RICHMOND FAUNAL ZONES IN WARREN AND CLINTON COUNTIES, OHIO

By George M. Austin
Of Wilmington, Ohio

Previous to 1897, when Winchell and Ulrich first used the term "Richmond Group" to designate the uppermost formation of the Cincinnatian series as then considered, no careful or extended work had been undertaken for the purpose of determining the vertical range and variation of its fossils, or to establish the boundaries or lithological characters of its subdivisions. Before that date writers, in describing new species from these strata, made no attempt to designate their exact position in the series, although, as is the case with some of these species, their vertical range does not exceed a very few feet. In almost all of these early descriptions of Richmond fossils the general statement that the particular species under discussion was from the upper part of the Hudson River group was considered sufficiently explicit.

As a result of later investigations during the last thirty years by such careful observers as Ulrich, Nickles, Foerste, Bassler, Cumings, and Shideler, the boundaries of the various subdivisions of the Richmond have been established and the vertical range of many of its species accurately determined. Also in the case of many of the species which first made their appearance in this region during the deposition of the Richmond rocks, much progress has been made in determining their previous habitat and the lines along which they extended their range into this territory. The writer has spent half a century in such studies and with the recent gift of his collection of Early Silurian fossils to the United States National Museum, it was thought fitting that some of his observations be put on record.

In the present paper it is our purpose first to call attention to a factor which we believe exerted a more potent influence in bringing about the many and often abrupt lithological and faunal changes met with in the Richmond than any other cause of which we now have knowledge. This factor was the oscillation of the sea floor with the resulting frequent and often considerable change in sea depth which there is ample evidence to show took place during the upbuilding of these strata. As in the seas of the present day we have littoral, off-shore and deep-water species whose range is largely determined by sea depth, and still other species which have the exceptional power of adapting themselves to a very considerable change in depth and other conditions, so in the ancient seas, life appears to have been subjected to the same laws of distribution. Then, as now, some species were evidently restricted to waters of so little depth that they were exposed at all times to the full force of the tides and waves; others to seas though always comparatively shallow during the period, yet of such depth that the agitation of their surfaces seldom if ever extended down to their floors or disturbed objects reposing upon them. In these shallow seas the remains of only such forms as possessed a skeleton sufficiently compact to withstand a long continued hammering in the surf after death, came through intact, as for instance the bryozoans, the thick-shelled species of brachiopods and gastropods and the true corals, while on the other hand the shells of all the frailer forms after the death of their occupants, were broken into fragments and these fragments were usually worn smooth and scattered widely about by the waves before the process of attrition was brought to an end by their being finally covered up in the mass of débris accumulating on the sea floor. It can be further said of these shallow sea deposits that the shells of such bivalves as escaped destruction usually present the evidences of erosion and as a rule have their valves separated and lying widely apart. Also in those beds, species whose skeletons were made up of a multitude of segments, as the trilobites, the crinoids, and the starfishes, have almost without exception had these coverings separated after death into their component parts and these parts scattered by the waves. This statement is especially true of some species of the genus *Acidaspis* whose range appears to have been restricted to very shallow waters. Although abundant during the Richmond, the constant turmoil of the waters in which they lived and died, left only these fragments to be preserved in the rocks. The same generally is true of the genus *Lichenocrinus* where only the solid modified root remains. Although it is generally conceded that the Richmond seas at no time attained abyssal depths and that all times its waters were comparatively shallow, there are good reasons for believing that not only once but many times during that period its waters deepened to such an extent their floors were no longer much affected by currents set in motion by forces acting upon their surfaces. As evidence of this we meet with beds usually of shale or marl in which the most delicate forms have been preserved intact and in the same position they were in when death overtook them. That these frail forms were thus so fully preserved by reason of the unbroken quiet of the waters about them and not because they were at once buried after death in the rapidly accumulating clay before their soft parts had time to disintegrate is proved by evidence often furnished by their fossil remains in the form of parasitic growths on their surfaces. In many instances after the death of these animals some parasitic species, such as an incrusting bryozoan, established its colony on the empty shell, reached maturity and died to be succeeded not infrequently by a second and different parasitic species which likewise had full time to complete its life cycle before all were finally covered by the accumulating clay.

Although the oscillations of the Richmond sea floor were many, the extremes in depth to which we have referred were not the usual outcome of these disturbances, since in most instances the changes stopped well within those limits. Yet a change from one to the other of those extremes did occur a number of times during the upbuilding of the group, and occasionally, as we shall see further on, quite abruptly, as measured by geologic time. At the horizons where these oscillations are recorded in the rocks a half-dozen feet in the vertical scale will in some instances take one from strata laid down in the quiet of deep water to other strata, whose broken and water-worn fossils indicate that they were formed in a shallow sea whose floor was subjected to the full force of the waves. While the character and conditions of the sediments of the Richmond seas were greatly affected by these oscillations, a still greater influence was exerted on its fauna. The species of the deep-water beds are almost all different from those met with in the shoal-water beds and so, to a lesser degree, do both differ from the life of the intermediate strata. As a rule, lamellibranchs greatly outnumber all other classes in the deep-sea beds, while in those formed in shallow waters the brachiopods and bryozoans are the predominating forms. Since by far the greater part of the Richmond species appear to have had their range determined by sea depth, and as many of these species, like the *Hebertella insculpta*, seems to have been unable to survive any considerable change in that condition, the oscillations that so frequently resulted in the deepening or shoaling up of the Richmond sea undoubtedly exerted a powerful influence on the life of its waters. Whether the sea floor was rising or sinking, every step in the change was reflected by a corresponding change in the fauna of the time. Single species, and at times whole groups of species, were forced to retire from the disturbed area since the change had rendered its waters untenable. These disappearing species were at once succeeded by other species adapted to the new conditions and these in turn by still other forms, and so on till the disturbance had reached its end. If the movement in turn was reversed as when a period of elevation succeeded one of subsidence, so in a reversed order many of the old species much changed in form reappear as the conditions necessary to their existence returned. As a result of the changes these disturbances produced we usually find at those horizons where the strata record a considerable change in depth an unusually rich and varied fauna. These species, ranging from the deep-water forms through all the intermediate types to those restricted to the turbulent water of a shallow sea, may follow each other in such rapid succession that all may be collected in a vertical range of a few feet.

