CHAPTER II.

GEOLOGIC RECONNAISSANCE.

In Iowa that particular phase of geologic inquiry which must always precede systematic investigations very closely coincided in point of time with the third quarter of the Nineteenth century. Prior to that period through a space of twenty-five years, the sundry observations made concerning the rock-formations of the State were incidental to the geographical explorations of the day. The various other results derived from the earliest definite inquiries started, were in no way connected with one another and they afforded little foundation for any subsequent investigations.

Singularly enough, although mining had been carried on for more than a century and a half previous to the first records in geology made within the area of the present state, the character and succession of the rock-layers containing mineral, and the relations of the one to the other excited almost no attention. Only occasionally was there even the faintest glimmer of the scientific trend in this regard. In after years these very subjects, in the Iowa field, became the themes of world-wide controversy and interest.

Several aspects of the geological reconnaissance-work had bearings that are more than State-wide. In the history of American geologic literature they assumed national import. The birth of modern stratigraphical geology dated from the first use of fossils to determine the relative succession of strata. The principle was soon definitely advanced in this country, first in Iowa fully thirty years before the New York geologists made known their use of the method.

Another noteworthy feature in this connection is the fact that the then new English classification of geologic formations, which has since been so generally adopted the world over, was, so far as its systematic subdivisions are concerned, first successfully fitted to the terranes of this continent in the Iowa part of the

Upper Mississippi valley. Moreover, the stratigraphic division-lines then proposed remain to-day essentially the same as when they were first drawn, a fact clearly indicative of the accuracy of the early observations, and attesting the wonderful scientific penetration of the pioneer workers.

A third consideration, and one of continental significance, is the remarkable parallelism thus early established between the general stratigraphic sequence of the Upper Mississippi valley and that of England. Of late years this great circumstance appears to have been largely lost sight of; yet the analogy remains as true to-day as it did then. In view of the fact that world-wide geologic correlations are now sought and that correlative methods more refined and more precise than fossil criteria are now possible of successful application, it seems likely that the Mississippi Valley succession of the later Paleozoic strata shall finally become the standard section for America rather than the New York section which has so long held dominance among scientific men.

To a very early period of geologic reconnaissance, or rather to pre-reconnaissance time, there is a bit of geologic work assigned which deserves special mention here. This is a certain old map and report published so long ago as 1752. As is well known the art of geologic cartography is barely a century old. In this country its most important precursor is Güttard's "Carte minéralogique ou l'on voit la nature du terrains du Canada et de la Louisiane," which illustrates a report on the mineral resources of New France, printed a short time prior to the loss of all that vast territory by the mother country. This work[39] was entitled "Mémoir dans lequel ou compare la Canada à la Suisse por rapport a ses minéreaux."

The first distinctive reference to the geologic composition of our Iowa-land appears to have been by General George Victor Collot, once governor of Guadaloupe, who, while traveling in America in 1793 in the interests of the French government, ascended the Mississippi river as far as Prairie du Chien. He noted[40] that between St. Louis and the point mentioned the

[39]Hist. de l'Acad. Royale des Sci., p. 189, pl. vii, Paris 1752.

[40]Voyage dans l'Amerique septentrionale ou description des pays arrosès par le Missisipi, l'Ohio, le Missouri et autres rivèires affluentes, T. I, p. 282, Paris, 1796.

"banks were composed of gray-stone, flint with which the Indians tip their arrows, or mill-stone, but most frequently of limestone."

On the first map of the United States colored geologically,[41] by William McClure, published in 1809, the great band of "alluvial deposits" is represented in the Mississippi valley as only reaching to the mouth of the Des Moines river. In a subsequent edition of this map issued eight years later, the great tract of secondary (Paleozoic) rocks touches the entire eastern boundary of present Iowa domain. The corrections on the second edition of the map and in the accompanying explanation, at least so far as the extreme western parts were concerned were due doubtless largely to the work of travelers in the West at that time. It was the irony of Fate that McClure's work, representing the last of the old régime should be covered so closely by that of his colleague's representing the first of the new.

The important part which our State has chanced to play in the founding of one of the great modern sciences is worthy of special record. In the history of that science as developed in the New World the circumstances surrounding the earliest discoveries deserve connected reiteration in a chapter all their own. They influenced the whole course of later geologic discovery. They seem destined yet to establish the standard systematic section for the entire American continent.

The scientific discoveries to which I allude were made in Iowa-land before Iowa was a state, before she was a territory, before she was hardly a part of the United States. It was in the earliest springtime of the last century, when our Nation was yet new, when the region was still remote and unknown, and when even the land itself was yet to receive its name.

For several reasons this pioneer scientific work is of exceptional historic interest. It was the first time that modern geological principles were successfully applied in this country. It was up to the time the boldest stroke at universal correlation of geological formations ever attempted by geologists. It was the first definite recognition of the two greatest geologic formations found on our continent. It was the first chronologic com-

[41]Trans. American Philos. Soc., Vol. VI, p. 411, Philadelphia, 1809.

parison of American Carboniferous rocks with those of the typical locality in the Old World. It furnished the clue to all subsequent investigations of the mid-continental region. It gave rise to a host of perplexing problems many of which are still unsolved. Where else in all the world have not the echoes of a century-long discussion long since died away? Singular is it that our Iowa should be the pivotal point.

When in England about a century ago, earth-study was made a modern science through William Smith's famous geologic discovery that the relative age and natural sequence of rock-layers were susceptible of accurate determination by means of the contained organic remains, America very early and from a wholly unexpected quarter furnished important aid in support of the newly established principles. The circumstances were long since all but forgotten. In the few casual references made to them in later years either their importance was misunderstood or familiarity with the attendant conditions was entirely wanting. As the first successful application of modern geological principles in the New World the episode must ever remain of great historic interest.

Singularly, this primal American effort to correlate by their faunal contents geologic formations widely separated geographically was not made in that portion of our continent which was most accessible and where it was most natural to expect it—that is, along the well-settled Atlantic border—but it was in the then remotest section of the Upper Mississippi valley. First fruits of research and observation were obtained in a region which was then perfect wilderness, but which now forms part of the great and populous state of Iowa. Moreover, these remarkable observations were made within a decade of the time when the novel method was originally announced in England. They antedated by fifteen years Samuel Morton's similar effort[42] on the Tertiaries of our Atlantic coast commonly regarded as the maiden attempt in America along these lines. By two decades they were in advance of the first work of that pioneer American paleontologist Lardner Vanuxem.[43] They anticipated by a full generation the famous investigations of Thomas Conrad and

[42]Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, pp. 72-100, 1829.
[43]Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, pp. 59-71, 1828.

James Hall in New York. Indeed they were the means of actually and correctly interpreting the true position and biotic relations of the Carboniferous rocks of the continental interior a half century before their geologic age was otherwise generally admitted. The Mississippian limestones, as the rocks are now called, remain today as compact and as sharply delimited a sequence of geologic terranes as they appeared when first recognized in that memorable summer of the year 1809.

This successful use in America of faunal criteria for purposes of solving problems of geologic correlation and of identifying geological formations was the first real ray of modern light to penetrate the stratigraphic darkness shrouding the New World. The happy application of these criteria was due directly to the keen scientific perception and peculiar reasoning of one who was never known as a geologist at all, but who was raised to fame through a wholly different channel of scientific activity. The name of this truly remarkable personage was Thomas Nuttall, botanist.

Nuttall's extensive travels in America were undertaken chiefly in the interests of his monumental works on North American plants and of his valuable contributions to American ornithology. On his first great trip, after traversing the southern shore of Lake Erie, and coasting by canoe Lakes Huron and Michigan, he entered Green bay, and, following that famous all-water route to the West which the Indians had used from time immemorial, ascended Fox river to the portage to the Wisconsin river down which latter stream he floated to its mouth near Prairie du Chien, thence down the Mississippi river to St. Louis. Subsequent trips took him far up the Missouri and Arkansas rivers.

On his Mississippi venture[44] besides garnering great quantities of interesting plants and taking voluminous notes on the birds, he appears to have made extensive collections of the fossils which he found throughout his path abundantly scattered through the limestones which in high cliffs bordered both sides of the great stream. In the course of his explanations of the geologic features of the region through which he passed Nuttall

[44] Obs. on Geol. Structure Miss. Valley: Jour. Acad. Nat. Sci., Philadelphia, Vol. II, pp. 14-52, Philadelphia 1821.

naively notes that he is "fully satisfied that almost every fossil shell figured and described in the *Petrifacta Derbiensia*" of Martin was to be found throughout the great calcareous platform of Secondary rocks exposed in the eastern Mississippi valley. Thus by means of fossils he parallels these limestones of the Mississippi river with the Mountain limestone of the Pennine range in Derbyshire, England, to which, several years later, Conybeare[45] gave the title of Carboniferous.

Along the Mississippi river, as we now know, Nuttall really encountered little else than rocks of Early Carboniferous age, so that his identifications of the fossils were doubtless with very few exceptions, correct. Moreover, at this date and for some time afterward the lower portion of the exposed stratigraphic sections, it must be remembered, was entirely undifferentiated, the great sequence of older beds which were subsequently separated from one another being jumbled together under the title of Transition group. It was not until more than a quarter of a century later that out of them in Britain Murchison and Sedgwich established the Cambrian, Silurian and Devonian systems.

Another important geologic correlation is to be credited to Nuttall. On his journey up the Missouri river in 1810, which he undertook with John Bradbury,[46] a Scotch naturalist, he reached the Mandan villages on the upper reaches of that stream. He makes especial mention of the Omaha villages situated below the mouth of the Big Sioux river. A short distance upstream from the last mentioned point he examined strata which by means of their fossils presumably, he referred to the Chalk division of the Floetz or Secondary rocks of northern France and southern England. This is the earliest definite recognition of beds of Cretaceous age in America. It preceded by a decade and a half the separation by John Finch of the newer Secondary rocks from the Tertiary section in the Atlantic states, and Lardner Vanuxem's and Samuel Morton's reference of the same deposits to the Cretaceous age. Thus also was another great succession of one of our main geologic periods discovered in a then remote part of our continent years before it was recognized in the East.

