NEW SERIES No. 104 MARCH 1, 1926

UNIVERSITY OF IOWA STUDIES

STUDIES IN NATURAL HISTORY

VOLUME XI NUMBER 8

PAPERS ON GEOLOGY

PUBLISHED BY THE UNIVERSITY, IOWA CITY, IOWA

Issued semi-monthly throughout the year. Entered at the post office at Iowa City, Iowa, as second class matter under the Act of October 3, 1917

TRAVELING LIBRARY

OF THE STATE OF IOWA

To communities, and schools, books for reloaning are loaned for a three month's period. To individuals and to clubs for study use, books are loaned for two to four weeks.

Borrowers are requested to return the books as soon as the need for them is passed, and *always* when books are due. Where books are re-loaned, fines may be charged by the *local* library and *retained* when the books are returned.

DAMAGES. The pages of these books must not be marked and librarians are required to note the condition of books when loaned to borrowers and when returned by such borrowers and to report damages beyond reasonable wear to the State Traveling Library.

10M-SE-40

UNIVERSITY OF IOWA STUDIES IN NATURAL HISTORY

HENRY FREDERICK WICKHAM, Editor

VOLUME XI NUMBER 8

PAPERS ON GEOLOGY

PUBLISHED BY THE UNIVERSITY, IOWA CITY, IOWA

CONTENTS

ADDITIONAL CYSTOIDS AND CRINOIDS FROM THE MAQUOKETA SHALE OF IOWA

A. O. THOMAS and H. S. LADD

(PLATES I-VI)

An excellent paper has recently appeared on the echinoderms of the Maquoketa of Iowa.[1] It was based on collections made several years ago and found almost wholly within Fayette county. During the past two or three years the junior author has made an extensive study of the entire Maquoketa terrane in Iowa and in the course of that investigation has made large collections of fossils at many horizons and localities. The echinodermal material collected presents not only new forms, but new facts about old forms and new locality records for others. Most of the new material described was found in the cherty and dolomitic beds of the Fort Atkinson limestone member (Middle Maquoketa). This member was found best exposed at its type locality, the quarry at the old blockhouse near the town of Fort Atkinson in Winneshiek county. Here a large amount of recently quarried rock yielded abundant echinodermal remains. Many fragmentary specimens of undetermined relationships were found. These assure the future student that the field is but partly worked.

The most interesting discovery is a heterostelean cystid which belongs to a little known race. Its relatives are largely European. It is placed in a new genus, *Iowacystis,* and it does not fit well into any of the defined families. A heterocrinid exhibiting thick and unusually large proximal stem columnals proves to be new and a *Porocrinus* which has undergone much reduction of its fold areas is described and illustrated.

The writers wish to acknowledge the valuable suggestions of Drs. Frank Springer and August F. Foerste to whom photographs were submitted and whose opinions were solicited concerning the new *Ectenocrinus* and *Iowacystis* respectively. The papers of Dr. F. A. Bather have been freely consulted in the study.

[1] Slocom, A. W., and Foerste, August F., New Echinoderms from the Maquoketa Beds of Fayette County, Iowa, Iowa Geol. Surv., vol. XXIX, pp. 315-384, 1924.

CYSTOIDEA von Buch

AMPHORIDEA Haeckel (*pars*)

Anomalocystidæ Meek

Iowacystis gen. nov.

Theca triangular, compressed, presumably concavo-convex, surrounded by a border of marginal plates which are extended to form a part of the surface on each side. A single process, or arm, composed of many small ossicles arises from a special group of circumoral plates near the apex of the convex or oral side. Body plates of the oral side smaller and more numerous than those of the opposite or posterior side where they display bilateral symmetry. Anal pore in sagittal plane at the lower left corner of the oral side.

Stem longer than the theca, tapering, composed of vertical rows of ossicles in which there is a short proximal series of thin columnals changing abruptly to a distal series of alternating polygonal pieces most of which are longer than wide.

This genus exhibits a group of characters which places it close to the family Anomalocystidæ and to which it is provisionally referred. However, the triangular outline of the theca, its stem characters, plate markings and single oral process located outside the sagittal plane are foreign to that family. Foerste suggests further relationship to the Mitrocystidæ or Lagynocystidæ. The genus may eventually be relegated to a new family.

Iowacystis sagittaria gen. nov. et sp. nov.

Plates I, figs. 1-5; II, fig. 1; IV, figs. 1-6; V, figs. 1,2.

The description is based on four specimens and a number of stem fragments. For convenience the four thecas may be referred to as *a, b, c,* and *d.* Specimen *a* is attached by its concave (posterior) side to a matrix of shaly dolomitic limestone. It is the largest and most nearly complete. The exposed convex (oral) side has been crushed in and the basal and lower marginals are wanting at one corner and disarranged at the other. Specimen *b* is free. Several fractures tend somewhat to destroy the identity of the sutures and the plates of the two sides have been pressed together obscuring the original concavo-convexity; the proximal part of the stem is preserved and the thecal apertures near the apex are well shown. Specimen *c* is the smallest. It was freed from the matrix with some difficulty. Its posterior side is well preserved and shows the bilateral symmetry and plate markings; the apical region is distorted. Specimen *d* is also free, of normal size, has lost some of the body plates but retains a full centimeter of the stem. It preserves best the plates of the anal pore.

Outline of the theca triangular or sagittate. Base arched gently upward and bearing centrally a re-entrant depression for the reception of the stem. Edges nearly straight, each meeting the base at an angle of approximately 64 degrees; basal corners rounded. Marginals thick and heavy, the lateral ones elongate; they are nine in number and form a frame encircling the theca except where it unites with the stem. There are three marginals on each side, the lower of which forms the corner; between the stem and the lower marginal is a single elongate basal marginal. The ninth plate is the apical marginal and it rests in an angle between the contiguous apical ends of the superior pair of marginals. The peripheral faces of the marginals are conspicuously decorated by an intricate system of ridges and grooves. The median marginals and to a certain extent those above and below them are constricted at their mid-length. In the broad depression thus formed lies a narrow transverse ridge which is a slender continuation of the smoother and less decorated posterior surface of the plate. Each marginal forms a part of the surface on the oral and on the posterior thecal sides but is asymmetrical in that it extends farther over the posterior side than over the oral. The apical plate is pentagonal in outline and protrudes beyond the remainder of the theca; the surface of its posterior face is flat and flush with the faces of the contiguous superior marginals; a smooth linguiform elevated band forms its extreme apical part and extends from the posterior surface, of which it is a continuation, down to the apical edge of plate *G;* a distinct groove flanks each side of this apical band, for the reception of which it is slightly undercut.

The somatic or body plates are fewer in number and larger on the posterior side where they achieve almost perfect bilateral symmetry (see Plate V, fig. 2). They are seven in number and are arranged as follows: one, the largest, is hexagonal in shape, and situated near the center; four others, smaller in size and irregularly polygonal in shape, are arranged in an arch whose ends rest on the basal marginals. The sixth is median in position and just above the stem. It is seven-sided, curved below and its lower border is thickened by a heavy ridge of which there is a lateral continuation in the form of a less prominent ridge on the adjoining basal marginals. This plate and its opponent on the oral side lie between the proximal ends of the basal marginals; all four apparently contribute to the area of the stem facet. The seventh is also polygonal and lies between the right lower and basal marginals; proximally it abuts against the lower right corner of the four-plate arch and distally it partially supports the anal pore. This small plate is the chief disturbing element in the symmetry of the posterior face. Its position and relations are well shown on specimens *b* and *d*.

On the oral side the somatic plates are fully forty in number. Their exact arrangement on the lower half of the theca is uncertain since on each of the specimens at hand a few of the plates are either lost or misplaced. On specimens *a* and *d* the median plate just above the stem appears to be in place and is much smaller than the opposite plate as seen on the posterior side of *b* and *d*; moreover, it does not bear a ridge along its lower border but a groove, thought to be the edge of the stem facet, is visible beneath its lower edge. The other plates of this side except those of the upper part are small, polygonal, and without symmetry.

Near the apical end of the oral side is a group of three special plates, two large and one small. Close to the right hand edge of the theca and on a level with the superior marginals the common edges of the three plates form an elongate groove which opens below into the theca. Out of this groove and over the opening arises a process composed of several small movable plates apparently in two rows and separated along their outer side to form a longitudinal slit. The total length of this arm-like appendage is unknown but on *b* the portion preserved extends beyond plate *A.M.* (see Plates I, figs. 4, 5; V, fig. 1). The right hand and lowermost plate of the three, here designated *O*, is polygonal and elevated into a thick lip around the lower edge of the oral aperture. Above it and to the left is an equally large irregular plate, here designated *G*. It is separated from *O* and the two small somatic plates by simple and nearly straight sutures, but the line of its contact with the left superior marginal is much crenulated to fit the ridges and depressions of the latter's surface. The plate is heavy and thick and the adapical part of its surface is elevated into a pointed cone directed outward and upward; in the apex of the cone is a small depression, evidently a pore, thought to be the gonopore. The small plate, here called *Y*, lies between the right superior marginal and plates *A.M.*, *G* and *O;* viewed from the right it is oblong quadrangular in shape and it fits closely about the base of the brachial process.

