THE DISTRIBUTION OF OSTRACODA AND FORAMINIFERA IN THE BENNETT SHALE

by

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INTRODUCTION

Purpose of the Investigation

The purpose of this study was to investigate the distribution of ostracodes and foraminifera in the Bennett shale. It was believed that a relationship between microfauna and lithofacies might be established and that data compiled might indicate the types of foraminifera and ostracodes that lived in the inferred toxic conditions during the deposition of the black shale. It was also believed that a biofacies-lithofacies association could be established that is characteristic of the Bennett shale and that either foraminifera or ostracodes might have been more sensitive to varying lithotopes.

Area of Investigation

The area of investigation included parts of three counties in northeastern Kansas. The northern boundary (as shown in Plate I) in southern Pottawatomie County, is along a line from Tuttle Creek Dam spillway to a point three miles north of the town of Belvue. The western border extended from Tuttle Creek Dam to a point four miles south of Manhattan, Riley County, Kansas on a branch of McDowell's Creek. The southern boundary of the area was along a line from a point four miles south of Manhattan to a point along Mill Creek, six miles south of the town of Alma, in south central Wabaunsee County. The area of investigation extended east to a point three miles east of

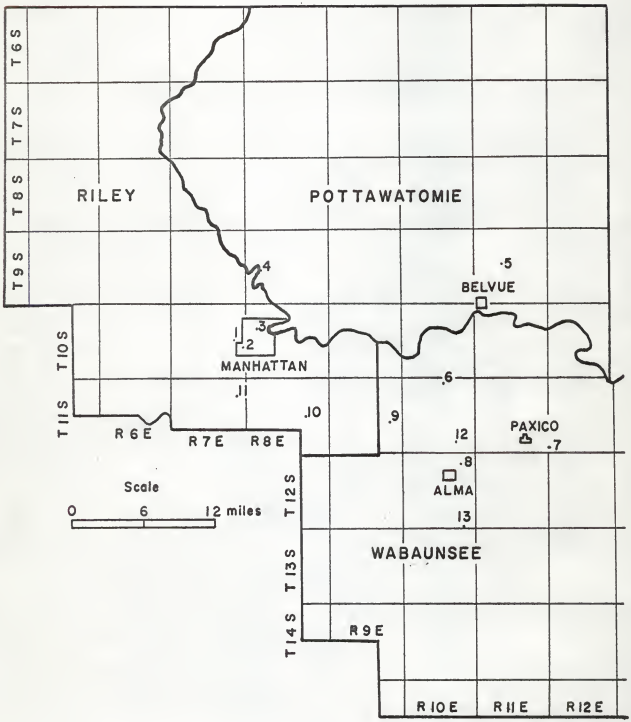
EXPLANATION OF PLATE I

Index Map of Measured Section Locations

Measured Section No.	Location
1	SE¼ SW¼ SW¼ 13-10S-7E
2	NW¼ SW¼ NE¼ 24-10S-7E
3	SW¼ SE¼ SE¼ 7-10S-8E
4	NW¼ NW¼ NE¼ 19- 9S-8E
5	SW¼ SW¼ SW¼ 16- 9X-11E
6	SW¼ SE¼ NW¼ 3-11S-10E
7	NW¼ NW¼ NW¼ 31-11S-12E
8	NE¼ NW¼ SE¼ 11-12S-10E
9	SW¼ SE¼ SE¼ 23-11S-9E
10	NW¼ SW¼ SW¼ 14-11S-8E
11	NE¼ SE¼ NW¼ 12-11S-7E
12	NW¼ NE¼ SW¼ 26-11S-10E
13	SE¼ SW¼ SW¼ 36-12S-10E

Detailed descriptions given in the Appendix.

PLATE I


T6S
T7S
T8S
T9S
T10S
T11S
R6E
R7E
R8E
R9E
R10E
R11E
R12E
T12S
T13S
T14S
RILEY
POTTAWATOMIE
WABAUNSEE
MANHATTAN
BELVUE
PAXICO
ALMA
Scale
0 6 12 miles

Paxico, Wabaunsee County, Kansas.

The Bennett shale crops out in an area 10 to 20 miles wide which trends north to south. The area of outcrop coincides with the axis of the Nemaha Anticline, which is the major structural feature in the area of investigation.

Previous Investigations

An investigation by Davis (1951), was made of the ostracodes found in the Wolfcampian stage limestones of the Permian Period. In the Glenrock limestone Davis found Bairdia reussiana, and Paraparchites humerosus were common and Haworthina bulleta was rare. Paraparchites humerosus was common and Haworthina bulleta and Bairdia beedei were rare in the Howe limestone.

Clark (1950) collected 33 species of ostracodes from the lower Permian shales. Bythocypris pediformis was common and Amphissites centronotus, Bairdia florenaensis, and Bairdia marmorea were rare in the Bennett shale.

Jewett and O'Connor (1952) stated that the Red Eagle limestone had the same general characteristics from southern Nebraska to Manhattan, Kansas. Between Manhattan and Alma the Glenrock limestone was absent in some places, but was present again south of Alma. They concluded that the Bennett shale changed from a shale to a limestone from Wabaunsee County, Kansas to Oklahoma. They also employed an Orbiculoidea zone to mark the base of the Bennett shale.