What should also be referred to in this connection is the remarkable fact that it was only during these periods of oscillation that new species made their first appearance in the Richmond seas and that these horizons where the changes were considerable, the beginning of the change is marked by the presence of exceptionally heavy layers of hard, fine-grained clay stone, formed apparently from sediment brought in by currents from a distance. Then it was also during these times of change that numerous old forms which had flourished earlier in the Ordovician seas either during the Trenton, the Cincinnati proper, or earlier in the Richmond reappear to be for a time a part of its fauna. Although, not infrequently, species long established in the Richmond seas degenerated, grew scarce, and finally wholly disappeared during a period of prolonged stability we would repeat that as far as our observation has gone, no new species appeared or old species reappeared in these waters at any other time than during the periods of disturbance caused by the rising or sinking of the sea floor.

Another interesting fact relating to the fauna that should be mentioned before we take up the consideration of the Richmond strata in detail is the marked effect these changes in depth had upon the size and form of the individuals of such species as passed through them. Notable among the species that were able to survive extreme variations of this nature is the *Rafinesquina alternata* and to a less degree the *Hebertella occidentalis* group and the *Platystrophias*. Taking the changes in these forms as an index, it can be stated as a general rule that brachiopods which grew in shallow turbulent waters developed a much thicker shell than those in deeper stations, their brachial valves were more highly arched, the lines of growth more frequently present and strongly developed, and there was a marked tendency to a strengthening of the hinge line much beyond the average. On the other hand in deep water these species developed much flatter and thinner shells than the average, had few if any lines of growth, but frequently became unusually elongated along the hinge line. Again during a number of these periods of disturbances, conditions appear to have developed that were extremely favorable to the growth of one or more of the species then existing. At several horizons where a considerable oscillation of the sea floor is indicated we find one or more of the species present so overgrown as to appear as veritable giants of their kind when compared with specimens from other levels. In other instances the charge was equally unfavorable to some species and we then see the individuals greatly dwarfed, although later under better conditions they usually regained their normal size.

In the Richmond seas one species at least, *Plectambonites rugosus* seemed to have thrived best in the unsettled conditions that marked the close of one period and the ushering in of the next. Its first appearance in the group is at the beginning of the Clarksville division before the change that brought that division into existence had ceased to act. There in the varietal form known as *P. rugosus clarksvillensis* it occurs in unsual numbers and of great size. Again on the heavy clay stones that marks the base of the Liberty and higher up where a similar heavy layer marks the beginning of the Whitewater, remains of countless millions of the species are to be found although the shell is not especially common at other horizons.

In preparing the following notes and geologic section, we have confined our statements almost wholly to the small area lying chiefly within the counties of Warren and Clinton in Ohio, east of the Little Miami River, because it is the region with which we are most familiar, having passed our entire life within its limits and many times each season visiting its exposures through a period exceeding 50 years. In referring to the divisions of the Richmond in the following pages, we are aware that the changes there suggested will probably be called in question. Yet we can say in this connection that these changes have not been made lightly, but only after a careful study of the junction of these divisions extending through many years, and made at practically all the exposures in this territory where they are to be seen and that if we desire accuracy, such changes must be made.

These repeated examinations have convinced us that in addition to the changes produced in the current life, and on the character of the sedimentary deposits, by changes in sea depth, which apparently were frequent and at times considerable—there were other powerful forces occurring entirely outside of this region, which exerted a greater influence than all others in determining the general changes that took place in the Richmond seas. Apparently these outside disturbances affected the existing life and developing strata in two distinct ways; first by turning loose at times floods of argillaceous material which not only greatly affected life, usually modifying or destroying it, but also deposited more or less heavy beds of nodular clay stone or more frequently one or more compact clay stone layers, thicker and quite different in character from those common to the group and second, by the breaking down of previous barriers, thus opening the way for the entrance of the many new species which appear abruptly in the Richmond strata just above or more rarely below these peculiar argillaceous deposits. Thus we are convinced that the changes produced in our Richmond seas by these outside disturbances were largely responsible for those differences which have made it necessary, or at least convenient to divide the group into its present recognized divisions and that those peculiar clay stone layers truly indicate the natural lines of demarkation between them. With one exception, the point of contact between the Fort Ancient and Clarksville, the lines of junction between all the divisions are clearly marked in this region by the presence of these unusual argillaceous deposits.

In conclusion we would say that the following lists lack much of being complete. There is quite a number of species in the group which have not been named and described, others present are so rare in their occurrence that we have failed to find them in this territory, while many more in such classes as the bryozoans and gastropods we have not been able to identify.

Again, in attempting to find out the vertical range of the various species of a division or of a group, one is certain to meet with the greatest difficulties if they are attempting a reasonable approach to accuracy. In numerous cases an individual may be unexpectedly found much below or far above where the species attains its full development in numbers. Other species, though present in the group are so rare that one is lucky to find a single specimen during a lifetime search. Still other species were restricted in life to widely scattered colonies, the remains of which may not through long periods be uncovered at any of the exposures in the territory.