The anal pore appears to be located close to the sagittal or marginal plane. It is at the lower left hand corner as seen from the oral side and is thus located as far as possible from the intake.[2] The opening is surrounded by a ring of small polygonal, mostly quadrangular, plates distal to which are two larger plates now closely appressed. The crushed condition of the specimen makes restoration of the pyramid difficult and it is believed that one or more plates have been lost from its apical part.

The stem is composed of two series of columnals, a proximal which is made up of pairs of ossicles which are much wider than long, and a distal series of alternating columnals most of which are longer than wide.

The thin proximal ossicles, although somewhat separated in all the specimens, appear to have fitted into each other much as does a number of nested pans with the extended slightly nodose peripheral edge proximal in position. The most distal ossicle of this series, as seen on *a*, is little more than a ring or band fitting around the tapering proximal extension of the first columnal of the larger series. On the posterior side (specimen *b*) where the basal re-entrant is deeper seven pairs of ossicles are visible; there are but five in view on the oral side. The alternating series of columnals, as seen on *a*, tapers gradually and ends in a number of disorganized small pieces which may or may not have belonged to the stem. In *a* there are seven columnals in place on the right and eight on the left. Each columnal on the right or left is in contact with the two on the opposite side. Proceeding distally the length of the contact border with the opposite upper columnal becomes successively longer for the left hand row and successively shorter for the right hand row. The stem at any point is flattened oval in cross-section. The regularity of the columnals as exhibited by *a* is much less apparent on some stem fragments collected at the type locality (Plate IV, figs. 3-6). In these, at intervals, small, more or less equidimensional ossicles occur singly or in groups. On the posterior side of one specimen (fig. 6) there is a tendency to have three ossicles at the same level in the stem.

The markings of the plates of the posterior side consist of a number of scattered low nodes which exhibit no definite arrangement ex-

---

[2] See Bather, F. A., Paleont. Zeitschr., Bd. VII, Heft 1, p. 6, 1925.

cept on plate *A.M.* and on the flanks of the superior marginals where they attain a more or less linear distribution parallel to the sides of the theca. The mosaic of small polygonal plates of the oral side is marked by an abundance of nodes and wavy ridges which have a more or less radial arrangement. The median plate just above the stem partakes of the same general pattern. Plates *O* and *G* have especially strong ridges which are notably prominent on the right half of *G* where they are normal to the suture between *G* and *O*. On the flanks of the apically perforated cone on *G* are a number of tiny pustules which have the appearance of being perforated; their purpose, if functional, is unknown. The elaborate system of grooves and ridges on the marginals and their evident continuity from plate to plate along the periphery of the theca suggest that they may have had a part to play in the economy of the animal other than decoration. The larger columnals of the stem are coarsely granular proximally but distally this disappears to the extent that the lowermost columnals are nearly smooth.

Measurements of the four cotypes are:

	a	*b*	*c*	*d*
Total length of theca	22.0 mm.	22.0 mm.	13.0 mm.	22.7 mm.
Width at base	21.0 mm.	20.0 mm.	11.5 mm.	20.5 mm.
Length of median marginal	7.6 mm.	8.2 mm.	5.0 mm.	7.9 mm.
Length of plate *O*	4.5 mm.	4.5 mm.	----	----
Length of plate *G*	6.0 mm.	6.0 mm.	----	5.5 mm.
Stem, total length[3]	34.0 mm.	----	----	----
Stem, oral side of proximal series	6.0 mm.	7.0 mm.	----	6.6 mm.
Stem, posterior side of proximal series	----	8.1 mm.	----	8.4 mm.

Occurrence: In the somewhat shaly and dolomitic beds of the Fort Atkinson limestone (Middle Maquoketa) at the old Fort Atkinson quarry, Winneshiek county, Iowa. Collected by A. O. Thomas and H. S. Ladd. The four specimens are regarded as cotypes and are in the paleontological collections at the University of Iowa. Specimens *a*, *b*, *c*, and *d* are numbered respectively 3525, 3526, 3527, and 3528. The stem fragments are entered as number 3529.

Undetermined cystid plate, *A*.

Plate IV, fig. 7.

A nearly perfect rhomb-bearing plate of callocystine characters was found in the highly fossiliferous zone near the top of the Ma-

---

[3] Stem measurements are of doubtful value since the plates of the proximal series are somewhat separated in the material at hand.

quoketa formation. The plate is small (7.2 x 6. mm.), is five-sided, gently curved in the direction of its greatest dimension, and decorated with vermicular sculpturing. It bears a deep-set half rhomb which is curved or somewhat boomerang-shaped. The border of the depression is sharply elevated and the bordering ridge is higher on the outer than on the inner edge of the pit. There are twenty-two dichopores, nine in the shorter and thirteen in the longer limb of the pit.

Collected by A. O. Thomas from the Maquoketa shale in Sec. 32, Fairfield township, Jackson county, Iowa, where it is associated with *Cornulites sterlingensis, Plectambonites sericeus, Zygospira* cf. *modesta, Calymene gracilis,* and others. The specimen is number 3530.

Miscellaneous cystid plates, *B, C,* and *D.*

Plate III, figs. 5, 8, 9.

The first of these is a large plate from the theca of some species of *Pleurocystites* similar to *P. beckeri* Foerste. It preserves well the characteristic markings. Maquoketa shale, upper fossiliferous zone, Stockton, Illinois. Collected by H. S. Ladd.

Specimen *C* is a thin six-sided plate marked by twelve heavy ridges which radiate from the center of the plate, one to each angle and one to the center of each edge. Between the radial lines are fine nodes and vermicular ridges. The inner face is smooth. It evidently corresponds to thecal plate *15* or *16* of *Pleurocystites beckeri* Foerste. Collected from the fossiliferous zone of the upper Maquoketa at Sec. 32, Fairfield township, Jackson county, Iowa, by A. O. Thomas.

Specimen *D* is a plate from the basal circlet of *Pleurocystites clermontensis* Foerste. The lower or basal end is thick and flat and makes up a part of the area for the attachment of the stem. A few strong ridges radiate upward from its lower margin. It appears to correspond with thecal plate *4* according to Bather's system of numbering. Collected by H. S. Ladd; Fort Atkinson member, Fort Atkinson, Iowa.

CRINOIDEA

INADUNATA

FISTULATA

Heterocrinidæ

Ectenocrinus elongatus sp. nov.

Plate II, figs. 3-8; V, figs. 3, 4.

This species is based on five specimens, four of them free and one attached to a chip of rock. They are here referred to as *a, b, c, d* and *e*. The first three preserve the basals, radials and part of the brachials, *d* preserves the basals and part of the radials, *e* is represented by a number of plates all more or less jumbled. All five preserve large proximal stem segments.

Calyx small, round, elongate, expanding gradually to the top of the radials just above which it becomes slightly constricted. Below the basals are two to five round heavy columnals which become successively narrower and shorter distally until they grade into the normal stem. This unusual feature gives the crinoid a very elongate appearance and a proportionally much wider diameter through the basals than is usual in heterocrinids.

Basals five, pentagonal, sides sub-parallel; the upper sutures which are in contact with the inferradials are longer than those in contact with the base of the undivided radials thus making four of the basals asymmetrical while the fifth which supports the inferradials of the right posterior and right anterior rays is a perfect pentagon. Radials five; the right posterior, the right anterior and the left anterior are compound; the superradials are larger than the inferradials and in direct line over them. The inferradials rest point downward between the basals; they are pentagonal in shape except the right anterior which is hexagonal due to a small suture at its upper left hand corner where it is in contact with the right posterior superradial. The right anterior and left posterior superradials are quadrangular, a little wider above than below; the right posterior is hexagonal due to truncation of opposite corners, one to receive the first anal and the other to make contact with the right anterior inferradial as mentioned above. The suture dividing each compound radial is curved gently downwards. The two undivided radials are the largest plates in the calyx, the anterior one is heptagonal and the left posterior is octagonal, the extra suture in the latter being due to the position of the anal. Primibrachs two, the first quadrangular, narrowed distally and transversely rounded just above its mid-length; the second shorter, pentangular, wider than long and inclined outward distally. The transverse suture at the base of the first primibrach is wide and located in a deep groove indicating considerable freedom of articulation at this point above which all plates appear to be movable. Plates beyond these unknown except a few displaced brachials at the upper end of *a*. Plates of the whole calyx thick and smooth. Anal plates lost except the first plate in specimen *b* which is so rotated out of its position that its exact shape cannot be determined. Ventral sac unknown.

The stem is extraordinary in that there is a number of thick heavy columnals below the basal circlet. These diminish in diameter and in length distally (see Plate V, fig. 3). The suture lines between the columnals are distinct and gently depressed below the surface; moreover the columnals are free along their joint faces as illustrated in *b*, *d* and *e* in which they have partly slipped out of line. The suture lines in *e* show crenelate edges and the exposed parts of the joint faces in *d* and others show the radially disposed crenellæ. The proximal suture at the base of the calyx is slightly indented just below each basal. Distally the diminishing heavier columnals give way to round thin ones of less than one millimeter in thickness. In specimen *e* there are two of these below the fifth heavy segment, then one thicker segment comparable in size to the fifth distal and beyond this another thin segment (Plate V, fig. 3). Beyond this the stem characters are unknown. Whether it continues as a series of thin ossicles or as thin ones alternating with heavier ones must await discovery of new material.