Mudge and Burton (1959) described the Bennett shale in Wa-

baunsee County as predominantly a brown silty to dark-gray calcareous shale. It has a thin argillaceous limestone lithotope in the middle of the Bennett shale near Paxico, Kansas. They also described a bioherm in the Bennett shale south of Eskridge, Kansas. Descriptions of ostracodes and foraminifera were not included in their measured sections.

Several measured sections of Bennett shale in Pottawatomie County, Kansas were described by Scott and others (1959). They described the Bennett shale as a dark gray, silty calcareous shale ranging in thickness from 2.4 to 8.7 feet. Microfaunal descriptions were not given.

McCrone (1961) concluded that the marine water shallowed from 160 feet in Glenrock time to 60 feet at the beginning of Bennett time. The depth of marine water was established by the fauna present in the Bennett shale and Glenrock limestone. Based on present day forms, Lingula found in the Bennett shale indicate a depth of 60 feet. McCrone also concluded, from the work of Elias, that fusulinids in the Glenrock limestone lived in a depth of 160 feet. The beginning of Bennett time was marked by reduced circulation restricted by unknown barriers somewhere in the southwest. This was a period of toxic euxinic conditions on the ocean floor. Based on their relative abundance, only Orbiculoidea and Lingula were able to live under these conditions. Later in Bennett time, the waters deepened and freer circulations reduced toxic conditions. Under these conditions normal benthonic faunas began to thrive.

McCrone (1961) collected 19 genera of ostracodes and 16 genera of foraminifera from the Red Eagle cyclothem. Detailed descriptions of the genera and species were not given.

Mudge and Yochelson (1962) described several Orbiculoidea zones in the Bennett shale of Kansas. They concluded that the lower Orbiculoidea zone at the base of the Bennett shale was the most characteristic. This zone can generally be traced across eastern Kansas. They stated that Orbiculoidea probably lived in a brackish water environment.

PROCEDURES

Field Procedures

Bennett shale outcrops are limited because of the Howe and Glenrock limestones. The overlying Howe limestone is only slightly resistant to weathering, and the underlying Glenrock limestone, though resistant to weathering, is too thin to form a bench. Most of the area of Pottawatomie and extreme northern Wabaunsee Counties is covered by glacial till. The Bennett shale outcrops invariably occur along stream banks and road cuts; they were located in the field with the aid of geologic maps of Riley County (Mudge and Beck, 1949), Wabaunsee County (Mudge and Burton, 1959), and Pottawatomie County (Scott and others, 1959). The measured Bennett shale sections were taken over an extensive area so that a wide variety of lithologies could be studied. These measured sections were distributed as evenly as possible over the area of investigation in order to yield a more

accurate picture of the distribution of the microfaunas.

Descriptions of the measured sections, for the most part, were done in the field. Folk's classification (1954, pp. 345-351) of fine-grained sedimentary rocks was used. Shales having twice as much silt as clay size materials were classified as silt-shale; shales possessing equal amounts of clay and silt were classified as mud-shales; and those having twice as much clay as silt were called clay-shales. The fine-grained rocks that were indurated and not fissile or laminated were called siltstones, mudstones or claystones; those fine-grained rocks which were indurated and fissile were called shales.

Field determinations were made of the approximate quantity of silt present with the aid of a hand lens. A color chart (Goddard and others, 1948) was used to determine the color of the rocks. Dilute hydrochloric acid was applied to the samples in the field to determine the presence of calcareous material in the shales. Measurements were made with a steel tape to the nearest 1/10th inch. All samples were checked in the laboratory with a binocular microscope to determine a more accurate approximation of clay and silt present.

The term massive is used when strata were more than four inches thick (Glossary of Geology and Related Sciences, 1957).

Marl was used to describe a rock composed of approximately 25 percent clay, 25 percent silt, and 50 percent calcite. This was determined by the relative amount of clay and silt left after the sample was dissolved in hydrochloric acid.

Channel samples were taken from every lithotope. This method consisted of taking samples representing the complete thickness of a lithotope. Channel sampling was used to obtain a better representation of faunal types. All samples consisted of unweathered material.

The measured sections were numbered in the order that they were described in the field. Each lithologic zone or lithotope of a measured section was numbered from top to bottom beginning with 1. A sample from the top of the twelfth measured section would be numbered 12-1.

Laboratory Procedures

Fifty samples from each of the different zones described in measured sections of the Bennett shale were prepared in the laboratory for microfossil identification.

Two methods of sample preparation were used. The first method made use of sodium hydroxide as a defloculation solution. A solution of 30 percent sodium hydroxide was added to a crushed sample. The mixture was allowed to set overnight to become thoroughly saturated. Then the sample was boiled from two to six hours, depending on the type of sample; the more indurated samples took longer. The sodium hydroxide method was suitable for shales, but it was inadequate for marls and argillaceous limestones.

In the second method a solution of 10 percent hydrogen peroxide, an oxidizing agent, was used. The hydrogen peroxide

was added to a crushed sample and allowed to set for two days. This permitted the hydrogen peroxide to oxidize the carbon and disintegrate the shale. After two days, water was added to dilute the hydrogen peroxide in the sample; the sample was then boiled for one hour. This method was more efficient and rapid in breaking down argillaceous limestones and the more indurated shales than was the sodium hydroxide method. Eighty percent of the samples were prepared by the use of the hydroxide peroxide method.