[45] Outlines of Geology of England and Wales, p. 353, London, 1822.
[46] Travels in Interior of America in 1809-1811, London, 1817.

At the mouth of the Big Sioux river Nuttall fell in with an old trapper who described to him the great falls which blocked navigation at a distance of 100 miles up that stream, and who told him of the famous Indian pipestone quarries beyond.

The analogy established by Nuttall between the general Carboniferous section of Iowa and the upper Mississippi valley and that of northern England was one of the important geologic discoveries in America. Its great significance was pointed out by Owen a couple of decades later. Its historical value grows with the advancing years. In the final recognition of a standard Carboniferous section for this continent the sequence displayed in the Mississippi basin must prevail, since it is now generally conceded that the Appalachian succession of strata can never be considered as the typical development.

So conspicuously botanical in character are Nuttall's services to science that one can but wonder under what circumstances he could have obtained his keen insight into matters geological. Elias Durand said of him immediately after his death that "No other explorer of the botany of North America has personally made more discoveries; no writer on American plants, except perhaps Asa Gray, has described more new genera and species." Lists of his published memoirs and papers quite generally omit all reference to his recorded geological observations, probably because their importance would hardly be appreciated by writers in other fields of science. In the present connection our main interest centers on the transplanting so early to the interior of the American continent of William Smith's novel ideas concerning fossils. Brief reference to some of the early events in Nuttall's life seem to offer a clue.

Nuttall was born in Yorkshire, England, in the Mountain limestone belt and near the scene of Martin's labors on the Carboniferous fossils of Derbyshire. He was early apprenticed to the printer's trade and after a few years removed to London. There he followed his trade until at the age of 22 he set out for America in 1808. He appears to have been a printer of the Benjamin Franklin order, since while engaged at his trade he became proficient in knowledge of the sciences, Greek and Latin and kindred subjects. During the period of six or seven years he was in London he appears to have made the acquaintance of a number of the scientific men of the day. At least it is probable that at this time he acquired some familiarity with Smith's discoveries which were at that date attracting wide attention from English scientists. It is also quite possible that Nuttall gained much of his scientific information through setting up the types for those very memoirs which have since become geologic classics. It is not unlikely also that he even met Smith, since the latter is known to have been often in London at this time and to have taken up his permanent residence there several years before the printer-naturalist left his native country.

At any rate Nuttall had been in America scarcely a year before he was putting his geological knowledge to test. His familiarity with Martin's *Petrifacta Derbyensia* and Smith's principles clearly indicate that he must certainly have acquired his information at least several years previous. Then, too, his acquaintance with that pioneer American geologist, William McClure, for twenty years president of the American Philosophical Society at this period, should not escape notice. Two other papers, partly geological in nature but chiefly mineralogical in character, on the rocks and minerals of Hoboken and of Sparta, New Jersey, and the many keen observations on the rocks recorded in his journal of a trip from Philedalphia to Pittsburg attest his unusual intimacy with matters in geology.

Notwithstanding the fact that the brief memoir which Thomas Nuttall published on Iowa-land and the contiguous regions was the only one which he seems ever to have printed on strictly geological subjects so important are the principles set forth for the first time in this single, simple, short contribution to the literature of American terranal correlation that it places its author in the front rank among pioneer geologists not only of Iowa but of our Country. Although one of the foremost botanists of his day and an ornothologist of world-wide reputation his great service in first pointing out by method and by means the fundamental concepts of modern historical geology in America should not be forgotten.

In a canoe-trip to the falls of St. Anthony[47] which Major Stephen H. Long made in 1817, only incidental mention is made of any of the geological features along the course. This journal although unpublished for more than forty years, was made liberal use of by Keating in his narrative of Long's expedition to the sources of the St. Peter river.

Edwin James, who as geologist accompanied Long's expedition to the Rocky mountains,[48] only traversed the extreme southwestern corner of the Iowa tract. Incidentally, he called attention to the probable great importance of the coal measures of the region.

On the return of the Cass expedition[49] to the sources of the Mississippi river, in 1820, Schoolcraft, who was the narrator and mineralogist of the party, made a special side-trip from Prairie du Chien to the Dubuque lead-mines. Of these he gave the best detailed description up to that time and for a generation thereafter. This traveler had already investigated the lead-mines of Missouri and had published a full account of them, and the methods of mining and smelting.

As a result of his Iowa visit Schoolcraft, as it appears, originated the notion that the two mineral districts were genetically connected in some way. He fancied that the lead-bearing beds of the two widely separated districts were geologically in the same terrane. This formation he called the "Metalliferous Limestone." The statement was repeated as fact for many years afterwards. It is instructive as indicating the method of geologic correlation at that time. The idea was later elaborated from time to time until its necessary consequences had to be finally supported by the assertion that the ore-bodies were primarily deposited under the influence of favorable local currents on the floor of the Ordovician ocean. In some form or other this curious notion prevailed for more than two generations; and even at the present day it is seriously upheld.

Keating, who as mineralogist accompanied Long on the expedition to the sources of the St. Peter (Minnesota) river, in 1823, and passed through the northeastern corner of the state, adds

[47] Coll. Hist. Soc. Minnesota, 1860, pp. 9-15.

[48] Account Exped. Pittsburg to Rocky Mts., in 1819-20, Vol. I, 1823.

[49] Narrative Journal of Travels, etc., to Source of Mississippi River, Cass Exped., 414 pp., Albany, 1821.

nothing to the knowledge of Iowa geology.[50] Mention of his account is made here because of an error to which were committed many of his followers in the region for many years afterwards. In attempting to reconcile Conybeare's descriptions of English rocks with his own observations in the Mississippi valley he erroneously concluded that the lead-bearing rocks of Dubuque belonged entirely to the Carboniferous Limestone division, whereas none of them can be so classed .

Although Featherstonhaugh[50a] was United States geologist when he made his so-called geological trips to the Northwest he gave in the accounts of his travels little detailed information concerning the geologic features of the Iowa region through which he passed. This writer stated that the Galeniferous formation of Dubuque belonged to the Carboniferous Limestone. He connected the metalliferous rock of the region directly with the lead-bearing formation of southeast Missouri, thus following Schoolcraft. Above Rock Island rapids of the Mississippi river he noted the occurrence of bituminous coal; and at Keokuk he found geodes containing crystals of sulphret of lead. His elaborate discussion of Murchison's and of Sedgwick's rock-formation of England has no connection with the geology of the region which he traversed.

Between the years 1838 and 1839 Jean N. Nicollet, a French geographer, was engaged, under the auspices of the Engineering corps of the United States army, in preparing a detailed map of the Upper Mississippi valley.[51] According to the high authority of Warren,[52] this map is "one of the greatest contributions ever made to American geography."

Along with his geographic and engineering knowledge Nicollet possessed a keen appreciation of geological matters. He was quite familiar with fossils, and with Murchison's new classification of rock-terranes. His strictly geologic observations in Iowa

[50]Narrative Exped. Source St. Peter's River, etc., under Major S. H. Long, Vol. I, p. 195, 1823.

[50a]Geol. Rept. of examination made in 1834 of elevated country between Missouri and Red Rivers. 97 pp. 1835. (23d Cong., 2d Sess., House Ex. Doc. No. 115.)

Rept. of reconnaissance made in 1835 from seat of government by way of Green Bay and Wisconsin Territory to Chouteau du Prairie, elevated ridge dividing Missouri from St. Peters River, 168 pp., 1836.

[51]Rept. Intended to Illustrate a Map of Hydrographic Basin of Upper Mississippi River, Twenty-sixth Cong., 2nd Sess., Sen. Doc., Vol. V, pt. ii, No. 237, 177 pp., 1843.

[52]Rept. Pacific Railroad Survs., Vol. XI, p. 41.

were only incidental to his work in hand. He described quite fully the glacial drift, but did not touch upon its origin. The physiographic descriptions which he presented were notable productions.

Among the interesting facts noted were that the uplands bordering the Mississippi river above Keokuk were made up of Carboniferous, or Mountain, limestones (Early Carboniferous). The geodes of this region were described in some detail. A good detailed section of the rock-succession at Burlington was recorded. This was called the "Burlington Group", a term having priority by twenty years over Hall's similar title for the main limestone member only. Singularly enough the limestones of the Missouri river, at the mouth of the Platte river, were erroneously regarded as the same as those exposed at Burlington. The Coal Measures were mentioned as extending from the present Minnesota-line southward to the Arkansas river.

The calcareous rocks outcropping near the mouth of the Sioux river were pronounced to be Cretaceous in age. Samples examined under the microscope by Prof. J. W. Bailey, of West Point, were found to be composed largely of very minute shells like those occurring in the typical chalk. In the lead-region the main limestone was correlated with the Cliff limestone of Ohio, and the fossils contained were compared with the Trenton forms of New York. Coal fossils were collected on the Des Moines river at the Raccoon forks.

Nicollet made a special announcement[53] of his discovery of the "Cretaceous Formations of the Missouri River," but the main limestone member at the base of the section and which he observed near the mouth of the Sioux river, he mistook for Carboniferous limestone.

In the course of his examination of the mineral lands of the Dubuque region, in 1839, Owen[54] introduced several novel features into the consideration of the geological formations of the Mississippi valley. Four years later a second edition[55] of Owen's report appeared, together with the maps and plates which were

[53]Am. Jour. Sci., (1), Vol. XLV, p. 153, New Haven, 1843.