Our classification of the Richmond strata in this area is given in the following composite section:

COMPOSITE SECTION OF THE RICHMOND GROUP IN WARREN AND CLINTON COUNTIES, OHIO

Elkhorn formation (Beds E. 1–3)

Upper division (E. 3). Blue clay, unfossiliferous except that a few layers 15 feet above the base contain *Cyphotrypa stidhami* and *Ctenodonta hilli* in abundance and the top stratum holds the species of annelids described by Foerste ---------- 42′

Middle division (E. 2). Thin bedded blue limestone with a few clay layers containing *Homotrypa wortheni prominens*, *Platystrophia moritura*, *Opisthoptera casei*, and *Lichenocrinus tuberculatus* with *Streptelasma rusticum*, *Protarea richmondensis*, and other longer ranging fossils ---------- 4′

Lower division (E. 1). Fossiliferous blue clay with *Ischyrodonta elongata*, *I. miseneri*, *Bellerophon mohri*, etc ---------- 2′

Whitewater formation (Beds Wh. 1–6)

Oakland division (Beds Wh. 3–6):

Drepanella richardsoni bed (Wh. 6). Light-colored clay capped by two or three heavy layers of impure limestone 8 to 10 inches thick apparently barren but crowded with ostracoda, *Drepanella richardsoni, Eurychilina striatomarginata, Leperditia caecigena, Primitia lativia*, etc., *Lichenocrinus tuberculata, Agelacrinus austini*, and *Helopora elegans* also present ---- 5′

Ischyrodonta bed (Wh. 5). Alternating thin bedded blue limestone and clay layers, the latter predominating with the upper beds containing great number of *Ischyrodonta decipiens, I. elongata, I. miseneri, I. ovalis*, and *Ctenodonta hilli* ---- 6′

Monticulipora cleavelandi bed (Wh. 4). Shelly limestone layers crowded with ramose bryozoa particularly *M. cleavelandi* and *Homotrypa austini* ---- 3′

Lower bed (Wh. 3). Nodular clay limestone with the interspaces filled with coarse clay. *Dermatostroma glyptus, Bellerophon mohri, Lichenocrinus tuberculatus, Strophomena sulcata, Hebertella occidentalis, Rafinesquina*, etc., present ---- 6′

Middle division (Wh. 2). Alternating clay and limestone layers with the latter predominating. The clays are almost unfossiliferous, the species present being attached to the limestone beds ---- 50′

Lower division (Wh. 1). Clay shale and occasionally layers of limestone containing an unusual number of species, among them *Homotrypa wortheni, Ptilodictya magnifica, Pachydictya fenstelliformis, Monticulipora parasitica, Xenocrinus baeri, Gyroceras baeri, Arctinurus harrisi, Gomphoceras eos*, and *Byssonychia richmondensis*, while *Streptelasma rusticum* is especially abundant and large in the lower part. Base marked by one or more unusually thick clay-stone layers, with *Plectambonites rugosus clarksvillensis* in great abundance ---- 10′

Liberty formation (Beds L. 1–3)

Upper beds (L. 3). Thick clay beds interspersed with rather thin (2 to 5 inches), even-bedded limestone layers abundantly fossiliferous but with the fossils usually attached to the limestone.

Constellaria limitaris bed (L. 2.) Fossiliferous clays and thin-bedded limestone holding *Constellaria limitaris* in abundance associated with *Gyroceras baeri, Cupulocrinus polydactylus, Dinorthis subquadrata, Phragmolites dyeri, Dalmanites breviceps*, etc. With these normal-sized species are dwarf forms of *Plectambonites rugosus clarksvillensis, Strophomena planumbona, Pterinea demissa*, and *Calymene meeki* ---- 10′

Basal beds (L. 1). Heavy clay-stone layers marking base of Liberty.

Waynesville formation (Beds W. 1–17)

Blanchester division (Beds W. 8–17):

Crinoid bed (W. 17). Compact, fine grained green blue clays with the crinoids *Glyptocrinus fornshelli, Canistrocrinus richardsoni, Compsocrinus miamiensis, Dendrocrinus casei, Reteocrinus nealli*, and *Heterocrinus juvenis* and the merostome *Megalograptus welchi* ---- 6′

Upper *Hebertella insculpta* bed (W. 16). Shaly limestone layers crowded with *Hebertella insculpta, Strophomena nutans, S. neglecta*, and other brachiopods in abundance, attached to the limestone ---- 5′

Blanchester division—Continued.

Coral bed (W. 15). Rather barren blue clay with a few even-bedded limestone layers showing fossils upon their surface. *Calapoecia cribriformis, Columnaria alveolata, C. vacua,* and *Tetradium* occur in the clay, while *Plectorthis* (*Austinella*) *scovillei* is found only in a thin limestone bed in the middle of the division ______ 8′

Upper disturbed layers (W. 14). Two layers, each about 6 inches thick, of disturbed material, chiefly shells of *Rafinesquina alternata* standing on edge. These two beds are separated by a foot of undisturbed shale and limestone. *Rhynchotrema dentatum* rare in the lower disturbed bed, its only occurrence in the Richmond of this area ______ 2′

Homotrypa dawsoni beds (W. 13). Compact blue clay, bearing an occasional thin limestone layer, with *Homotrypa dawsoni,* the most common fossil. *Mastigograptus gracillimus* and *Ateleocystites balanoides* also present ______ 3′

Strophomena nutans bed (W. 12). Thin shelly limestone crowded with *Strophomena nutans* and *S. neglecta,* also with specimens of *S. planumbona elongata* ______ 4–5′

Platystrophia annieana bed (W. 11). Even-bedded layers of limestone and shale with *Platystrophia annieana, Reteocrinus nealli,* and *Streptelasma dispandum* appearing for the first time ______ 3′

Lower disturbed layer (W. 10). Shaly limestone layers 6 inches thick filled with valves of *Rafinesquina alternata* standing on end, underlaid by one foot of clay and thin limestone with few fossils ______ 1.5′