After treating the samples with either method, they were wet sieved. U. S. standard screens of 18, 35, and 120 meshes were used. After sieving the sample wet and washing away clay and other fine particles, the samples were placed in a crucible and dried in a gas oven at 150° F. for 20 minutes.

A number 00 sable hair brush, a black cardboard picking tray marked off in a one inch square grid, a binocular microscope and storage slides were used in scanning and picking microfossils from the samples.

A total of 10 grams of each sample, including 4 grams of 120 mesh material and 6 grams of 35 mesh material, was examined for microfossils. They were collected and put in storage slides. The best preserved specimens, representing the different genera and species, were selected for photographing. These specimens were glued to a glass plate and placed over a 6 X 8 inch shadow box, which was used as a black background to sharpen the image of the specimens in the photographs. The specimens were photo-

graphed at 30 times their normal size by the use of a 120 mm. Leitz camera.

STRATIGRAPHY

Red Eagle Limestone

The Red Eagle limestone of Permian age is a formation of the Council Grove group. Its members are the Howe limestone; the Bennett shale, subject of investigation; and the Glenrock limestone. The stratigraphic location of the Red Eagle limestone and its members is:

Wolfcampian Stage
- Chase Group
- Council Grove Group
  - Speiser Shale
  - Funston Limestone
  - Blue Rapids Shale
  - Crouse Limestone
  - Easly Creek Shale
  - Bader Limestone
  - Stearns Shale
  - Beattie Limestone
    - Morrill Limestone member
    - Florena Shale member
    - Cottonwood Limestone member
  - Eskridge Shale
  - Grenola Limestone
    - Neva Limestone member
    - Salem Point Shale member
    - Burr Limestone member
    - Legion Shale member
    - Sallyards Limestone member
  - Roca Shale
  - *Red Eagle Limestone
    - *Howe Limestone member
    - *Bennett Shale member
    - *Glenrock Limestone member
  - Johnson Shale
  - Foraker Limestone
    - Long Creek Limestone member
    - Hughes Creek Shale member
    - Americus Limestone
- Admire Group

Howe Limestone

Condra (1927, p. 86) named the Howe limestone from outcrops south of Howe, Nebraska. He described the Howe limestone:

> . . . in its unweathered condition, dark gray, massive, and dense, with considerable free calcite; weathers buff to yellowish, granular, vesicular or cavernous, and very irregular; thickness about 4 feet. This carries geodes at places. It has few fossils.

The Howe limestone in the area of investigation was characteristically well indurated and massive. It is predominantly a yellow-brown or a gray-yellow limestone which weathers yellow-gray, cavernous and very irregular. Due to poor resistance to weathering, it generally forms a poor outcrop. Fossils are scarce; however, a few fusulinids, crinoids, and high-spired gastropods were identified in places.

The Howe limestone had a tendency, in many instances, to become thin in places where the Bennett shale was thicker than normal. Thickness of the Howe limestone ranged from 1.7 to 5.1 feet. The average thickness was 4 feet.

Bennett Shale

The Bennett shale was named by Condra (1927, p. 86) from exposures along the Little Nemaha and its tributaries near Bennett, Nebraska. Condra described it as being

> . . . formed of bluish gray and nearly black argillaceous shale, with one carbonaceous streak resembling coal and a thin yellowish to brownish limestone; combined thickness 5 to 11 feet.
>
> Fauna: Orbiculoidea missouriensis, Lingula sp., Composita subtilita, Spirifer cameratus, and a few other species.

The Bennett shale in the area of investigation generally can be divided into a lower and an upper unit. The lower unit is characteristically olive-gray to dark gray shales. The unit generally was composed of slightly to moderately calcareous clay or mudshales. One or two beds of black, well-laminated clay-shales occur only in the Manhattan area. Orbiculoidea and conodonts were relatively abundant in these lower dark shales.

The upper unit of the Bennett shale was more calcareous than the lower dark shales. Several lithologies comprise this part of the Bennett shale. In the Manhattan area it was dominantly composed of a gray or an olive-gray mudstone facies. A local olive-gray siltstone lithotope overlays the olive-gray mudstone lithotope at measured section 11 near Manhattan. East and southward from Manhattan the mudstone grades into a dusky yellow mud-shale lithotope. Along Interstate Highway 70, from its intersection with state Highway 99 to Paxico and southward, several thin limestone lithotopes occur (Plate VI and Plate VII, Fig. 2). Brachiopods and ostracodes generally were abundant in these lithotopes. Diagnostic fossils do not occur in the upper unit of the Bennett shale. The upper unit of the Bennett shale has a greater variety of fossils.

Both units of the Bennett shale become more calcareous and generally thicken to the south. Its thickness varies from 2.8 to 7.7 feet. At measured section 9, the approximate location of the Nemaha anticline axis, the Bennett shale thins to 2.8 feet. This suggests that the Nemaha anticline was uplifted

during Bennett deposition.

Fossils of the Bennett shale were most abundant in limestones, mudstones and the calcareous, dusky yellow shales. A wide variety of ostracodes and foraminifera occur in these lithologies. In places, conodonts were abundant in the calcareous, dusky yellow shales.

Glenrock Limestone

The lowest member of the Red Eagle limestone is the Glenrock limestone. It was named by Condra (1927, p. 86) from exposures northwest of Glenrock, Nebraska. Condra describes the limestone as being a:

> . . . hard gray, dense, weathering light gray or slightly buff; thickness 1 to 2 feet. This forms a rectangular block. The leading fossils are fusulina, bryozoa, brachiopods, and Pinna sp.