The following measurements taken in millimeters are added:

	a	*b*	*c*	*d*	*e*
Length of stem preserved	7.6	6.1	2.4	6.5	5.5
Diameter of largest columnal	4.1	3.8	3.0	3.7	3.0
Length of largest columnal	3.1	2.9	1.7	2.4	1.6
Length of calyx to top of radials	5.0	5.0	4.0	----	----
Diameter of calyx at top of radials	5.1	5.0	----	----	----
Length of anterior radial	3.0	2.8	----	----	----

Dr. Frank Springer to whom a photograph of this species was submitted writes[4] that "there is a tendency in some members of the Cincinnatian series toward such enlargement. One form called *Heterocrinus juvenis* not only does that but the crown has broken

[4] Personal communication, April 26, 1925.

off above the basals and then rejuvenated so that we get a crown no larger than the stem.''[5]

Occurrence: In the Fort Atkinson limestone (Middle Maquoketa) at Fort Atkinson, Iowa. Collected by A. O. Thomas and H. S. Ladd. The specimens are preserved in the paleontological collections of the University of Iowa. Specimens *a* to *e* are numbered respectively 3771-3775.

Ectenocrinus raymondi Slocom

Pl. II, fig. 2.

1924. *Ectenocrinus raymondi* Slocom, Iowa Geol. Surv., Vol. XXIX, p. 337, pl. XXIX, figs. 5-9.

A fine specimen with six expanded arms lying anterior side uppermost was found attached to a slab of soft shaly dolomitic limestone near Clermont. In general proportions, shape and size of the calyx and stem characters, it is very similar to Slocom's holotype from the same locality. The specimen was removed from the slab and the anal side was uncovered but unfortunately the anal series of plates are lost, and some of the other plates of the posterior side are much displaced.

The five basals are more regularly pentagonal than in the holotype and the complete radials show well the small facets at their basal angles where they meet the neighboring inferradials. Three of the radials are compound and two are complete. The anterior radial is the largest plate in the calyx; superficially it appears to be four-sided but the small edges at the lower angles increase the number of sides to six. The other complete radial is heptagonal due to truncation of its upper right hand corner for the reception of the first anal plate. The three superradials are four-sided except the posterior one which is pentagonal due to position of the anal. Primibrachs two, the first quadrangular, wider than long, the second pentangular, also wider than long. Secundibrachs many, one arm has over thirty; rectangular or wedge-shaped and uniserially arranged. Sides of the plates flat. The outspread position of the arms is advantageous for study but no evidence can be seen of the ''shallow, rounded grooves'' mentioned by Slocom; slender ramules are present and attached to the ventral side of the arms.

Stem round, tapering, columnals thin.

---

[5] For illustration see *H. juvenis* Hall, 24th Rep. New York State Cab. Nat. Hist., 1872, pl. 5, figs. 9, 10. Also 32nd Ann. Rept. Ontario Dept. of Mines, Part IV, p. 10, pl. I, fig. 7, 1925.

Length of stem 3.85 mm.; length of calyx to top of IBr_2, 8.25 mm.; length of largest arm above IBr_2, 28.5 mm.

Occurrence: Elgin shaly limestone (part of Lower Maquoketa), Root's farm, 2.5 miles northeast of Clermont, Iowa. Collected by A. O. Thomas. University of Iowa Collection, number 3770.

Cyathocrinidæ

Porocrinus fayettensis Slocom

Plates II, figs. 9-16; IV, fig. 8; V, figs. 6, 7.

1924. *Porocrinus fayettensis* Slocom, Iowa Geol. Surv., Vol. XXIX, p. 333, pl. XXIX, figs. 14-22, pl. XXX, fig. 14.

Four specimens (nos. 3696, 3697a, 3697b, 3699) and some fragments referable to this species were found at the old Fort Atkinson quarry. They preserve more or less of the thin-ossicled tapering stem. Three of them are partly imbedded in a hard matrix but the fourth (no. 3696) is free. It is nearly globular in shape and the ornamenting ridges are sharper and slightly more nodose than on Slocom's paratypes which are at hand for comparison. Moreover, none of the Fort Atkinson specimens show the fine granulations observed by Slocom on his specimens from Clermont and Bloomfield.

One specimen (no. 3693) with decidedly smooth but not ridgeless plates, has prominent transverse ridges on the infrabasals just above the stem-facet and well sunken and somewhat reduced fold-areas. It was found in a road gutter about two miles southeast of Nordness, Winneshiek county. Several loose plates, chiefly radials, were also found here.

Another interesting theca (no. 3692) picked up at this locality is laterally compressed and is decorated with five prominent angular ridges which rise at the lateral infrabasal sutures and pass to the middle of the basals. Here they divide into a Y each upper branch of which extends to an arm-facet above. Other ridges on the thecal plates, except as noted ahead, are much subdued or practically wanting. This ridge pattern divides the surface of the theca into ten polygons, the lower five of which are elongate pentagons, the base of each in turn being an edge of the stem-facet; the five upper polygons are subrhomboidal in shape, their distal angles being rounded and situated between the arm-facets. A light but readily discernible horizontal ridge follows the shortest diagonal of each rhomb and pentagon. Each pentagon and each rhomb encloses two fold-areas except posteriorly where on account of the radianal plate one rhomb cross section and the sharp ridges at the angles of the stem are beset at intervals with thornlike points. The segments are very thin there being about 23 in five mm.; the suture-lines are flush and inconspicuous except under a high power lens. The joint-face is marked by delicate marginal crenellæ; lumen pentagonal and relatively large. Figure 21 is an incomplete slender stem 32 mm. in length. It is made up of a series of star-shaped segments with strong heavy points. In the succession of segments the points are so arranged that they form a spiral about the stem. This type of stem is fairly common in the Fort Atkinson member. Figure 22 is a part of the stem of *Dendrocrinus kayi* Slocom. It is pentagonal in cross section and 42 mm. in length. Segments are alternately thick and thin, the thick ones being nodose at the angles. The joint-faces are marked by a distinct pattern of crenellæ which extend from the margin to the small five-sided lumen. Fragments and isolated segments of the stem of this species are common in the marly shales near the top of the Brainard member and are very plentiful at the type locality, Patterson's Springs, near Brainard, Iowa. Numbers 17 and 19 to 22 were collected by H. S. Ladd. Number 17 in Fairfield township, Jackson county (uppermost beds of Maquoketa), number 19 in Orleans township, Winneshiek county (Elgin member), number 20 at Clermont (Clermont member), number 21 at Fort Atkinson (Fort Atkinson member), and number 22 at Patterson's Springs (Brainard member). Number 18 was collected by A. O. Thomas in the road gutters two and one-half miles southeast of Nordness (Elgin member). On Plate IV, figures 9 and 10, are illustrated two views of a crushed specimen preserving a part of the arms and stem. The plates of the lower cup are out of place and some of them are lost. The specimen aids the collecter in associating certain stem and arm fragments which occur abundantly in the Ft. Atkinson beds.

A THEORY OF ORIGIN OF SOME LIMESTONE MASSES AND SEPTARIA

A. L. LUGN

Certain lensy "limestone" masses that abound in the Des Moines series of the Coal Measures strata of south central Iowa have been observed by many workers. These masses have been rather indiscriminately called, "limestone boulders", nodules, limestone lenses and septaria. The first term applies to none while the other terms are applicable to some of the masses. It is the purpose here to state a theory of secondary origin, arrived at by the writer during the field investigation and based entirely on field evidence. Subsequent to the field work and after the theory suggested below had taken definite form, the writer in conference with Dr. W. A. Parks of Toronto, Canada, learned that he had observed similar limestone masses in the shales of Ordovician age in Ontario. These he had described in a manuscript which he was preparing and was suggesting an explanation of their origin essentially in accord with the views here presented.[1]

Two distinct types of these masses were studied, which for convenience, here only, are designated, type A (strictly limestone lenses) and type B (true septaria). The first type (A) occurs as lensy masses varying from small ovoid bodies a few inches in diameter to large flattened masses several yards in maximum dimensions. The two longer dimensions are oriented parallel to the bedding planes of the shale in which they lie. In the sections where they may be seen, they are confined to definite horizons, commonly only to one. The individual sizes increase as the horizon is traced toward a larger lens of limestone at the same level. These larger platelike lenses have an areal extent of a few acres to a few square miles and are not limited to very definite places in the series. They are of little value in stratigraphy except where their horizons can be accurately re-

[1] Since the preparation of the present manuscript, Dr. Parks' paper, above referred to, has come from the press. It is on "The Stratigraphy and Correlation of the Dundas Formation," in the Thirty-Second Annual Report of the Ontario Department of Mines, Vol. XXXII, part VII, pp. 97-99, 1923. (Published 1925).

lated. This is possible only where exposures are close together. The smaller masses of type A border or fringe the larger lenses. This relation is shown in cross-section in figure 1.

