of the five species being confined there to the underlying Gun River formation.

THE WOLCOTT LIMESTONE.—For reasons stated with sufficient clearness by Chadwick (*op. cit.*, p. 347) the term Wolcott limestone, which had previously been used so loosely that it included the lower Pentamerus-bearing Reynales limestone of the Rochester section, is restricted to the "Upper Pentamerus" limestone, the typical outcrop of which occurs on small creeks near Wolcott village. In this vicinity the Wolcott limestone apparently attains its maximum thickness of 22 feet. To the west it pinches out rapidly, being much thinner at Williamson and entirely absent in the Rochester section. It thins less rapidly, though taking on a shaly character, also in an easterly direction but evidently fails entirely before reaching Clinton. Chadwick correlated this limestone with the calcareous "shales above the oolitic ore at Clinton" (*loc. cit.*), but the physical and faunal evidence in hand is so uniformly and strongly at variance with this view that we feel obliged to set it aside as erroneous.

Some twenty species of fossils from the Wolcott limestone, procured by the writer mainly from an outcrop on Second Creek, near Alton, New York, show that the fauna of this formation is totally different from that of the underlying Sodus shale. The Sodus fauna is a typical Atlantic Silurian association, in this case consisting of little besides a considerable variety of Ostracoda and the two species of Anoplotheca. The Wolcott limestone fauna, on the contrary, has no Ostracoda, lacks also the Anoplothecas, and is made up mainly of types of Bryozoa and Brachiopoda that occur elsewhere in America only in faunas that invaded the continent from the south. The Bryozoa comprise about half of the fauna and these particularly remind of species that appear first in the Brassfield-Cataract zone of the Medinan and reappear, with slight though usually distinguishable modifications and more striking loss or gain of temporarily characteristic species, in the Reynales limestone near the base of the Clinton, again in the Wolcott limestone, next in the Rochester shale at the top of the Clinton, and finally in the Waldron shale of the Upper Niagaran. Regarding their occurrence in the Wolcott limestone close comparison with the other appearances of the fauna shows that the Trepostomata, the Chasmatopora and the broadly frondescent Phaenoporas which characterize the older occurrences are now lacking leaving only the Fenestellidae and other Cryptostomata that are known to pass on into the Rochester age. But the host of other Bryozoa that distinguishes that later stage from the preceding facies is still lacking.

None of these Bryozoa nor any of the other types of fossils that usually are associated with them ever occur in the Silurian faunas that invaded the continent from the east. When one of these eastern faunas is directly succeeded by one of southern origin the differences between the two usually are very striking. Yet these apparently great breaks in the faunal sequence commonly do not signify long lapses of time during which the character of a fauna might be expected to change greatly through ordinary processes of evolution. In most cases, as is surely so of these Clinton breaks, they mean only changes in the direction of supply. In this manner we account for the absence in the Appalachian region of Maryland and adjoining States of many species and often whole faunas that occur in nearly synchronous deposits in more interior parts of the continent.

The Lower Clinton in Northwestern Ontario

The ostracod fauna of the Dyer Bay dolomite of Ontario proved so interesting in the present study that the following paragraphs were believed appropriate. The Dyer Bay dolomite was originally referred by Williams to the base of the Lockport, but in his final work[1] on the concerned formations he classifies it as a part of the Cabot Head shale which he regards as representing the greater part of the Upper Medina or Cataract formation in northwestern Ontario. As the Dyer Bay dolomite contains the brachiopod *Virgiana mayvillensis*, Williams correlates the Dyer Bay with the Mayville dolomite of the Silurian section in eastern Wisconsin.

[1] Williams, M. Y., The Silurian Geology and Faunas of Ontario Peninsula and Manitoulin and adjacent islands: Canada Dept. of Mines, Memoir 111, No. 91, Geological Series, 1919, p. 36.

In our opinion this reference of these dolomitic limestones to the Medinan is unwarranted. The problem is complicated and its full discussion is reserved for another occasion. It is mentioned here mainly because specimens of three of the Ostracoda described and illustrated in this volume come from the typical locality of the Dyer Bay dolomite and the desirability of some explanation for our reference of these species to a higher position in the time scale than that given them by Williams. Briefly, the evidence in the case is as follows: The senior author has collected more than 100 species of fossils from the Mayville dolomite near Mayville, Wis. These fossils certainly are neither of "Alexandrian" age, as Savage[1] classifies the formation, nor of the age of the Cataract or Upper Medina as Williams has it. They are Niagaran and probably represent some part of the Clinton, whether Lower, Middle or Upper Clinton need not be decided at present. The Dyer Bay dolomite being, as is generally admitted, of the age of the Mayville must therefore also be of Niagaran and not Medinan age. Confirmation of this conclusion is found in the Dyer Bay Ostracoda that were studied by us for Doctor Williams and partially listed by him under the preliminary names then applied to them (*op. cit.*, p. 37). In all, six species were distinguished: *Chilobolbina billingsi*, *C. punctata*, *Zygobolba williamsi*, two species of *Leperditia*, neither of which has yet been described, and a species of *Bythocypris* that has no particular stratigraphic significance. The two species of Chilobolbina occur in both the Gun River and Jupiter River formations in Anticosti; and the longer of the two species of *Leperditia* is found above the middle of the Gun River formation at Hannah Cliff. Varieties of both of the Chilobolbinas occur in the Mastigobolbina lata zone at Cumberland, Md.

As shown on preceding pages the Gun River and Jupiter River formations are of Lower Clinton age; and the Mastigobolbina lata zone is the most typical and persistent part of the Middle Clinton. According to this ostracod evidence, then, it appears that the Dyer Bay dolomite corresponds to the latter part of the Lower Clinton or the early part of the Middle

[1] Savage, T. A., Alexandrian rocks of northeastern Illinois and eastern Wisconsin: Bull. Geol. Soc. America, vol. xxvii, p. 310, 1916.

Clinton, with the former interpretation the more likely of the two. With the exception of the species collected on Fitzwilliam Island and referred by Williams to the Dyer Bay dolomite there is nothing in the remainder of the fossils of this bed as listed by him that would not look as well or better in a Clinton fauna than a Medinan one. Indeed, where else does one see corals like *Syringopora retiformis, Favosites cristatus,* and *F. obliquus,* or brachiopods like *Strophonella striata,* and *Rhynchonella bidens,* or a pelecypod like *Pterinea undata* or a trilobite of the genus *Liocalymene* (*Calymene cf. clintoni*), in rocks of pre-Clinton age? And how are we to explain that of the 10 fossiliferous Dyer Bay exposures given in Williams' tabulated list of fossils the so-called "Alexandrian" species occur only in the column of Fitzwilliam Island? Of the six fossils listed from this island only one (*Virgiana mayvillensis*) is noted as occurring in another of the 10 localities. The suggested possibility that the supposed Dyer Bay dolomite on Fitzwilliam Island is really an older bed should have been considered before Williams changed his belief regarding the post-Medina age of the Dyer Bay dolomite.

Just how this Clinton fauna got into the Michigan Basin is not easily explained. The Liocalymene and the Ostracoda at least, and less certainly also some of the Brachiopoda, doubtless are Atlantic types. But we see no possible chance of deriving them by direct migration from the Appalachian region across the Ohio Valley to the Great Lakes region. The only paths that now are suggested as probable are to the north from Lake Huron to Hudson Bay or in a more easterly direction across Quebec to the Gulf of St. Lawrence. Some definite basis for the belief that the Dyer Bay Ostracoda actually invaded the Great Lakes region from the northeast has come to us through a few slabs of fossiliferous limestone collected on the southeast branch of Blanch River north of Cobalt, Ontario. One of these pieces of limestone contains the *Leperditia* and *Chilobolbina punctata* which the Dyer Bay holds in common with the Gun River formation of Anticosti, and with them the *Zygobolba williamsi* which is so far known only from Ontario.

The facts in the case as above outlined may be summed up by saying that the trend of all the evidence—physical and stratigraphical as well as the purely faunal—now available is unqualifiedly opposed to the reference of the Dyer Bay dolomite of the Lake Huron region and also the in part contemporaneous Mayville dolomite in eastern Wisconsin to a pre-Niagaran age. The Mayville and Dyer Bay dolomites probably belong in the lower half of the Clinton group, but they certainly are neither "Alexandrian" nor Medinan in age.

The Middle Clinton in New York

The scene of the Clinton sequence is now shifted to the east where—between Clinton and New Hartford—the Middle Clinton is imperfectly exposed at a number of places along the sinuous outcrop of the formation. The recognition of the Middle Clinton in New York is based mainly on fossil evidence. Its top is rather satisfactorily indicated at the base of the oolitic iron ore at Clinton. However, the base of the Middle Clinton in this region is somewhat doubtful. It may extend down to and include the Oneida conglomerate and thus comprise all of the 125 feet or more of Clinton shale and sandstone that is known to underlie the oolitic ore at Clinton; or the basal part of this 125-foot interval may contain a thinned representation of one or more of the Lower Clinton beds. At present this question cannot be decided, but in the meantime the absence of any evidence whatever to the contrary warrants our assumption that at least the greater part of the doubtful interval is of Middle and not Lower Clinton age. In other words, that the Lower Clinton either has already pinched out beneath the town of Clinton or that the complete failure of the Lower Clinton is deferred to some place to the east of Clinton, in which case the section here would still retain some reduced and as yet unrecognized part or parts of the Lower Clinton.

NOMENCLATURE.—The matter of a geographic name for the Middle Clinton of New York is in doubt. In a paper read by the senior author before the Geological Society of America in 1917 the term Kirkland was used for it. At the same meeting Chadwick's paper on the Stratigraphy of the New York Clinton was read by title. The publication of the latter in the following year shows that its author proposes the term Sauquoit beds for the 125-foot interval between the base of the oolitic iron ore bed at Clinton and the underlying Oneida conglomerate. Chadwick's name Sauquoit may then be the one that will finally be adopted, but for reasons given in the preceding paragraph it seems unwise to take a definite stand on the point before certain features of the problem shall have been tested in the field. In the meantime the less definite term Middle Clinton will serve immediate purposes very well.

FAUNAL EVIDENCE.—As stated above the recognition of the Middle Clinton in New York is based mainly on fossil evidence. We know, for instance, that the sandstones and sandy shales which outcrop in the vicinity of New Hartford, in Oneida County, and which distinctly underlie the horizon of the oolitic iron ore bed at Clinton, contain an abundant and characteristic fauna of which the Ostracoda constitute the more important element. We know also that this fauna has not been observed in any of the Clinton beds found to the west of Oneida County nor in the beds which overlie the base of the oolitic iron ore in Oneida County. Finally, we know that this fauna is widely distributed in the Appalachian Valley and that it there overlies the zone that contains the characteristic Ostracoda of the Sodus shale of New York and the Jupiter River formation in Anticosti and underlies, as it does also at Clinton, N. Y., the Upper Clinton Bonnemaia rudis and Mastigobolbina typus zones. These stratigraphic relations have been definitely established in central Pennsylvania, at Cumberland, Md., and at localities in southwestern Virginia. Moreover, its absolute distinctness from Lower and Upper Clinton zones is established by the fact that near Armuchee, Ga., the Clinton group is represented apparently solely by that part of the group of which the Mastigobolbina lata fauna is particularly characteristic. With facts like these we can do no other than regard the Middle Clinton in New York as a deposit that is geographically limited in east-west direction and laid down in a special minor trough which we may view as the northern extremity of an arm of the larger depression in which the Clinton deposits of the Appalachian Valley were deposited.

It is true that the *Mastigobolbina lata*, the most characteristic of the Middle Clinton fossils, has been cited by geologists up to the publication of Chadwick's paper in 1918 as occurring in such other zones of the New

York Clinton as the "upper shale" at Rochester, the true Sodus shale, and the calcareous shale which overlies the oolitic iron ore at Clinton, but in all of these instances the identification of this species is erroneous. The Ostracoda found at Rochester are not of this species nor of any other that is found with it at New Hartford, but they belong to species of another genus, Zygobolba, that are characteristic of their own zone. Those in the Sodus shale also belong to Zygobolba but to other species of the genus that also are confined to a particular zone of their own. Essentially the same is to be said of the Ostracoda in the shale above the ore at Clinton. These belong to Plethobolbina, Bonnemaia and to large species of Mastigobolbina which are quite different from the *M. lata*, *M. vanuxemi*, *M. clarkei* and such other common and widely distributed Middle Clinton species as *Zygobolbina conradi*. The species found above the oolitic ore at Clinton indubitably mark their own zone which is recognized by the same association of forms from central Pennsylvania to southwestern Virginia and thence through Kentucky to south-central Ohio.

In New York the Middle Clinton contains other fossils besides the Ostracoda. But these seldom are abundant and well preserved and not many kinds have been found. However, in southern Pennsylvania and northwestern Georgia, a few localities are known where the member, especially its lower third, contains many fairly good brachiopods and pelecypods. Some of these may prove valuable for correlation purposes but need more detailed investigation before much use can be made of them. In any event their occurrence is too sporadic to permit them to rival their ubiquitous ostracod associates as guide fossils.

The Upper Clinton in New York

Under this provisional designation we include all the beds between the base of the true Williamson shale and the top of the Rochester shale, the proposed Gates limestone of Chadwick at the top of the Rochester being in doubt. The decided faunal break between the Middle and Upper Clinton in New York has long been recognized. It is manifested also very clearly in the Clinton sections of the Appalachian Valley from central Pennsylvania to the southwestern extremity of Virginia. The importance of the break in the latter region, though involving smaller numbers of species, is more truly indicative of actual change in the marine life of contributing oceanic basins than appears in comparing the several faunas of the Clinton in New York west of Clinton. Namely, in the Clinton faunas of the Appalachian Valley we are dealing almost exclusively with periodic incursions of the Atlantic fauna whereas in the Clinton faunal sequence of New York the pure Atlantic incursions that pertain to the Zygobolba anticostiensis zone (Bear Creek shale), the Sodus shale, the Williamson shale, and the Mastigobolbina typus or Paleocyclus rotuloides zone alternate with the strictly southern invasions that make up the whole of the Reynales and Wolcott faunas and over 90 per cent of the Rochester fauna as developed at Rochester and Lockport. Incidentally, we may mention that facts like these, referring particularly to the source of faunal supply, have an important, though almost universally neglected bearing on questions of correlation of formations and their classification into groups.[1]

COASTAL WARPING AND FAUNAL INVASIONS.—The Upper Clinton is distinguished from the Middle and Lower Clinton also in its geographic distribution and by crustal warping that caused the changes in geographic

[1] This remark is suggested by Chadwick's proposal to divide the pre-Lockport Silurian, which he calls "Eontaric or Anticostian" into two groups. The "Lower Eontaric" comprises the upper part of the Medinan series and the Lower and Middle Clinton, beginning with the Whirlpool sandstone and ending with the Wolcott Furnace iron ore bed on the top of the Wolcott limestone, the "Upper Eontaric" beginning with the Williamson shale and ending with the Gates limestone which lies on the Rochester shale and thus corresponding very nearly with our Upper Clinton. In our opinion the most commendable feature of this proposed classification is the recognition of the alliance of the Rochester shale with the underlying Irondequoit limestone and the Williamson shale rather than with the overlying Lockport dolomite. As for the remaining innovations we can say only that they do not fit the conditions required in the Appalachian region and that our study of the Clinton and Medina formations in New York and Ontario tends without exception to show the absolute invalidity of the arguments presented by Chadwick in proposing them. This statement is quite apart from certain errors in the sequence and correlation of some of the stratigraphic units and also the fact that Chadwick failed entirely to observe the distinctness of what is here called Middle Clinton. Chadwick's otherwise praiseworthy effort in this case is merely another good illustration of the danger of introducing important changes in the classification of formations without adequate field and laboratory data and experience wide enough to include all the concerned areas.

patterns. In areal extent the Upper Clinton greatly exceeds the preceding divisions of the group. Though relatively local oscillations are suggested by irregularities in the distribution of certain of the Upper Clinton faunas there is still abundant evidence to show that deposits with fossils indicating more or less clearly certain middle and later stages of this time occur to the northeast as far as Littleton, N. H., and to the west in southern Ohio. Both of these extensions of the normal Clinton marine area of deposition are of the Mastigobolbina typus zone, which carries a purely Atlantic fauna; but no preceding Atlantic Clinton fauna is known in either of these outlying places and only one later extends by a different path so far west from the Appalachian Valley as Ohio.