The Glenrock limestone characteristically is dense in the area of investigation. It commonly is a yellow-gray limestone which weathers gray-yellow and blocky. Clay nodules from 0.02 to 0.20 inches in diameter are present in the limestone in measured sections 3 and 4 near Manhattan.

The Glenrock limestone was identified easily and was characterized by the presence of fusulinids. Echinoids, crinoids, and brachiopods are also present.

The thickness of the Glenrock limestone ranges from 0 to 1.9 feet. The limestone is absent from measured sections 11 and 12. Evidence was not found to indicate that the limestone was deposited in these areas. At section 12 along Interstate

Highway 70, fusulinids over 3 mm. in length, typical of the Glenrock limestone, occur near the base of the Bennett shale. This suggests that the Glenrock limestone probably grades laterally, in this area, into a calcareous mud-shale. The presence of a thick siltstone and absence of the Glenrock limestone at measured section 11 indicates the nearness of a source area for fine clastic sediments during Bennett and Glenrock deposition.

SYSTEMATIC DESCRIPTIONS OF OSTRACODA AND FORAMINIFERA MICROFAUNAS

The systematic description used by Benson (1960) from the "Treatise on Invertebrate Paleontology" was followed in the identification and classification of ostracodes. These descriptions ranged from subclass to generic levels, inclusive. Species descriptions were derived from other sources. Many of the species descriptions were taken from the "Catalogue of Ostracoda" (Ellis and Messina, 1952); most of the remaining descriptions were found in the "Journal of Paleontology."

The classification and the systematic description of foraminifera were based on classifications compiled by Cushman (1928). All descriptions of foraminifera species were acquired from the "Catalogue of Foraminifera" (Ellis and Messina, 1952) and from the "Journal of Paleontology."

Differences between the type specimens and the specimens of the Bennett shale belonging to the same species were discussed after each type description.

Phylum PROTOZOA

Class SARCODINA

Order FORAMINIFERA

Family AMMODISCIDAE

Subfamily AMMODISCINAE

Genus AMMODISCUS Reuss, 1861

AMMODISCUS Reuss, 1861 (Cushman, 1928, p. 99)

Ammodiscus Reuss, Sitz. Akad. Wiss. Wien, vol. 44, 1861, p. 365

Operculina (part) D'Orbigny, in De La Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, p. 49.

Orbis Strickland, Quart. Journ. Geol. Soc., vol. 2, 1848, p. 30 (not Orbis Philipps).

Spirillina Williamson, Rec. Foram. Great Britain, 1858, p. 93 (not Spirillina Ehrenberg, 1841).

Test free, planispiral, with a proloculum and long tubular undivided second chamber, coiled regularly in one plane; wall finely arenaceous with a large proportion of yellowish or reddish-brown cement, surface smooth; aperture formed by the open end of the chamber.

Silurian to Recent. Recent species widely distributed, most abundant in colder and deeper waters, but occasionally in warm shallow water. Specimens are very abundant in the Pennsylvanian.

AMMODISCUS SEMICONSTRICTUS Waters, 1927

(Plate II, Figure 2.)

AMMODISCUS SEMICONSTRICTUS Waters, 1927 (Ellis and Messina, 1940, Vol. 1)

Type Reference: Waters, J. A., "A group of foraminifera from the Dornick Hills formation of the Ardmore Basin. "Jour. Pal., Menasha, Wis., U. S. A., 1927, vol. 1, p. 132.

Type Description: "Test nearly circular, planispiral, biconcave; proloculum small, ovoid; tubular second chamber oval in transverse section, irregularly constricted, open at the terminal end, about nine coils in the

adult test; wall coarsely arenaceous, the sand grains cemented with a small proportion of cement; aperture a circular opening at the end of the tubular chamber; color, white. Diameter of test, 1 mm.; diameter of tube at aperture, 0.1 mm.; thickness of wall at aperture, 0.03 mm. This species differs from Ammodiscus incertus d'Orbigny in the very marked constrictions of the tubular chamber and the smaller proportion of cement. The wall is proportionately thick as is indicated in Figure 1d. In some respects, the species resembles Trochamminoides especially in the more definitely constricted specimens."

Type Level: Lower Pennsylvanian. Dornick Hills formation of Ardmore Basin in shales between Jolliff and Otterville limestones.

Type Locality: SE¼ Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma, U. S. A.

Discussion: Tests collected by the author are all finely arenaceous. A few irregular constrictions are on the second chambers of the specimens. The number of coils of the writer's specimens range from five to seven. All the forms identified are smaller than the type specimen.

The test diameter of the figured specimen is 0.31 mm.

The figured form was in a black, clay-shale along a railroad cut at Manhattan, Riley County, Kansas (measured section No. 2-2).

Family LITUOLIDAE

Subfamily HAPLOPHRAGMIINAE

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES Cushman, 1910 (Cushman, 1928, p. 107)

Ammobaculites Cushman, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 114.

Spirolina (part) D'Orbigny, For. Foss Bass. Tert. Vienne, 1846, p. 137.

Haplophragmium (part) of authors.

Test free, the early chambers close coiled, later ones uncoiling with typically a linear series of chambers, simple; wall arenaceous with a chitinous lining; aperture in the early stages at the base of the apertural face, in the adult circular and terminal.