The small masses of this first type are always more prolific in fossil remains than the surrounding shale and in most cases a little less so than the larger lenses. Under the microscope most of the lime carbonate, not occurring as fossil shells, is seen to be crystalline, suggesting that it is a secondary deposit from ground water. It can hardly be recrystallized original calcium carbonate for the original shells are preserved and the crystalline material is confined to the

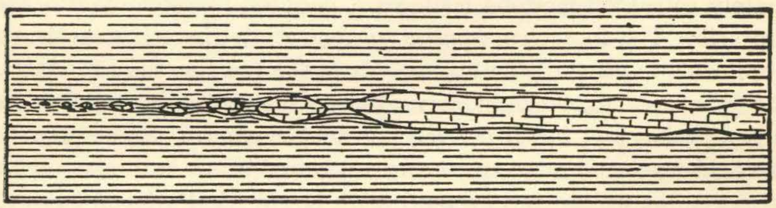
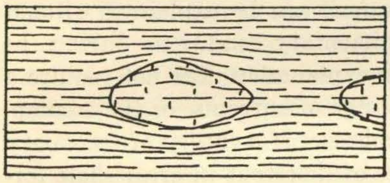


Figure 1. Relationship of the fossiliferous limestone masses to the larger lenses, showing their gradation in size and their occurrence at the same level.

spaces between the fossils and also encloses more or less of the argillaceous sediment. The surrounding shale is quite barren of original fossil remains but in places molds of brachiopod, pelecypod and gastropod shells abound. The lime carbonate of the fossil shells has been removed by solution and now the shale, in most places, is relatively lean in calcium carbonate. The fossiliferous limestone masses and lenses still preserve the original bedding which can be traced into the adjacent shale. The bedding planes bend upward and downward in passing through them. This is shown in figure 2.

It is believed that the masses of type A and many of the larger limestone lenses can be explained on the basis of a secondary concentration of calcium carbonate. The sediment at the time of deposition was highly argillaceous and essentially uniform throughout. Shells of organisms were more or less evenly scattered through the mud. Certain thin zones or limited horizons of small lateral extent may originally have been a little richer in the number of calcareous shells but the deposit as a whole was essentially one of shale-forming material. With subsequent uplift above sea level, the moderately compacted material became subject to the action of ground water.

Calcium carbonate, dissolved from the shale, became concentrated in certain zones, preserving the original fossils and accounting for the secondary calcite which surrounds the shells in these masses and lenses. This process has been of diminishing importance as the material has become more and more compact. The masses and lenses thus preserve the original bedding and very nearly the original thickness of the bed. The bending of the bedding planes on either side of, through and around them is the result of settling and compacting of the enclosing sediment. This volume shrinkage is in part due to the removal of lime carbonate by solution and leaching, leaving only more or less distorted molds of the original fossil shells in the surrounding shale. The abundance of molds of shells in the shale excludes the possibility of the extreme localization of living organisms that has sometimes been assumed for these flat limestone lenses. The present limestone lenses then represent those favorable places or zones where secondary lime carbonate has been precipitated before the enclosed shells had been dissolved.



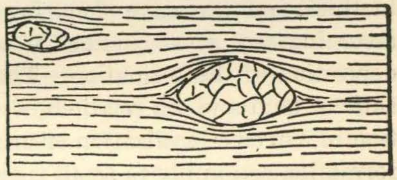


Figure 2. The fossiliferous limestone masses, showing the bending of the bedding planes and their general relation to the enclosing shale.

Figure 3. The septaria, showing their occurrence at different levels and their relation to the surrounding shale.

Masses of the B type are true septaria.[2] They contain no fossil shells or at least fewer shells than the surrounding shale. The bedding planes of the enclosing shale do not pass through but very clearly bend around them. These masses are made up of about fifty per cent crystalline calcium carbonate and nearly all of the remainder consists of clastic material of textures below 1/64 mm. This fine material is like that of the surrounding shale. The septaria are not limited to a single horizon, even in a single exposure. The veins of the septaria, which are characteristic of type B, are usually filled

[2] Grabau, A. W., "Intercretions", Principles of Stratigraphy, pp. 719-720, (1913).

with very clear calcite, in some cases with pyrite and in a few a little sphalerite was found.

The complete or nearly complete absence of fossils in the septaria is believed to be due to a nearly complete solution of all fossil shells and a leaching of the shale of its lime carbonate before the secondary concretionary accumulation as septaria began. That these masses are not confined to definite horizons leads to the conclusion that their centers of growth were determined after the local solution and leaching of the primary calcium carbonate had taken place. It is not evident just what determined the position or the beginning of these secondary centers of crystallization. It is evident, however, that with the accumulation of the secondary calcite the surrounding shale is largely pushed out of the way by the force of crystallization. The growing septaria incorporated some of the original sediment now heterogeneously scattered through them. This accounts for the bending of the bedding planes around them and for the absence of bedding within.

If the evidence presented above has been correctly interpreted it is clear that many if not most small masses of limestone that occur in thick and extensive shale formations can be explained without assuming any great changes of sedimentary conditions during the deposition of the formation. Their explanation does not require a shift of land and sea relations, a change of currents, or the assumption of extreme localization of organisms. If a theory of secondary formation can apply to small masses of limestone in great shale formations, as parts of the Des Moines series, may it not within reasonable limits be applied in part to larger, thicker and more extensive strata of limestone throughout the geologic column?

The writer is indebted to Prof. W. A. Parks of Toronto, Canada and to Prof. A. C. Trowbridge of Iowa City, Iowa for encouragement in presenting the above view; and to Prof. A. O. Thomas also of Iowa City for criticisms of the manuscript.

METHODS OF COLLECTING SEDIMENT SAMPLES FROM THE MISSISSIPPI RIVER

A. L. LUGN

(PLATES VII and VIII)

The object of this paper is to describe the methods and procedure employed in collecting samples of sediment from the Mississippi river during the summer of 1925. A few suggestions which occurred to the writer while engaged in the field operation are added. It is not the purpose to discuss the laboratory study of these materials nor to state conclusions.

Various types of sediment samples were taken from Davenport, Iowa, to Cairo, Illinois, a distance of almost exactly five hundred miles as measured along the main channel. The acquisition of these samples was financed in part by the Graduate College of the State University of Iowa and was done under the supervision of Professor A. C. Trowbridge of the Department of Geology. Except for some previous work done by Dr. Trowbridge at the mouths of the river and in the Gulf of Mexico, the present project is the beginning of a comprehensive study of the whole Mississippi river system. It seems proper at this time to present the field methods and procedures employed, since the present work is the first of its kind to be done in a systematic study of any considerable length of a great river.

There are many factors to be considered in an initial undertaking of such a project. A suitable boat or boats must be secured, sampling apparatus must be selected or invented, the types of samples to be collected must be decided upon, a procedure for taking each kind of sample and methods of recording data must be worked out. The spacing and selection of places at which to collect material must also be determined in some systematic way. Most of these things could not be decided before beginning the work as there were no precedents to follow.

A suitable and adequate boat is almost indispensable in making a study of a considerable length of a large river. The writer was very fortunate in securing the boat shown in Plate VIII, owned by Mr. C. E. Delene of Moline, Illinois. Mr. Clovis E. Delene Jr., a student at Augustana college, accompanied the writer as boats-man and general helper. In these capacities he was efficient and capable in every way.

The Delene was propelled by a stern wheel operated by a Ford engine and could make from five to seven miles an hour in quiet water. In pulling against the current the rate of progress was rather slow but other desirable features outweighed this disadvantage. Some of these features were: length 32 feet over all, beam 8 feet, flat bottom and draft of only 8 to 12 inches. The shallow draft made landing possible at almost any point as well as permitting travel in shoal water. The cabin was commodious and comfortable and with the large space under the forward deck gave ample room for all supplies and equipment. As collected materials accumulated, they were shipped to Iowa City from time to time. The cabin was tightly screened and so constructed as to give complete protection to the occupants from both weather and insects. Every night was spent on the boat and all cooking was done on a portable gasoline camp stove.

A fourteen foot flat-bottomed skiff of the "John-boat" type was towed alongside. This was found to be an essential part of the outfit for it allowed greater mobility and was used in taking almost all of the samples. Such a small boat is also of great value for general use and is a necessity in case of motor or other boat trouble. It can be propelled by an outboard motor or rowed by hand. In the present instance only oars were used but the writer recommends the outboard motor. One man handled the skiff while the other operated the sampling apparatus.

In case an intensive study of a short segment of a large river is to be made, the larger boat may not be so essential since bases of operation can be established at towns or camps and only a small boat with outboard motor need be used. Camp may be moved as often as desired either by car or by boat. This procedure is recommended only where an accessible portion of a river of less than one hundred miles is to be studied in a field season of six to ten weeks. A small river having a shallow channel may be fairly conveniently studied by traveling in a car and many of the samples of sediment can be taken by operating the samplers from bridges, since small streams are usually bridged at short intervals. Travel in this way is faster than by boat and may be of considerable value even on some large streams when a boat is not available. However, the disadvantages are obvious.

Sediment samples were taken which are believed to represent most nearly the river's activity and working capacity at the time of collection. It was decided at the outset to collect material from the bed of the river, from sand and mud bars, from islands as well as suspended débris. In time of high water many of the bars are submerged and in such cases "bar" samples are taken as "bottom" samples. At the time the present project was started the river was rising and this continued during the time taken to traverse about one half of the distance covered. A receding stage was experienced during the remainder of the distance to Cairo and low water prevailed during the return trip. This was considered a favorable sequence of water conditions. Most of the samples were taken on the down river part of the trip due to the favorable stage of the water and to the uncertainty in regard to the time required to carry out the project. There is also considerable economy of time in making the collections while going down stream.