As previously remarked the southern fauna repeatedly invaded and alternated with the Atlantic fauna in occupying the Clinton area of western and central New York. Both the Reynales and the Wolcott limestone faunas are of southern origin and they remain uncontaminated to their easternmost extent. Evidently these invasions were either separated by some land barrier from the Appalachian Valley sea of the time or the latter trough was not submerged at their times. The Rochester shale fauna, on the contrary, does show contamination and mixture of Atlantic and southern faunas so that we cannot readily escape the conviction that the barrier which had kept the preceding faunas apart was now at least less effective.

ROCHESTER FAUNA.—The fauna of the Rochester shale in western New York, where its fossils have been collected assiduously through nearly a century, comprises approximately 235 species. Nearly a third of this large number consists of Bryozoa, every one of which suggests only a southern origin. In other words, the Rochester Bryozoa are without exception more or less closely allied to older or younger genera and species in western and southern formations—the Waldron shale, Osgood limestone and Brassfield-Cataract formations—whose faunas are confidently viewed as invading from the south. In tracing the Rochester horizon eastward from its typical locality its fauna becomes rapidly less, so that diligent search of the formation at localities in Wayne County, at which the Rochester yet maintains its typical lithological facies, failed to reveal more than a fifth of the species found in this formation 40 to 50 miles west. At Clinton nearly all that is left of the remarkably prolific southern Rochester fauna consists of about a dozen of its Bryozoa which occur there in fragmentary though still recognizable condition in the upper or red flux ore bed.

Accordingly, then, we infer that the southeastward tilt of the Appalachian land which had made possible the invasion of northwestern Georgia by an Atlantic Middle Clinton fauna was reversed in direction so that the Georgia locality was emerged whereas the wide area between the Adirondacks and central Kentucky was subjected to Atlantic submergence through a more northern inlet.

The exceedingly few (two or three fragments of) Bryozoa that have been observed in the Appalachian Clinton deposits north of Alabama occur in the M. typus zone of the Upper Clinton. Only one of these specimens is specifically determinable, and this is referred to *Phylloporina asperatostriata*, a characteristic Rochester species. Whether this is a venturesome straggler of the southern host or whether this species ranged also in the Atlantic and invaded Maryland with its associated faunas cannot be satisfactorily determined at this time. Its present main interest and value is as a guide fossil that helps other fossils in proving the Rochester age of at least some part of the Upper Clinton as developed in Pennsylvania and Maryland.

In the Red Mountain Clinton of Alabama remains of Bryozoa are rather common and very similar in character to those found in the Wolcott limestone in New York. But none of the other kinds of fossils associated with them is a distinctly Atlantic type. Besides, the Alabama deposits of this age are separated from the southern extremity of the Middle Appalachian Clinton trough by more than the width of the State of Tennessee in which deposits of Clinton age are almost entirely absent. It appears, therefore, the Alabama Clinton faunas are entirely southern in origin.

Reverting to the Rochester fauna of New York it is to be observed that in the collections made at Lockport and Rochester this fauna contains about 20 species of Ostracoda, trilobites and graptolites that we regard as North Atlantic types and not as southern. This conclusion is based on two facts, (1) most of them are either specifically the same as, or have their closest allies among species found in the Appalachian Valley region north of Tennessee; (2) none of them has been found in rocks of Silurian age in the Ohio and Mississippi valleys whose faunas may be confidently viewed as having invaded the continent from the south. In addition to these 20 Atlantic species the typical Rochester fauna includes a few brachiopods, notably Clorinda, *Nucleospira pisiformis*, and *Stropheodonta profunda*, which while common in Atlantic faunas of this time are rare or not found at all in southern faunas before Upper Niagaran time. The only manner in which we can account for these facts is by assuming sufficient communication between the southern and eastern waters during the Rochester and Irondequoit stages of the Upper Clinton age to permit such intermingling of faunas. The connection between the two seas must have occurred across north central Pennsylvania.

As already indicated the Upper Clinton was a time of general though oscillating subsidence in the middle Appalachian and Allegheny Plateau regions. But the subsidence was never sufficient to permit unrestricted and general blending of faunas. Most of the transfusion was from the east westward and much of the latter concerned crustacea that seem better travelers and less susceptible to changes in environment than other classes of marine animals. Among them are *Paraechmina spinosa*, *P. abnormis*, *Dizygopleura symmetrica*, *Bythocypris niagarensis*, species of Octonaria, *Dalmanites limulurus* and *Homalonotus delphinocephalus*, all of which occur in the Upper Clinton of Maryland and Pennsylvania but not in the Ohio Valley. The nine dendroid and reticulate graptolites that have been described from the Rochester in western New York are wholly unrecorded in southern Silurian faunas except perhaps one or two cosmopolitan species of Dictyonema which are found also in the Cataract formation in Ontario and the Brassfield in Ohio. Graptolites of the same types do, however, occur in the Atlantic faunas of the east, though it must be confessed that their remains are not common in the Appalachian Clinton formations.

Besides the 20 or more species in the Rochester fauna of western New York which have been picked out as probably having been derived from the east this fauna includes five or six pelecypods that also suggest an eastern rather than a southern origin. However this question may finally be decided, it cannot be denied that most if not all of the Rochester pelecypods have very close and perhaps indistinguishable allies in the Clinton faunas of Pennsylvania. As yet, however, the Clinton pelecypods require closer investigation not only of their structural characters but also regarding both their geographic distribution and their vertical range before their testimony in questions of correlation may be properly appreciated and evaluated.

UPPER CLINTON FORMATIONS.—Continuing with the New York section, the first of the Upper Clinton formations is the Williamson shale as redefined by Chadwick. In the section at Rochester the true Williamson is represented by only the five or six feet of dark graptolite-bearing shale which lies immediately beneath the Irondequoit limestone. Going eastward from Rochester this shale formation increases to its supposed maximum of about 100 feet in the deep well at Lakeport. Beneath it in this well is a shaly limestone that all agree is the Wolcott limestone. To the east of Lakeport the Williamson thins so rapidly and changes so greatly in lithological character in the largely drift-covered 25 miles that intervene between this place and the outcrops at Clinton that some doubt exists as to its presence in the section at the latter place. If, as we think is highly probable, the Williamson shale is represented in the typical section of the Clinton, then it must be by that part which begins with the oolitic iron ore bed and extends above the ore to some undetermined line in the overlying 18 feet of interbedded soft shale and harder calcareous shale.

More than 40 species of fossils were collected by the senior author from the greenish soft shale that is removed with the ore in mining the oolitic bed at Clinton. From one to two feet of this shale lies between the two ore benches, and we were assured by the miner that no more than a foot or two of the shale that overlies the upper bench is ever removed in the mining operations. Though most of the fossils came from the roof of the mine it is certain that a part of the collection is from the shale parting. So far as observed there is no essential difference between the fossils found immediately above and beneath the upper of the two oolitic layers.

This and other collections of fossils made at Clinton are exceedingly important in determining the age relations of Maryland Upper Clinton zones to those in New York. Lists are given on following pages. Here we are concerned more particularly with the relation of the oolitic iron ore and the fossiliferous shale that is intimately associated with it at Clinton to the typical Williamson shale.

According to present conceptions the most characteristic fossil of the Williamson shale is *Monograptus clintonensis*. This graptolite occurs in the oolitic iron ore zone at Clinton. The Williamson also has the first of the Clinton occurrences of Plectambonites (probably *P. elegantulus*) and the same species occurs with the Monograptus at Clinton. A third characteristic fossil that is found in both is a supposedly new species of Ischadites. These three species—especially in view of the fact that none of the other fossils associated with them in either the typical Williamson or in the shales that are associated with the oolitic ore at Clinton tend to contradict their testimony—should suffice in establishing the essential contemporaneity of the two beds. Regarding the other fossils in both beds we may add that by far the greater number of them are decidedly much more closely allied to succeeding Irondequoit and Rochester species than to the older Middle and Lower Clinton species.

In the more limy zone which lies from 3 to 15 feet above the oolitic ore at Clinton is another fauna. A number of the species of the underlying bed pass into this zone, but the introduction of four or five other species gives it a distinct aspect that seems to be quite characteristic of the zone. Among the added forms are *Dalmanella elegantula*, *Bilobites biloba*, and *Nucleospira pisiformis*, three prolific members of the Irondequoit and Rochester faunas. But the most abundant and also the most striking of the new things is the coral *Palaeocyclus rotuloides*, and this, moreover, seems to be confined to this zone.

Clinton Section at Clinton, N. Y.

The general character and relations of the Clinton section at Clinton, New York, is given below followed by columnar sections showing the sequence of beds at Rochester, Wolcott, Lakeport, Clinton, and Cruger's Mill on Days Creek.

SECTION AT CLINTON, N. Y.

	Feet
Clinton group	
Unexposed beds of undetermined but evidently small thickness.......	?
Upper Clinton	
9. Calcareous sandstone, rather thin bedded, with thin shaly layers (Herkimer sandstone of Chadwick), about.........	50
8. Red flux iron ore bed, filled with broken remains of Rochester Bryozoa	3-6
7. Thin, irregularly bedded calcareous sandstones in upper half and thinner layers of arenaceous shale in lower half.......	7
6. Hard, streaky, ferruginous and clayey suboolitic limestone, full of large and small crinoid columnals and a few undetermined Bryozoa	2
(Beds 6 and 7 probably correspond to the Irondequoit limestone at Rochester and to the Keefer sandstone of Maryland and Pennsylvania.)	
5. Bluish or greenish shale with thin layers of sandy, often fossiliferous limestone mainly in the middle third; fossils: *Palaeocyclus rotuloides*, *Dalmanella elegantula*, *Bilobites biloba*, *Nucleospira pisiformis*, *Mastigobolbina punctata*, *Plethobolbina typicalis*, etc. At base a softer shale with large and partly different fauna, including Monograptus and other graptolites....................................	18
4. Oolitic iron ore locally in two beds with a fossiliferous shale parting; and occasional quartz pebbles in base...........	2.5-3
(Beds 4 and 5 correspond to the Williamson shale of Wayne County, and to the Mastigobolbina typus zone in Pennsylvania, Maryland, Virginia, Kentucky, and Ohio.)	
Middle and possibly Lower Clinton	
3. Greenish shale and very thin sandstone layers, almost barren of fossils; exposed about..................................	25
Unexposed but as indicated by log of deep well:	
2. Shale with beds of sandstone about.........................	105
1. Oneida conglomerate	50
Ordovician	
Frankfort shale	
Shale, light colored and sandy.................................	30
Dark shale	662
Trenton limestone in bottom of well.	

As indicated above in the section at Clinton beds 4 and 5 are correlated with the Williamson shale, and beds 6 and 7 with the Irondequoit. However, bed 8, the conglomeratic red flux ore bed, must be a younger formation. It consists mainly of cemented crinoid columnals and fragments of common Rochester shale Bryozoa. Although only a small part of the material collected from this bed has been subjected to study at least nine

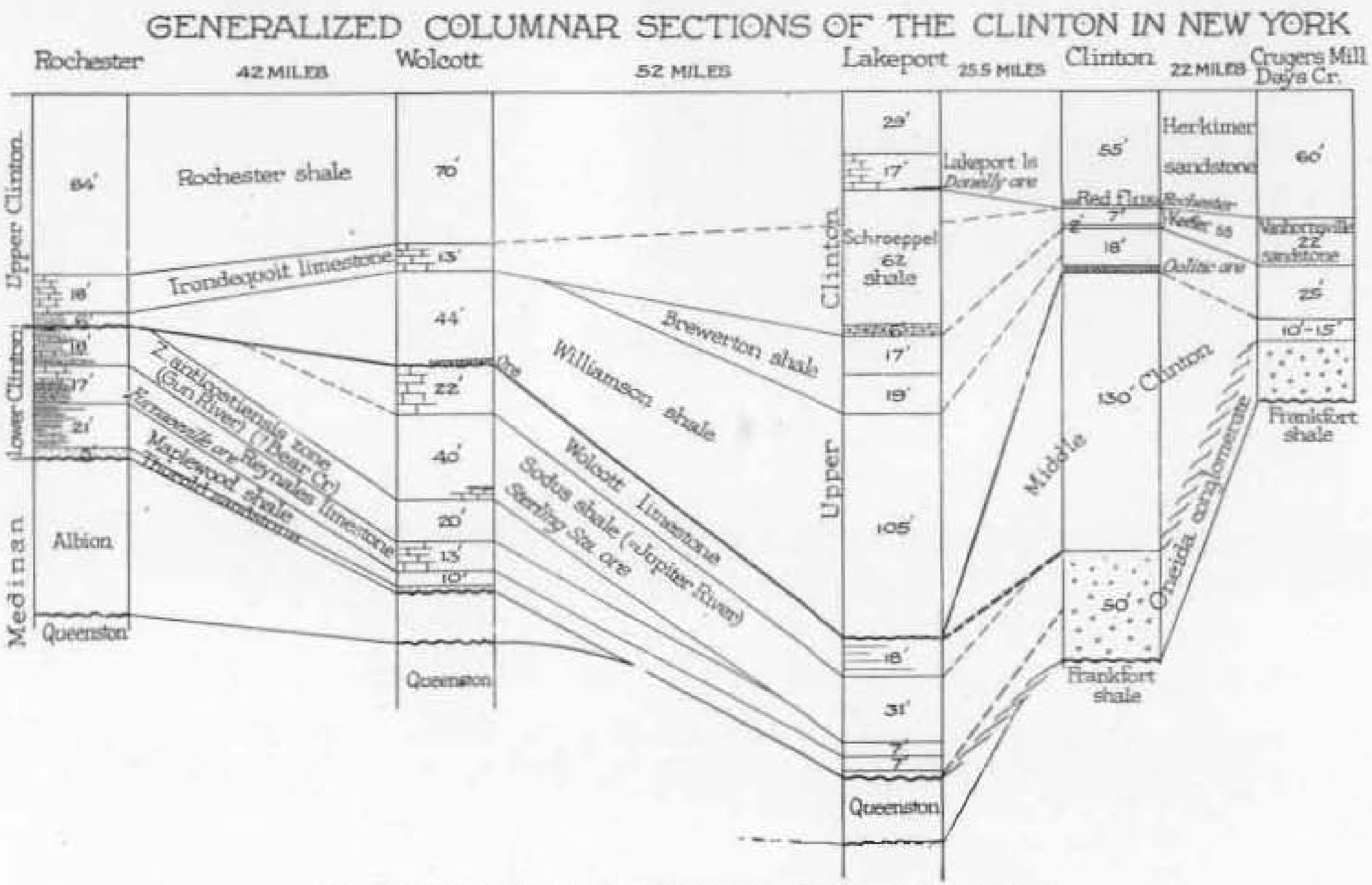

FIG. 26.—GENERALIZED COLUMNAR SECTIONS OF THE CLINTON IN NEW YORK.