Carboniferous to Recent. There is a wide range of habitat in the present ocean, some species only found in cold, deep water, others in very shallow warm waters of the tropics.

AMMOBACULITES STORMI Cushman and Waters, 1928

(Plate II, Figure 1)

AMMOBACULITES STORMI Cushman and Waters, 1928 (Ellis and Messina, 1940, Vol. 1)

Type Reference: Cushman, J. A. and J. A. Waters, "Some foraminifera from the Pennsylvanian and Permian of Texas." Contr. Cushman Lab. Foram, Res., Sharon, Mass., U. S. A., 1928, vol. 4, pt. 2, no. 59, p. 41.

Type Description: "Test short and stout, periphery broadly curved, early chambers close coiled, planispiral, usually five in a coil, later chambers in a rectilinear series, typically three, circular in transverse section; sutures distinct but only slightly depressed; wall finely arenaceous, of small grains of uniform size with a large proportion of cement, smoothly finished; aperture large, circular in the adult. Length 0.50 mm.; breadth of coiled portion 0.35 mm.; diameter of adult chambers 0.20 mm.

"The species is a short, stout one with very smooth surface. The early stages may be easily mistaken for Endothyra."

Type Level: Pennsylvanian. Strawn, 25 feet below the Palopinto limestone.

Type Locality: Nine miles E. of Graford, Palopinto Co., Texas, U. S. A.

Discussion: All specimens, except one which is slightly larger, are smaller than the holotype. Either three or four chambers form a rectilinear series. The figured specimen has eight chambers in a coil and three other chambers which forms

a rectilinear series.

Measurements of the figured specimen are: length 0.56 mm., breadth of the coiled portion is 0.36 mm., and diameter of adult chambers 0.21 mm.

The figured specimen of A. stormi was in an olive-gray, slightly calcareous, clay-shale in a road cut along the spur of U. S. 24 near Manhattan, Riley Co., Kansas (measured section no. 1-2).

Family FUSULINIDAE

Subfamily FUSULININAE

Genus STAFFELLA Ozawa, 1925

STAFFELLA Ozawa, 1925 (Cushman, 1928, p. 131)

Staffella Ozawa, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, art. 4, 1925, p. 24.

Fusulina (part) Abich, Mem. Acad. Imp. Sci., St. Petersbourg, ser. 6, vol. 7, 1859, p. 418.

Fusulinella (part) Moller, l. c., ser. 7, vol. 25, no. 9, 1878, p. 114.

Fusulinella Staff, Neues Jahrb., Beil. Bd. 27, 1909, p. 486 (not of Moller).

Test lenticular or spheroidal; axis of the volutions making the smaller diameter; wall composed of median lamella, mesh-structure and deposition layers, of which the mesh-structure is often indistinct or obsolute, septa almost plane and pierced by a relatively large, single buccal aperture.

Carboniferous to Permian.

STAFFELLA CISCOENSIS Harlton

(Plate II, Figure 5)

STAFFELLA CISCOENSIS Harlton (Cushman, 1928, p. 307)

Test free, very small, closely coiled, biconvex, chambers numerous, peripheral margin acute; sutures limbate, the thickenings developed in a raised clear ridge; wall calcareous, smooth; aperture single, large, at the apertural face. Diameter, 0.35 mm. more or less.

Cisco formation, 4 1/2 miles west of Cisco, on main Cisco-Abilene Road, Eastland County, Texas. Cotype, U. S. National Museum Coll., No. 71729.

This minute organism is characterized by its hyaline texture and the curved suture lines which in most cases are indistinct. The surface appears to be finely perforate. This form is very common at the type locality.

Discussion: The specimens collected by the author adhered more closely to the description of S. ciscoensis than to that of other described species; but there are still several points of disagreement with Harlton's type description. All the specimens of S. ciscoensis are larger than the type description. Instead of being finely perforated, they are finely granular. Also, the limbate sutures do not form a raised ridge as mentioned in the type description. The aperture face of the specimens are covered with matrix, thus making the identification of the aperture type impossible. These disagreements may warrant erection of a new species of Staffella.

The diameter of the test is 0.45 mm.

The figured specimen was in a dusky yellow, calcareous, mudshale along a road cut on Interstate Highway 70, three miles east of Paxico, Wabaunsee County, Kansas (measured section no. 7-1).

STAFFELLA KEYTEI Roth and Skinner

(Plate II, Figures 6 and 7)

STAFFELLA KEYTEI Roth and Skinner (Howe, 1930, p. 347)

Test minute, sub-globular, the axis of coiling being the shortest diameter. Length 0.55 mm., and width 0.64 mm. Form ratio is about 1:0.86. Shells of this size possess about 5 whorls.

The numerous septa are straight, or nearly so, and apparently are not porous. Septal count of the figured specimen is 10-16-19-22-26.

Chomata are strongly developed, especially for a shell having such thin walls. Aperture rounded, relatively large but increasing very slowly with the growth of the shell. The tunnel angle measures approximately 15 degrees. Proloculum minute, varying from 31 to 60 u. in diameter. Walls very thin, measuring about 24 u. in the fourth whorl and displaying typical non-alveolar structure.

The species is named for Dr. I. A. Keyte of Colorado Springs.

Collections 174, 175 and 177.

Discussion: Only one specimen of S. keytei, smaller than Roth and Skinner's form, was identified. The aperture face is covered with matrix. A dark spot in this area may be the location of the aperture.