One of the essential requirements of bottom samples is that they represent the material being handled by the river at the time collection is made. For this reason samples that represent a vertical section of even a few inches of bottom sediment are likely to be undesirable. Sediment that is scraped from the bed of the river to a depth of less than an inch will best represent the material being handled by the river at that place and time; for the bottom surface at any place is either a site of deposition or of erosion. The methods and apparatus used in taking bottom materials will be described in detail later.

Samples of débris from bars and islands were easily taken by hand and preserved in stout cloth bags. The conclusion was reached early in the work that samples of material dredged or pumped from the river's bed might be of great value. Accordingly, gravel and sand samples were secured from commercial dealers wherever possible. In all cases these were taken by hand from the dredge or barge or from the unscreened pile and represented the "river run". Dredged material of this kind is not of quite the same value as the bottom samples but does, in nearly every case, represent the work of the river at its maximum capacity. A "live" gravel or sand bar may be completely removed in a single flood or such a bar of large dimensions may be deposited in one period of high water. A mechanical analysis of gravel or sand from such a deposit gives a composite result and shows nothing of the sorting within the bar. The greatest value of such samples is that they contain the largest gravels and cobbles, sometimes with diametral dimensions of four to six inches. Such large cobbles are usually of more or less local origin, from nearby tributaries; in all cases they show the effect of stream wear and bear evidence of water handling. The size of such samples was necessarily large in order to represent the various textural grades in proper proportion. They also were preserved in stout cloth bags.

Much can be learned even by a casual study of the sand and gravel piles of commercial dealers. The same type of material can be observed at many places in the levees where these have been built of sediment pumped or dredged from the river in the immediate vicinity. A few "levee" samples were taken. In addition "hand-picked" gravels and cobbles were collected from gravel barges and levees to show the maximum sizes, the degree of rounding, the shapes and the rock and mineral types in the larger grades.

Samples of mechanically suspended matter were taken in order to find out the texture and quantity of solid matter being transported in a known volume of water at different depths at the prevailing stage. These samples were taken in most cases from the main channel where the water was deepest and the velocity greatest. A half gallon of water, with its contained sediment, was secured by an apparatus described below. This was transferred to a half gallon Mason fruit jar and the sediment allowed to settle. After a sufficient time the clear water was siphoned off and the wet sediment was preserved in an air-tight four ounce wide-mouthed bottle. Usually three such half gallon samples of water and suspended sediment were taken at the same place but at different depths; at the surface, at about one foot from the bottom and at an intermediate depth.

The first device used for collecting water samples, with suspended débris, was a common kitchen sink force pump, with three sections of garden hose. One twenty foot and two ten foot lengths of hose were used. The free end was weighted and submerged to the chosen depth and water was pumped into a container. This apparatus is satisfactory in quiet water but is cumbersome and bulky. It can not conveniently be operated from a small skiff. Where there is much current the intake or free end of the hose is carried down stream and its depth becomes uncertain.

The pump was discarded for a simpler and far more satisfactory device, consisting of a weighted half gallon can made of heavy galvanized sheet iron. It is illustrated on Plate VII, figure 3. This can was closed by a one inch cork to which a heavy cord was attached. The whole, filled with air, was lowered into the water on the end of a line to the desired depth and the cork pulled out. The apparatus filled easily and quickly and as the neck and mouth had a relatively small diameter very little interchange of the contents with the surrounding water occurred in raising it to the surface. It was operated from the skiff and to obviate the effect of the current on its depth when submerged the boat was allowed to drift down stream while the can filled. This usually amounted to only a few rods. The total weight of the device is about nine and one-half pounds. The limit of depth at which it was found to work satisfactorily was about forty feet. At greater depths the cork was very hard to pull out against the increased pressure. A heavier can with double or treble the weight of the above should operate at somewhat greater depths.

Another device for taking samples of water and contained sediment at almost any depth likely to be encountered in a river is illustrated in the drawing on Plate VII, figure 4. This is a can, of any suitable volume, similar to the one described above but attached rigidly to a rod two or three times its length. Two adequate weights are also attached to the rod, one at each end and to each of these a line is fastened. The apparatus is lowered by the line attached at B, with the open end of the can directed downward. At the proper depth the line at A is brought taut and the one at B is released thus reversing the can, which allows the air to escape and water to enter. This eliminates the difficulty of removing a cork against water pressure but permits a little error in quantity of contained suspended matter as some water enters as it is being lowered due to the compression of the air in the can as the depth increases. This error increases in direct proportion to the increase of pressure (or depth) but is more or less compensated since the quantity of suspended matter also increases with depth. This device was not put into actual operation.

The "telegraph snapper" bottom sampler was the first apparatus tried for taking material from the river's bed. This device is illustrated on Plate VII, figure 1 (open) and figure 2 (closed). It was weighted and operated at the end of a line in the usual way. A rigid rod would probably be better than a line in quiet and relatively shallow water. It is opened and lowered to the bottom; on striking the bottom the jaws are spread sufficiently to release the toggle irons which hold them apart and they close around a small quantity of sediment. This sampler is well adapted to taking uniformly fine materials, such as mud and silt when fairly compact, but is unsatisfactory in gravel and even in fine sand. It does not take a sufficient quantity, where the deposit contains particles over a few millimeters in diameter nor does it always close tightly enough, for large grains may be caught in such a way as to hold the jaws partly open. Even grains of sand may hold the jaws far enough apart to allow fine material to be washed out in lifting it to the surface. When the total quantity of heterogeneous material secured is small such losses may be appreciable. The most serious objection to this sampler is that at nearly every trial sand grains worked into the hinges of the toggles and prevented them from completely releasing the jaws. The grains of sand had to be tediously worked out by moving the parts by hand until they operated freely again. It commonly required as many as a dozen trials to secure a single sample. Even had the apparatus worked perfectly, it would have been inadequate because of its small size and the textures of material encountered.

The "Shaw" sampler, suited to taking fine sediment, was also inadequate for collecting gravel and sand. It could not be used except in mud deposits and by the time the project was well under way the sampler designed by the writer and described below rendered its use unnecessary. The Shaw sampler takes "section" samples of small diameter which penetrate the deposit to a depth of several inches and are for that reason, as intimated above, unsatisfactory.

By the time the first thirty miles of the project had been covered, it was plainly evident that the sampling apparatus in hand was entirely inadequate and that something new would have to be designed and made. It should be emphasized that any sampler had to be operated by hand and in most cases from the skiff.

The device illustrated on Plate VII, figures 5, 6, 7 and 8 was designed by the writer and made at a machine shop in Muscatine, Ia. It consists of two weights rigidly attached to a central stem and a loose-fitting cup, which rests around a shoulder on the lower weight. Its total mass is about eleven pounds and its length over all is nineteen and one-half inches. The lower weight was made from a piece of steel shafting three inches long and three inches in diameter. The upper end was turned off, making a shoulder one half inch high and exactly one and fifteen-sixteenths inches in diameter around which the cup fits loosely. A threaded hole receives the stem in the center of the top of this weight. The lower weight weighs about five and one-half pounds. The stem has a diameter of five-eighths of an inch and is bent into an eye at the upper end. The upper weight is two and one-half inches in length and two inches in diameter and was sawed from a piece of steel shafting. It fits over the stem and is held in place by a rivet. Its lower end is about twelve inches above the top of the shoulder on the lower weight. It weighs about two pounds and the stem an equal amount. The cup was cut from a piece of boiler tubing and is six inches long. It has an inside diameter of exactly two and one-sixteenth inches. This inside diameter is one-eighth inch greater than the diameter of the shoulder on the lower weight around which the cup rests. It is important that the cup should fit neither too tightly nor too loosely around the shoulder. The diametral relations of these parts must be such that the cup can incline easily when the apparatus is prone and settle back again to the vertical position when the sampler is brought upright in lifting it from the bottom. These positions may be seen on Plate VII in figures 8 and 6 respectively. The shoulder must be high enough to prevent the cup from slipping off too easily, in which case the load is lost in raising it from the bottom. This scarcely ever happened. The cup easily slides off the apparatus over the upper weight. This allows other cups of different size and shape to be used interchangeably on the same weight and stem system.

This sampler was operated in most cases from the stern of the skiff. It was lowered to the bottom by means of a stout line; on touching the bottom it inclines to the prone position as shown on Plate VII, figure 8. The skiff was either rowed across the current or allowed to drift with it and the sampler dragged for a short distance. The cup filled with bottom surface sediment usually after being dragged only a few feet. It was then raised to the surface and the contents were emptied into a half-pint Mason fruit jar by lifting the cup off of the shoulder. The first part of this operation is shown on Plate VII, figure 7. The apparatus gave the best results when the amount of line let out was from fifty to one hundred per cent greater than the depth of water. Samples were successfully taken at depths of thirty-five feet with only fifty feet of line.