Rochester species were recognized in it. These are: *Chilotrypa ostiolata*, *Hallopora elegantula*, *Batostomella granulifera*, *Eridotrypa solida*, *Lioclema asperum*, *Nicholsonella florida*, *Phænopora canadensis*, *Pachydictya crassa*, and *Clathropora frondosa*. Besides these there were specimens of two wider species of Phænopora, others of a species of Meekopora that may be the *M. bassleri*, and finally a few of a species of Rhinopora. Remains of other classes are rare and poorly preserved. Among them is a brachiopod like *Whitfieldella oblata*, fragments of trilobites probably belonging to *Calymene niagarensis* and *Dalmanites* cf. *limulurus*. Also two undetermined cup corals. Further search doubtless would reveal other species of like stratigraphic significance but in the absence of anything of opposing nature it has seemed unnecessary to seek additional proof of the Rochester age of the red flux ore bed.

In making this assignment of the red flux ore bed to the age of the Rochester shale it is to be understood that we contemplate merely a stage following the termination of Irondequoit limestone deposition in western New York. The red flux ore bed accordingly would represent some part of the lower half of the Rochester shale leaving the overlying sandstone in the Clinton section to represent higher parts of the Rochester.

Chadwick denied the presence of beds corresponding stratigraphically to the Rochester shale in the section at Clinton. The evidence cited by him in support of his view consists mainly of unproved and altogether improbable assertions regarding progressive loss by erosion of members from the top of the Clinton in going eastward from Rochester. We, on the contrary, see no valid reason, either paleontological or physical, for any such conclusion. Of course, the top surface of the Clinton was subjected to some erosion during the eastwardly increasing time marked by the hiatus between its top and the overlapping base of the succeeding Lockport and Cayugan formations. But as commonly happened in such cases the amount of rock removed was comparatively insignificant.[1]

In this connection it should be remembered that Chadwick failed to recognize the Williamson age of the oolitic iron ore bed at Clinton which

[1] A good illustration of the almost inappreciable effect of erosion during long periods of Paleozoic emergence is the case of the Fernvale limestone in Missouri which, as described by Ulrich in the Revision of the Paleozoic Systems, p. 305, maintains approximately the same thickness whether the next succeeding bed is of a later Richmond age or a Mississippian formation.

be correlated with the Verona iron ore that lies at the base of the Wolcott limestone or lower. Also that he recognizes the Lower Clinton Sodus and Maplewood shales, and, doubtless inadvertently, also the "Martville" shale, in the Middle Clinton south and east of Utica. These misapprehensions probably are largely responsible for the belief in great erosion loss from the top of the Clinton. Nor should we overlook the unconcealed fact that Chadwick depended for his faunal evidence from localities in Oneida and Herkimer counties mainly on citations in the old reports by Vanuxem and Hall.

Judging from our own investigations none of the Clinton fossils so far collected at localities in Oneida and Herkimer counties indicates Lower Clinton; and in the latter county they are all of Upper Clinton age. Obviously then, the eastward thinning of the Clinton is mainly by overlap and consequent loss of beds from the bottom instead of from the top.

Ostracod Zones of the Clinton

Study of the field relations of the Clinton Ostracoda described in this volume has brought out the fact that they occur in a number of more or less clearly distinguishable zones. Nine of these zones are recognized; and those species that are confined to one or another of the zones constitute by far the majority of the total number. Most of the remainder are common to two of the zones, while a few may even be found in three. The latter, however, are of the relatively simple forms among which close specific discrimination is difficult.

Each of the major divisions of the Clinton—commonly designated in this work as Lower Clinton, Middle Clinton, and Upper Clinton—comprises three zones, arranged and named as in the following table:

CLINTON OSTRACOD ZONES IN THE APPALACHIAN VALLEY REGION

9. Drepanellina clarki zone	Upper Clinton or Lakemont formation
8. Mastigobolbina typus zone	
7. Bonnemaia rudis zone	
6. Zygosella postica zone	Middle Clinton
5. Mastigobolbina lata zone	
4. Zygobolbina emaciata zone	
3. Zygobolba decora zone	Lower Clinton
2. Zygobolba anticostiensis zone	
1. Zygobolba erecta zone	

Except the two uppermost zones, which are separated by the Keefer sandstone, it is not claimed that these zones are definitely limited above and below. Possibly such limits might be established if one could find and study very carefully the several beds in perfectly exposed sections. But such favorable exposures of Clinton deposits are seldom found in the Appalachian Valley, and those that have been observed rarely extend through more than two or three of the zones. Nearly always some much needed part is covered. Besides the successive beds of shale and sandstone are so much alike in lithologic character and so many prove practically barren of organic remains that the criteria usually relied on in separating members of formations are only very imperfectly serviceable in this case.

For the present, then, most of these fossil zones serve mainly in giving an approximate indication of particular horizons in an otherwise exceedingly uncertain sequence of deposits. Each zone is recognized and distinguished from the others by one to ten or more species of Ostracoda whose vertical range has been established by field experience, careful collecting and exhaustive study and comparison of everything contained in each collection. Some species were thus shown to range through hundreds of feet of beds. Many others, on the contrary, seem to be confined to much narrower vertical limits. Fortunately, most of them occur in veritable swarms, and it is only very seldom that a species occurs unaccompanied by others. Though the usual presence of a number of more or less closely related forms in each of the fossiliferous layers adds to the difficulty of identifying the specimens, the combinations of two or more closely drawn characteristic species makes the extra trouble worth while by adding greatly to the certainty of their age determination.

As might be expected, certain of these zones are not only more definitely determinable but also more easily than others. Some also, and this applies particularly to the first (*Zygobolba erecta*) and sixth (*Zygosella postica*) zones, are known to occur at only a few places. The seventh, Bonnemaia rudis zone, also has not been recognized in many of the Clinton sections. This is unfortunate because the B. rudis zone is perhaps the most prolific of the Clinton ostracod zones and very easily distinguished from the underlying zones. At the four places where this zone has been recognized—one in central Pennsylvania, one in Maryland, one in southwestern Virginia, and one in northeastern Tennessee—occasional thin sandstone layers in it are simply crowded with large specimens of *Bonnemaia rudis* and other species of this genus that have so far been found only in this zone.

Considering the geographic distribution of the Ostracoda of each of the three major divisions of the Clinton we quickly learn that in each case it is the middle zone that is the most widely and generally distributed. In Lower Clinton exposures the second or Zygobolba anticostiensis fauna is recognized oftener than are either the underlying Z. erecta zone or the overlying Z. decora zone. In the Middle Clinton the Mastigobolbina lata fauna is much more persistent than either the Zygobolbina emaciata or the Zygosella postica faunas. And so also in the Upper Clinton it is the Mastigobolbina typus zone that is always present, whereas either or both of the two other zones of this division may be absent or at least unrecognizable over wide areas. These facts suggest shifting of seas and alternating retreat and advance of shore lines.

The general absence of the Z. erecta fauna except in central Pennsylvania (Blair, Mifflin, Huntingdon, Juniata, and Perry counties), considered with the two facts (1) that where it is present the Clinton section as a whole is thicker than elsewhere and (2) where it has not been recognized the second or Z. anticostiensis fauna lies nearer the base of the Clinton than it does in sections showing both zones, suggests the inference that the Clinton sea first invaded central Pennsylvania and in the second stage spread from there northward to western New York and southward to southwestern Virginia. At the close of the second stage, however, the Appalachian sea retreated from the south so that the third or Z. decora fauna is confined to the area between northern Virginia and central New York. Similarly, the Zygobolbina emaciata fauna has been recognized in typical development only in south central Pennsylvania, whereas the succeeding Mastigobolbina lata fauna is well developed in Oneida County, New York, and generally present in the Clinton sections in Pennsylvania, Maryland, and Virginia. But on this occasion the sea apparently retreated from the north so that the succeeding Zygosella postica fauna is found only to the south of Pennsylvania.

A generalized statement of geographic changes during the Upper Clinton has already been given in discussing the New York Clinton section. Here it will suffice to say that the patchy distribution of the Bonnemaia rudis zone from central Pennsylvania to northern Tennessee indicates preceding slight warping of the Appalachian region, with increasing subsidence to the southwest. The submergence of the succeeding Mastigobolbina typus stage involved a much wider area extending to southern Ohio on the west and to New York on the north.

Evidently tilting of the surface of eastern United States occurred alternately in northeast and southwest directions, the area of submergence increasing toward the north when the tilt took that direction and to the south and west when the direction of the tilt was reversed. The process was further complicated by similarly alternating differential movements in east-west directions, which caused considerable overlap by deposits and faunas of southern origin over the western edges of deposits that had been laid down by Atlantic waters; and vice versa. In consequence of these various differential movements and warpings of the surface of the continent the geographic pattern was ever changing. The more important of these are shown in paleogeographic maps in another chapter.

CLINTON SECTIONS IN PENNSYLVANIA AND MARYLAND.—In view of the preceding observations it is not to be expected that all of the nine Clinton ostracod zones should be generally found and clearly recognized in all or even in many widely separated exposures of the group. In fact they are not generally present or at least not so developed that one may always be certain as to what is or is not present. Still, some sections are known in Pennsylvania and Maryland in which most if not all of the zones have been recognized. To insure the removal of all doubt in the mind of the reader that these zones are not based on merely local variations of the Clinton fauna but are actually superposed one over the other, a few of such sections will be given. The most complete of these sections occurs in Juniata County, Pennsylvania, on the northwest slope of Tuscarora Mountain between Honey Grove (sometimes called Bealetown) and the edge of Perry County. Another, in the same state, is 1 mile north of Marklesburg in Huntington County; the third, also in Pennsylvania, is at Hollidaysburg; the fourth at Cumberland, Md.

SECTION NEAR HONEY GROVE, PA.

The following very complete section was measured by Charles Butts and E. O. Ulrich, and the fossils were determined by the latter:

SECTION OF THE CLINTON GROUP ON FLANKS OF TUSCARORA MOUNTAIN, SOUTHEAST OF HONEY GROVE, JUNIATA COUNTY, PENNSYLVANIA

	Feet
Cayugan: McKenzie formation	
Niagaran	
Upper Clinton	
Drepanellina clarki zone	
Soft pale yellow and greenish calcareous shale with the characteristic ostracods and shells of this zone..........	50
Keefer sandstone member	
Hard, thick-bedded quartzose sandstone in lower part and more flaggy fossiliferous sandstone in upper third, about.	28
Fossils: 2 sizes of "Monocraterion"-like worm burrows, *Dalmanella* cf. *elegantula*, *Rhipidomella* cf. *hybrida*, *Rafinesquina* sp., *Orthotetes* sp., *Spirifer crispus*, *Camarotoechia* cf. *plicatella*, *Modiolopsis* sp., *Ischyrodonta* ? sp., *Ctenodonta* sp., *Tentaculites* sp., *Leperditia* sp., *Dizygopleura* sp., *Calymene* cf. *blumenbachi*, *Homalonotus* cf. *delphinocephalus*.	
Mastigobolbina typus zone	
Greenish and purplish shale with plates of sandstone, the latter often fossiliferous, about..........................	100
Fossils: *Dalmanella* cf. *elegantula*, *Chonetes cornutus*, *Anoplotheca obsoleta* Ulrich (outline rounded and plications nearly obsolete—characteristic of this and underlying zones), *Mastigobolbina typus*, *M. triplicata*, *M. punctata*, *Plethobolbina typicalis*, *Bonnemaia celsa*, *B. crassa*, *B. longa*, *B. perlonga*, *B. obliqua*, *Zygosella vallata*, *Z. nodifera alta*, *Liocalymene clintoni*.	
Bonnemaia rudis zone	
Interbedded sandstone and shale, certain layers filled with the fauna of this zone, about..............................	100
Fossils: *Anoplotheca obsoleta*, *Bonnemaia rudis*, *B. fissa*, *B. longa*, *Mastigobolbina bifida*, *Zygosella vallata* var., *Calymene* "*blumenbachi*," *Liocalymene clintoni* ?, *Tentaculites* sp.	
Middle Clinton	
Faunal zones not indicated by fossils; upper part perhaps Upper Clinton	
Shale and sandstone, the former dark green but weathering to purple tints, the latter more or less ferruginous, mainly fine grained and weathering rusty. No fossils observed. If present should include the Zygosella postica zone; about.	200

Highest observed appearance of the Mastigobolbina lata fauna — Feet

Shale and sandstone like the overlying 200 feet, but several beds contain fossils of the M. lata fauna; about.......... 50

Fossils: *Dalmanella* aff. *elegantula*, *Chonetes* sp. (same in Zygobolba decora zone), *Mastigobolbina lata*, *M. vanuxemi*, *Zygobolbina emaciata* ?, *Z. conradi*, *Plethobolbina* sp., *Calymene* "*blumenbachi*," *Liocalymene* cf. *clintoni* and crinoid columnals.

Covered except for occasional thin ledges of blocky ferruginous sandstone, the covered spaces probably mostly shale. No fossils observed; about.................................. 100

Poorly exposed band with thin fossiliferous sandstone; about.... 20

Fossils: *Zygobolba erecta*, *Z. bimuralis*, *Zygobolbina emaciata* ?, *Mastigobolbina lata nana*, *M. vanuxemi*, *Calymene* "*blumenbachi*," *Liocalymene* cf. *clintoni*, *Bucaniella trilobata*, and two undeterminable trepostomatous Bryozoa. Evidently an early Middle Clinton fauna though not a typical expression of the Z. emaciata zone.

Covered 40

Lower Clinton

Zygobolba decora and ? Z. anticostiensis zones

Showing mainly as surface debris with occasional bands of thin sandstone in place. Many of the slabs of sandstone are fossiliferous, especially in the upper part; about...... 200

Fossils: *Zygobolba decora*, *Z. elongata*, *Z.* cf. *erecta*, *Z. carinifera*, *Z. robusta*, *Z. intermedia*, *Zygobolbina carinata*, crinoid columnals, *Chonetes* sp., *Liocalymene* cf. *clintoni*.

The lower two-thirds of this interval was only very hurriedly searched for fossils. There being ample space for the Zygobolba anticostiensis zone it seems probable that more careful investigation would reveal the fauna of this zone also.