[54]Rept. Geol. Expl. Iowa, Wisconsin and Illinois, 26th Cong., 1st Sess., House Doc. No. 239, 161 pp., 1840.

[55]Twenty-eighth Cong., 1st Sess., Sen. Doc. 407, 191 pp., 1844.

omitted from the first edition. This volume contains the first complete outline of a classification of the geologic formations of Iowa in accordance with modern criteria.

In several respects Owen's work was especially noteworthy. By it were accurately paralleled for the first time in America the English systems, the names and lines of demarcation of which had been then just proposed by Phillips and which now are recognized throughout the world.

Murchison's Silurian system was defined[56] in 1835; as was also Sedgwick's Cambrian system.[57] Lonsdale's determination of the Devonian system was announced two years later.[58] Until 1848 American geologists west of the Appalachians following Featherstonhaugh were in the custom of calling all the strata beneath the coal measures, the Mountain limestone, or Carboniferous limestone. In the year mentioned De Verneuil[59] pointed out the fact that some of these limestones carried true Silurian fossils and, therefore, could not be properly termed Carboniferous in age.

Up to the time of the appearance of Owen's report (1844) Conrad[60] seems to have been the only American geologist who was at all inclined to recognize the new English classification. His application of it to the New York rocks was surprisingly unfortunate. While he was superintendent of the New York geological survey and the annual reports of the four districts were being published the attempt was made to harmonize the New York section with that of England. The effort was not so successful as it was hoped. Partly for this reason and partly perhaps on account of the fact that the New York geologists, after Conrad had left the survey, were carried away with the idea of establishing, out of the Paleozoic sequence, a "New York system," the final reports came out, in 1843, with Conrad's plans entirely abandoned. Moreover, the four geologists of the respective districts were hopelessly at variance as to the limita-

[56]Philosophical Magazine, (3), Vol. VII, p. 47, 1835.
[57]Ibid., p. 483.
[58]Proc. Geol. Soc. London, Vol. III, p. 281, 1837.
[59]Bull. Soc. géol. de France, t. II, p. 166, 1840.
[60]Jour. Acad. Nat. Sci. Philadelphia, Vol. VIII, p. 228, 1842.

tions of the different formations in different parts of the state, as Williams[61] points out in some detail.

When, then, the second and revised edition of the "Report of the Geological Exploration of Iowa, Wisconsin and Illinois" appeared, in 1844, Owen was the only geologist who had accepted the new English classification of rock-formations and who had accurately determined their stratigraphic delimitations in a definite section. His earlier subdivision of the "Cliff" limestone into three parts of Upper, Middle, and Lower, were here called the Upper Shell-beds, the Middle Coralline beds, and the Lower Lead-bearing beds.[62] These several divisions were, he astutely remarks, also distinguished by their contained fossils, and he enumerated and illustrated some of the most characteristic forms.

Immediately beneath the coal measures he described the Carboniferous limestones. Then came the Upper Shell-beds—the white limestones of the Red Cedar, Wapsipinicon and Rock rivers and of Iowa City, which he regarded as contemporaneously formed with the shell-beds of the Falls of the Ohio river. He had already referred the lower parts of this formation, the "knobs" in Kentucky, to the Devonian system of England and the Chemung terrane of New York.[63]

The Middle Coralline dolomites, carrying chain-corals and the brachiopod, *Pentamerus oblongus,* he assigned to the Upper Silurian system. The Lower Lead-bearing dolomites he placed without any hesitation in the Lower Silurian system.

The rocks of the Cambrian system, as they are now called, could not very well have attracted Owen's attention at this time, since, with the exception of a few unimportant outcrops near water-level in the Mississippi river, their areal distribution in this region was mainly outside of the section investigated. Four years later,[64] however, he was permitted to examine that part of the geological section for he announced that north of the mouth of the Wisconsin river there were magnesian limestones which

[61]Bull. 80, U. S. G. S., p. 57, 1891.
[62]Twenty-eight Cong., 1st Sess., Sen. Doc. 407, p. 32, 1844.
[63]Am. Jour. Sci., (1), Vol. XLV, p. 152, 1843.
[64]Thirtieth Cong., 1st Sess., Sen. Ex. Doc. No. 57, 1848.

were older than the lowest formations of the Ohio valley, a part at least corresponding to the Potsdam sandstone of the New York section, which he had previously compared[65] with the Cambrian section of Sedgwick.

During the years 1848-9 the rocks exposed along the Mississippi, Cedar, Iowa, Des Moines, and Missouri rivers were particularly examined by Owen. The results of these investigations were embraced in a large volume, published by the General Land Office in 1852.[66] Associated with him, as assistants in the work, were half a dozen men who afterwards became distinguished in the annals of American geology.

Owen was a man of remarkably keen geological insight. The acumen which, as a pioneer in a perfectly unknown country, he displayed in deciphering the problems presented would have done credit to any one even to-day. In this state and in Missouri and Minnesota I have personally in the field gone over much of his work and I have had repeated occasion to verify his recorded results in detail. I cannot but express the warmest admiration for his great skill in unraveling difficult problems, his remarkable accuracy of observation, and his sound geologic reasoning. In his method of investigation three features are conspicuously presented. His plan of correlating geologic sections by means of the combined methods of lithologic resemblance, stratigraphic continuity, and continuity of lithologic sequence, and of plotting the sections along exposed lines of streams preceded by a generation the general adoption of this method by American field-geologists. By half a century he anticipated modern geologic requirements, when he defined his terranes by clearly noting, as essential elements their topographic expression, their geographic extent, their lithologic character, their stratigraphic delimitation, their biotic definition, and their economic content. In soundness of logical deduction his generalizations stand every modern test. All of these characteristics are repeatedly displayed in the published results of his investigations in Iowa.

[65]Twenty-eighth Cong., 1st Sess., Sen. Doc. 407, p. 18, 1844.
[66]Rept. Geol. Surv. Wisconsin, Iowa and Minnesota, etc., 638 pp., Philadelphia, 1852.

One of the curious analogies which his keen penetration established was the remarkable parallelism existing between the sequence of Carboniferous limestones as displayed in Iowa and the succession as worked out by Phillips[67] in Yorkshire, England. The comparison clearly indicates the great influence of his English training in geology.

Very much as they are demarcated to-day Owen again delimited in Iowa and the Upper Mississippi valley the systemic groups of the rocks. Their areal distribution ascribed by him indicates closely the outlines now recognized in somewhat greater detail but determined many years afterwards. In Owen's determinations of Iowa stratigraphy several points should be particularly emphasized;

(1.) The present serial subdivision of the Paleozioc rock-sequence was distinctly foreshadowed; only the application of geographic names, which modern custom encourages, was lacking.

(2.) In his Upper Magnesian formation, which has since been found to embrace Ordovician and Silurian beds, the Maquoketa shales were not recognized.

(3.) The Cedar Valley limestones were closely correlated with the then new Hamilton section of New York state. Since Owen's day little progress has been made in the subdivision of this great succession of limestones.

(4.) With great nicity and detail was the Iowa section of the Early Carboniferous rocks differentiated. A notable feature was its separation into an upper series and a lower series at the horizon of the present Warsaw limestone. Sixty years afterward this same scheme was proposed as new and original in the most modern consideration of the subject by Schuchert[68] and by Ulrich.[69]

(5.) The geologic section along the Des Moines river from its mouth to the Lizard fork, at Fort Dodge, was one of the most detailed, most complete, and most accurate cross sections of the time. It stands to-day a model of exact stratigraphic correlation.

[67]Geology of Yorkshire, p. 26, 1836.
[68]Bull. Geol. Soc. America, Vol. XX, p. 548, 1910.
[69]Ibid, Vol. XXII, pl. 29, 1911.

(6.) For the first time the remarkable marl hills at Council Bluffs and on the Missouri river were compared with famous similar deposits of the Rhine valley, in Germany, and here as there they are correctly called loess.

(7.) The Carboniferous limestones of the Missouri valley Owen regarded as the equivalents of the Early Carboniferous limestones of the Mississippi side of the state. In this he was mistaken; but the very fact of this error shows, as late investigations have thoroughly demonstrated, how closely, although so widely separated stratigraphically, the two maritime formations resemble each other. Owen had never seen the full Carboniferous section of the Missouri and Kansas region. He could not, while in Iowa, make the necessary investigations to work out in detail the stratigraphy, as it was later done, showing the intercalation of the great productive coal measures between two great barren measures. Nor had he at this time been able to visit places that would indicate to him that instead of the productive coal measures being only 100 feet in thickness, they were really, although not in Iowa, thicker than all the rest of the Paleozoic section of the region. Long years afterwards in the far-away Arkansas River valley Owen was permitted to make the very observations necessary[70] and to supply something of the missing-link to his complete effort. Yet still another half century was to pass before the exact stratigraphic equivalency of the section was to be determined beyond peradventure.[71]

(8.) Owen described the first organic remains new to science which had been found in Iowa rocks, and he beautifully illustrated them by his own drawings which are really works of art.

The first geologic inquiry publically undertaken by the State of Iowa was a reconnaissance of the eastern half of the domain. The Legislature of 1855 passed a law providing for a geological survey of the state and annually appropriating $2,500 for the biennial period. It was approved by Governor Grimes on January 23, 1855. Under the authority of this Act James Hall, of New York, was appointed state geologist, and J. D. Whitney,

[70]Rept. Geol. Reconnaissance, Part of Arkansas, pp. 17-141, Little Rock, 1858.
[71]Bull. Geol. Soc. America, Vol. XII, p. 173, 1901.

of Massachusetts, was selected for chemist. A. H. Worthen, afterwards state geologist of Illinois, was an assistant. The succeeding legislature appropriated $10,000.00 for the continuance of the work, and made provision for the publication of a report. Field-work was carried on during the three years of 1855-7.