The sampler described above was very successful and from its first trial was used to take every bottom sample secured between Muscatine, Iowa, and Cairo, Illinois. It takes a distinctly bottom surface sample and was successful in nearly every instance with the first trial. The quantity of sediment was usually adequate, averaging about six fluid ounces. It worked equally well in mud, sand and fairly coarse gravel, containing a few pebbles up to an inch in diameter. The leakage of fine material was very little, in fact negligible in view of the size of the samples. All bottom samples were preserved in their wet condition in half pint air-tight Mason fruit jars.

A systematic method of procedure to be followed in collecting samples had to be developed early in the work. Obviously bar, commercial and levee samples had to be taken where they were available, so there could be little uniformity in collecting these. Only representative materials were secured from typical and representative bars. Every bar or island could not be sampled nor was it necessary. The determining factors in this collecting of material were local and had to be determined in the field.

Bottom samples were taken in series of from about four to ten at a place and in section across the river at right angles to the channel from bank to bank. These stations, where series of bottom samples were taken, varied from five to twenty miles apart along the river. This spacing was also determined by local factors. In some places the sections were taken where the river was straight and open with no islands or bars exposed above water; in other places where it had many islands and bars. The sections were usually directed from one bank to an island or bar and from there across to the opposite bank. Where the river is divided by an island one side or chute as a rule is relatively narrow and shallow while the other side is wide and deep. The main channel in most cases is through the wider chute. This relation prevails whether the island is associated with a bend in the course of the river or where its course is straight. This procedure of collecting samples was decided upon early in the work and was adhered to throughout. The only modification made was in increasing the average distance between the section stations as the work progressed down the river. Comparable channel samples, taken in the deepest and fastest water, were also secured at irregular intervals between the section stations. Sets of three half gallon water samples, with their suspended sediment, were collected from the main channel at about every fourth or fifth section station. Miscellaneous suspended sediment samples were gotten at numerous other places.

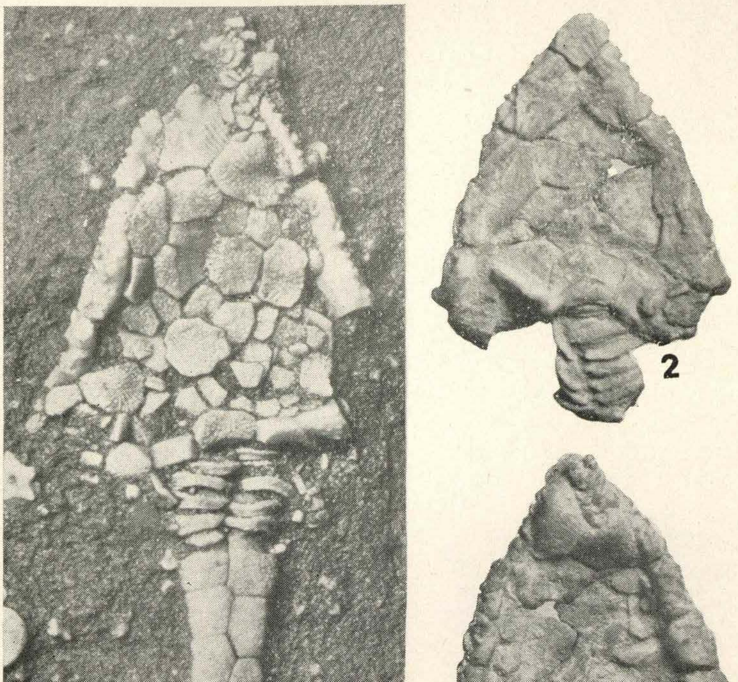
Sections of samples were taken across all of the main tributaries a short distance above their deboucheurs. Missouri River was given especial attention, in that more than the ordinary number of samples were collected about a mile above its mouth. Water with suspended matter was also gotten from some of the tributaries.

The location of every section station or of other individual samples was carefully noted on the large scale charts published by the Mississippi River Commission. A notebook record of depth of water, position relative to islands or bars and the location relative to a located point on the bank was made for every sample. The position of a sample relative to the main channel of the river was also noted. The locations of samples, taken in a section, relative to the starting point were determined by means of a Hymans pocket range-finder (Hymans and Cox, Cambridge). The large boat, the Delene, described above, was tied to the bank or anchored off the point of an island or bar and served as a starting point. The height of the top of the cabin above the water line was known. Using this fixed unit, the distance of any point from the boat could be determined within a few feet or yards. This eliminated the inconvenience of using a stadia rod.

The stage of the water was carefully noted at all gaging stations so that the stage prevailing at the times and places where samples were collected was known quite accurately. The velocity was estimated at many places.

The sediment samples collected from the Mississippi river according to the methods outlined above are being subjected to laboratory studies of texture, shape and lithology.

The writer gratefully acknowledges the valuable criticism of this paper by Professor A. O. Thomas of Iowa City, Iowa.



(For explanations see next page)

PLATE I

PAGE

Iowacystis sagittaria Thomas and Ladd.. 4

All views on this plate x2.

Fig. 1. Oral view of cotype *a* attached by posterior side to a rock slab. The plates of the lower part of the theca are partly displaced and the corners are lost. Note the radial markings on the plates, the protruding part of plate *O* at the base of the arm, the length of the median marginal, and the dual nature of the stem. The upper right hand plate of the distal series of stem ossicles shows the contracted part about which fitted the ring-like columnals of the distal part of the nearer series. Specimen number 3525, S. U. I. collection.

Figs. 2-5. Four views of cotype *b*, number 3526, S. U. I.

2. Posterior view showing position of plate *A.M.* and its relation to the other marginals. Note how far the marginals extend over the body surface. Something of the large size and bilateral symmetry of the body plates can be made out. Compare the median plate just above the stem with that in same position on oral side in figure 1.

3. Oral view showing the circumoral group of plates. Many of the smaller somatic plates are lost and the smooth inner surfaces of the plates of the posterior side are exposed. The position of the thick apical group and the relation of these plates to the oral process is shown. Compare amount of stem shown on the two sides.

4. Lateral view, oral face to the right. Note the protruding stump of the oral process and the elevated cone on plate *G*. The upright attitude of plate *A.M.* and the peripheral decorations of the marginals can be seen.

5. Lateral view, oral face to the left. This side shows better the peripheral markings of the marginals.

PLATE II

PAGE

Fig. 1. *Iowacystis sagittaria* Thomas and Ladd.. 4

Posterior view of specimen *c*, x2, S. U. I. 3527. A small specimen attached to the matrix when illustrated. Note the small anal plates at lower right hand corner.

Fig. 2. *Ectenocrinus raymondi* Slocom.. 12

Natural size, S. U. I. 3770. Anterior view of a fine specimen attached to the matrix.

Figs. 3-8. *Ectenocrinus elongatus* Thomas and Ladd... 10

Fig. 3. S. U. I. 3775. A dismembered calyx but with the large proximal stem segments in place. Note how the segments taper distally down to the small ossicles of the normal stem.

Fig. 4. S. U. I. 3771. Right posterior view of a nearly complete specimen showing compound radials. The proximal stem ossicles are the largest of any in the collection. This is the type, others are cotypes.

Figs. 5, 6. S. U. I. 3772. Right and posterior views of a specimen in which there is a rapid decrease distally in the size of the stem columnals.

Fig. 7. S. U. I. 3773. Specimen showing partly separated columnals; basals and one or two radials in position.