Isotelus gigas bed (W. 9). Compact blue clay abounding in well-preserved fossils, particularly pelecypods (*Opisthoptera, Psiloconcha, Cuneamya,* etc.), and containing entire specimens of *I. gigas* more abundantly than at any other horizon ______ 3′

Basal beds (W. 8). Claystone and shale with many long ranged species. *Dalmanella meeki, Plectambonites rugosus clarksvillensis,* and *Zygospira modesta* noted ______ 7′

Clarksville division (Beds W. 5–7):

Lower *Hebertella insculpta* bed (W. 7). Blue limestone and shale like that at base (W. 5) but containing *Hebertella insculpta, Protarea richmondensis* and *Pterinea corrugata, Catazyga headi schuchertana, Dinorthis carleyi-insolens,* etc. A heavy compact argillaceous layer up to 7 inches thick forms the capstone to this bed with *Dalmanella meeki* in abundance ______ 3′

Middle beds (W. 6). Lumpy, dark blue, rubbly limestone mingled with granular, dark blue clay containing broken and waterworn shell fragments, particularly *Dalmanella meeki* and holding many minute fossils (*Cyclora,* etc.) ______ 9′

Plectambonites clarksvillensis bed (W. 5). Rather even bedded blue limestone and shale with first appearance of *Streptelasma rusticum, Plectambonites rugosus clarksvillensis, Rhynchotrema capax, Strophomena sulcata, S. planumbona,* and crowded with *Dalmanella meeki* ______ 3′

Fort Ancient division (Beds W. 1–4):

Orthoceras fosteri bed (W. 4). Soft, dove colored clay with many fossils especially *Orthoceras fosteri, Calymene meeki, Paleschara beani, Cyphotrypa clarksvillensis, Suecoceras inequabile, Columnaria alveolata, Tetradium, Stromatocerium ohioensis, Spatiopora tuberculata,* etc ______ 5′

Fort Ancient division—Continued.

Anomalodonta gigantea bed (W. 3). Purer blue limestone beds interbedded with shale, with many pelecypods, particularly *Anomalodonta gigantea, A. alata, Pholadomorpha pholadiformis, Pterinea demissa*, etc., at their greatest development — 12′

Rafinesquina loxorhytis bed (W. 2). Argillaceous blue limestone beds alternating with more or less heavy layers of shale. Fossils rather few. *R. alternata, R. loxorhytis, Dalmanella meeki*, etc — 40′

Strophomena concordensis bed (W. 1). Massive, nodular, light blue argillaceous limestone with little clay, rather unfossiliferous but containing *Strophomena concordensis, Cyclonema humerosum, Anomalodonta alata*, and *Rafinesquina* species — 5′

Arnheim formation (Beds A. 1–3)

Oregonia division (Beds A. 2, 3).

Homotrypa bassleri beds (A. 3). Dark blue shales and lumpy, rubbly, argillaceous limestone crowded with fossils; *Cyclonema fluctuatum, Anomalodonta alata, A. gigantea, Mesotrypa orbiculata, Homotrypa bassleri, Batostoma varians*, and many microscopic fossils (species of *Cyclora, Primitia cincinnatiensis, Bollia regularis, Ctenobolbina hammelli, Aparchites oblongus*, etc.) — 20′

Dinorthis carleyi bed (A. 2). More even bedded blue limestone alternating with beds of clay with valves and entire examples of this characteristic species and also *Leptaena richmondensis precursor* and *Platystrophia ponderosa* — 3′–5′

Sunset division (A. 1). Rather unfossiliferous, light drab colored clays alternating with thin layers of clay stone of the same color, which contrasts strongly with the Mount Auburn beds below and the Oregonia above. *Rafinesquina alternata* var. common at the bottom and near the top. *Cyclonema fluctuatum, Peronopora decipiens*, and *Pterinea demissa* usually found — 20′

Maysville Group (Ordovician).

RICHMOND FOSSILS IN WARREN AND CLINTON COUNTIES, OHIO, SHOWING STATIGRAPHIC RANGE

Acrolichas shideleri (Foerste), Wh. 1.
Agelacrinus austini Foerste, Wh. 6.
Agelacrinus rectiradiatus (Williams), L. 3.
Anomalodonta alata (Meek), A. 3, W. 2.
Anomalodonta gigantea Miller, A. 3, W. 2.
Aparchites minutissimus (Hall), A. 3.
Aparchites oblongus Ulrich, A. 3.
Arabellites procursus Foerste, E. 3.
Archinacella richmondensis Ulrich, Wh. 5.
Arctinurus harrisi (Miller), Wh. 1.
Arthraria biclavata Miller, A–E.
Arthropora shafferi (Meek), W. 3, 8, Wh. 2, 5, 6.
Arthropora shafferi, var. *robusta* Ulrich, L. 2.
Atactopora angularis Ulrich and Bassler, W.
Atactoporella schucherti Ulrich, W.
Ateleocystites balanoides (Meek), W. 13.
Batostoma variabile (Ulrich), Wh. 4.
Batostoma varians (James), W. 3, 5, 6, 8; A. 3.
Bellerophon mohri Miller, Wh. 3, E. 1.