? Zygobolba erecta zone

Vermilion and brownish red sandstone in thin layers, some of them fossiliferous, about.............................. 20

Fossils: *Mastigobolbina* cf. *incipiens*, *M. producta*, *Zygobolba anticostiensis* ?, *Chonetes* sp., *Anoplotheca hemispherica*, *Liocalymene* n. sp.

Covered space to top of Tuscarora sandstone; about............ 40

Total thickness of Clinton about.................. 940

It is to be regretted that only an hour or two was devoted to the collection of fossils from the lower 650 feet of this great Clinton section. With more time, doubtless, other and probably more characteristic expressions of the fossil zones would have been found. As it is we have one fairly characteristic Middle Clinton fauna, the M. lata zone being clearly indicated by the listed species. But the next underlying fossiliferous zone which lies 100 feet beneath the M. lata bed lacks some things, mainly other than Ostracoda, that one would expect in a typically developed Zygobolbina emaciata fauna. It may be either a little younger or older. The Lower Clinton fauna that was collected some 40 to 80 feet lower in the section contains a number of the most characteristic species of the Z. decora zone, but with these are specimens like *Zygobolba elongata, Z. erecta,* and *Z. carinifera* which have been referred to the Z. erecta zone. On the other hand, there is also *Zygobolbina carinata* which is a member of the Frankstown ore bed. However, the exact position of the last is not definitely known, though the probabilities strongly favor its being an upper subzone of the Z. decora zone and a possible contemporary of the Wolcott limestone and Wolcott Furnace ore bed of the New York section.

As stated above there is ample room in this section between the layers containing this possibly mixed facies of the Z. decora fauna and the next lower observed fossiliferous bed which lies about 150 feet beneath it for the apparently missing or at least undiscovered Z. anticostiensis fauna. In other words, there are beds here that may well correspond to that zone even if the fauna itself should prove to be absent here.

Regarding the lowest of the Clinton fossiliferous beds in the Honey Grove section even more doubt prevails than in the overlying cases. Only a single small hand sample of this was taken by Mr. Butts, who alone investigated the basal part of this section. The six species above listed were found in the laboratory when this rock sample was broken up. None of them is strictly characteristic of the Z. erecta fauna as typically developed in a similarly bright red sandstone and in the ore bed associated with it in the basal part of the Clinton section near Marklesburg, Pa. We are certain only that it is a Lower Clinton fauna; and it is referred provisionally to the Z. erecta zone for no other reason than that it occurs near the base of an uncommonly thick sequence of Clinton deposits.

No better place than this is likely to arise in this discussion of the Clinton faunal zones for the candid admission that the Lower Clinton in the Appalachian region is not readily divisible into three definitely recognizable zones. While there is practically no uncertainty and no difficulty worth mentioning in distinguishing the Lower Clinton faunas from those of Middle Clinton age, the case as yet is very different when one is called upon to decide the exact position of isolated collections of Lower Clinton faunas. However, such difficulties are to be expected, especially in the early stages of inquiries seeking to establish the stratigraphic sequence by modifications in the characters of species and in the combinations of forms or faunal associations. Evidently the changes in the specific characters came about slowly and gradually, and when we are dealing with the more or less frequently repeated invasions of the same fauna it is impossible to decide from the fauna itself whether the apparently incongruous elements in many of our fossil faunas are to be explained as forerunners or holdovers. It is only after thorough collecting in many places that we may finally learn to harmonize and evaluate the fossil evidence on which stratigraphic correlations must primarily rest. We have not reached this stage in the investigation of the Lower Clinton faunas in the Appalachian region. Here the depositional record is more complete than in most other places, and the transitional phases of the Atlantic Clinton fauna—more of which happen to be preserved than elsewhere—tend correspondingly to efface the sharper delimitation of the faunal zones that prevail in places like New York where the gaps in the section are greater and the total depositional record of the epoch is less complete.

In New York, the Island of Anticosti, and also at Cumberland, Md., the absolute distinctness of the Zygobolba anticostiensis and Z. decora faunal zones is undeniable. In these places the characteristic Ostracoda of each are confined to a few, or at least not exceeding 50 feet of beds; and within these limits the respective faunas are reasonably pure, if we may use this expression. However, in these thicker Pennsylvania sections which, moreover, probably lie nearer the Atlantic inlet and the originating source of the fauna, the exact equivalent of what we are calling the "pure" expressions of these faunas may yet await discovery. Besides, here the chances of finding modified associations of intermediate as well as both preceding and succeeding stages of development are greater.

TUSSEY MOUNTAIN SECTION IN PENNSYLVANIA

Regarding the actual existence and perhaps independence of the Clinton zones just mentioned reasonable doubt is warranted at present only in the case of the lowest which is provisionally distinguished under the term Zygobolba erecta zone. So far as known it is typically developed only in the Tussey Mountain anticline. Here, as indicated in the following section, it lies 45 to 30 feet above the Tuscarora sandstone.

SECTION OF THE CLINTON GROUP ON THE SOUTHWEST SLOPE OF TUSSEY MOUNTAIN AND MAINLY AS EXPOSED IN A MINE TUNNEL 1 MILE NORTH OF MARKLESBURG, PA.[1]

Cayugan series or group	
McKenzie formation—limestone and shale	
Niagaran	
Clinton group	
Upper Clinton or Lakemont formation	Feet
Shale and thin layers of limestone, the Drepanellina clarki zone	60 ±
Sandstone, coarse, thickbedded, calcareous, ferruginous, fossiliferous, the Keefer sandstone member	10
Iron ore, fossiliferous	2
Shale, calcareous, representing the Mastigobolbina typus zone present but not separated from underlying shale, say about	40
Middle and Lower Clinton	
Shale usually soft and greenish, with thin fine-grained green or yellow layers of sandstone	575
Sandstone, hard, fine-grained, grayish to greenish, medium thick-bedded	40
Sandstone, ferruginous, blocky, yields red sandstone debris.	1-2
Fossils: The typical Zygobolba erecta fauna, comprising *Anoplotheca hemispherica*, *Tentaculites minutus*, *Eukrimitia buttsi*, *Zygobolba curvinifera*, *Z. elongata*, *Z. erecta*, *Z. limbata*, *Z. prolifnita*, *Z.* cf. *arcta*, *Z. reversa*, *Z. pulchella*, *Zygobolbina* cf. *emaciata*.	
Iron ore, oolitic, fine-grained, occasionally with inclusions of fossiliferous shale locally developed	4

[1] This section was measured by Mr. Charles Butts and subsequently verified as to its lower and upper parts by E. O. Ulrich.

	Feet.
Fossils: *Bythotrephis gracilis*, Arthophycus and other trails, *Anoplotheca hemispherica*, and numerous Ostracoda mainly of the genus Zygobolba but specimens too much weathered to be determined specifically.	
Shale, bluish	3
Sandstone, argillaceous, hard, fine-grained greenish	2
Shale	2
Sandstone, hard 3-inch flags	14
Shale, may have some thin sandstone layers	30
Sandstone, greenish and bluish gray, quartzose hard, fine grained	5
Shaly beds with thin firmer sandy layers	0-10
Total thickness about	793

Medinan

Tuscarora sandstone

In this Tussey Mountain section only the lower 60 feet of the Clinton was carefully searched for fossils. The Middle Clinton doubtless is represented in the 575 feet of shaly beds but was not differentiated from the Lower Clinton. However, the Keefer sandstone and the Drepanellina zone at the top of the section were satisfactorily identified.

CLINTON SECTION IN VICINITY OF HOLLIDAYSBURG, PA.

The zones of the Upper Clinton are very well displayed in highway and railroad cuttings in the vicinity of Hollidaysburg, Pa., especially at Lakemont Park, along the highway about midway between Hollidaysburg and Altoona. Large collections of fossils have been made at these places. Composite lists of these follow the description of the section.

SECTION OF THE UPPER CLINTON OR LAKEMONT FORMATION IN THE VICINITY OF HOLLIDAYSBURG, PA.[1]

	Feet
Cayugan series	
McKenzie formation, about	275
At the base one or two thick ledges of irregularly laminated argillaceous limestone, weathering into boulder-like masses, indicating reefy deposition; contains an abundant fauna comprising corals, Spirorbis, ostracoda, and brachiopods, all different from preceding faunules. As is to be expected the bed varies in thickness, appearance and in abundance of organic remains	

[1] Compiled from sections measured by Charles Butts, Edwin Kirk, and E. O. Ulrich.

	Feet
from place to place. In the roadside cut at Lakemont, about midway between Altoona and Hollidaysburg, the bed is 10 to 12 feet thick, characteristically developed and its relations to overlying and underlying beds well displayed. It is regarded as the initial deposit of the McKenzie formation.	
Niagaran series	
Clinton group	
Lakemont formation or limestone (Upper Clinton)[1]	
Drepanellina clarki zone	
Shale and limestone interbedded, the limestones subcrystalline, fossiliferous, in layers varying from one to six inches in thickness and aggregating nearly a third of the total. At the base one foot of limestone overlain by three feet consisting almost entirely of shale. The fauna is made up mainly of minute ostracoda, among which species of Paraechmina are prominent, and brachiopoda	18.0
Shale with fewer and thinner lenses and layers of sparingly fossiliferous limestone	13.0
Prominent, highly fossiliferous layer of limestone, 5 to 7 inches thick. The fauna comprises the usual brachiopoda and ostracoda of this zone. The most striking, largest and characteristic of the latter is *Drepanellina clarki*. Typical *Dalmanites limulurus* also is rather abundant	0.5
Brown and greenish shale, in part slightly sandy, with one to three thin (1 to 3 inches) layers of fossiliferous limestone in upper third to half and locally one in the lower half. Fossils indicate same fauna as in thicker limestone layer next above	33.0
Purple oolitic iron ore bed, often shaly in upper half, the whole varying from 13 to 8 inches	1.5
Total thickness of Drepanellina zone	66.0
Horizon of Keefer sandstone	
Conspicuous, thick-bedded zone of more or less sandy and ferruginous argillaceous limestone weathering ochreously brown and yellow, 8 feet to	12.0
	12.0

[1] The term Lakemont limestone or formation is proposed for the Upper Clinton as developed in central Pennsylvania. The type section is at Lakemont Park along the highway between Hollidaysburg and Altoona, Pa. The advantage of using this new name for the Upper Clinton in Maryland seems assured, but in southwestern Virginia where the corresponding beds consist entirely of sandstone and sandy shale some other designation probably is desirable. The propriety of its use for New York deposits of similar age also is questionable.

	Feet.
Mastigobolbina typus zone	
Mainly shale with more or less ferruginous thin layers of limestone in the upper half and at base, and one, two or three thin layers of fossiliferous oolitic iron ore in lower half, 6 feet to	9.0
Greenish calcareous shale including two or more 1- to 3-inch layers of fossiliferous limestone	8.5
Shale, the upper half or more usually of chocolate color, with a 3- to 4-inch layer of fossiliferous limestone next beneath and usually three or four 1- to 9-inch layers of similar limestone in the lower third or fourth, 7 feet to	8.5
Greenish, often slightly sandy shale, 4.5 feet to	6.0
Limestone, 0 to 9 inches, with a large fauna including nearly all of the common fossils of the zone besides *Paleocyclus rotuloides* which seems to be confined to this bed	0.7
Chocolate shale makes up most of the upper half and grayish or greenish shale the lower half. Between these two parts is a foot and one-half of greenish shale with intercalated thin seams of fossiliferous limestone. All of these contain *Mastigobolbina typus*, *Plethobolbina typicalis* and other ostracoda as well as brachiopoda that are characteristic of this zone	12.0
Total thickness of the M. typus zone	44.7
Middle and Lower Clinton shales and sandstones to top of Tuscarora sandstone, about	450

Beneath the M. typus zone the outcrop at Lakemont Park shows about 100 feet of mainly dark shale, with occasional bands weathering to purplish tints. This shale may correspond to the Williamson shale of New York, but the correlation is doubtful. Beneath it comes about 50 feet of more greenish and slightly arenaceous shale, suggesting some Middle Clinton zone, but in the absence of fossil evidence this possible correlation also is in doubt. The exposures of the underlying beds of the Clinton in this vicinity are always unsatisfactory, but the width of the areas involved and the dip of the exposed harder ledges makes it reasonably certain that the aggregate thickness of these lower beds of the Clinton is not less than 400 feet. The Frankstown ore bed, which closely underlies some very fossiliferous layers, occurs near the middle of these 400 feet. The fossils associated with it indicate a position well up in the Lower Clinton. Loose slabs of laminated sandstone, filled with fossils, indicating the Zygobolba decora zone, occur in such a position as to suggest the presence of this zone about 50 feet beneath the horizon of the Frankstown ore. Near the base of the Clinton is another fossiliferous iron ore horizon that may correspond to the Zygobolba erecta zone which lies near the bottom of the Clinton in the Tussey Mountain section near Marklesburg given on a preceding page. The total thickness of the Clinton in the vicinity of Hollidaysburg, Pa., is approximately 660 feet.

So far as determined the fossils found in these Clinton zones in the vicinity of Hollidaysburg, Pa., may be listed as follows, beginning at the top and proceeding downward through the section to the top of the underlying Tuscarora quartzite:

COMPOSITE FAUNA OF THE DREPANELLINA CLARKI ZONE OF THE LAKEMONT FORMATION IN THE VICINITY OF HOLLIDAYSBURG, PA.

Zaphrentis sp. (cf. Polydilasma turbinatum Hall)
Duncanella ? sp.
Pholidops squamiformis
Leptæna rhomboidalis
Brachioprion
Stropheodonta aff. profunda
S. cf. striata
Schuchertella subplana
Dalmanella elegantula
Rhipidomella hybrida
R. cf. circulus and hybrida
Anoplotheca cf. obsoleta (in extreme base)
Atrypa reticularis (Rochester shale varieties)
Nucleospira pisum
Whitfieldella oblata
W. cf. nitida
Eospirifer sp. (with 2 or 3 broad plications on each side of fold)
Delthyris bicostatus
Camarotœchia neglecta
C. aff. neglecta
C. aff. acinus
C. aff. whitei
Camarotœchia sp. (sinus nearly obsolete)
Rhynchonella ? cf. robusta and plicatella (Hall)
Chonetes aff. cornutus
Diaphorostoma niagarensis
Orthoceras sp. (small and tapering rapidly)
Cornulites sp. cancellatus
Paræchmina spinosa
Paræchmina postica
Drepanellina clarki
D. modesta
Beyrichia veronica
Klœdenia cacaponensis
Haploprimitea sp.
Klœdenella sp.
Dizygopleura lacunosa
D. symmetrica
Bythocypris sp.
Leperditia aff. alta
Calymene niagarensis
Homalonotus delphinocephalus
Dalmanites limulurus
? Onchus deweyi

FAUNA OF THE MASTIGOBOLBINA TYPUS ZONE IN THE VICINITY OF HOLLIDAYSBURG, PA.