PLATE II

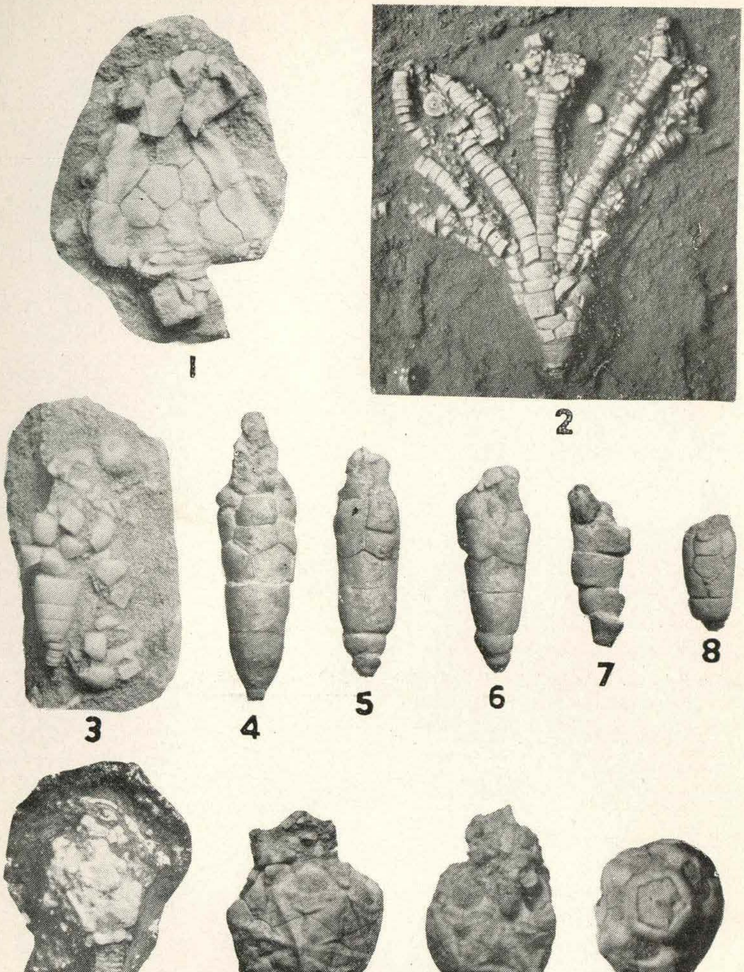


PLATE III

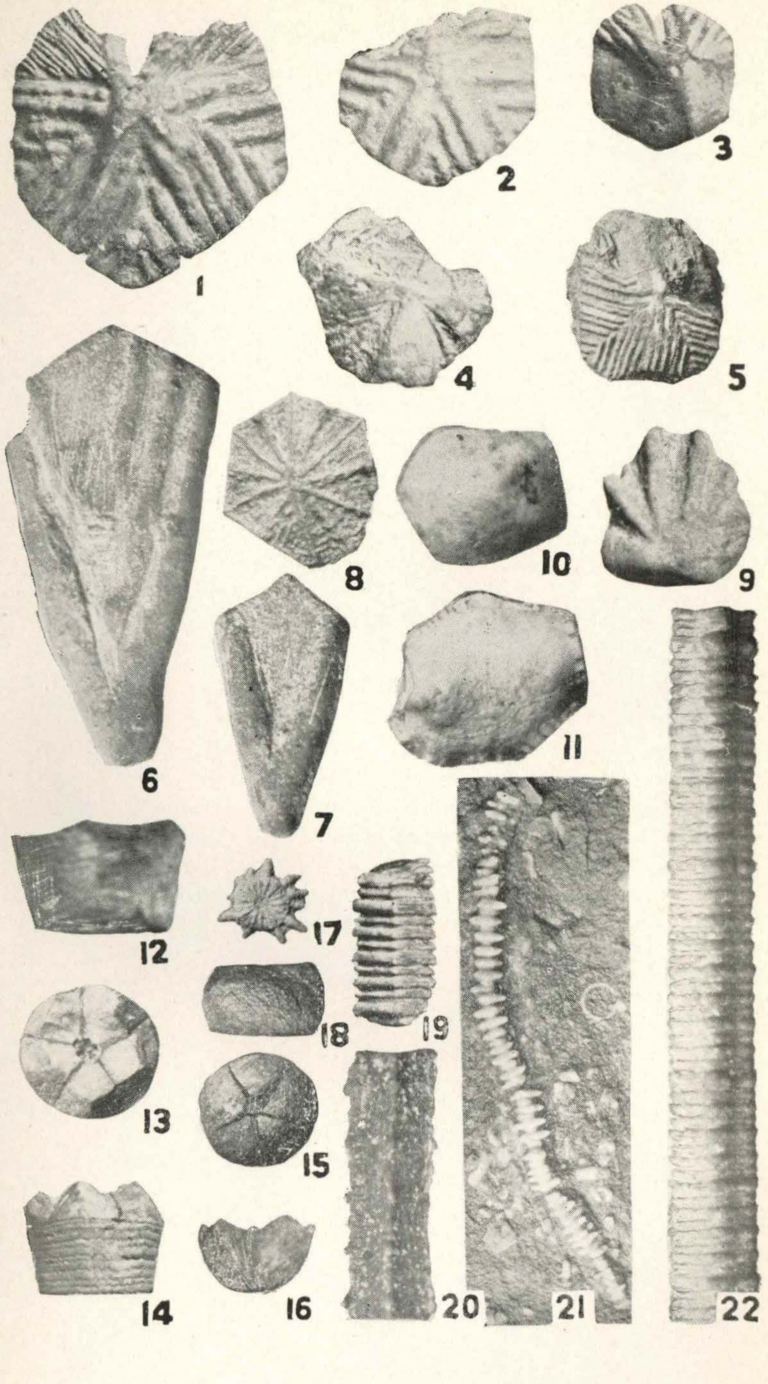

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

PLATE IV

PAGE

Figs. 1-6. *Iowacystis sagittaria* Thomas and Ladd 4

Fig. 1. Posterior view of specimen *d*, S. U. I. collection, no. 3528, x2. A theca preserving the marginal frame. The proximal stem ossicles are much displaced. Anal plates well shown.

Fig. 2. Oral view of same specimen. Anal plates more or less disorganized. Plate *G* is in place but plate *O* is wanting.

Figs. 3, 4. Oral and posterior sides of a stem broken in two parts, x2. Note the small ossicles set among the longer ones. Compare Plate I, fig. 1. S. U. I., 3529.

Figs. 5, 6. Opposite sides of a piece of stem showing tendency to have three plates at same level, x2. S. U. I., 3529.

Fig. 7. Rhomb-bearing plate of some unknown cystid, x2. S. U. I. No. 3230 8

Fig. 8. *Porocrinus fayettensis* Slocom 13

Terminal view x2 of a theca showing the star-shaped peristome and the anal opening. S. U. I. No. 3696.

Figs. 9, 10. Opposite views of an undetermined crinoid from Fort Atkinson. No. 3791. Collected by H. S. Ladd.

Fig. 11. Base of stem and roots of an unknown crinoid, x2. Fort Atkinson. S. U. I., No. 3793. Collected by H. S. Ladd.

PLATE IV

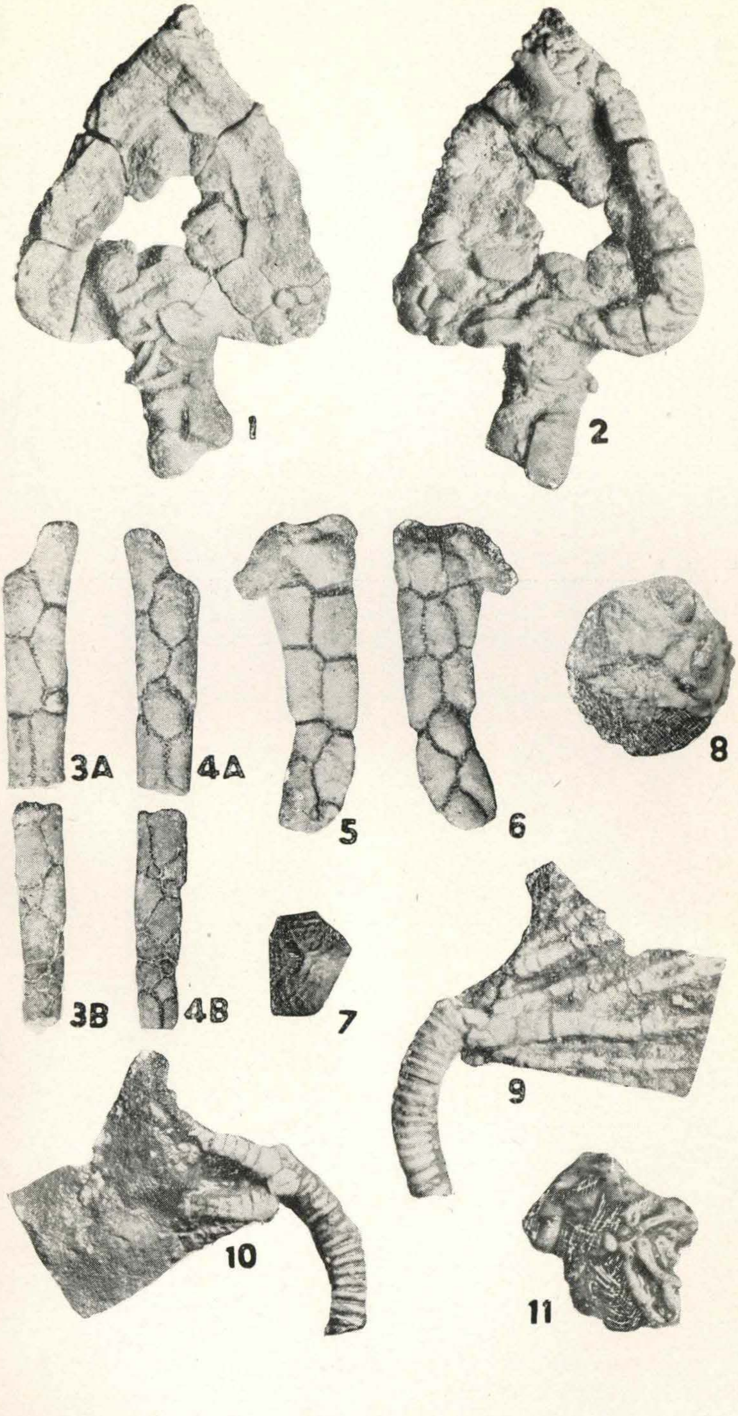


PLATE V

Fig. 1. Diagram of oral side, enlarged. Drawn chiefly from specimen *b*, anal pore from *d*. *Br*, brachial process; *O*, oral plate from which the arm arises; *G*, gonopore plate bearing a small perforated cone at its upper left-hand corner; *Y*, a small plate, oblong quadrangular as viewed from the right, bearing a depression in which lower part of the arm rests.

Fig. 2. Posterior side showing bilateralism. Drawn chiefly from specimen *b*, anal pore from *d*, stem from a separate fragment. *A.M.* apical marginal; *S.M.* superior marginal; *M.M.* median marginal; *L.M.* lower marginal; *B.M.* basal marginal. Note that more of the proximal series of stem ossicles are visible from this side.