Measurements of the specimen are: length 0.2 mm., and width 0.26 mm.

The specimen was in a dusky yellow, calcareous, mud-shale in a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee County, Kansas (measured section no. 7-1).

Family TROCHAMMINIDAE

Subfamily TROCHAMMININAE

Genus GLOBIVALVULINA Schubert, 1920

GLOBIVALVULINA Schubert, 1920 (Cushman, 1928, p. 171)

Globivalvulina Schubert, Pal. Zeitschr., vol. 3, 1920, p. 153.

Valvulina (part) H. B. Brady (not D'Orbigny), Pal. Soc. Mon. 30, 1876, p. 89.

Test trochoid, subglobular or plano-convex, the ventral side flattened, dorsal side strongly convex; periphery rounded; chambers inflated, few; wall finely arenaceous with much cement, the main wall perforate, occasionally appearing with a thin outer layer; aperture low, arched, at the umbilical margin of the last-formed chamber.

Paleozoic. Pennsylvanian and Permian.

GLOBIVALVULINA BISERIALIS Cushman and Waters, 1928

(Plate II, Figure 9)

GLOBIVALVULINA BISERIALIS Cushman and Waters, 1928 (Ellis and Messina, Vol. 10)

Type Reference: Cushman, J. A., and J. A. Waters, "Additional Cisco foraminifera from Texas." Contr. Cushman Lab. Foram. Res., Sharon, Mass., U. S. A., 1928, vol. 4, pt. 3, no. 61, p. 64.

Type Description: "Test essentially biserial, the early portion covered by the later coils, whole test hemispherical, chambers added alternately on either side of an elongate axis, each strongly overlapping the preceding ones; chambers from the surface elongate, elliptical, due to the overlapping; sutures depressed, distinct; wall finely arenaceous, smoothly finished; aperture on the ventral side of the test in a broad depression with a distinct valvular projection of the chamber. Diameter 0.50 mm.; height 0.22 mm.

"This species may be distinguished from the others of the genus by the peculiar 'braided' appearance, all the chambers, even the last-formed one, being on opposite sides of the nearly straight axis."

Type Level: Pennsylvanian. Graham formation of the Cisco.

Type Locality: Bunger limestone, 3.2 miles Northeast of South Bend, Young Co., Texas, U. S. A.

Discussion: Only one specimen of G. biserialis was identified. It agrees with all points of the type description except that it has a smaller diameter and a greater height than the holotype.

Dimensions of the figured specimen are: diameter 0.37 mm., and the height 0.27 mm.

The specimen was in a dusky yellow, calcareous mud-shale from a stream bank along a branch of McDowell's Creek, Riley Co., Kansas (measured section no. 11-4).

GLOBIVALVULINA CORA Harlton, 1928

(Plate II, Figure 10)

GLOBIVALVULINA CORA Harlton, 1928 (Ellis and Messina, Vol. 10)

Type Reference: Harlton, B. H., "Pennsylvanian foraminifera of Oklahoma and Texas." Jour. Pal., Menasha, Wis., U. S. A., 1928, vol. 1, p. 309.

Type Description: "Test free, more or less rounded; chambers few inflated, subspherical, each succeeding one considerably larger than its predecessor, seven visible from the apertural face; on the opposite side five visible; inferior surface slightly concave; wall calcareous, very finely perforate, smooth; aperture an arched slit into the umbilicus. Diameter of holotype, 0.46 mm. The most characteristic feature of this species is the very rapid increase of size of the successive chambers, which are strongly inflated."

Type Level: Pennsylvanian. Gaptank formation.

Type Locality: 4 miles west of Marathon, along railroad cut near mile post 580, Brewster County, Texas, U. S. A.

Discussion: All the specimens collected by the author are slightly smaller than the holotype; in all other respects they agreed.

The diameter of the figured specimen is 0.35 mm.

The figured specimen was in a pale olive, mottled dark gray, marl in a road cut near the intersection of Interstate 70 and Highway 99, Wabaunsee County, Kansas.

GLOBIVALVULINA OVATA Cushman and Waters, 1928

(Plate II, Figure 8)

GLOBIVALVULINA OVATA Cushman and Waters, 1928 (Ellis and Messina, 1940, Vol. 10)

Type Reference: Cushman, J. A., and J. A. Waters, "Additional Cisco foraminifera from Texas." Contr. Cushman Lab. Foram. Res., Sharon, Mass., U. S. A., 1928, vol. 4, pt. 3, no. 61, p. 65.

Type Description: "Test mainly biserial, the whole test ovate, chambers except the final one added alternately on either side of an elongate axis, each slightly overlapping the preceding ones; chambers from the surface broadly elliptical; sutures depressed, distinct; wall finely arenaceous, smoothly finished; aperture on the ventral side of the test in a very broad depression, with a slight valvular projection. Diameter 0.50 mm.; height 0.30 mm.

"This species may be distinguished from the preceding (Globivalvulina biserialis Cushman and Waters) by the final chamber extending clear across the periphery breaking the biserial series, the broader exposure of the chambers on the surface due to the slighter overlap."

Type Level: Pennsylvanian. Graham formation of the Cisco.

Type Locality: One foot below the Gunsight limestone, 1 mile West of Graham, Young Co., Texas, U. S. A.

Discussion: No specimens of G. ovata identified had a diameter as large as the holotype. The specimens agree with all other points of the type description.