Paleocyclus rotuloides
Favosites sp. (small, hemispheric)
Crinoid columnals (¼ to ⅓ inch diameter)
Dalmanella elegantula
D. cf. elegantula (small variety)
Leptæna rhomboidalis (Clinton variety)
Stropheodonta corrugata
S. aff. profunda
Schuchertella subplana
Plectambonites transversalis
Chonetes cornutus
C. sp. undet.
Spirifer bicostatus
S. aff. eudora
S. cf. niagarensis
S. radiatus
Atrypa reticularis
A. cf. nodostriata
Anoplotheca obsoleta Ulrich n. sp.
Atrypina disparilis
Whitfieldella cf. crassirostrum
Nucleospira pisiformis
Rhynchotreta ? robusta
Camarotœchia aff. acinus
C. aff. indianensis
C. aff. neglecta
C. aff. whitei
Cyrtoceras cf. cancellatum
Cornulites flexuosus
Eridoconcha rotunda
Haploprimitia aff. humilis
Apatobolbina granifera
Paræchmina crassa
P. punctata
Klœdenia cacaponensis?
Zygosella vallata
Plethobolbina typicalis
P. ornata
Bonnemaia crassa
B. celsa
Mastigobolbina arctilimbata
M. arguta
M. glabra
M. intermedia
M. punctata
M. trilobata
M. triplicata
M. typus
Beyrichia kirki
B. lakemontensis
Dizygopleura symmetrica
D. loculata
Bythocypris sp.
Xestoleberis sp.
Pterinea emacerata
Hormotoma cf. subulata
Diaphorostoma niagarensis
Tentaculites cf. minutus
Calymene aff. niagarensis
Liocalymene clintoni
Dalmanites clintonensis Ulrich n. sp.
Homalonotus cf. delphinocephalus

Middle Clinton faunas probably present but not collected from the vicinity of Hollidaysburg, Pa.

LOWER CLINTON FAUNAS

FAUNA COLLECTED FROM SHALES, SANDSTONES, AND THIN LAYERS OF IRON ORE 6 TO 10 FEET ABOVE THE MAIN FRANKSTOWN ORE BED NORTH OF HOLLIDAYSBURG, PA.

Crinoid columnals and plates
Helopora, 2 species, perhaps the same as forms occurring in the Jupiter River formation on the Island of Anticosti
Phænopora sp.
Ramose and unilamellar species of Bryozoa, specifically undeterminable
Dalmanella aff. elegantula
Apatobolbina appressa
Chilobolbina cf. billingsi
Mastigobolbina retifera
Mastigobolbina incipiens
M. producta
Kloedenia obscura
Zygobolba hulli
Z. rustica
Z. pulchella
Z. obsoleta
Zygobolbina emaciata?
Z. carinata
Z. conradi latimarginata?
Z. panda
Calymene aff. blumenbachi

The presence of three species of Mastigobolbina and four of Zygobolbina in this fauna suggests at least a late Lower Clinton time if not rather an early Middle Clinton stage. Provisionally it seems best to view the Frankstown ore horizon as a but locally developed and distinguishable subdivision of the Zygobolba decora zone that is marked particularly by *Mastigobolbina retifera* and *Zygobolbina carinata*. Compared with the beds of the New York Clinton it should fall in somewhere between the top of the Sodus shale and the base of the Middle Clinton. It may then correspond, at least in apparent position, to either the typical Wolcott limestone or the Wolcott Furnace ore. However, this does not mean that we regard the two as contemporaneous. The faunas of the respective beds are totally different in character and origin, that of the Wolcott limestone and iron ore being of southern origin whereas the Frankstown ore fauna is no less clearly of the Atlantic facies of the time. In view of the fact that the two faunas are not found in the same localities, either as separate entities or in commingling form, we must conclude either that they represent slightly different ages or, if strictly of the same age, that commingling of the southern and eastern faunas was prohibited by some land barrier. Though provisionally inclining to the former alternative we must admit the almost equal plausibility of the latter conception.

FOSSILS OF THE ZYGOBOLBA DECORA ZONE, FOUND IN THIN-BEDDED SANDSTONE ABOUT 50 FEET BENEATH THE FRANKSTOWN IRON ORE HORIZON NEAR HOLLIDAYSBURG, PA.

Unilamellar bryozoan (? Ceramopora)
Anoplotheca hemispherica
Anoplotheca sp. (small rounded form)
Rafinesquina cf. corrugata
Tentaculites minutus
Zygobolba decora and other species of the family

BASAL CLINTON FOSSILS (FROM SAME PLACE AS THE PRECEDING)

Anoplotheca hemispherica
Euprimitia buttsi
Zygobolba erecta
Zygobolba carinifera
Pterinea ? sp. nov. (closely allied to a Medina species)

The ostracods and brachiopod of this small list occur in a gray, very finely sandy shale that directly follows a coarser and rather heavy bedded highly ferruginous sandstone. The latter lies but a few feet above the Tuscarora and is known as the red keel or hard fossil ore. Its fossils apparently consist almost entirely of pelecypods, and of these only the listed Pterinea is abundant and in condition to be determined generically. The three ostracods in the shale above the red sandstone are all believed to be characteristic of the Zygobolba erecta zone as developed in the Tussey Mountain section between Marklesburg and Cherrytown about 12 miles to the east of Hollidaysburg.

CLINTON SECTION AT CUMBERLAND, MD.

The Clinton rocks are not so continuously exposed as desirable in the vicinity of Cumberland but the following is probably a reasonable approximation to the sequence as known.

SECTION AND FOSSILS OF THE CLINTON GROUP IN THE GORGE OF WILLS CREEK AT CUMBERLAND, MD.

	Feet
Cayugan series	
McKenzie formation, about	250
Niagaran series	
Clinton group	
Upper Clinton (Lakemont formation)	
Drepanellina clarki zone	
Mainly dark shale with frequent layers of bluish crystalline fossiliferous limestone	35

Feet

Fossils: *Dalmanites limulurus* characteristic of the lower two-thirds and *Nucleospira pisiformis* abundant in upper third. Ostracoda occur in most of the limestones but are particularly abundant and represented by the following species in a layer about 25 feet above the Keefer sandstone; *Drepanellina clarki*, *D. modesta*, *Beyrichia veronica*, *Leperditia rosseri*, *Paraechmina abnormis*, *P. cumberlandica*, *P. postica*, *P. spinosa*, *Dizygopleura asymmetrica*, *D. proutyi*, *D. symmetrica*, *Aparchites alleghaniensis*. About 50 other kinds of fossils have been found in this zone and are described in this volume by Professors Prouty and Swartz.

Keefer sandstone member

Sandstone, gray, quartzitic, in part ferruginous, especially at top.. 10

Mastigobolbina typus zone

Olive or gray shale with thin limestone at top and a ledge of ferruginous and highly fossiliferous sandstone 30 to 32 feet beneath top.. 70

Fossils: *Dalmanella* sp., *Rhynchonella neglecta*, *R.* aff. *bidentata*, *Anoplotheca obsoleta*, *Whitfieldella* sp., *Delthyris* cf. *crispus*, *Mastigobolbina typus*, *M. triplicata*, *Plethobolbina typicalis*, *P. cornigera*, *Bonnemaia celsa*, *P. crassa*, *Dizygopleura symmetrica*, *Liocalymene clintoni*.

Bonnemaia rudis zone

Brownish or reddish ferruginous shale with the following Ostracoda: *Bonnemaia obliqua*, *B. pulchella*, *B. longa*, *Mastigobolbina virginica* 25

Middle Clinton

Zygosella postica-Mastigobolbina lata zones

Shales, greenish and olive, mostly concealed, apparently consisting mainly of soft beds with occasional thin sandstone, about 265

Fossils: Three fossiliferous zones, all indicated by loose sandstone slabs, were observed in the upper 235 feet of this series of beds. The first occurs about 170 feet beneath the Keefer sandstone. This contains *Homaeospira* aff. *apriniformis*, *Chonetes novascoticus*, *Calymene cresapensis* ?, *Zygosella postica*, *Z. brevis*, *Z. gracilis*, and *Mastigobolbina modesta*, the Ostracoda clearly indicating the Zygosella postica zone. The second lies about 100 feet lower in the section (275 feet above the Tuscarora). Here only ostracods were found indicating an upper layer of the Mastigobolbina lata zone: *Zygobolbina conradi*, *Z.*

Feet

conradi-latimarginata, *Zygosella brevis*, *Zygobolba bimuralis*, and *Z. arcta*. The third lies approximately 50 feet beneath the second (35 feet above the Cresaptown iron sandstone). The steel gray sandstone slabs here contained a typical expression of the Mastigobolbina lata fauna. Associated with the mentioned guide fossil are *Mastigobolbina vanuxemi*, *M. clarki*, *Zygobolbina conradi*, *Z. conradi-latimarginata*, *Chilobolbina billingsi*, *C. punctata-brevis*, *Tentaculites minutus*, and *Anoplotheca aff. hemispherica*. Beneath these three fossiliferous beds collections were made recently by the senior author and Mr. R. D. Mesler from green shale 9-14 feet above the Cresaptown ore and from a thin layer of sandstone 2 or 3 feet above the ore. In both of these layers Ostracoda are exceedingly abundant and well preserved, the commonest being *Zygobolba bimuralis*. The lower of the two is referred to in the descriptive part of the work as 173 feet above the Tuscarora sandstone. The new collections contain undescribed species.

Cresaptown iron sandstone, Zygobolbina emaciata zone

Sandstone, coarse grained, in part conglomeratic, highly ferruginous, including a few seams that contain determinable Ostracoda and other fossils. Among them we recognize *Anoplotheca* cf. *hemispherica*, *Tentaculites* cf. *minutus*, *Zygobolbina emaciata*, *Zygobolbina* cf. *conradi* and *Mastigobolbina* aff. *lata*. The Z. emaciata being abundant and of the typical form this bed may be regarded as corresponding to this zone............ 3-10

Lower Clinton

Zygobolba decora and Z. anticostiensis zones

Shale with occasional thin layers of sandstone, the latter often containing fossils, mainly Ostracoda, and becoming thicker and more abundant in the lower 50 feet... 170

Fossils: Four fossiliferous horizons were observed in these 170 feet of beds: the first in a thin sandstone about 20 feet beneath the Cresaptown iron sandstone, the second in a similar layer of sandstone 5 feet lower, the third in a half-inch layer 72 feet beneath the iron sandstone (98 feet above the Tuscarora sandstone), the fourth in shaly sandstone about 40 feet lower (55 to 60 feet above the Tuscarora). The first two of these fossiliferous layers contain *Zygobolba decora* and other species of its zone with Anoplotheca, Tentaculites and other fossils; the third contains numerous Ostracoda and shells of

Feet

Anoplotheca, the former suggesting the Z. anticostiensis zone perhaps as much as the Z. decora zone. Closer study of recently procured material from this third layer needs to be made before a decision as to its relations to the mentioned zones is warranted. However, the fourth fossiliferous bed, which lies between 55 and 63 feet above the Tuscarora sandstone, is less doubtful. It contains many ostracods and a few brachiopods like *Anoplotheca hemispherica* and *Chonetes novascoticus*. Also one or two undetermined pelecypods. The ostracods clearly indicate the Zygobolba anticostiensis zone. The following species have been identified: *Aparchites variolatus*, *Paraechmina* n. sp., aff. *spinosa*, *Beyrichia emaciata*, *Plethobolbina cribraria*, *Zygobolba anticostiensis*, *Z. curta*, *Z. excavata*, *Z. oblonga*, *Z. rectangula*, *Z. twenhofeli*, and *Zygobolbina* cf. *emaciata*.

Total thickness of Clinton group about........ 585

Among the important facts brought out by the section at Cumberland is (1) the absence of the lowest of the Clinton zones, namely the Zygobolba erecta zone, observed in the preceding sections at Marklesburg and other places in central Pennsylvania. As the latter sections are considerably thicker we are probably warranted in concluding that the absence of this zone is due to overlap and resulting loss of beds from the bottom in southwesterly direction.

(2) As the Zygobolba anticostiensis zone, which is clearly indicated at 55 to 60 feet above the base of the Clinton at Cumberland, contains the most characteristic Ostracoda of the purple "Upper" shale (probably = Chadwick's Bear Creek shale) at Rochester, N. Y., the Cumberland section proves that this second zone of the Lower Clinton underlies at least the Middle Clinton Mastigobolbina lata zone of Oneida County, New York, and does not pass into the latter or overlie it as thought by Chadwick.[1] That the third or Zygobolba decora zone of the Lower Clinton also underlies the Mastigobolbina lata zone was already established by the Honey Grove section and is again shown in the section at Cumberland where moreover it underlies the Zygobolbina emaciata zone.

[1] Bull. Geol. Soc. of Amer., vol. xxix, pp. 327-368, 1918.

(3) The Cumberland section corroborates the evidence of the preceding sections, particularly the one at Honey Grove, Pa., in establishing the sequence of ostracod zones here recognized, excepting the lowest which is absent at Cumberland.

CORRELATION OF OSTRACOD ZONES.—The general sequence of the ostracod zones of the Clinton in the Appalachian region of Pennsylvania and Maryland has been reasonably established by the foregoing sections and lists of fossils. It remains to determine as satisfactorily as is now possible the relations of these zones to those worked out in New York and elsewhere in North America. This may be done most advantageously by discussing the several zones in the order of their deposition. However, as the lowest of these zones, namely the Zygobolba erecta zone, is definitely known only in the thickest of the Pennsylvania sections mention of its possible correlate in the Anticosti section is postponed to a succeeding paragraph dealing with the Ostracoda of the basal part of the Gun River formation.

The Zygobolba anticostiensis Zone.—This, the second of the Clinton ostracod zones, is typically developed in the Island of Anticosti where, according to collections made by Schuchert and Twenhofel, it is best expressed in Bed 9, which comprises the upper 100 feet or so of their Gun River formation. The Ostracoda are very well preserved in the mentioned bed and when subjected to critical study proved separable into a number of closely drawn species. The most useful of these for present purposes are six species of Zygobolba, all figured in this work on Plates LXIV and LXV under the names *Zygobolba anticostiensis, Z. rectangularis, Z. excavata, Z. inflata, Z. recurva,* and *Z. twenhofeli.* In New York at least four of these six species occur in the purple shale and included pearly limestones that overlie the Pentamerus oblongus limestone at Rochester. Four of them have been identified also in the lower 65 feet of the Clinton at Cumberland, Md. Still further south, namely at Hagans, near the southwestern extremity of the State of Virginia, five of the six have been found. In Anticosti this association of species occurs in limestone, at Rochester in limestone and shale, at Cumberland in shale and sandstone, at Hagans in shale. At the Virginia locality the Gun River species are found with three other species of the genus—*Z. curta*, *Z. oblonga*, and *Z. prolixa*—that have not been observed in Anticosti. But the first and second of these additional species are found with the others at Cumberland and the third occurs at Rochester.

At each of these four widely separated localities the Ostracoda are associated with the typical long-hinged form of *Anoplotheca hemispherica;* and none of the other occurrences of this brachiopod is precisely like this one. Apparently, then, if precise correlation by means of detailed matching of fossils is as feasible as we believe, then we have established the Zygobolba anticostiensis zone as a faunal datum plane extending through eastern America from the Gulf of St. Lawrence to the southwestern corner of Virginia. At the same time we have proved the Lower Clinton age of at least the upper half of the Gun River formation beyond all reasonable doubt.