Fig. 3. Diagram of large basal columnals grading distally into the normal stem. Enlarged from specimen 3775. Note the uneven proximal edge of the uppermost segment due to the shape of the basals. Compare Plate II, fig. 3.

Fig. 4. Analysis of calyx. Note the three divided and the two undivided radials.

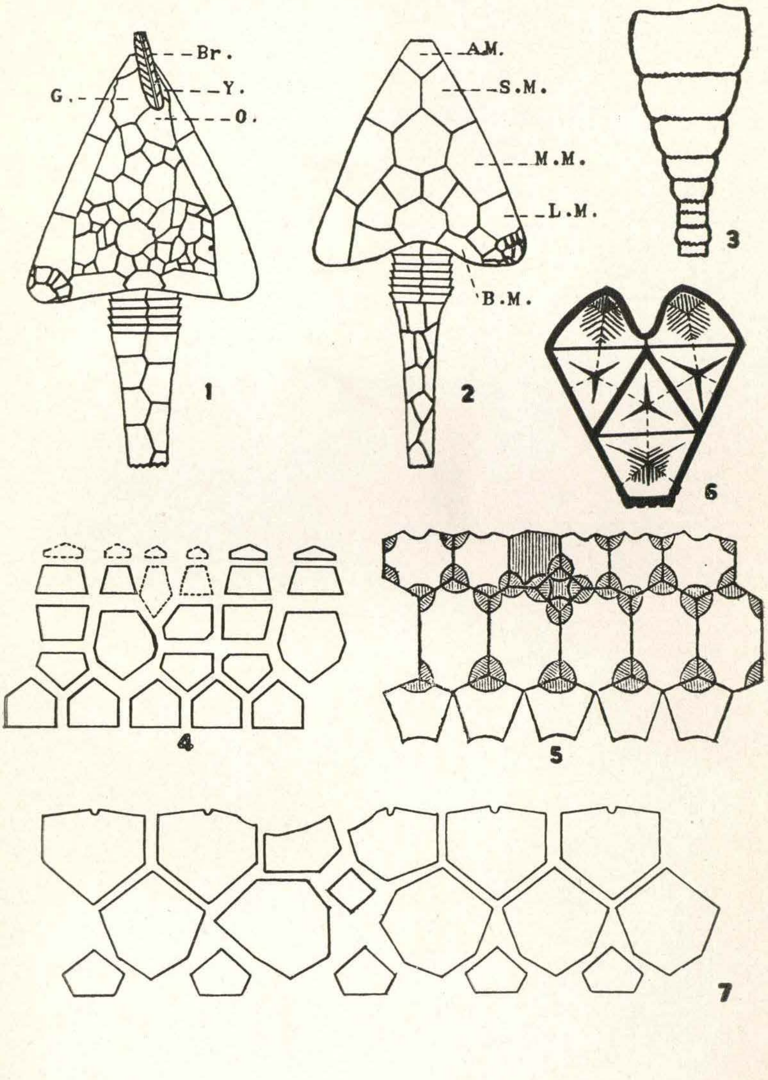
Fig. 5. *Porocrinus conicus* Billings.

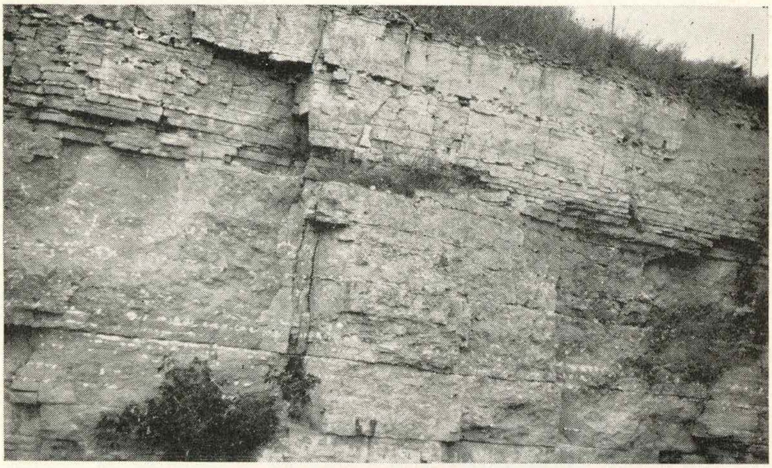
Analysis after Billings, enlarged (see Geol. Surv. Canada, dec. 4, 1859, p. 34). The anal and radianal plates are vertically ruled. The twenty-two fold-areas are inserted at the corners of the plates. Introduced for comparison with fig. 7.

Fig. 6. From specimen 3692. Diagram of parts of several plates to bring out the reduction of the folds in the peripheral fold-areas and in the upper third of the lower fold-area. Note the vestigial folds, the pentagon and rhombs outlined by the heavy plate ridges and the lighter ridges which bisect each. Sutures are represented by broken lines. Compare Plate II, fig. 10.

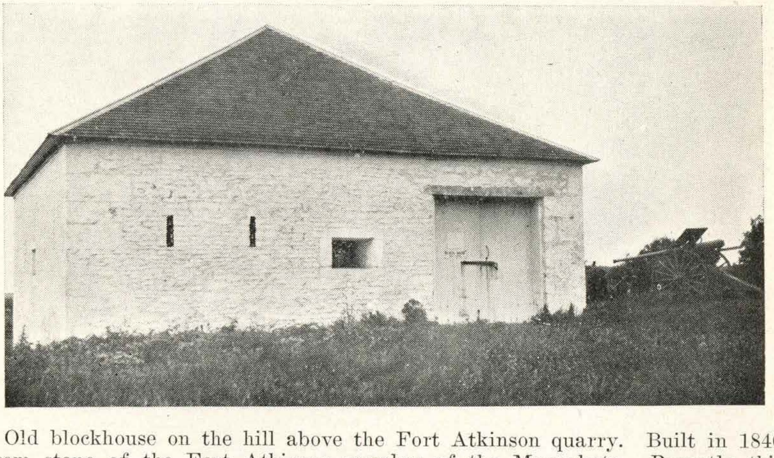
Fig. 7. Analysis of thecal plates, enlarged. The fold-areas have not been inserted. After specimen number 3692.

PLATE V

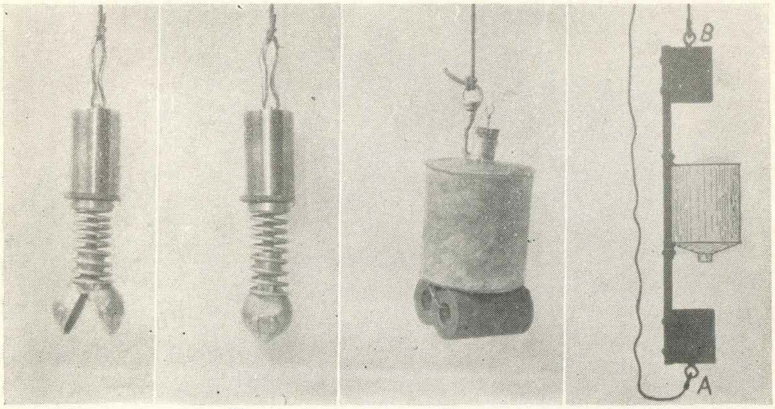




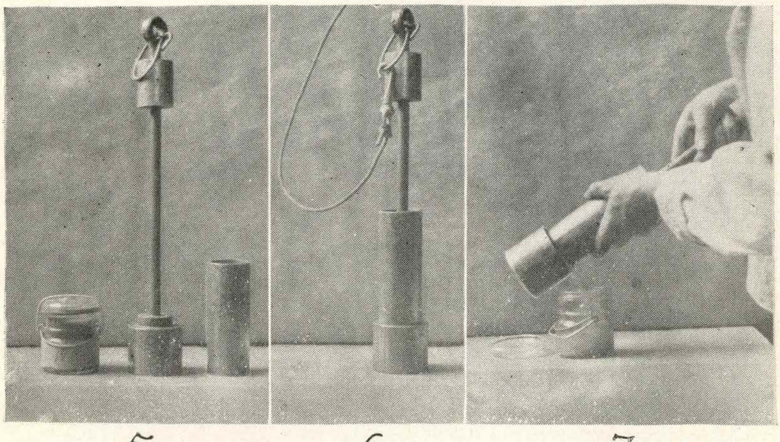
Type exposure of the Fort Atkinson limestone member of the Maquoketa shale. Abandoned quarry near the old blockhouse, Fort Atkinson, Iowa. Note even bedding and chert bands.



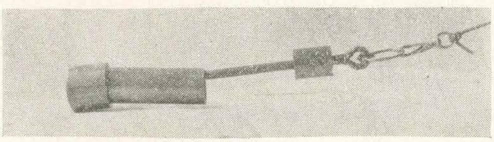
Old blockhouse on the hill above the Fort Atkinson quarry. Built in 1840 from stone of the Fort Atkinson member of the Maquoketa. Recently this land was purchased by the State, and the old buildings are being repaired with newly quarried rock.



1 2 3 4



5 6 7



8

PLATE VIII

Obtainable from the University Editor: Price $0.50