Berenicea primitiva Ulrich, Wh. 3–6.
Bollia persulcata Ulrich, A–E.
Bollia pumila Ulrich, W.
Bollia regularis (Emmons), A. 3.
Brachiospongia tuberculata (James), L. 3.
Bucania simulatrix Ulrich, Wh. 1.
Buthotrephis gracilis Hall, A–E.
Byssonychia cultrata Ulrich, W. 3, 4, 9.
Byssonychia grandis Ulrich, W. 3, 4.
Byssonychia cf. *radiata* (Hall), A–E.
Byssonychia richmondensis Ulrich, Wh. 1, 2.
Byssonychia subrecta Ulrich, W. 4, 9, Wh. 1.
Byssonychia tenuistriata Ulrich, Wh. 5.
Bythocypris cylindrica (Hall), A–E.
Bythopora delicatula (Nicholson), Wh. 2, 4, L. 2, Wh. 5, 6.
Bythopora meeki (James) W. 3, 5, 8, 9. Wh. 2, L. 2.
Bythopora striata Ulrich, A., W., L. 2, Wh. 2.
Calapoecia cribriformis (Nicholson), W. 9, 15.
Calloporella circularis (James), W.
Calymene meeki Foerste, A–E.
Calymene meeki retrorsa Foerste, Wh. 1.
Canistrocrinas richardsoni (Wetherby), W. 17.
Catazyga headi schuchertana Ulrich, W. 7.
Ceramoporella granulosa Ulrich, A–E.
Ceramoporella ohioensis (Nicholson), A–E.
Ceramoporella whitei (James), A 3.
Ceratopsis robusta (Ulrich), A–E.
Ceraurinus icarus (Billings), Wh. 1.
Clathrospira subconica (Hall), E. 1.
Clidophorus fabula (Hall), A–E.
Coleolus iowensis James, A–E.
Columnaria alveolata (Goldfuss), W. 4, 7, 15.
Columnaria vacua Foerste, W. 16, 15.
Compsocrinus harrisi (Miller), W. 17.
Compsocrinus miamiensis (Miller), W. 17.
Constellaria limitaris (Ulrich), L. 2, W. and Wh.
Constellaria polystomella Nicholson, W. 17 Wh., E.
Conularia formosa (Miller and Dyer), W. 4.
Corallidomus concentricus Whitfield, W. 9.
Cornulites richmondensis (Miller), W. 2, 4, 8.
Corynotrypa delicatula (James), A–E.
Corynotrypa inflata (Hall), A–E.
Crania laelia Hall, A–E.
Crania scabiosa Hall, A–E.
Ctenobolbina hammelli (Miller and Faber), A. 3.
Ctenodonta albertina Ulrich, W. 3, 9.
Ctenodonta hilli (Miller), Wh. 5, E. 3.
Ctenodonta obliqua (Hall), A–E.
Cuneamya curta Whitfield, W. 9.
Cuneamya miamiensis Hall and Whitfield, W. 3, 4, 9.
Cuneamya neglecta (Meek), W. 4, 9, A. 3.
Cuneamya scapha Hall and Whitfield, W. 9.
Cupulocrinus polydactylus (Shumard), Wh. 1, L. 2.

Cyclonema bilix (Conrad), W. 2, 5, 6, 8, 13.
Cyclonema fluctuatum (James), A. 1–3, W. 5.
Cyclonema cf. *humerosum* Ulrich, W. 1, A. 3.
Cyclora depressa Ulrich, A–E.
Cyclora hoffmani Miller, A–E.
Cyclora minuta Hall, A–E.
Cyclora parvula (Hall), A–E.
Cyclora pulcella Miller, A. 3.
Cymatonota constricta Ulrich, W. 3, 4, 9.
Cymatonota cylindrica (Miller and Faber), W. 3, 4, 9.
Cymatonota semistriata Ulrich, W. 4, 9.
Cymatonota typicalis Ulrich, W. 4, 9.
Cyphotrypa clarksvillensis Ulrich, W. 4.
Cyphotrypa stidhami (Ulrich), E. 3.
Cyrtoceras faberi James, W. 4.
Cyrtoceras tenuiseptum Faber, W. 4.
Cyrtolites ornatus Conrad, W. 3, 9, Wh. 2.
Dalmanella meeki (Miller), W. 2, 4, 6, 8.
Dalmanites breviceps (Hall), Wh. 1, L. 2.
Dendrocrinus caduceus (Hall), W. 17.
Dendrocrinus casei Meek, W. 17.
Dermatostroma corrugatum (Foerste), Wh. 5.
Dermatostroma glyptum (Foerste), Wh. 3.
Dermatostroma papillatum (James), A–E.
Dermotostroma scabrum (James), W. 2.
Dicranopora fragilis (Billings), L. 2.
Dinorthis carleyi (Hall), A. 2.
Dinorthis carleyi insolens Foerste, W. 7.
Dinorthis subquadrata (Hall), L. 2, Wh. 1, 2.
Drepanella richardsoni (Miller), Wh. 6.
Endoceras proteiforme (Hall), Wh. 1, 3, 4, Wh. 3.
Eridotrypa simulatrix (Ulrich), W.
Eunicites confinis Foerste, E. 3.
Eunicites falcatus Foerste, E. 3.
Eunicites paululus Foerste, E. 3.
Eurychilina striatomarginata (Miller), Wh. 6.
Fenestella granulosa Whitfield, Wh.
Glyptocrinus? fornshelli Miller, W. 17.
Gomphoceros eos Hall and Whitfield, Wh. 1.
Gyroceras baeri (Meek and Worthen), Wh. 1, L. 2.
Hallopora frondosa (Cumings), W.
Hallopora subnodosa (Ulrich), W. L. 2.
Hebertella alveata Foerste, Wh. 1, 2, 5, 6.
Hebertella alveata richmondensis Foerste, E–2.
Hebertella insculpta (Hall), W. 7, 16.
Hebertella occidentalis Hall, W. 3, 5, 8, 16, L. 2, Wh. 1–6, E. 3.
Hebertella occidentalis sinuata (Hall), W–E.
Helopora elegans Ulrich, Wh. 6.
Helopora harrisi James, W. L. 2.
Heterocrinus juvenis (Hall), W. 5, 17.
Heterotrypa subramosa (Ulrich), W.
Heterotrypa subramosa prolifica Ulrich, W. 13.
Homotrypa austini Bassler, Wh. 4.