Among the more important of the strictly geologic results may be mentioned:

(1.) The introduction of the New York classification of geologic terranes, and the New York formational nomenclature.

(2.) The application for the first time in the state of Murchison's plan of giving geographic names to the prominent rock formations.

(3.) The finding of the Maquoketa shales between the two great divisions of the Magnesian limestone of the northeastern part of the state.

(4.) The undertaking of a preliminary, but important, investigation of the lead deposits, by Whitney.

(5.) The construction of a detailed geologic cross section along the entire eastern border of the state, in which the tectonic and stratigraphic relations of the different formations are graphically represented. This section was continued southward to the Ohio river. The geographical names used to designate the Carboniferous terranes were local terms.

(6) The determination of the unconformable relation of the coal measures upon the beveled edges of all earlier formations was emphasized as new, although Norwood had, several years previously, demonstrated the fact elsewhere in the Upper Mississippi valley.

(7.) The general use of fossils in determining questions of geologic history was a feature displayed throughout the report; and the second part (volume) was devoted entirely to the description and illustration of the ancient organic remains.

(8.) The selection of small units for the detailed areal reports was manifested by the brief accounts of the geologic resources of six counties, showing at this early time that this political unit was the logical unit for the areal reports and maps of a state geological survey.

In introducing the New York classification Hall appears to have displayed the same intense prejudice against the new English scheme that he did a decade earlier in his eastern reports. There is no mention of the English system in his table of formations. The notation of some of them on the accompanying map appears to have been done by other hands.

For many years the New York formational names given by Hall to western terranes prevailed in the geologic literature of the region. Gradually they have been displaced as unsuitable, until at the present time only two or three of them remain.

A decade after the preliminary survey of the eastern half of Iowa was finished by Hall, a reconnaissance of the geology of the western half of the state,[72] by Charles A. White, was undertaken. Orestes St. John was appointed chief assistant geologist. For a period of four years $6,500.00 were annually appropriated by the Legislature to carry on the work. The results were published in two volumes.

Some of the more important scientific facts brought out in the course of the investigations were:

(1.) The establishment of the existence of unconformable relations between the St. Louis limestone and the older terranes.

(2.) The determination of the great extent and thickness of the coal-bearing formations of the state.

(3.) The detection of the occurrence of workable coal seams in the so-called upper coal measures (Missouri series) of the southwestern part of the state.

(4.) The proof of the great extent and thickness of the Cretaceous formations in northwestern Iowa.

(5.) The detailed determination of many stratigraphic features concerning the coal measures.

(6.) The outlining of the local geologic features of the western counties of the state.

After the discontinuance of the survey-work under White the State was long in getting into step again with her sister states. During this quarter of a century two especially notable efforts in geologic investigation were accomplished. Neither of them are properly termed reconnaissance; they were too mon-

[72]Rept. Geol. Surv. Iowa, 2 vols., Des Moines, 1870.

umental and monographical in character. Neither do they come in the class of public systematic inquiry. Yet they are both perhaps as well considered here between the two chapters relating to original geologic investigation.

In northeastern Iowa W J McGee had for a period of years conducted extensive examinations of the glacial deposits. The results were originally intended to appear in other form, but they grew so voluminous that they were finally incorporated in a great monograph and published by the Federal government.[73]

Along paleontological lines Charles Wachsmuth and Frank Springer conducted comprehensive studies on certain groups of fossils. The printed volumes already published form one of the most exhaustive contributions ever made to the literature of American science.[74]

Both of these efforts are not only highly creditable to the authors but they extend great honor to the State and the country. They would have reflected a much larger share of credit upon the State had they been accomplished under public auspices, instead of through private enterprise. Although aided in no way by the State these investigations are of the highest character scientifically and mark the first performances within the boundaries of Iowa of private research work of first rank in the domains of geology.

The great scientific value of McGee's "Pleistocene History of Northeastern Iowa" lies in the fact that there are recognized two distinct drift-sheets, indicating two glacial epochs, or two advancements of the continental ice-mass. Besides a large amount of detailed information concerning the geological formations of that part of the state there is presented in an exhaustive manner evidence of the dual character of the drift of Iowa. This testimony came at a time when it was generally held by the scientific world that there was strict unity of the great ice age.

At this time the theme was new and suitable criteria for correlating observations had yet to be formulated. The character of the phenomena presented were also unique in the annals of

[73]Eleventh Ann. Rept., U. S. G. S., pp. 190-577, 1893.
[74]Memoirs of Museum Comparative Zoology, 3 vols., Cambridge, 1895.

geology. McGee, himself, well expresses the conditions: "The most startling induction of geology, if not of modern science, is the glacial theory; but in the solution of the problem of these pages it is necessary to do more than assume the existence and action of the great sheet of ice hundreds or thousands of feet in thickness and hundreds or thousands of miles in extent. In order to explain the sum of the phenomena it is necessary to picture the great ice-sheet not only in its general form and extent, but in its local features, its thickness, its direction and rate of movement over each square league, the inclination of its surface both at the top and bottom, and the relation of these slopes to the subjacent surface of earth and rock; and all this without a single stria or inch of ice-polish, save in one small spot, in the whole tract of 16,500 square miles. It is necessary to conceive not only the mode of melting of the ice at each league of its retreat, but also every considerable brook, every river, and every lake or pond formed by the melting, both at its under surface and on its upper surface; it is necessary to restore not only the margin of the *mer de glace* under each minute of latitude it occupied, but, as well, the canyons by which it was cleft, the floe-bearing lakes and mud-charged marshes with which it was fringed, each island of ice, and each ice-bound lake formed within its limits. And it is not only necessary to reconstruct the geography of a dozen episodes, as does the anatomist the skeleton from a few bones, but to develop a geography such as civilized eye has never seen, and which could exist only under conditions such as utterly transcend the experience of civilized man. All this has been done. The trail of the ice monster has been traced, his magnitude measured, his form and even his features figured forth, and all from the slime of his body alone, where even his characteristic tracks fail."

In another connection the author notes that the "Two incursions of ice from the north have each spread a drift-sheet upon this district, and in each case only little of the drift can be ascribed to local origin. Probably ninety-five per cent. of both the earlier and the later till and of the associated stratified deposits came from areas north of Iowa. Boulders of small size, comprising many of hornblende-schist characterize the lower and older till, while the upper till has many large boulders of granitoid and gneissic rocks, usually occurring of all sizes up to 15 feet. Often much larger boulders are found, and one was measured having a diameter of 47 feet.

"A very remarkable feature of the early glaciation of this district is the absence of glacial striæ, except in one isolated locality, on the bed-rocks of a drift-covered country. Not all of the preglacial residuary clay was removed, and no glacial erosion of the underlying rocks took place. Between the first and second ice incursions forests grew on this area and their remains form a forest-bed of abundant logs and branches, with occasional peat accumulations, encountered by nearly every well of whole townships and traceable over several counties, lying between the lower and upper tills.

"The eastern part of the district is covered with loess, and the western border of the loess has a descent like a terrace ten to twenty feet or more, to the surface of the sheet of till which stretches thence westward upon the tract that was covered by the Minnesota and Iowa lobe of the ice-sheet while the loess was being deposited. Upon the till the loess occurs here and there forming ridges much higher than the surrounding land. These ridges, named paha, trend in parallelism with the movement of the ice-sheet, and were deposited, like the gravel and sand eskers of other regions, in ice-walled channels of glacial rivers during the departure of the ice."

This Pleistocene history may be summed up as follows: "Northeastern Iowa has been twice invaded by northern ice. The first ice-sheet was thick, pressed hard on the land, lay long, and slowly melted. It displaced the magnificent fauna of the Tertiary, few representatives of which survived its disappearance; and it was followed by a vast period of forest growth and soil accumulation. The second ice-sheet entered the territory very long after the first; it was only a few hundred feet in thickness at the most, ran quickly to its farthest limit, and quickly melted. Before its destruction it met the Iowa-Wisconsin ice-lobe, and behind the two a great lake formed which drained over the Iowa sheet; and as this sheet melted, rivers ran between the lobelets, lakes accumulated on its surface, and glacial mud gathered in the channels of the rivers and the basins of the lakes; and thus there was developed a combined topographic configuration and aqueo-glacial structure without parallel elsewhere on the known earth.''

One feature of McGee's investigation is particularly noteworthy. For the first time he found extensive loess formations reposing between two till-sheets, thus recording the facts which are the main proofs of the complexity of the Glacial period. The circumstances surrounding this great discovery and Iowa's role in establishing the fact are briefly related.

Louis Agassiz's theory of continental glaciation was one of the most brilliant generalizations of modern science although it was neither so complete nor so widely applicable as was at first supposed. What was even more important to its scientific value than the bare statement of the conception itself was the recognition of the fact that there were not one but many glacial epochs in the earth's history. Of course Croll's hypothesis urged the necessity of successive glacial periods but it was soon shown that his astronomical dates were too far apart to account for the vicissitudes of the epoch which we are now mainly studying. So we have to go back to the testimony of the glacial deposits themselves for our fundamental data.

In the great world-wide controversy which warmly waged for more than a generation Iowa chanced to bear a conspicuous part. It was in Iowa that the first real evidences were found indicating the multiple instead of the unal character of the glacial epoch. They were Iowa men who made this great discovery. In Iowa were finally differentiated not one but five great glacial drift-sheets, or deposits, marking the successive advancements of the vast fields of northern continental ice. On Iowa men chiefly devolved the responsibility of first working out the complete and genetic relationships of these remarkable glacial till mantles.