So far as known the fauna of the Gun River formation contains nothing that is definitely opposed to its assignment as a whole to Lower Clinton time. On the contrary the fossils of even its lowest bed (D 5 of Schuchert and Twenhofel's section) have a decidedly more Clinton than Medinan aspect. Among them we note particularly four or five species of Zygobolba, with species of Apatobolbina, Chilobolbina, Bollia, Primitia, and Bythocypris that seem scarcely if at all distinguishable from species of the mentioned genera found in the upper part of the Jupiter River formation. Only the Zygobolbas are clearly different. All of them are relatively obese forms with sharp, crest-like carinæ, and thus suggest species like *Z. erecta*, *Z. carinifera*, and *Z. reversa* which are found in Pennsylvania mainly or only in the lowest of the Clinton zones. The fourth reminds very much of *Z. rectangula* and *Z. twenhofeli*. So far as known the genus Zygobolba appears for the first time in the Anticosti section in this basal zone of the Gun River formation.

The Zygobolba decora Zone.—The third ostracod zone of the Clinton, like the second, is typically developed in the Anticosti section where it attains to best expression in Bed E 9, which includes the upper 158 feet of Twenhofel and Schuchert's Jupiter River formation. This bed lies approximately 600 feet above Bed D 9 of the Gun River formation in which the Zygobolba anticostiensis fauna is best displayed. In the Jupiter River formation this zone is characterized by *Zygobolba decora*, *Z. intermedia*, *Z. robusta*, and *Chilobolbina billingsi* besides a number of other more simple types of Ostracoda that have not yet been found outside of Anticosti. All three of these species of Zygobolba occur quite as abundantly in the typical Sodus shale near Alton, N. Y., as in the Jupiter River formation. In fact they constitute the known ostracod fauna of the Sodus shale. All three have been recognized also in the Tussey Mountain section at Honey Grove, Pa. At the last place, however, they are associated with three other species of Zygobolba and one of Zygobolbina that so far have not been found outside of the State of Pennsylvania.

As previously remarked, there is some and perhaps sufficient room in the section at Cumberland, Md., for the Zygobolba decora zone, but the characteristic Ostracoda of this zone have so far not been discovered in Maryland nor at any place south of Pennsylvania. Besides, in southwestern Virginia the Mastigobolbina lata zone lies so near beds holding species of the Zygobolba anticostiensis zone that it is difficult to escape the conviction that the Z. decora zone is nearly or wholly lacking in Virginia.

Whenever the ostracods of the Z. decora zone have been found they are associated with particular unnamed varieties of *Anoplotheca hemispherica* that are not precisely duplicated in any of the other Clinton zones. These brachiopod shells may therefore help in identifying this zone.

In Anticosti *Pentamerus oblongus* enters the section in the Gun River formation beneath the Z. anticostiensis zone and ranges upward to the top of the Jupiter River formation. In New York it occurs in two zones—the first in the upper third of the "Reynales" limestone, hence just beneath the Z. anticostiensis zone, the second in the Wolcott limestone which immediately succeeds the Sodus shale that contains the ostracods and varieties of Anoplotheca which mark the Z. decora zone. But *Pentamerus oblongus*, as generally defined, attained very wide geographic distribution and lived through practically the entire time of the Niagaran epoch. Therefore, considering this large brachiopod merely as a specific type, its indexical value in stratigraphic correlation is correspondingly broad. Still, as this shell invaded the continental seas only at certain definitely determinable times—invading sometimes from the east, at other times from the south, and on other mainly later occasions from the north—tracing of any one of these invasions may well lead to very accurate time correlations.

In discussing the locally varying sequence of Clinton formations in New York it was pointed out that the purplish shale which overlies the "Reynales" limestone Pentamerus zone at Rochester contains a typical representation of the Zygobolba anticostiensis fauna, whereas the similar true Sodus shale that lies between this lower Pentamerus zone and the second occurrence of Pentamerus in the true Wolcott limestone contains the most characteristic of the Ostracoda and Anoplothecas of the Zygobolba decora zone. Chadwick in his recent work on the Clinton formations in New York regards these two shales as passing laterally into each other and therefore as the same bed. But their respective faunas are not the same. In fact, as said, the one at Rochester contains highly characteristic Gun River Ostracoda and Brachiopoda, the other has Ostracoda and shells that occur in Anticosti only in the upper part of the Jupiter River formation; and in Anticosti the corresponding faunal zones are separated by 600 feet of calcareous shale and limestone. What happened in New York while this great thickness of limy deposits was being laid down in Anticosti?

Except to say that the process of marine sedimentation must have been interrupted and discontinued for a long time in New York we shall not even try to answer this question. For present purposes it is enough to realize the plain inference that in even the thickest of the Appalachian Clinton sections the Lower Clinton part is far inferior in actual thickness of deposits to the combined thickness—nearly 1000 feet—of the corresponding Gun River and Jupiter River formations. And we should not ignore the fact that the latter formations consist mainly of limestone whereas the others consist mainly or wholly of sandstone and shale. This is only one of literally hundreds of similar instances in American stratigraphy that teach a lesson that might well be taken to heart by those who persistently and blindly strive to destroy or belittle the conception of differential vertical movement of the surface of the lithosphere and deny most of the local breaks in stratigraphic sequences that resulted from their operation.

The ostracod evidence on which formations and faunal zones in Anticosti, New York, Pennsylvania, Maryland, and Virginia are correlated and referred to the Lower Clinton may be graphically summarized in tabular form as follows:

GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF LOWER CLINTON SPECIES OF ZYGOBOLBA WHICH HAVE BEEN FOUND IN TWO OR MORE WIDELY SEPARATED PLACES

	Z. erecta zone		Z. anticostiensis zone				Z. decora zone		
	Pa.	L G	U G	R	C	H	J	A	Pa.
Z. carinifera	x	?	...	...	...	...	...	...	...
Z. erecta	x	?	...	...	...	...	...	...	...
Z. reversa	x	?	...	...	...	...	...	...	...
Z. anticostiensis	...	...	x	...	x	x	...	...	...
Z. rectangularis	...	?	x	x	x	x	...	...	...
Z. excavata	...	...	x	x	x	x	...	...	...
Z. inflata	...	...	x	x	...	x	...	...	...
Z. recurva	...	...	x	x	...	x	...	...	...
Z. prolixa	...	...	...	x	...	x	...	...	...
Z. oblonga	...	...	...	...	x	x	...	...	...
Z. curta	...	...	...	...	x	x	...	...	...
Z. twenhofeli	...	?	x	...	x	...	...	...	...
Z. decora	...	...	...	...	...	...	x	x	x
Z. intermedia	...	...	...	...	...	...	x	x	?
Z. robusta	...	...	...	...	...	...	x	x	x

Pa. = localities in central Pennsylvania.
L G = lower 50 feet of the Gun River formation, Island of Anticosti.
U G = upper part of the Gun River formation, Island of Anticosti.
R = purple shale above Pentamerus oblongus zone at Rochester, N. Y.
C = 60 feet above base of Clinton at Cumberland, Md.
H = purple shale and iron ore of Lower Clinton at Hagans, Va.
J = upper 50 feet of Jupiter River formation, Island of Anticosti.
A = true Sodus shale, near Alton, N. Y.

The Zygobolbina emaciata Zone.—The typical locality of this zone is in Cove Gap through Cove and Tuscarora mountains along the pike from Mercersburg to McConnellsburg, Pa. Here it consists mainly of rather soft greenish-gray shale with beds of yellow porous sandstone highly fossiliferous and probably originally calcareous. The total thickness of the Clinton at this place is approximately 750 feet and the Z. emaciata zone lies apparently less than 200 feet above the base of the formation.

The following fossils were collected a short distance east of the toll-gate: molds of a ramose bryozoan suggesting a species of *Bythopora*, *Trematis* n. sp., related to *T. oblata*, two varieties of *Anoplotheca hemispherica*, *Tentaculites* cf. *minutus*, *Pterinea* aff. *emacerata*, two species of *Ctenodonta*, *Cleidophorus* sp., *Cyrtodonta* sp., *Paracyclas* ? n. sp., *Orthodesma* cf. *curtum*, *Modiolopsis subulatus*, *Zygosella limula*, *Zygobolba bimuralis*, *Zygobolbina emaciata* (exceedingly abundant), *Mastigobolbina declivis*, *M. lata-nana*, *M.* cf. *vanuxemi*, *M. virginia*, *Plethobolbina sulcata*, *Paraechmina postmuralis*, *Bythocypris* sp. Except the pelecypods these fossils occur in both the shales and the sandstones. The pelecypods are found only in the shale, and this probably explains why they are so rarely seen in weathered natural outcrops.

The most abundant of the ostracods is the *Zygobolbina emaciata.* It occurs here literally by thousands. The species when typically developed and well preserved is easily distinguished by its rather long oblique form, prominent thin U-shape ridge and generally emaciated appearance. Varieties in which the ridge is not so high as it should be occur in Lower Clinton zones. But those are never found in association with species of Mastigobolbina like those cited above. The latter are tending toward characteristic Middle Clinton species like *M. lata* and *M. vanuxemi.* The Zygosella and the Zygobolba also indicate Middle Clinton. On the other hand—considering only known Clinton occurrences—the pelecypods at first sight suggest Lower Clinton. But here again further investigation shows that the zone shares two or three species also with the Drepanellina clarki zone at the very top of the Clinton. Still the total combination of species is different from all other Clinton associations, and being intermediate in character between those that are clearly of Lower Clinton time and those of Upper Clinton facies there is on this ground alone sufficient warrant for placing the zone in the Middle Clinton.

The assignment of the Z. emaciata zone to the base of the Middle Clinton rests primarily on the fact that at Cumberland, Md., the denominating guide fossil occurs abundantly and in typical form in the Cresaptown iron sandstone which underlies beds containing a fairly typical development of the Mastigobolbina lata fauna. In the section on Tuscarora Mountain near Honey Grove, Pennsylvania the Z. emaciata zone lies about 300 feet above the base of the Clinton. At this place only the thin sandstones were available for collecting, and this probably accounts for the absence of the pelecypods, these having been observed elsewhere only in the shales exposed in new road excavations. Finally, the position of the Z. emaciata zone is fixed in the Honey Grove section by the occurrence of the M. lata fauna above it and that of the Zygobolba decora zone beneath.

The Mastigobolbina lata Zone.—The M. lata zone is perhaps the most generally recognized of the Clinton zones in the Appalachian region. In New York its highly characteristic fauna occurs in typical development in Oneida County. The best and most fossiliferous exposures are found to the southwest of Utica in the vicinity of New Hartford. The evidence in hand indicates that the beds which contain this fauna pinch out rapidly to the west of Clinton. They pinch out, apparently by overlap, also to the eastward, in which direction moreover the shales and fine-grained sandstones are largely replaced by coarser clastics. Passing southwardly under younger deposits the zone emerges again in central Pennsylvania. It was clearly recognized on the south side of Jacks Mountain between Lewistown and Reedsville, Mifflin County, where it lies about 325-350 feet above the Tuscarora sandstone. Also at various places on Tussey and Tuscarora mountains, in which sections it lies near the middle of the Clinton. In Maryland it is clearly indicated above the horizon of the Cresaptown iron sandstone at Cumberland. In Virginia its fossils were collected and its position in the section determined 1.5 miles northwest of Warm Springs, 1 mile west of Narrows, at Cumberland Gap, and other places in the State. The band that contains the M. lata zone at Cumberland Gap extends some 30 or 40 miles into Tennessee, and although Clinton fossils of every kind become very rare in that direction *M. lata* was observed near the southern extremity of this extension. Finally, an unmistakable representation of this fauna occurs in Lavender Mountain near Armuchee, Ga. At this place, however, the guide fossils are associated with species that do not accompany them in Virginia, Maryland, and Pennsylvania, and on this account we are inclined to view this Georgia occurrence of the fauna as indicating a separate though contemporaneous invasion from the Atlantic near Savannah.

As usual with Clinton faunas the main guide fossils of this zone are Ostracoda of the family Zygobolbidæ. The most serviceable of these are *Mastigobolbina lata*, *M. vanuxemi*, *M. clarkei*, and *Zygobolbina conradi*. All four of these species are found associated on the same slabs in New York, and at least two, often three and sometimes all four were found wherever collections from the M. lata zone were made in Pennsylvania, Maryland, Virginia, and northeastern Tennessee. Undoubtedly, other fossils than Ostracods are confined to this zone. However, they are not so generally present and their use in correlation, pending their subjection to more detailed investigation than they have yet received, must necessarily be uncertain and hazardous. In the meantime the mentioned Ostracoda serve this purpose very well.

The Zygosella postica Zone.—This zone is not so clearly indicated by its fauna and therefore not so easily recognized as the preceding Mastigobolbina lata zone. However, in the Appalachian area between southern Pennsylvania and southwestern Virginia there is usually a more or less sparingly fossiliferous interval between the well characterized zone with *M. lata* and the first appearance of the Upper Clinton Bonnemaia rudis fauna. Though the Z. postica fauna was not observed in the section at Honey Grove, Pa., there is an ample thickness of beds at the place in the section corresponding to its usual position from which no fossils were procured but in which closer search might have revealed its presence. Loose slabs of sandstone containing *Zygosella postica*, *Z. brevis*, *Z. gracilis*, and *Mastigobolbina modesta*, all supposedly characteristic Ostracoda of this zone, together with a peculiar Calymene, *Chonetes* cf. *novascoticus*, and *Homœospira apriniformis*, were found above the range of *Mastigobolbina lata* at Cumberland, Md. *Z. postica* and *Z. gracilis* were found in the proper position also in the section along New River, 1 mile west of Narrows, Va. These collections indicate that the Z. postica zone is distinctly younger than the M. lata zone. But we have other collections—one from Warm Springs, Va., another from Gate City, Va.—that prove either that the two zones locally come so close together as to cause mixture of their respective faunas in collecting or that *Mastigobolbina modesta*, *Zygosella mimica*, *Z. gracilis* and even *Z. postica* invaded the Appalachian Valley before the final extinction of *Mastigobolbina lata* and *Zygobolbina conradi* therein. With the material in hand it is impossible to decide between these alternatives.

The Bonnemaia rudis Zone.—The Upper Clinton, as herein determined, begins with the B. rudis zone. Its fauna was first observed in Mulberry Gap, Powell Mountain, 5 miles northwest of Sneedville, Tenn. Here the zone constitutes the top member of the Clinton, being immediately succeeded by the Sneedville limestone of Cayugan age. The beds here being also more profusely fossiliferous and readily accessible than any other of Clinton age then known, the fauna of the zone, especially the Ostracoda, was collected and studied with uncommon thoroughness and determined as follows: *Bonnemaia rudis* (exceedingly abundant), *B. fissa*, *B. longa*, *B. obliqua*, *B. pulchella*, *B. transita*, *B. transita-transversa*, *Zygosella alta*, *Z. vallata-nodifera*, *Mastigobolbina typus-praenuntia*, *M. bifidus*. None of these eleven species are known to occur in any of the older zones, and only the third, fourth, and ninth of the list pass into the succeeding zone. Other localities add *Mastigobolbina micula* and *M. ultima*. In view of the relatively large number of characteristic species the B. rudis zone is at least as easily recognizable as any other of the Clinton zones here distinguished. The large size of most of the species helps materially in distinguishing the zone from those underlying it.