Dimensions of the figured specimen are diameter 0.33 mm. and height 0.30 mm.

The figured specimen was in a pale olive, calcareous, mudshale in a stream bank along Mill Creek, six miles south of Alma, Wabaunsee County, Kansas (measured section no. 13-1).

Family ORBITOLINIDAE

Genus TETRATAXIS Ehrenberg, 1843

TETRATAXIS Ehrenberg, 1843 (Cushman, 1928, p. 179)

Tetrataxis Ehrenberg, Bericht. Preuss. Akad. Wiss. Berlin, 1843, p. 106.

Valvulina (part) H. B. Brady (not D'Orbigny), Pal. Soc. Mon. 30, 1876, p. 81.

Test conical, consisting of a proloculum and elongate second chamber, later broken up into elongate, crescentic chambers which may be divided into chamberlets in some species; aperture elongate, at the margin of the umbilical border of the chamber.

Carboniferous and Permian.

TETRATAXIS CORONA Cushman and Waters, 1928

(Plate II, Figure 4)

TETRATAXIS CORONA Cushman and Waters, 1928 (Ellis and Messina, 1940, Vol. 25)

Type Reference: Cushman, J. A., and J. A. Waters, "Additional Cisco foraminifera from Texas." Contr. Cushman Lab. Foram. Res., Sharon, Mass., U. S. A., 1928, vol. 4, pt. 3, no. 61, p. 65.

Type Description: "Test with the central portion high, rounded conical, the later portion spreading, in side view concave; chambers of the early portion less distinct than the later, spreading ones, early developing in four series; sutures distinct in later development, slightly depressed, less distinct in the early portion; wall fairly smooth, the outer arenaceous layer more marked in the conical young. Diameter 0.50 mm.; height 0.20 mm.

"This is a very fine little species with the early portion in a rounded conical shape and the later chambers flaring. It does not attain a large size."

Type Level: Pennsylvanian. Graham formation of the Cisco. Other level: Pueblo formation of the Cisco.

Type Locality: Five feet above the Gunsight limestone, one mile West of Graham, Young Co. Other locality: 1 1/2 miles Northeast of Camp Colorado, Coleman Co., Texas, U. S. A.

Discussion: Most of the specimens are smaller than the form described by Cushman and Waters. The author's specimens fit all other points of the type description.

Measurements of the figured specimen are: length 0.41 mm., and height 0.17 mm.

The figured specimen was in a light olive-gray marl in a road cut along Riley County Road 911, west of Deep Creek (measured section no. 10-2).

Family PTYCHOCLADIIDAE

Genus BDELLOIDINA Carter, 1877

BDELLOIDINA Carter, 1877 (Elias, 1950, p. 301)

> Test adherent, depressed; consisting of a number of closely approximated chambers, arranged more or less regularly in a single, simple or branched, linear series, and intercommunicating by a row of pores on each septal face. Segments very short (on the axis of growth) and broad; curved or irregular in outline; subdivided more or less completely by numerous secondary septa. Walls rough externally, inferior surface smooth. Aperture porous. Diameter of the adherent patches 1/6 inch (4 mm.) or more.

BDELLOIDINA (?) PERMICA Elias, 1950

(Plate II, Figure 4)

BDELLOIDINA (?) PERMICA Elias, 1950 (Elias, 1950, p. 302)

> All specimens are silicified, being obtained by hydrochloric acid etching from a small specimen of limestone. There is hardly any doubt that silicification is secondary, because all other invertebrate fossils, which are normally calcareous and have been also obtained from the same rock, are similarly silicified.
>
> Some specimens have been recovered with the substratum silicified and attached to them. In all these cases the substratum was either spines of brachiopods or subcylindrical branches of Bryozoa, so that it appears as if some hard cylindrical surfaces were generally selected for the attachment and development of this foraminifer. However, the ventral or adoral side of the conch, which is invariably

concave, does not seem to be a mere reflection of the cylindrical surfaces of the substratum, but is gentler, wider, and more nearly regularly concave, than the convex surfaces of the substratum. The uniserial sequences of the chambers are dorsoventrally compressed, the dorsal side being very gently convex. Height of the chamber varies from 0.03 to 0.1 mm; width from 0.1 to 0.5 mm. The longest obtained incomplete growth form is about 2.2 mm. long. External and internal surfaces of wall more or less smooth. The thickness of wall about 0.02-0.03 mm.

All specimens from the brown fossiliferous limestone from the Wolfcamp series (Lower Permian), Glass Mountains, Texas; collected by King and King.

Discussion: Only one specimen of B. (?) permica was identified. The author's specimen has a calcareous test with a hyaline texture. The specimen also seems to be faintly granular. All other points of this writer's specimen are in accord with Elias' type description.

The dimensions of the specimen are: height of chambers 0.03 mm. to 0.09 mm., length 0.61 mm., and width 0.06 mm. to 0.17 mm. There are a total of 10 chambers.

The specimen of B. (?) permica was in a dusky yellow, calcareous mud-shale along a road cut on Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

Phylum ARTHROPODA

Class CRUSTACEA

Subclass OSTRACODA Latreille, 1806

Order PALAEOCOPIDA Henningsmoen, 1953

Suborder BEYRICHICOPINA Scott, n. suborder

Superfamily HOLLINACEA Swartz, 1936

Family HOLLINIDAE Swartz, 1936

Genus HOLLINA Ulrich and Bassler, 1908

HOLLINA Ulrich and Bassler, 1908 (Ellis and Messina, 1952, Vol. 2.)