In order fully to appreciate the genuine importance of the Iowa results bearing upon glacial complexity as opposed to glacial unity the facts leading up to the birth of the idea may be briefly reviewed. So early as 1870 Edward Orton observed peat-beds in the glacial deposits of Ohio and he rightly concluded that this feature indicated a warm interglacial epoch. He stated that evidence was at hand for the orderly arrangement of post-Tertiary deposits. This dual aspect of the glacial débris was further substantiated by Leverett, Chamberlin, Gilbert, McGee and others. In the prolix discussion which followed on the duality of the Glacial period the real facts were overlooked, or misinterpreted, and the possibility of a multiple instead of either a unal or dual Ice-age was lost sight of. Once suggested, the multiple hypothesis, about the year 1893, rapidly gained general acceptance among scientific men.

The arguments for a dual Glacial period and at the time of its proposal of a multiple Ice age were based mainly upon the fact of the presence in till sections of thin black soil streaks replaced here and there by thicker peat-beds. That there might be extensive inter-glacial sand or clay deposits was not thought of. Yet they were actually recorded and described a full decade prior to the time when their true significance was pointed out. Such an interglacial deposit clearly intercalated between two great till-sheets is the one on Capitol Hill, in Des Moines, described in detail by W J McGee and R. E. Call in 1882. It seems to be the first one ever recorded the stratigraphical relations of which were unmistakable.

The spot where the depositional proofs of the complexity of the Glacial epoch were first obtained is for several reasons of unusual interest. The section, originally well displayed, is now fast disappearing. It is also this section which later gave the first intimation of the eolian origin of the American loess-loams.

At this time and at this distance there are few of us who have any adequate appreciation of the great difficulties which the problem once presented. Still fewer of us there are who understand from direct experience what it really means actively and determinedly to contend on the battle-line of the unknowable. McGee was in position best to know intimately the intricacies of attempting to decipher the great glacial puzzle of that day.

The now famous geologic section under consideration is situated on the crest of Capitol Hill, at the south end of the State capitol grounds. As originally described in the American Journal of Science for 1882 (Vol. XXIV, p. 202) the exposure of deposits presents the following relations:

5. Till, light reddish buff clay, with pebbles......(feet) 7
4. Till, contorted and interstratified with loess......... 5
3. Loess, with numerous fossils 15
2. Till, dark red clay, with abundant pebbles.......... 6
1. Shale (Carboniferous) exposed 10

The important features especially to be noted are that: (1) The lower till (No. 2) represents what is now called the Kansan drift which was formed when the great continental glacier reaching southward to St. Louis and Kansas City, attained its greatest extent and thickness; (2) the loess members (Nos. 3 and 4), composed of fine loams, constitute the soil formations during a long interglacial epoch when the climate was not very different from what it is at the present day; and, (3) the upper till (No. 5) represents what is now known as the great Wisconsin drift-sheet.

At the time when these observations were made (1882) as already indicated, the possible complexity of the Glacial period was not yet even surmised. Possibilities of a second Glacial epoch were only vaguely being considered. The prolix and bitter controversy on the duality versus the unity of the Glacial period was just beginning. Under these circumstances it is not at all surprising that the facts presented were partially misinterpreted, and that their true significance was for a considerable time overlooked. Then, too, the prevailing theory of the origin of the loess tended to obscure the proper understanding of the accurately recorded data.

Notwithstanding the fact that both McGee and Call were inclined at the time to attach rather slight importance to their observations, and to regard the phenomena as indicating mere local advance of the ice-sheet it soon became manifest that the two till-sheets separated by a thick loess formation was impeachable testimony in support of two distinct and great ice movements within what was previously regarded as a single one. So far as is known this appears to the first and most important recorded evidence showing conclusively the complex character of the Ice age.

Of similar import was the somewhat later description of a great drift section several miles farther south on the Des Moines river. In a paper read before the Iowa Academy of Science in 1890, it was shown that there was still another thick member to be reckoned with below the loess. In later years the officers of the State Geological Survey have been inclined to regard it as representing the pre-Kansan Aftonian beds.

The Capitol Hill section is now one of the notable drift localities in America. During the past quarter of a century the place and vicinity have been visited by many of the most eminent scientists of the world.

As it is, our fellow Iowan barely escaped making one of the half dozen great geological generalizations or discoveries of the nineteenth century—the establishment of the fact of the complexity of the Glacial period.

In an entirely different field is the great effort of Wachsmuth and Springer on the "North American Fossil Crinoidea Camerata." Its main features may be briefly reviewed.[75] Although the work is first of all morphological in character from the foundation up, and the product of inquiries more thoroughly grounded in biological philosophy than any other work perhaps that has ever been issued on the fossil invertebrates in this country, it is also of such high utility in stratigraphy, especially in the great Mississippi basin, that it may be truly said no other one work has ever furnished so valuable criteria for the purposes of correct correlation of geological formations.

Of all fossil remains none are more admirably adapted to morphological study than those of the echinoderms. On account of their abundance, their peculiarities in geographic and geologic distribution, and their structure, the stalked feather-stars, or stone-lilies, are preëminent. With the skeletal parts composed of regular plates, or ossicles, definitely grouped and frequently highly sculptured, all structural changes are readily deciphered.

The introduction embraces an historical résumé of opinion and a full explanation of the terminology employed in descrip-

[75]Journal of Geology, Vol. IV, pp. 221-240, 1896.

tion. Special attention should be called to the clear and concise definitions given of the various structural parts. The terms should be universally adopted as they form by far the best collection ever proposed. American writers especially will need no appeal to at once use them not only to secure uniformity in nomenclature but precision of description. Heretofore the names of the various plates or groups of ossicles have been used in a rather haphazard way. Not only have different designations been given to the same part, but the same title has been repeatedly applied to structures widely separated morphologically.

The morphological part contains the full discussion of the data upon which the entire classification of the crinoids rest, of the genetic relationships of the various groups, and of the structural characteristics.

The plates in general are separated into "Primary" and "Supplementary" pieces. The former occur in every crinoid and comprise the ossicles represented in the early larva, the basals, the infrabasals, the various plates of the rays or arms, the orals, and the joints of the stem. The supplementary pieces, which make their appearance in the more advanced stages, but which are altogether unrepresented in some groups, comprise the remaining plates. The primary ossicles belong to the "abactinal" or to the "actinal" system. Those of the former include all the plates, connected with the chambered organ and axial cords; the others comprise those communicating with the mouth and the annular vessels surrounding it.

The stem is much more important than generally considered. It is composed of *nodal* and *internodal* joints, and continually increases in length in the growing crinoid by the production of new joints. The nodal plates in the Inadunata, Camerata, and a few of the Mesozoic and recent crinoids, are introduced directly beneath the proximal plate of the calyx, so that the uppermost joint for the time being, is the youngest joint of the stem. In the young Comatula, however, in which the top joint subsequently develops into a controversal, in the Mesozoic Millerocrinus and Apiocrinus, in the recent Rhizocrinus and Calamocrinus, and in all Ichthyocrinidae, forms in which the top joint in the early larva anchylose with the infrabasals, the new nodals are introduced below the top joint. The internodals are interposed between the nodal joints and increase continually in a downward direction during the life of the organisms *pari passu* with the formation of new nodal pieces. The stem matures from the root up, and remains permanently in a state of immaturity at its upper end. The maximum number of internodal joints varies among different forms. Sometimes there are many to the internode, as in the case of most species of Platycrinus, in Mespilocrinus and Rhizocrinus: sometimes only a very few; while Rhodocrinus, throughout its stem generally, has but one.

The cirri in Palæozoic crinoids are, as a rule, more formidable than in later forms, and in most of them they are confined to the lower part of the stem, often occuring only at the distal end. They are given off from the nodal joints, and are generally arranged singly, rarely in whorls as in recent forms.

It has been the general opinion that all Palæocrinoids are fixed forms, but this view is not now believed to be true. The facts appear to lead to the conclusion that at least many of the species in the later part of life were free for a portion of the time, as in the case of the recent Pentacrinidæ, in which the stem at some time at or near the maturity becomes separated from the root. The terminal end in most of the old crinoids tapers to a sharp point, but a root is rarely attached, while detached roots are found abundantly, but scarcely ever associated in the same stratum with the crown.

The real morphological relations of the Basals and Infrabasals is of particular interest. The latter term is adopted for the first plates in the base, and "basals" for the circlet next to radials. The basals of dicyclic crinoids always consist of five pieces; the infrabasals of five, rarely three. In monocyclic forms the base is divided into five, four, three and two pieces, or all five plates may be anchylosed, so as to form a single piece. Among the Camerata five basals are restricted to the Lower Silurian forms, four basals to those from the Upper Silurian and Devonian, three to those from Upper Silurian to the Lower Carboniferous, and two in only some forms from the Carboniferous. The diminution in number takes place in geological succession, and is the result of fusion of two or more of the original five plates, as is clearly seen in genera without an anal plate between the radials. In forms, however, in which an anal plate is represented and the basal disk is consequently changed from a pentagonal to hexagonal shape the case is somewhat more complicated, for a bisection of the plates in the hexagonal base would produce six basals instead of five. The introduction of the anal among all the monocyclic groups is accompanied with an increase in the size of one of the basals, there being no special basi-anal plate. In the tripartite base, the smaller plate—always the left antero-lateral one—doubles its size. In the quadripartite base the increase is towards the right of the posterior plate; while in the bisected base in which the left postero-lateral basal, and the anterio-lateral and the anterior one are fused, the two plates of the opposite side increase in size so as to correspond with the compound plate to the left. In dicyclic crinoids the introduction of the anal does not affect the arrangements of the infrabasals, and only slightly the form of the basals. In species with three infrabasals, one of the plates is always only one-half the size of the other two. This ossicle is, in the Ichthyocrinidæ and comatula larva directed toward the right posterior radial; but in the Inadunata its position is not constant. The basals of dicyclic crinoids are but little affected by the presence of the anal, only the upper angle of the posterior plate being slightly truncated.