Homotrypa bassleri Nickles, A. 3.
Homotrypa communis Bassler, W.
Homotrypa cylindrica Bassler, Wh.
Homotrypa dawsoni (Nicholson), W. 13.
Homotrypa flabellaris Ulrich, W. 3.
Homotrypa flabellaris spinifera Bassler, Wh.
Homotrypa libana Bassler, A. 3.
Homotrypa wortheni (James), E. 2, Wh. 1, 2.
Homotrypa wortheni prominens Bassler, E.
Homotrypella (*Prasopora*) *hospitalis* (Nicholson), W. Wh. L
Hormotoma gracilis (Hall), W. 2.
Hyolithes? dubius Miller and Faber, A. 3, W. 3.
Iocrinus subcrassus Meek and Worthen, E–2.
Ischyrodonta decipiens Ulrich, Wh. 5.
Ischyrodonta elongata Ulrich, Wh. 5, E. 1.
Ischyrodonta miseneri Ulrich, E. 1, Wh. 5.
Ischyrodonta ovalis Ulrich, Wh. 5.
Ischyrodonta truncata Ulrich, Wh. 4, 5.
Isotelus brachycephalus Foerste, W. 9, 16, 17.
Isotelus gigas DeKay, A–E.
Isotelus maximus (Locke), A–E.
Leperditia caecigena? Miller, Wh. 6.
Lepidocoleus jamesi (Hall and Whitfield), W. 3.
Leptaena richmondensis Foerste, E. 2.
Leptaena richmondensis precursor Foerste, A. 2.
Leptotrypa cf. *ornata* Ulrich, W. 7.
Liclemella subfusiformis (James), L. 2.
Lichenocrinus affinis Miller, W. 7, 8, 16.
Lichenocrinus tuberculatus Miller, Wh. 3, 5, 6, E. 2.
Lingula vanhorni Miller, W. 3, W. 16.
Liospira vitruvia (Billings), W. 2–4, 9.
Lophospira bowdeni (Safford), A–E.
Lophospira tropidophora (Meek), W. 3, 4, A. E.
Lumbriconerites austini Foerste, E. 3.
Lyrodesma major (Ulrich), W. 9.
Mastigograptus cf. *gracillimus* (Lesquereux), W. 13.
Megalograptus welchi Miller, W. 17.
Mesotrypa orbiculata Cumings and Galloway, A. 3.
Mesotrypa patella (Ulrich), Wh. 1–6.
Microceras inornatum Hall, A–E.
Modiolodon subovalis Ulrich, W. 3.
Modiolopsis concentrica Hall and Whitfield, W. 3–5, 9.
Modiolopsis cfr. *modiolaris* (Conrad), W. 4.
Monticulipora clevelandi James, Wh. 4.
Monticulipora epidermata? Ulrich and Bassler, E, 2.
Monticulipora parasitica Ulrich, Wh. 1, 2.
Nereidavus varians Grinnell, A–E.
Nicholsonella peculiaris Cumings and Galloway, W.
Odontopleura onealli (Miller), W.
Oenonites decipiens Foerste, E. 3.
Opisthoptera casei (Meek and Worthen), Wh. 5, E. 2.
Opisthoptera concordensis Foerste, W. 9.
Opisthoptera fissicosta (Meek), W. 3, 5.

Opisthoptera obliqua Ulrich, W. 9.
Orthoceras clarksvillensis Foerste, W. 17.
Orthoceras duseri Hall and Whitfield, W. 3.
Orthoceras fosteri Miller, W. 4, 5.
Orthoceras mohri Miller, A, 1, 3.
Orthodesma canaliculatum Ulrich, A. 3.
Orthodesma curvatum (Hall and Whitfield), W. 3, 5, 9.
Orthodesma rectum (Hall and Whitfield), W. 3, 4, 9.
Orthodesma subangulatum Ulrich, W. 9.
Pachydictya fenestelliformis (Nicholson), Wh. 1, W. 2.
Paleschara beani (James), W. 4, 9.
Peronopora decipiens (Rominger), A-E.
Petraster speciosa (Miller and Dyer), L. 3.
Phragmolites dyeri (Hall), W, L. 2.
Platystrophia acutilirata (Conrad), Wh. 1, 6.
Platystrophia acutilirata, var. E. 1.
Platystrophia annieana (James), W. 11.
Platystrophia clarksvillensis Foerste, W. 3, 5.
Platystrophia cypha versaillesensis Foerste, W. 9.
Platystrophia laticosta (James), W. 5.
Platystrophia moritura Cumings, E. 2.
Platystrophia ponderosa Foerste, A. 2.
Plectambonites rugosus clarksvillensis Foerste, W. 5, L. 1, 2, Wh. 1. 2.
Plectorthis (*Austinella*) *scovillei* (Miller), W. 15.
Primitia concinnatiensis (Miller), A. 3, W.
Primitia lativia Ulrich, Wh. 6.
Primitia milleri Ulrich, W.
Proboscina auloporoides Nicholson, W.
Proboscina frondosa (Nicholson), A. 3.
Protarea richmondensis Foerste, W-E.
Psiloconcha elliptica Ulrich, W. 9.
Psiloconcha grandis Ulrich, W. 9.
Psiloconcha subrecta Ulrich, W. 9.
Pterinea corrugata (James), W.
Pterinea demissa (Conrad), A–E.
Ptilodictya magnifica Miller, Wh. 1.
Ptilodictya nodosa James, W. 15, L., Wh. 1, 2.
Ptilodictya plumaria James, Wh. 2.
Rafinesquina alternata (Emmons) var. A-E.
Rafinesquina alternata loxorhytis (Meek), W. 2, 3
Reteocrinus magnificus Miller, W. 17.
Reteocrinus nealli (Hall), W. 11, 17.
Rhaphanocrinus sculptus (Miller), W. 17.
Rhinidictya lata (Ulrich), W. 5
Rhombotrypa quadrata (Rominger), W–E.
Rhombotrypa subquadrata (Ulrich), W. 3.
Rhopalonaria venosa Ulrich, W. 3, 5, 6, A. 3.
Rhynchotrema capax (Conrad), W–E.
Rhynchotrema dentatum Hall, W. 14.
Rusophycus biloba Vanuxum, A–E.
Salpingostoma richmondensis Ulrich Wh.
Schizocrania filosa Hall, A. 2.
Schizolopha moorei (Ulrich), W. 3, 5, 8.
Sinuites cancellatus (Hall), A–E.