Three of the characteristic species of the zone, including *Bonnemaia rudis*, were found in the Honey Grove, Pa., section 200-250 feet beneath the top of the Clinton. The beds containing these fossils lie more than 200 feet above the highest observed occurrence of *Mastigobolbina lata*. In the opposite direction the first appearance of *M. typus* is nearly 100 feet nearer the top of the group, that is about 150 feet beneath the top.

A piece of sandstone, found by some unknown collector in the vicinity of Cumberland, Md., contains *B. rudis ?*, *B. longa*, *B. pulchella*, *B. obliqua*, and *Mastigobolbina virginia*. This association of species can hardly mean anything else but the B. rudis zone, and may be accepted as reasonably conclusive evidence of the presence of this zone in the Clinton section at

Cumberland. Unfortunately, data are lacking as to the relations of the occurrence to overlying and underlying zones. The zone seems to be represented also in the section at Six Mile House, Md., where *Zygosella vallata-nodifera*, *Mastigobolbina micula*, and *M. ultima* were found 102 feet beneath the Keefer sandstone or 25 feet beneath the lowest occurrence of *M. typus* which is 77 feet beneath the Keefer.

In Virginia the zone was doubtfully identified at Williamsville, but there is no doubt about its presence in the Clinton section at Big Stone Gap. If it occurs along the strike between Big Stone and Cumberland Gap the fact remains to be established. The Clinton sections in this stretch suggest contemporary oscillation and resulting absence of beds and also considerable erosion of the surface of the Clinton during the following Devonian period. At Hagans, for instance, the Lower Clinton lies scarcely 200 feet beneath the Black shale, with no visible evidence of Upper Clinton beds. To the northeast at Big Stone Gap the B. rudis zone is succeeded by a good development of the Mastigobolbina typus zone and this by Cayugan and Helderbergian limestones and then about 800 feet of Upper Devonian shale. In the opposite direction at Cumberland Gap the B. rudis zone was not recognized, but the succeeding M. typus zone is present though not thick. Over it comes about 450 feet of Mississippian Black shale. Farther southwest along the same strike in Powell Mountain, Tenn., the Clinton is terminated above by a strong development of the B. rudis zone and on this comes first the Sneedville limestone and then Chattanooga shale.

The Mastigobolbina typus Zone.—This zone has a wider and more definitely ascertainable distribution in eastern America than any other of the Clinton zones. It contains a large fauna—apparently 75 species—and by far the majority of these are confined to this zone. However, anything approaching a complete representation of the fauna can be expected or procured only at places in which the zone is uncommonly calcareous with many thin limestone plates. The corals and most of the brachiopods are at least rare and often entirely wanting to the south of Maryland and also in the western part of this state, in which directions the limy facies of the zone, which prevails in central Pennsylvania and extends southward to

Great Cacapon, W. Va., is replaced by siliceous shales and sandstones. The character of the fauna as developed in the calcareous facies is correctly though not completely indicated by the list of species found in this zone in the vicinity of Hollidaysburg, Pa.

Of the 75 species so far collected from the M. typus zone more than 30 are Ostracoda. The latter, fortunately, are less partial to particular kinds of rock than are most of the other classes. Most of the Ostracoda seem also to have been excellent travelers, for we find their remains often in great numbers in the thick and thin sandstones that make up a large part of the Upper Clinton in southwestern Virginia and in the sandy shales of corresponding age in east central Kentucky and southern Ohio. Consequently, we are forced to depend almost entirely on the Ostracoda in recognizing the deposits of this age in the mentioned areas. Even in the calcareous northern phase of the zone we have found it advisable to depend mainly on the Ostracoda without, however, any intention to ignore whatever of help that may be offered by other kinds of fossil remains.

The Brachiopoda of the zone are of value particularly in establishing the Upper Clinton age of the beds. This is accomplished, we believe, beyond question by the presence of *Schuchertella subplana*, the four species of *Spirifer*, the two of *Atrypa*, and the *Nucleospira*. But these species occur also in the Rochester shale in New York and in Maryland and Pennsylvania are found in the Drepanellina clarki zone as well as in the M. typus zone. The case is similar with respect to the five rhynchonelloids; and even *Anoplotheca obsoleta*, *Chonetes cornutus*, and *Dalmanella elegantula* are represented by scarcely distinguishable mutations in the two zones. The Brachiopoda, therefore, are of as little value in distinguishing the several Upper Clinton zones from each other as they were found to be in separating the Middle and Lower Clinton zones.

Whether the molluscan shells are any better for our purposes is doubtful. To begin with, we know too little about them, either as regards their specific characters or their vertical ranges. Besides, their state of preservation commonly is too unfavorable for precise identification and their occurrence usually too sporadic to fit them for practical guide fossils.

The trilobites probably could be made useful, but no one has yet subjected the Clinton forms to the minutely discriminating investigation required to fully bring out their indexical qualifications. At present all of the Calymenidæ having pygidia with smooth pleural lobes are referred to *Liocalymene clintoni*. But preliminary study of the Clinton trilobites of this genus suggests that the form which occurs in the Mastigobolbina typus zone is not strictly the same as those that are found in the Middle and Lower Clinton. Moreover, the former has not been found above the Keefer sandstone so that it may be set down as one of the characteristic fossils of the M. typus zone. In our experience the presence in American formations of a species of Dalmanites with posteriorly acuminate pygidium is certainly not older than the M. typus zone. Such a species occurs in both the M. typus and Drepanellina zones, and both have been referred by authors to *Dalmanites limulurus*. But the two are not the same, the younger of the two being the true *D. limulurus* whereas the older belongs to an undescribed species with fewer pygidial segments for which the name *Dalmanites clintonensis* is proposed. The latter then also is to be added to the guide fossils of the M. typus zone.

After all, however, it is the Ostracoda that supply the most distinctive and ever-present—therefore the most practical and serviceable—guide fossils of this zone. As already stated, more than 30 species have been determined, and among these are at least nine large species that may be expected at any outcrop of the zone from New York to southwestern Virginia and thence through Kentucky to southern Ohio. These are *Mastigobolbina typus, M. arguta, M. trilobata, M. triplicata, M. punctata, Plethobolbina typicalis, Bonnemaia celsa, B. crassa*, and *Zygosella vallata*. So far as now known all of these nine species are strictly confined to the *M. typus* zone.

To illustrate the geographic distribution and general unity of this ostracod fauna the following lists of species collected at widely separated localities are presented.

At Clinton, N. Y., in 15 feet of shale and thin limestones immediately overlying the oolitic iron ore bed: *Mastigobolbina typus, M. trilobata, M. punctata, Plethobolbina typicalis.*

In the vicinity of Hollidaysburg, Pa., the species cited in the long list given on p. 362 occur in limestones.

In sandstone on Tuscarora Mountain, near Honey Grove, Pa.: *Mastigobolbina typus, Bonnemaia celsa, B. crassa, B. longa, B. perlonga, Zygosella vallata.*

In limestones two miles east of Great Cacapon, W. Va.: *Mastigobolbina typus, M. arguta, M. intermedia, M. triplicata, Plethobolbina typicalis, P. ornata, Bonnemaia crassa, Zygosella vallata, Beyrichia lakemontensis, Æchmina crassa, Dizygopleura loculata, Apatobolbina granifera.*

At Cumberland, Md., in sandstone: *Mastigobolbina typus, M. triplicata, M. virginia, Plethobolbina typicalis, P. cornigera, Bonnemaia celsa, B. crassa.*

At Big Stone Gap, Va., in sandstone: *M. typus, M. arguta, M. virginia, Plethobolbina typicalis, Bonnemaia celsa, B. crassa, B. oblonga.*

In argillaceous and slightly sandy shale in the upper (Estill clay) member of the Alger formation in the western part of Lewis County, Kentucky: *Mastigobolbina typus, M. triplicata, M. trilobata, M. glabra ?, Plethobolbina* sp., *Zygosella vallata.* Associated with these Ostracoda are *Rafinesquina* or *Brachioprion* sp., *Chonetes cornutus, Anoplotheca* cf. *obsoleta, Camarotoechia neglecta ?, C.* sp., *Ctenodonta* 2 sp., *Cyrtodonta* sp., *Bucaniella* aff. *trilobata, Dalmanites clintonensis, Liocalymene* cf. *clintonensis.*

In Adams County, Ohio, in shaly sandstone of the Alger formation, collected by Dr. A. F. Foerste: *M. typus, M. arguta, M. modesta, M. trilobata, M. triplicata, M. punctata, Plethobolbina typicalis, Zygosella vallata*; associated with other fossils similar to those listed from Lewis County, Kentucky.

In comparing these lists the outstanding fact is that all four of the species found at Clinton, N. Y., are among those listed from Lewis County, Kentucky, and those collected by Doctor Foerste from the upper member of the Alger formation ("Niagara shales") in Adams County, Ohio. The absence of one or more of them in some of the other lists doubtless is due to the fact that the time devoted to the making of the collections was in all of such cases very brief. Only the exposures at Hollidaysburg, Pa., were searched with anything like thoroughness. It should be observed also that seven of the eight species that were found in Ohio are included in the list of 25 species that rewarded our efforts at Hollidaysburg to gain a comprehensive conception of the fauna of the M. typus zone. The exception, *Mastigobolbina modesta*, has not been found north of Virginia.

One of the most important features of the present inquiry is the determination of the presence of the M. typus zone at Clinton, N. Y., and how much of the section at that place should be correlated with it. As stated in the discussion of the New York Clinton sections the oolitic iron ore and the 18 feet of shale and thin limestones over it in the section at Clinton are regarded as corresponding to the M. typus zone of the Appalachian Valley. This conclusion is based primarily on the presence of at least four of the most characteristic Ostracoda of the M. typus zone in the mentioned beds at Clinton. But there is considerable other faunal evidence to support the testimony offered by the ostracods; and it is rendered all the more probable by the fact that this correlation fits in very well with views advocated here respecting the relations of preceding and succeeding Clinton formations or zones in the concerned regions.

The shales interbedded with and directly overlying the oolitic iron ore at Clinton, N. Y., have yielded a fauna of nearly 50 species. Unfortunately, many of these species cannot be cited specifically, being unnamed. Some of them also require closer investigation before their stratigraphic significance is clearly established. Still the following lists include besides the Ostracoda many brachiopods, pelecypods, and trilobites that tend to prove at least that the oolitic iron ore is not older than the M. typus zone. Moreover, a few of them must be accepted as offering positive corroboration of the testimony of the Ostracoda that Beds 4 and 5 of the section at Clinton are of the same age as the M. typus zone of central Pennsylvania and Maryland.

FOSSILS FROM THE SHALE REMOVED IN MINING OF OOLITIC IRON ORE AT CLINTON, N. Y.

Roots of Eucalyptocrinus
w Ischadites n. sp.
w Monograptus clintoni
Dendrograptus rectus
Cactograptus crassus
Paleodictyota bella
P. clintonensis
Cyclograptus rotadentatus
Dictyonema retiformis
Paleschara sp.
Helopora aff. fragilis
n Lingula lamellata
L. n. sp. (surface beautifully spinose)
m r Plectambonites transversalis
Brachioprion ? sp.
m Leptæna rhomboidalis
r Schuchertella subplana
m Chonetes cornutus
m Anoplotheca obsoleta
m r Atrypina disparilis
m r Eospirifer radiatus
m Camarotœchia aff. indianensis
m r Camarotœchia neglecta
m r Pterinea emacerata
r Posidonomya ? rhomboidea ?
Modiolopsis sp. nov.
m Ctenodonta cf. elliptica
Cleidophorus sp.
Whitella sp. cf. Avicula ? orbiculata)
Rhytimya sp. nov. (1)
R. sp. nov. (2)
Cuneamya sp. nov. (aff. C. scapha)
Loxonema sp.
Seelya aff. loydii
Hyolithus sp.
r Dawsonoceras annulatum
Arabellites
Serpulites (aff. S. dissolutus)
m Mastigobolbina typus
m Mastigobolbina trilobata
m Mastigobolbina punctata
m Plethobolbina typicalis
m Liocalymene clintoni
m Dalmanites clintonensis

FOSSILS FROM THE PALÆOCYCLUS LAYER LESS THAN 10 FEET ABOVE THE OOLITIC IRON ORE AT SAME PLACE

m Palæocyclus rotuloides
Eridotrypa sp.
Phænopora cf. canadensis
Helopora aff. fragilis
m r Dalmanella elegantula
m r Nucleospira pisiformis
And the four ostracods of the preceding list

Of the above lists, aggregating 50 species, 16 are preceded by the letter m, indicating that the species so marked occurs also in the Mastigobolbina typus zone in Pennsylvania and Maryland. Of the remaining 34 species we may disregard all the graptolites and most of the pelecypods and other mollusks because these are found only in the soft freshly excavated shale at Clinton, which type of rock was not available for collecting at any of the natural outcrops of the M. typus zone searched for fossils in the states to the south of New York. For similar reason we would eliminate also the Ischadites, the two Lingulas, and the Serpulites. With these eliminations, aggregating about 22 species, the remaining species of the two lists constitute a fairly normal Mastigobolbina typus fauna.

In earlier discussions of the age of the beds associated with the oolitic iron ore at Clinton and of their unquestioned correlate, the Mastigobolbina typus zone, in Maryland the strongly expressed similarity of the faunas to that of the Rochester shale (species preceded by the letter r) seemed so striking that correlation with the latter appeared unavoidable. This apparent Rochester alliance is particularly notable in comparing the brachiopods which constitute the most conspicuous element of the fauna in the limy facies of the M. typus zone. Among these are *Pholidops squamiformis, Dalmanella elegantula, Schuchertella subplana, Plectambonites transversalis, Spirifer bicostatus, S. eudora, S. niagarensis, S. radiatus, Atrypa reticularis, A. nodostriatus, Atrypina disparilis, Nucleospira pisiformis* and species of *Camarotœchia* that are scarcely distinguishable from *C. acinus, C. indianensis, C. bidentata,* and *C. neglecta.* Practically all of these shells are typically represented in the fauna of the Rochester shale; and this relationship was further emphasized before we learned to distinguish the *Dalmanites* that occurs with them in the M. typus zone in Maryland and Pennsylvania and in the oolitic iron ore at Clinton from the true *D. limulurus* of the Rochester shale.

However, since those earlier conclusions much evidence has accumulated tending to establish the now accepted fact that the presence of the mentioned brachiopods in the M. typus zone signifies merely a preceding invasion of species previously believed to be indicative of the Rochester age. Even in New York most of them are now known to range down into the reefy bed at the top of the Irondequoit limestone; and some of them occur also in the Williamson shale. The last occurrence, as stated before, doubtless corresponds to the one at Clinton and both of these to that in the M. typus zone in Maryland. One of the best pieces of evidence favoring the latter correlation, and which has not yet been brought out as it deserves, concerns the coral *Palæocyclus rotuloides.* This peculiar fossil was originally described from specimens found at Clinton, N. Y., where it is confined to a thin bed lying a few feet above the oolitic ore. The same coral occurs in the lower half of the M. typus zone at Hollidaysburg, Pa.