When it was discovered several years ago, by Wachsmuth and Springer that among the Palæocrinidæ there is a regular alternation of the successive parts below the radials it was also found that the orientation of the stem in the monocyclic groups is reversed in dicyclic forms. In the former the sharp outer angles of the stem are radial; in the latter interradial. The central canal and the cirri are interradial in the first mentioned forms, but radial in others. The law is, however, applicable to its full extent only in species with pentangular or pentapartite stems, but it is concluded from analogy that the circular stem, wherever it occurs is also practically interradial in dicyclic crinoids and radial in monocyclic ones. However, on applying the rule to mesozoic and later crinoidæ it appears that in most of the so-called monocyclic forms, the orientation of the stem, central canal, and cirri agrees with the dicyclic type, the infrabasals being succeeded by a radial stem, as in those crinoids in which these plates are present but too small to be visible on account of being completely covered by the upper stem joint. Upon the strength of these observations, partly, these authors suggested that such forms either had small infrabasals hidden beneath the top stem joint, or those pieces had been represented in the larva. Other observations led to the same conclusion. In Extracrinus and in two species of Millerocrinus, the former belonging to the Pentacrinidæ, the latter to the Apiocrinidæ, two of the principal families of the Pseudomonocyclia, small infrabasals actually exist, and it appears very improbable that those plates should be present in genera of the same family, and even among species of the same genus, and absent in others, especially when the space which in some of them is occupied by small infrabasals, is vacant in others, and interradially disposed instead of radially as it would be if the space represented the axial canal. On applying these observations to the Comatulæ it was found that the outer angles of the top stem joint in the Pentacrinoid larva of the Antedon, and the angles of the centrodorsal in the mature animal, did not come under the rules laid down for the Monocylica, and this led to the conclusion that the Comatulæ also were built upon the dicyclic plan, and had infrabasals in early life. The predictions, which had been based exclusively upon palaeontological evidence were afterwards verified by the observations of Bury, who actually found infrabasals in the ciliated larva of Antedon. They consist of three unequal pieces, which in the Pentacrinoid stage are fused together with the top joint, so as to form with the latter one large plate with the five angles radial in position. A similar fusion evidently takes place among palæozoic Ichthyocrinidæ, in which the infrabasals are also coalesced with the upper stem joint, as is shown by specimens in which the stem is detached from the crown. These individuals are in the same condition morphologically, as the two species of Millericrinus figured by de Loriol, in which the infrabasals coalesce with the stem contrary to the other species of that genus, and allied forms having the infrabasals more or less completely fused with the top joint. As this structure prevents the formation of new joints directly beneath the calyx, it is contended, from the analogy, that in all forms in which the infrabasals coalesce with the stem, the new stem plates are introduced at some point beneath the top joint. The case is quite different in the Pentacrinidæ, where the youngest joint for the time being is the upper joint of the stem. Of the genera referred to this family, Extracrinus has small infrabasals persistent through life; while in Pentacrinus and Metacrinus no trace of these plates can be found in the adult; their stems are disposed interradially as in Extracrinus and other true dicyclic forms. That the plates are fused with the upper stem joint, is scarcely possible, as it would prevent the formation of new joints at the top; it is more probable as indicated by palæontological evidence that the infrabasals within the group, gradually diminished in size, and finally disappeared altogether. The structure of the Pentacrinidæ in this respect is very different from that of the Apiocrinidæ and Comatulæ, and it appears that crinoids in which the upper stem joint is the youngest, cannot be derived from types in which the upper joint is fused with the infrabasals. The latter therefore should be placed near the Ichthyocrinidæ and the Pentacrinidæ with, or close to the Inadunata.

These generalizations, so far as now known, meet with but two exceptions: the axial canal in the stem of Pentacrinus, contrary to that of Metacrinus and Extracrinus is interradially disposed; that of the monocyclic *Glyptocrinus fornshelli,* unlike that of the other species of the same genus, radially, so that the direction of the canals corresponds with the angles of the stem instead of alternating with them. This however does not invalidate the law, but simply points to the existence of the transition forms between the monocyclica and the dicyclica, as must have occurred at some time in the developmental history of the two groups if the one was evolved from the other.

The radials are less complicated in their morphological relations than the plates which they succeed. The term is now restricted to the first plate of each ray; and all succeeding pieces in a radial direction, whether free or incorporated into the calyx, are called brachials. In the earlier Inadunata and articulata but not in the Camerata so far as observed, the radials are frequently compound, being constructed of two segments, united by a horizontal suture, which in the organization of the crinoid corresponds to one plate. In most of the genera having compound radials the double ossicles, the two sections of which are called "infraradial" and "superradial," are confined to the right posterior ray, but they occur also in other rays but never in more than three, two of the radials at least being simple.

Recognizing the radials as practically a single plate in each ray, all plates above must be regarded as brachials to which pinnules may be attached. The terms costals, distichals and palmars are appropriately applied to the first, second and third orders of brachials respectively. When there are further divisions in the rays, the plates are designated as postpalmars, or as brachials of the fourth and fifth orders, and so on. A discrimination is also made between fixed and free brachials, the latter often being termed the arms. The arms are composed of one or two rows of plates. All biserial arms are uniserial in the young crinoid and gradually enter the biserial stage by an interlocking of the joints from opposite sides. In most of the families belonging to the Camerata the uniserial type is restricted to the Silurian, except in Hexacrinitæ. Among the Inadunata biserial arms occur only in a few genera found in the Kaskaskia, in the Coal Measures and in the Trias, but associated with the forms having the uniserial type. All Articulata, palæozoic as well as neozoic have uniserial brachial appendages.

The pinnules in a general way are repetitions of the arms on a small scale. When represented they spring alternately on opposite sides from every second joint and every joint bears a pinnule except in cases of a syzygy, in which the syzygyial plates must be counted in the alternation of the pinnules as one ossicle. Syzygies occur among Palæozoic crinoids either in successive series throughout the arm, as in the Heterocrinidæ and Belemnocrinidæ, or there is but one syzygy to each order of brachials, formed by the two proximal plates, as in Poteriocrinus, Dichocrinus, and in most species of Platycrinus. In Dichocrinus the various orders of brachials to the last axillary consist of two plates each, the first non-pinnulate, the upper bearing an arm instead of a pinnule. A similar arrangement occurs above the costals in most species of Platycrinus and it is quite evident that the plates in question, as in Dichocrinus for example, do form a syzygy. This, however, is not the case in such forms as *Platycrinus huntsvillæ* and a few other species. Here the first pinnule is given off from the proximal distichal, and the second on the same side from the first palmar. It shows clearly that the arm partakes of the alternation of the pinnules, and suggests that the armlets are enlarged pinnules. This is shown more conclusively by the structure of *Glyptocrinus dyeri*. While in most species of Glyptocrinus the second bifurcation takes place from the second distichal, that plate in *G. dyeri* gives off in place of an arm a large pinnule, more than twice as large as an ordinary one, which bending outward forms an angle as in the case of a true bifurcation. The second pinnule, which is somewhat smaller starts off from the fourth distichal on the opposite side as in the other species of the genus. All succeeding pinnules are small, and are given off alternately from successive joints.

The oral plates have been the subject of much controversy, but their identification in the different groups is now pretty well established. According to Wachsmuth and Springer the orals are not always represented in the adult. When present they surround the mouth or cover it. They may occupy the whole face of the vental disk or only its median portion. In the former case they rest upon the edges of the radials; in the latter against the perisome. In crinoids with a regular pentamerous symmetry they consist of five pieces interradially disposed, and form the center of the disk. When the symmetry is irregular they are pushed more or less to the anterior side. The former condition prevails among recent crinoids; the latter is the general rule among palæozoic forms. When asymmetrical, the posterior oral by the encroachment of the anal plates, is pushed between the four others, so as to attain a more or less central position. The plate is generally larger than the other four. The orals in all groups in which they are represented consist of five pieces. There is no such thing as an orocentral plate, as some writers have supposed. In some instances the orals seem to be wholly or partly resorbed; the former condition probably is the case among the Camerata, the latter in certain species of the Fistulata. In regard to the Ambulacra it is now generally admitted that the aperture in the tegmen of palæozoic crinoids is not the oral opening but the anus, and the mouth is subtegminal forming the center of radiation, which, however, is not necessarily the geometrical center. The ambulacra follow the grooves along the ventral side of the arms, and extend from the tips of the pinnules to the mouth. Their inner ends are either exposed upon the disk, or covered wholly or in part by plates of the tegmen. The upper face of the ambulacra is occupied by the food grooves, which are roofed over by the covering plates and frequently are boarded by side pieces. In recent crinoids the covering plates are movable from the tips of the pinnules to the entrance to the mouth; but in most palæozoic ones those of the disk are rigid, so far as known, often heavier, and larger than the intervening plates. The disk portions of the ambulacra in the Camerata, if tegminal form a component part of the tegmen, their plates being suturally connected with one another and with surrounding plates; those in the Fistulata rest upon the edges of large interradial pieces. When the ambulacra are subtegminal they enter the calyx by the arm openings, and follow the inner floor to the proximity of the mouth.