Sinuites morrowensis (Miller), W. 4.
Sinuites subcompressus (Ulrich), W. 4.
Spatiopora corticans Nicholson, W. 4.
Spatiopora montifera Ulrich, W. 4.
Spatiopora tuberculata (Edwards and Haime), W. 4, 9.
Spirorbis cincinnatiensis (Miller and Dyer), W. 4.
Stomatopora arachnoidea (Hall), A–E.
Streptelasma dispandum Foerste, W. 11.
Streptelasma divaricans (Nicholson), Wh. 1, L. 2.
Streptelasma rusticum Billings, W–E.
Stromatocerium huronense (Billings), W. 4, L. Wh.
Stromatocerium montiferum (Ulrich), Wh.
Strophomena neglecta (James), W. 12.
Strophomena nutans Meek, W. 12.
Strophomena planumbona (Hall), W., Wh. 1, 5, L. 2.
Strophomena planumbona-elongata (James), W. 5, 17, L. 2.
Strophomena planumbona gerontica Foerste, W. 7.
Strophomena sulcata (Verneuil), W. 5, L. 2, Wh. 1–5.
Strophomena vetusta (James), Wh. 5.
Suecoceras (*Cameroceras*) *inequabile* (Miller), W. 4, Wh. 1.
Tetradella lunatifera (Ulrich), W–E.
Tetradella quadrilirata (Hall and Whitfield), L. 2.
Tetradella simplex (Ulrich), W–E.
Tetradium approximatum Ulrich, W–E.
Trematis millepunctata Hall, A–E.
Ulrichia nodosa (Ulrich), A–E.
Whiteavesia pholadiformis (Hall), W. 3–5, 9, Wh. 1.
Whitella obliquata Ulrich, W. 4, 13.
Whitella ohioensis Ulrich, W. 9.
Whitella quadrangularis (Whitfield), Wh. 1, 11.
Xenocrinus baeri (Meek), Wh. 1.
Zygospira kentuckiensis James, W. 9.
Zygospira modesta (Hall), A–E.

TYPE LOCALITIES

Warren and Clinton Counties have furnished the type specimens of a number of Richmond species, some of them so rare and so restricted in vertical range that it was thought appropriate to record the following observations for the benefit of future collectors.

Agelacrinus austini (Foerste): The type of this species was collected from the surface of the thick cap rock of the *Drepanella richardsoni* bed of the Whitewater in Dutch Creek, near Oakland, Ohio. It is also present at the same horizon in Hales Branch, also near Oakland and in upper Cowans Creek near Villars Chapel, Clinton County, Ohio. It has never been noted at any other horizon.

Brachiospongia tuberculata (James): The type specimen was found by a farmer and presented to the late Dr. L. B. Welch, of Wilmington, Ohio. It was taken from strata exposed in a small stream which flows into Todds Fork just below the bridge on the Wilmington and Lebanon pike one mile west of Sligo, Clinton

County, Ohio. Since all the strata exposed in this short tributary belong to the upper part of the Liberty, the specimen was undoubtedly derived from that horizon. We know of no other specimen of the species having been found in this territory. This type is now in Wilmington College together with the rest of the Welch collection.

Canistrocrinus richardsoni (Wetherby): The type of this species was discovered by Mr. J. M. Richardson in the crinoid bed (W. 17) at the top of the Waynesville on Cowan's Creek, Clinton County, Ohio, from which were taken the numerous specimens of *Lichenocrinus affinis* which established the fact that *Lichenocrinus* is not a cystid but a true crinoid. Although Mr. Richardson found a considerable number of *C. richardsoni* at this locality with their bodies well preserved, very few good specimens have been found elsewhere. One peculiarity of this species was the unusual length of its large column. One may occasionally find continuous sections five to six feet long lying partly imbedded on the surface of a limestone layer; the length of the entire column must have been much greater than this. As far as we know, its range is restricted to this bed.

Catazyga headi schuchertana (Ulrich): This species comes in a foot or two below the top of the Clarksville in the lower *Hebertella insculpta* bed. It appears to have been gregarious in its habits, developing widely separated colonies with only an occasional individual between. There is such a populous colony exposed in Mill Run, a little tributary of Todd's Fork just north of Clarksville, Ohio, and another at Blanchester, Ohio, in a little stream that enters into Second Creek. At other localities where its horizon is exposed, it is only on rare occasions that a specimen is to be found. This species appears to be confined in the region to the very limited range named above, not being found at any other horizon in the Richmond.

Compsocrinus miamiensis (Miller): From Jonahs Run near Harveysburg, and from Roaring Run near Wellman, both localities in Warren County, Ohio, we have collected this species from the crinoid bed (W. 17) at the top of the Waynesville. Whether its range extends beyond this horizon we can not say, but we have no knowledge of its occurrence elsewhere.

Dendrocrinus caduceus (Hall): The type of this species was found in Longstreth Branch at Oregonia, Warren County, Ohio, apparently in the crinoid bed (W. 17) at the top of the Waynesville. We have no knowledge of its occurrence east of the Little Miami River, nor do we know the extent of its vertical range.