Here also it is confined to a single layer of limestone less than a foot thick. No reason is known why these two occurrences should not be accepted as strictly contemporaneous.

Nearly if not quite as valuable as the coral and the Ostracoda in proving the essential contemporaneity of these beds is the *Chonetes cornutus*, the *Anoplotheca obsoleta*, the *Liocalymene clintonensis* (s. st.), and the *Dalmanites clintonensis*. All of these are represented by precisely the same varieties in the two beds.

The Keefer Sandstone and Supposed Equivalents in Pennsylvania and New York.—The Keefer sandstone varies considerably in thickness and character from place to place in Maryland. Evidently some oscillation and land elevation occurred at this time, and these movements increased the supply of clastic material. The Keefer is 11 feet thick at Cumberland, about 40 feet thick near Hancock, and somewhat less than 25 feet thick in North Mountain. The evidence in hand suggests that this sandstone member is little more than a lithologic facies that toward the east, as in North Mountain, possibly covers the whole of Upper Clinton time. Its position is usually indicated in the Clinton sections in Pennsylvania, and a bed regarded as marking the same time is so designated in the section at Clinton, N. Y. A sandy and ferruginous limestone in the section at Hollidaysburg, Pa., is referred to this zone. In the Honey Grove section the same zone is represented by a rather coarse grained sandstone.

Except in the vicinity of Flintstone fossils are not commonly found in the Keefer in Maryland. Stose, in 1910, found some remains of Eurypteridæ in a black shale interbedded with the sandstone a few miles west of Hancock. These suggested Cayugan species of Hughmilleria and Pterygotus, and it was on this, then supposedly determinative evidence, that the Keefer was erroneously placed at the base of the McKenzie formation and with it in the Cayugan epoch of the Silurian.

No list of the fossils found in the Keefer sandstone at Flintstone is available, so we cannot say whether they are more closely allied to the overlying or the underlying fauna. Perhaps their relations are no more decisive than are those of the 6 species procured from this bed at Honey Grove, Pa., listed on p. 353. Still, three of the brachiopods at the latter place, *Rhipidomella* cf. *hybrida*, *Spirifer crispus*, and *Camarotoechia* cf. *plicatella*, and the *Dizygopleura* lean toward the succeeding fauna rather than the preceding.

In describing the section at Clinton, N. Y., beds 6 and 7 of the section are said to "probably correspond to the Irondequoit limestone at Rochester and to the Keefer sandstone of Maryland and Pennsylvania." This view is suggested primarily by the fact that these beds follow shaly layers containing the Mastigobolbina typus fauna and are overlain by the red flux iron ore bed which is filled with Rochester Bryozoa. The zone thus occupies the position of the Keefer. The few fossils found in it at Clinton throw no definite light on the question, but at the same time they offer nothing opposing the suggested correlation.

No Ostracoda were found in the supposed Keefer representative at Clinton. But fossils of this class were procured from the Irondequoit limestone. The senior author, namely, collected at least six species of Ostracoda out of a block of Irondequoit limestone found about 8 miles east of Lockport. One of these species, *Beyrichia hartnageli*, is described and figured in this volume. The others comprise a species of *Kloedenella*, a *Dizygopleura* (allied to *D. proutyi* and *D. swartzi* of the Drepanellina clarki zone in Maryland but a clearly distinct new species), a *Thlipsura* and two species of *Bythocypris*. Except the last, which are too simple in structure to be of value in refined stratigraphic correlation, none of these Ostracoda is precisely like any of the Silurian species found in Maryland. But they are all of Atlantic types and so must have invaded New York from the east or southeast. Then, as these species have not been found in the Upper Clinton of either Maryland or Pennsylvania, they could hardly have passed through here without leaving fossil traces of their line of migration except during the deposition of the Keefer.

By comparison of these Irondequoit Ostracoda with their relatives in Appalachian formations we are again led to the conclusion that the Irondequoit probably correlates with the Keefer. Thus, the *Beyrichia hartnageli* is intermediate in its characters between *B. lakemontensis*, a species of the M. typus zone, and *B. veronica* or *B. normalis*, both of which belong to the Drepanellina clarki fauna. The inturning of the dorsal extremity of the posterior lobe is a primitive character that is still well developed in *B. hartnageli* but is almost entirely lost in *B. veronica* and *B. normalis*. As for the new *Dizygopleura* it might well represent an antecedent stage in the development of a species like *D. pricei*. Finally, *Thlipsura* is a British Silurian genus that is otherwise wholly unknown in American deposits of this period. We had expected to find species of this peculiar genus in the Appalachian Silurian formations, but our search for American representatives of this age proved unavailing except in this single block of Irondequoit limestone.

The Drepanellina clarki Zone.—This is the highest of the Clinton zones in Maryland and Pennsylvania and in our opinion is the only part of the Appalachian facies of the Clinton that we feel warranted in correlating with the Rochester shale. Some of the reasons for this conclusion were given in the preceding discussion of the Clinton sections in New York. In our argument trying to establish our view that the invading Atlantic and southern seas and faunas of this time actually intermingled in Pennsylvania and New York we also endeavored to explain why only a few of the southern invaders reached Maryland. It appears, in fact, that the Rochester element in the Drepanellina clarki zone in Maryland and Pennsylvania is made up very largely of species that migrated to western New York from the east. Much the greater part of the southern element, especially the Bryozoa, in the Rochester fauna, on the contrary, dropped out of the race very soon after passing Rochester. Only a few remain at Clinton, N. Y., and hardly any reached central Pennsylvania and Maryland.

METHODS OF CORRELATION.—Facts like the above show the absolute futility and error of trying to correlate formations of distinct provinces by the percentage method of faunal comparison. In the present case the fauna of the Appalachian zone that we regard as corresponding in age to the Rochester shale of New York comprises only a small percentage of the species found in the Rochester at Lockport, N. Y.; and even this minor part is largely made up of species that as now defined are known to have a wide geographic and long vertical range. Most of the latter, and this includes more than three-fourths of the brachiopods and mollusks, are

Upper Clinton or even Niagaran fossils and not only Rochester species. Closer study of these long-ranging species probably would result in their separation into distinguishable mutations, each of which would be characteristic of only one of the several divisions of the Upper Clinton. But this requires many and uncommonly good specimens and much work that remains as yet to be done. We need also to learn where they were raised and what paths they followed to get to the places where their remains are now to be found.

Something approaching the comprehensive investigation required to render such fossils of value in detailed correlation has been given to the Silurian Ostracoda. Also to the Dalmanites and a few other species of this zone that happened to belong to genera which have been subjected to close study. On the principle of correlation by minute structural comparison and identification of biologically non-essential features[1] only a few of such completely similar forms held in common by formations of distinct provinces are required to establish the practical contemporaneity of the beds holding them. Therefore, although the Atlantic species that migrated as far west as Niagara Falls constitute less than 10 per cent of the total Rochester fauna and the southern species that passed on from western New York into the Appalachian province are so few, if any, as to be almost negligible, we may yet accomplish the correlation of the Rochester shale and the Drepanellina clarki zone with reasonable confidence and certainty.

The first step in this correlation was already taken when in the preceding discussion of the Clinton of New York the species of Rochester Bryozoa in the red flux ore bed, which overlies the correlates of the Keefer sandstone and the Mastigobolbina typus zone in the section at Clinton, were enumerated. Anyone who would deny the Rochester age of the red flux ore bed must either disprove the identification of the Bryozoa or ignore their testimony entirely.

The second step is accomplished by noting the presence of Ostracoda belonging to the Appalachian and Atlantic faunas of the time in the

[1] Ulrich, E. O., Correlation by displacements of the strand-line: Bull. Geol. Soc. America, vol. xxvii, p. 488, 1916.

typical outcrops of the Rochester shale. Evidently communication between the Atlantic and Southern waters across northern Pennsylvania was far from free and open. The barrier between the two must yet have been pretty effective because we know of only three of the Appalachian Beyrichiacea that reached Lockport, N. Y. These are *Paraechmina spinosa*, *P. abnormis*, and *Dizygopleura symmetrica*. The Rochester shale contains at least four other Ostracoda, but three of these are Cypridæ which occurred in both seas at this time and are too simple in structure to be of use in correlation. The fourth is a *Ctenobolbina*, a southern type, that is unknown in either Silurian or Ordovician Appalachian faunas.

Three of the trilobites of the Drepanellina clarki zone seem to be precisely like species found in the Rochester. One of these is the *Calymene niagarensis*, which perhaps is not so worthy of confidence as a guide fossil as is either the second, *Homalonotus delphinocephalus*, or the third, *Dalmanites limulurus*. All three of these trilobites are represented by closely allied species or varieties in the underlying Mastigobolbina typus zone. But the latter are not precisely like the Rochester types of the species, whereas those found in the Drepanellina zone seem to agree in every detail.

About 25 species of Brachiopoda occur in the Drepanellina zone. Eight of these are described as new species in this volume by Professors Prouty and Swartz. With two or three exceptions the remainder of the list consists of species that have not been distinguished from Rochester fossils. Many of the latter have been studied also by the writers with the result that we also failed to discover satisfactory differences by which the Maryland and Pennsylvania specimens might be distinguished from those found in the Rochester shale of western New York. This striking similarity in the brachiopods of the two formations might then be accepted as strong confirmation of the preceding seemingly weaker evidence of the trilobites and ostracods. But we must not overlook the fact that the majority of these brachiopods are widely distributed and mostly long-ranging species that not only occur also in the Mastigobolbina typus zone in Maryland and in the Irondequoit limestone in New York but have closely allied ancestors in yet earlier Clinton and even late Medinan formations. Still, some of these shells that are common to the Drepanellina zone and the Rochester shale have so far not been found in beds known to be older than the Rochester. Of these the most noteworthy, perhaps, are *Rhipidomella hybrida*, a particular variety of *Atrypa reticularis*, *Spirifer crispus*, *Trematospira camura*, and *Whitfieldella oblata*.

OSTRACODS OF THE BISHER DOLOMITE.—Very unexpectedly we receive further light on this perplexing correlation problem from Ohio. Recently the senior author made the fortunate discovery of a considerable ostracod fauna in the Bisher member of the West Union formation in Adams and Highland counties, Ohio. These Ostracoda occur in thin lenses of white chert developed in a fine-grained dolomitic matrix; and most of them are in a fine state of preservation. Among them we recognize *Dizygopleura lacunosa*, the typical and other varieties of *D. symmetrica*, *D. asymmetrica*, *D. loculosa*, *Paraechmina spinosa*, and *Primitiella æquilateralis*, all of which are described in this volume as characteristic fossils in Maryland and Pennsylvania of the uppermost shaly calcareous beds of the Clinton group to which we have applied the term Drepanellina clarki zone.

This close agreement in ostracod faunal contents between the Bisher of Ohio and the Drepanellina clarki zone of the Clinton as developed in the middle Appalachian region carry much weight in deciding the age relations of the Ohio formation to the generalized time scale of the Silurian in America. It is significant further to note that the evidence of the Ostracoda in this case is in essential agreement with that of the associated other classes of fossils. The Bisher fauna of southern Ohio and Lewis County, Kentucky, aggregating, exclusive of the Ostracoda, 45 species, has been listed and discussed by Foerste[1] as follows:

"An approximate correlation of the Bisher member with Niagaran strata in New York State is made possible by the fact that the upper part of the Crab Orchard shale, which lies immediately beneath the Bisher member, contains *Liocalymene clintoni*, *Beyrichia lata*, and other fossils occurring in the middle part of the typical Clinton section of New York.

[1] Foerste, A. F., Silurian fossils from Ohio, with notes on related species from other horizons: The Ohio Journal of Science, vol. xix, p. 374, 1919.

In the overlying Irondequoit limestone, however, at the top of the Clinton of New York, occur numerous species found also in the Bisher member, including *Cornulites clintoni, Orthis flabellites, Spirifer radiatus, Rhynchotreta americana, Whitfieldella cylindrica, Anastrophia interplicata, Stephanocrinus gemmiformis, Trimerus delphinocephalus* and *Bumastus ioxus.* Provisionally, therefore, the Bisher member is correlated with the Irondequoit limestone of New York."

On the preceding page Foerste tentatively correlates the Bisher with the Osgood limestone of Indiana.

The present writers in dissenting from Foerste's view just quoted would point out (1) that the *Liocalymene clintoni* and the "*Beyrichia lata*" (*Mastigobolbina triplicata* (Foerste)) of the upper part of the Crab Orchard shale are not the Middle Clinton forms of New York but the Upper Clinton species that are confined to the Mastigobolbina typus zone in Virginia, Maryland, Pennsylvania, and at Clinton, N. Y.; (2) that with possibly one or two exceptions the fossils mentioned in the latter half of the quotation are found in the Rochester shale as well as in the Irondequoit limestone; and (3) that many of the other fossils given in the full Bisher list published by Foerste on p. 369 of the cited paper agree, like the previously mentioned Ostracoda, perfectly with species found in the Drepanellina zone in Maryland. On these grounds, then, we are thoroughly convinced of the contemporaneity of the Bisher member of the West Union formation of Ohio and the Drepanellina zone of Maryland and Pennsylvania; and it follows that the preceding arguments advocating correlation of the Drepanellina zone with the Rochester apply with equal force in the case of the Bisher. Regarding the Osgood limestone of Indiana it is well known that we long ago favored its correlation with the Rochester. Also that we are now thoroughly in accord with Foerste in referring the Osgood and the Bisher to the same stratigraphic plane.

The faunal agreement between the Osgood on the one hand and the Bisher and Drepanellina zone on the other is, as noted by Foerste, very weak. But we see good reason for this weakness in the probable fact that the Bisher and the Osgood were laid down in separate troughs that communicated only in northern Pennsylvania. The Bisher fauna consists mainly of Atlantic invaders that traveled southwestward in their own bay from, say, Cumberland, Md., through West Virginia and northeastern Kentucky to Adams and adjoining counties in Ohio. The southern fauna of the Osgood limestone and the Rochester shale on the contrary is believed to have traveled northeastward from Indiana around the north side of the Cincinnati dome to western New York by way of a trough beneath the northern part of the Ohio coal measures. The two faunas are supposed to have intermingled in western Pennsylvania, making it possible for a few stragglers of the Osgood fauna to reach the head of the Drepanellina clarki bay in south-central Ohio. These separate troughs and bays are indicated in the concerned paleogeographic map on another page.

Our main objection to the view that the Bisher and consequently also its unquestionable correlate, the Drepanellina zone of Maryland and Pennsylvania, are to be assigned to the age of the Irondequoit limestone of New York rests on the fact that the Ostracoda of the Irondequoit, though generically the same, are in no instance precisely the same as their congeners in either the D. clarki zone or in the Bisher. On the other hand, two of the Rochester Ostracoda, namely, *Dizygopleura symmetrica* and *Paraechmina spinosa*, are represented by exactly similar specimens in both the Bisher and the D. clarki zone.