The "supplementary plates" comprise all calcareous particles between the basals and orals, and between the rays and their subdivisions. They are interradial, interaxillary or anal. The interradial plates which are separated into interbrachials and interambulacrals, comprise all pieces between the basals and orals interradially disposed, the former being confined to the dorsal cup; the interambulacrals occupy only the spaces between the ambulacra. The interaxillaries, which consist of the interdistichals and interpalmers are located within the axils of the second and third orders of brachials respectively. The anal plates are restricted to the posterior interradial area, and support the anal tube. Another system of supplementary plates occurs in the acrocrinidæ, between the basals and radials. In groups in which the arms are not entirely free from above the radials, the lower arm plates are incorporated into the calyx by means of interbrachials; and the orals are carried inward toward the actinal center by interambulacrals. The supplementary plates increase in number in the growing crinoid. They are undeveloped in the early larva and in the Laviformiæ. In the Fistulata they are represented only in the tegmen, except in the case of the anal piece. The plates vary exceedingly in form and character, being in some groups well developed and rigid, in others irregular and imperfectly formed or mere lime particles within soft tissues. The great variation in the structure of the plates formerly led to the belief that the rigid and regularly arranged pieces, so characteristic of the Camerata, did not belong to the same system as the irregular small pieces which unite the rays in recent forms. A distinction was also made between the ossicles of the tegmen. The heavy, rigid components of the palæozoic forms were called "vault" pieces the irregular smaller ones "disk" plates; and it was supposed that many of the older crinoids had a vault with a disk underneath. That they had two integuments was believed to be indicated by the condition of the ambulacra, which in recent crinoids are exposed, while in palæozoic types they are either completely subtegminal, or the food grooves are rigidly closed by immovable covering pieces. This supposition, however, has proved to be an illusion and to be based upon inaccurate observation. Even in species of Batocrinus and Dorycrinus, in which deception seemed to be almost impossible, it is ascertained from excellent material, that the tegmen consists of but one set of ossicles and that the plates are suturally connected and solid on the outside, but perforated and vesicular within. The condition of the ambulacra in camerate crinoids, whether tegminal or subtegminal, does not represent an essential structural feature, but is a natural consequence of differences in the form and construction of the tegmen in the respective groups and as such cannot be of much value from a morphological or classificatory point of view. Subtegminal ambulacra, as a rule, are most prevalent in species with high dome and bulging arm basis; while forms with a flat or depressed ventral surface generally have tegminal ambulacra. The two styles occur side by side among species of the same genus, and there exist all possible transition forms between the two extremes, *i. e.,* specimens in which the ambulacra are subtegminal at the median portions of the disk, and tegminal near the periphery. By comparing the younger individuals with the older, it appears that the covering of the ambulacra is produced in the growing animal by the gradual extension of the interambulacral areas along the lines of the ambulacra, either completely covering them, or leaving the portions next to the arm basis exposed. The ambulacra of the Camerata, therefore, are covered not by an element unrepresented in other groups, but by small superimposed plates passing out from the disk proper. These plates were quite small in the Silurian species, but change essentially until in the Carboniferous they frequently attain the large size and rigidness of the other plates in the tegmen. As to the closure of the mouth, it is now believed that it was subsequent to the introduction of the anal plate, by means of which the posterior oral was pushed in between the four others so as to close the opening.

The interbrachials and interambulacrals, in most of the Camerata, pass insensibly into one another, there being no line of demarcation by which they may be separated, except that produced by the arms, and it is difficult to understand how these plates can be distinct structures as is generally supposed. That their morphological relations are very close is conclusively shown by the fact that the very same plates which in the Actinocrinidæ and Batocrinidæ are strictly interbrachial, are in the Platycrinidæ and Hexacrinidæ partly interbrachial and partly interambulacral, and in the Cyathocrinidæ exclusively interambulacral. That the plates of the two hemispheres occasionally are interrupted (notably in Batocrinus, Catocrinus and Strocrinus, is readily explained by the large increase that here takes place in the number of arms, which prevents the development of interbrachials around the arm bases.

Essentially different is the ventral structure of the Fistulata, which have no interradial plates in the dorsal cup, the anal plate excepted, but which have these pieces extensively developed in the tegmen. Four of the interambulacral spaces are raised but little above the level of the arm bases, while the posterior area is extended abruptly upward, and is formed into a tube or sac of variable shape and size, rising beyond the tips of the arms. This sac, which may be regarded as a greatly extended anal area, probably lodged a large portion of the visceral mass. The sac is generally composed of longitudinal rows of hexagonal plates, and is often perforated by pores. The structure at the four other sides of the disk is rarely observed except among the Cyathocrinidæ in which it is probably more substantial than in other groups. In Cyathocrinus there are six plates, interradially disposed, resting against the inflected upper edges of the radials, the lateral margins being covered by the ambulacra. Four of them are large and of equal size, the two others, lying at the posterior side, are quite narrow and enclose a madreporite. The margins of the larger plates are roofed over in perfect specimens by numerous small irregular pieces, while the perforated plate is exposed to view.

Most of the Ichthyocrinidæ have interbrachial plates, which in some forms are large and massive, in others small; some are arranged regularly, others irregularly, but all are movable. The plates of the tegmen are very minute and irregularly arranged, the ambulacra are tegminal, and the mouth and food grooves are open. Thus there is among palæozoic crinoids a tegmen having all the characteristics of the disk in recent species, demonstrating conclusively that the disk as a ventral structure is not confined to the neocrinoids as generally supposed. Moreover, a careful study of the various tegmens in the different groups shows that there are represented among them all intermediate stages from the simplest disk to the most rigid and complicated "vault" of the Actinocrinidæ, and that the so-called vault is a highly modified form of the disk.

The anal plates bear a most important part in the phylogeny of palæozoic crinoids, and they are among the best criteria for purposes of classification. When present they occupy, in the Camerata, the median line of the posterior area so as to divide the interbrachial plates into two equal sets, and being in rows containing an odd number they have the effect, as it were, of breaking up the middle plate into two, as in cases where no anal plate is inserted between the sections. The anal plates vary considerably in their position and distribution, and, in some groups are absent altogether. As a rule they are largely represented in species with a stout tube or a lateral opening, and are wanting or are poorly developed when the anus is central.

Among the Fistulata the term "anal plates" has been applied to two ossicles of different origin, the one radial, the other interradial. The latter is the homologue of the first anal of the Camerata, and rests upon the truncated posterior basal. The other, which is not a supplementary plate but the lower section of the compound right posterior radial, performs anal functions only in certain genera. When both plates support the ventral sac as in most of the Poteriocrinidæ, the second, which is actually the first or lowest in point of position, is placed obliquely to the right of the other, without disturbing the orientation or the alternate arrangement with the basals. Both plates undergo many modifications, and the various phases as they occur in different geological stages, may be regarded as excellent criteria for generic separation. The earlier Camerata have neither a radi-anal nor a regular anal plate both of which make their appearance with the increasing size of the ventral sac. As this grows larger, the two posterior radials which previously were in contact laterally, part, and the anal piece is introduced to support the sac. Afterwards when the central sac attains still greater proportions, the supraradial is shifted to the right in a position almost directly above the right postero-lateral basal, so as to give to the infraradial which retains its place, a rather oblique direction. In the Poteriocrinidæ, in which the lower faces of the costals fill up the whole width of the radials, leaving no room for attachment, the lower plates of the sac enter the calyx. At the close of the Carboniferous, the sac becomes reduced again to its former significance, the anal plates generally disappear, and the two posterior radials meet again laterally. This interpretation of the origin of the anal piece (or plate x as it is frequently called) differs essentially from that given by the English writers on the crinoids who regard the plate as primitively derived from a brachial, which in time passed down from above into the dorsal cup. These authors a[illegible] claim that in the older forms with a compound right-poster[illegible] radial, such as in Iocrinus and Heterocrinus, the plate in question is supported by the supraradial and does not touch the infrabasal; but that, further, in Hybocrinus and Dendrocrinus, it passes down from above the radial and finally rests with its lower half between the two posterior radials, then being supported partly by the basals and partly by the infraradial; and that in Carabocrinus, Botryocrinus, and allied forms the said ossicle has sunk to a line with the radials. Evidently there have been confounded plates which are morphologically quite distinct. In the above genera the plate under consideration is represented only by Dendrocrinus, Carabocrinus, and Botrycrinus. The piece to which reference is made in Iocrinus, Heterocrinus and Hybocrinus is a plate of the vental sac, as is conclusively proven by Dendrocrinus, otherwise it must be admitted that the plate would be represented twice in the same specimen, by the true anal plate which rests upon the basals, and by the tube plate (of Iocrinus) which is supported by the supraradial. The anal area of Dendrocrinus is like that of Poteriocrinus, only that the supraradial of the former does not move away from the infraradial, as it does in the latter. This is not necessary in a form like Dendrocrinus in which the arm-facets occupy a comparatively small part of the radials and leave ample space for the support of the tube. In the Poteriocrinidæ, however, in which the upper surface of the radials is taken up completely by the costals, the foundation of the tube is not adequate to the width and the deficiency is manifestly made up by a shifting of the supraradial and the introduction of another plate for the support of the tube.

In the anal interradius, as it appears in the various families of the Camerata, a close agreement is found between the anal plate (x) and the tube plates of the Fistulata on one side, and the anal plate and interradials on the other. Admitting this, a more satisfactory explanation of the anal plates of the Fistulata is reached than that usually given. If it were true that what is known as Bather's plate x of Iocrinus passed down in later forms from above the supraradial to the basals, it would certainly require a partial revolution of the whole tube; but this is clearly disproved by the structure itself, which throughout its full length is composed of hexangular pieces, regularly arranged in longitudinal rows. Bather also regards the anals of the Camerata as morphologically distinct from those of the Fistulata, while there actually seems to be good grounds for believing that the plate x of the latter is homologous with the first anal in the Camerata, and also with the anal which for a time occurs in the larva of the Comatulæ; but that the Camerata have no radi-anal for the simple reason that they have no compound radials. The anals of the Icthyocrinidæ are arranged in a similar way to those in the Fistulata. Some of them have only a plate x represented, others only the radi-anal, still others both, and some of them have no anal plate at all. The Larviformia have neither the one nor the other, although they have frequently compound radials. The anal tube where it occurs, is inserted intermediate between the radials and orals.