Dendrocrinus casei (Meek): This species also appears to have made its first entrance into the Richmond at the crinoid bed (W. 17) at the top of the Waynesville. At one locality near Clarksville, Ohio, it was collected from this bed, where it was associated with *Reteocrinus nealli* and *Megalograptus welchi.* The species extends upward through the Liberty, where it is most frequently met with, and up to a height of ten feet or more in the Whitewater.

Dermatostroma corrugatum (Foerste): The type of this species was found in the Ischyrodonta bed (Wh. 5) of the Whitewater along Dutch Creek, Clinton County, Ohio. Like all the colonies of *D. glytum* we have seen, this specimen had chosen as its host the shell of *Endoceras proteiforme.* Partial decay of the latter left the specimen free, and subsequent pressure had caused it to break into several rather large fragments, one of which Doctor Foerste chose as the type.

Dermatostroma glyptum (Foerste): The type of this species now in the National Museum was collected in the lower bed (Wh. 3) of the Oakland division in Dutch Creek, near Oakland, Clinton County, Ohio. The species is apparently rare and does not seem to extend higher than about 15 feet above the base of this division.

Drepanella richardsoni (Miller): The type of this interesting ostracod came from the beds of the same name (Wh. 6 of the Oakland division) along Dutch Creek, Clinton County, Ohio. Here its free and entire shells outnumber those of all other species of the class associated with it. In the region its entire vertical range does not exceed six feet, ending with the close of the Oakland.

Glyptocrinus? fornshelli (Miller): The type of this species was found by Frank Fornshell in the crinoid bed (W. 17) at the top of the Waynesville, 2½ miles below Clarksville, Ohio, in the middle one of three small streams which cross the Clarksville and Morrow pike and later along unite to form one of the tributaries of Todds Fork. These branches are locally known as Madden's Run.

Lichenocrinus affinis (Miller): On lower Cowan's Creek in Clinton County, Ohio, one-half mile above the crossing of the Wilmington and Clarksville pike and the stream, there is an extensive exposure along the left bank, near the base of which the upper *Hebertella insculpta* bed is exposed. During the summer of 1898 we found in this bed a lenticular mass of rock four or five feet in diameter and not more than one or two inches thick at the center, the thickest part. This sheet was made up largely of the shells of *Zygospira modesta*, a few bryozoans and many fragments of *Isotelus maximus*, the interspaces being filled with clay and all tightly bound together by crystallization. Attached to many of the bryozoans and to many of the fragments of *Isotelus* were the basis of *Lichenocrinus affinis.* Again arising from the center of many of these disks were slender crinoidal columns which extended out from ths disk through the clay for a greater or less distance to the point where they had been broken off. With these were sections of other columns identical in size and structure with these which when followed along away from the point of fracture ended at last in the body and arms of a very small crinoid. In this bed there were many disks and many crinoid bodies from which the columns had been entirely broken off and swept away and a still greater number of sections of columns showing fractures at both ends. Yet through all this material there runs such a unity of form that after a careful examination of these disconnected parts one can not doubt that in life they were all parts in the structure of the little crinoid whose highly modified root and the disk of the *Lichenocrinus* were one and the same.

Megalograptus welchi (Miller): One-half mile west of Clarksville, Ohio, the Clarksville and Morrow Pike crosses Todd's Fork and a little farther on a small tributary of that stream flowing from the north, just before reaching this last crossing, the Fort Ancient pike leaves the Morrow road and follows up the east bank of the tributary to the general level ¼ mile above. Near the top of this grade a little house stands on the west side of the pike and in the tributary, immediately at the rear of the house, the crinoid bed (W. 17) at the top of the Waynesville is well exposed. Here in 1874, Dr. L. B. Welch of Wilmington, Ohio, discovered a pocket containing many columns and bodies of *Reteocrinus nealli* along with a less number of *Dendrocrinus casei*. While exploring the pocket for these species he unexpectedly uncovered the specimen which has served as the type of this species. This specimen lay apparently entire in the bed but was badly broken up in the removal and only a few fragments saved. We have never collected this form and do not know the extent of its vertical range. The locality is given in such detail that future collectors may rediscover this unique fossil.

Platystrophia annieana (James): The type of James species was found in a small stream to the west of Blanchester, Ohio, and just beyond the corporation limits. As the exposures in this stream and in Second Creek into which it flows do not extend but a few feet above the level of the *P. annieana* bed (W. 11) of the Blanchester division. It is to be assumed that this specimen came from this horizon. We have collected this form in the little stream at Blanchester and also in Stony Hollow at Clarksville, Ohio from this horizon.

Plectorthis (*Austinella*) *scovillei* (Miller): The range of this species appears to be confined to one or two limestone layers which together do not have a thickness of more than five of six inches. This bed is about five feet below the base of the upper *Hebertella insculpta* bed and is at the same level at which *Rhynchotrema capax* reappears in the Richmond (W. 15 of the Blanchester division). We have never seen this species in any of the exposures of this bed in Clinton County but in the Blacksmith Hollow and in other streams around Oregonia, Ohio, it is fairly common within the narrow limits of its range. Although detached brachial and pedicle valves are equally common, we have never collected a specimen with these valves found in their natural position.

Ptilodictya nodosa (James): The type of this species was collected by the late Dr. L. B. Welch from a limestone layer at the mouth of Cowan Creek, Clinton County, Ohio. The strata at this point belongs to the Blanchester division and comes in at about the level of the coral bed (W. 15). This apparently marks its point of entrance into the Richmond of this region. Its range extends upward through the remainder of the Blanchester through the entire thickness of the Liberty and up 15 to 20 feet in the Whitewater. This is a rare form throughout its entire range.

O