The systematic arrangement of the crinoids as proposed by Wachsmuth and Springer is one that will require but few material changes for a century to come. Based entirely upon morphological principles, with a completeness and wealth of ontogenetic and phylogenetic data that are rarely obtainable among fossil organisms, the essential elements of classification are more firmly grounded than perhaps in any other group. No attempt in recent years towards a natural and rational orderly arrangement of a large and complex assemblage of organic remains has been so signally successful. Nor has the evolution of the groups in time and space been neglected. For classificatory purposes special emphasis should be placed upon a number of features. Of very great importance is the growth of the stem, whether the young joints are formed beneath the proximal ring of the calyx or beneath the top stem joint. Particular stress is also to be placed on the alternate arrangement of the stem with the lower ring of plates in the calyx, by which it is determined that by far the large majority of the neozoic crinoids are dicyclic and not monocyclic. Of exceptional significance are certain features in the Ichthyocrinidæ which clearly indicate affinities with the Apiocrinidæ, Bourgueticrinidæ, Eugeniacrinidæ, and Comatulæ, all five groups of which are placed together among the Articulata. All have a disk composed of small, irregular, and movable pieces, with open mouth and open grooves, all are dicyclic, but the infrabasals coalesce with the top stem joint, so as to prevent the introduction of new joints directly beneath the calyx. From the Articulata are excluded the Encrinidæ and Pentacrinidæ which are generally arranged with them. The infrabasals of the former of the two families are very small, or are resorbed in the growing animal, but they do not coalesce with the top joint which is therefore for the time being the youngest joint of the stem. The Pentacrinidæ have, through the Encrinidæ, close affinities with the Poterocrinidæ, and probably are their descendants, but if they really belong to the Inadunata as is now believed they represent somewhat abberant types, for the lower brachials take part in the calyx.

Not less important than the morphological contributions to a knowledge of the stemmed echinoderms are the advancements made in their classification, and it is safe to say that the systematic arrangement of the group is now practically settled for a century to come.

The three groups of stalked echinoderms, the cystids, blastoids and crinoids are regarded as orders of equal rank. The forms of the first are earliest in time and lowest in taxonomic position, and may be considered the ancestral types of the other two. The crinoid type itself is a very old one, dating from the Cambrian, in which it was already in a high stage of development. During the Ordovician the cystidian features almost wholly disappeared. The crinoidal group is remarkable for the persistency it has shown in preserving its pentamerous symmetry, and although the introduction of the anal plate was a disturbing element so great as to well-nigh produce a lasting bilateral arrangement, the former type was finally permanently retained.

The two primary groups of crinoids which were formerly almost universally accepted are abandoned. These are the Neocrinoidea and Palæocrinoidea. In their stead are recognized three principal subdivisions: Inadunata, Camerata and Articulata. It is particularly noteworthy that this ternate grouping of the crinoids is essentally the same as Wachsmuth originally proposed more than twenty years ago and that after being compelled by students of the recent forms to abandon it and to substitute others, a final careful survey, in the light of recent discoveries, of all crinoids both living and fossil, has clearly shown that the main subdivisions first suggested are essentially valid and are applicable to all known forms. The criteria for separating the crinoids into orders are briefly:

1. Condition of arms, whether free above the radials, or partly incorporated in the calyx.
2. Mode of union between plates of the calyx, whether movable or rigid.
3. Growth of the stem, whether new plates are formed beneath the proximal ring of the calyx or beneath the top stem joint.

The simplest forms of the Crinoidea Inadunata have the dorsal cup composed invariably of only two circlets of plates or three where infrabasals are present; there are no supplementary ossicles except an anal piece which is however not always present; the arms are free from the radials up. In the construction of the ventral disk two different plans are recognizable and upon these are established two subgroups—the Larviformia and Fistulata. The former has the disk in its simplest possible form, being made up of five large orals arranged in a pyramid; the second has the ventral side extended into a sac or closed tube, often reaching beyond the ends of the arms.

The Camerata are distinguished by the large number of supplementary pieces which bring the proximal arm plates into the calyx, thus enlarging the visceral cavity. All plates are heavy and immovable and the mouth and food grooves are tightly closed.

The Articulata have to some extent the incorporation of the lower arm plates with the calyx, but the plates are movable instead of rigid. The mouth and food grooves are open. The infrabasals are fused with the top stem joint which is not the youngest plate of the stalk. According to whether or not the pinnules are present two suborders are recognized: the Pinnata and Impinnata.

For the family distinctions the supplementary plates constitute excellent features for classification, and while of small importance physiologically, they form a good example of a truth which is met with everywhere in biology that characters of physiological value are not always of equally great utility for purposes of classification. Of prime import in this regard are the anal pieces.

Of the three groups of crinoids having ordinal rank, that constituting the Camerata is by far the most important. An analysis of the families is briefly as follows:

I. Lower Brachials and Interbrachials Forming an Important Part of the Dorsal Cup.

A. Interradials poorly defined.
Lower plates of rays more or less completely separated from those of other rays and from primary interradials by irregular supplementary pieces; anal interradius divided by a row of conspicuous plates; (dicyclic or monocyclic) ....Reteocrinidæ

B. Interradials well defined.
1. Dicyclic.
a. Radials in contact, except at the posterior side....Thysanocrinidæ
b. Radials separated all around ....Rhodocrinidæ

2. Monocyclic.
a. Radials in contact all around. Symmetry of the dorsal cup if not strictly pentamerous, disturbed by the introduction of anals between the brachials only ....Melocrinidæ
Arms borne in compartments formed by partitions attached to tegmen; dorsal cup perfectly pentamerous; plates of calyx limited to a definite number ....Calyptocrinidæ
b. Radials separated at the posterior side by an anal plate. First anal plate heptagonal, followed by a second between interbrachials ....Batocrinidæ
First anal plate hexagonal, followed by two interbrachials without a second anal; arms branching from two main trunks by alternate bifurcation ....Actinocrinidæ

II. Brachials and Interbrachials Only Slightly Represented in the Dorsal Cup.

1. Dicyclic.
Radials in contact except at the posterior side........Crotalocrinidæ

2. Monocyclic.
a. Radials in contact all around; base pentagonal......Platycrinidæ
b. Radials separated on posterior side by an anal plate; base hexagonal. Basals directly followed by the radials.......Hexacrinidæ
Basals separated from radials by accessory pieces.......Acrocrinidæ

While the morphological and classificatory chapters of the monograph on North American crinoids appeal more directly to palæontologists interested in the biological side of the subject, the descriptive part will be of greatest practical value to the stratigraphical geologists. This portion of the work is a complete revision of all Camerata known from this country up to September, 1894. Every species is fully and clearly described, compared with closely related forms, beautifully illustrated and referred to its proper geological horizon; the full literature of each and the localities where it occurs are also given. All the species have been redescribed from the most perfect material that could be found in all museums and private collections. The liberality shown Wachsmuth and Springer by those persons who possessed suitable specimens in placing them at free disposal is to be commended in the highest terms. It was the means of making accessible nearly all the type specimens known, and in fact, most of the crinoid material in the country. In addition there were the authors' own magnificent collections which contain more than nine-tenths of the known American species and over two-thirds of the European, of which many are represented by scores and even hundreds of individuals. These large collections gave new ideas regarding the limits of the different species and enabled a discrimination to be made between species and varieties, and between the young specimens and the adults, which led to the elimination of a large number previously recognized. The establishment of species on rational morphological grounds and not on trivial superficial or accidental characters which are relatively unimportant as classificatory criteria is a point of excellence which cannot be too highly praised, and one which should be the central consideration in the revision of the nomenclature of all groups of fossils as well as living organisms. That there has long existed a burdensome and extensive synonomy among crinoidal as well as all other classes of animals no one who has given the subject attention will for a moment question. The most casual consideration has rendered apparent the urgent necessity of a careful and complete revision of nearly all groups. The wide geographical distribution of many species and the concomitant changes of environment may readily be referred to as among the chief causes of local variation in species now living. Among fossil forms, however, there is in addition a greater factor of geological range which must be carefully considered. Notwithstanding the careful and conscientious labors of a large number of writers, little attention has been given in the description of species to these highly important factors which for the most part have been entirely overlooked. But the contributions to synonymy have not originated wholly in the manner mentioned. A still greater number of invalid names have come from a practice which cannot be condemned in terms too severe. It is the tendency to describe species, and genera also, from imperfectly preserved material, often from a single aberrant specimen, without making adequate comparisons with allied forms. This deplorable state of things, which in the natural course of events should be continually getting better with the advance of knowledge, appears of late years to have become so virulent that it is a serious question whether such work should not properly be ignored altogether. It will ever remain one of the crowning glories of Wachsmuth and Springer's efforts that they have shown no sympathy whatever with such work; and that with calm, untrammeled and truly scientific judgment they have relegated to oblivion such a large number of worse than useless specific names which have so long stood as a menace to progress in this field of palæontologic research. A full list of synonyms so far as they apply to the Camerata is given.

The preparation of the monograph occupied over seven years of continuous work, but this gives but a faint idea of the vast amount of labor involved. This work will be indispensable to all future writers on crinoids, as well as to the collector in the identification of his material. It embraces the whole literature on the subject and thus dispenses wth dozens of papers which are not accessible to the student. Besides it has the great advantage that the same terms are used throughout the whole work, and that these terms are clearly and accurately defined. The identification of the forms is facilitated by analytic tables for families and genera; and the species are arranged under the various genera in such a way that those most closely related are placed near one another.