Type Reference: Ulrich, E. O., and R. S. Bassler, "New American Paleozoic Ostracoda; Preliminary revision of the Beyrichiidae, with descriptions of new genera." U. S. Nat. Mus., Proc., Washington, D. C., 1908, vol. 35, no. 1646, p. 315.

Type Description: "Carapace elongate, produced and tapering somewhat anteriorly, essentially equivalved. Valves provided with a marginal frill, concave on the inner side, overhanging the contact edge, often wanting at the anterior end. Except for two constant rounded nodes, the lobation of the surface varies greatly. One of the constant nodes is situated close to and partly in front of the middle of the hinge line; the other, usually the smaller, is placed lower and more or less behind the center of the valve. Occasionally the hollow between these two nodes is excavated. In most species there is a continuous or broken ridge in the ventral part; in one (Hollina kolmodini) this ridge continues up the hinder end to the dorsal angle; in others (Hollina insolens and Hollina tricollina) the post-dorsal extremity remains prominent and forms a rounded node, the remainder of the ridge being dissected and tending to obsolescence; in two other species (Hollina granifera and Hollina antespinosa) the ventral ridge joins the two constant nodes, the result being a loop as in Bollia. Finally, in a later stage (as, for instance, in Hollina radiata), the ventral ridge is obsolete and only two rounded nodes remain. Occasionally an extra node is developed near the anterior margin. A ventral pouch, as in Beyrichia, has not been observed.

HOLLINA BASSLERI Knight, 1928

(Plate II, Figures 18 and 19)

HOLLINA BASSLERI Knight, 1928, (Ellis and Messina, 1952, Vol. 2)

Type Reference: Knight, J. B., "Some Pennsylvanian ostracodes from the Henrietta formation of eastern Missouri; Part I." Jour. Pal., Bridgewater, Mass., 1928, vol. 2, no. 3, p. 240.

Type Description: "Outline, neglecting the frill and nodes, entirely similar to Hollina buehleri Knight. The anterior node, is, however, slightly less prominent; the frill is reduced to a linear row of papillae or short spines somewhat uneven in length, which occupies the exact position of the frill in preceding species (Hollina buehleri, Hollina fortscottensis Knight, and Hollina ulrichi Knight) and unquestionably is its morphological equivalent. A second row of spines extends around the ventral and end margins close to the margin of the valve and reaches almost if not quite to the hinge-line at both ends. The latter row is irregularly two ranks deep. The ventral and end margins of the left valve are slightly beveled as in Hollina buehleri and also carry the marginal row of minute beads. I have no right valves. The surface of the valves is minutely but strikingly papillose.

The dimensions of the specimen figured are:

Length	0.97 mm.
Height	0.56 mm.

Type Level: Pennsylvanian, Desmoinesian, Henrietta group, upper Fort Scott limestone, in shale partings.

Type Locality: Locality 38 (exposure in south bank of creek east of Price Road and south of Ladue Road, just east of Ladue village, St. Louis County, Missouri; fide Knight, 1928, Jour. Pal., vol. 2, no. 4, p. 337).

Discussion: All specimens of H. bassleri are smaller than the holotype described by Knight. All other points are in agreement with the type description.

Measurements of figured specimens are as follows:

	Length	Height
Plate II Figure 18	0.90 mm.	0.50 mm.
Plate II Figure 19	0.60 mm.	0.32 mm.

The figured specimens were in a pale olive, calcareous, mud-shale at the intersection of Kansas Highway 99 and Interstate Highway 70 in Wabaunsee Co., Kansas (measured section no. 12-1).

Genus HOLLINELLA Coryell, 1928

HOLLINELLA Coryell, 1928 (Ellis and Messina, 1952, Vol. 2)

Type Reference: Coryell, H. N., "Some new Pennsylvanian Ostracoda." Jour. Pal., Bridgewater, Mass., 1928, vol. 2, no. 4, p. 378.

Type Description: "Small, subquadrangular, equivalved, and straight-hinge-lined ostracods; the surface of each valve is finely or coarsely granulose, with a median sinus lying in the dorsal half, about which an irregular U-shaped swelling rises; the dorsal ends of the swelling are raised into prominent lobes, the anterior one larger and more regularly hemispherical than the posterior; the free margin may be bordered with a low ridge, a broken or continuous row of spine-like extensions, or there may be no marginal ornamentation present. The genus Hollinella includes ten undescribed species besides the three new ones described here (Hollinella dentata, Hollinella ovata and Hollinella regularis Coryell, 1928), Family Beyrichiidae, Pennsylvanian."

Type Species: Genoholotype: Hollinella dentata Coryell, 1928.

HOLLINELLA CUSHMANI Kellett, 1933

(Plate 11, Figure 17)

HOLLINELLA CUSHMANI Kellett, 1933 (Ellis and Messina, 1953, Vol. 3)

Type Reference: Kellett, B., "Ostracodes of the Upper Pennsylvanian and the Lower Permian strata of Kansas; I - The Aparchitidae, Beyrichiidae, Glyptopleuridae, Kloedenellidae, Kirkbyidae, and Youngiellidae." Jour. Pal., Menasha, Wis., 1933, vol. 7, no. 1, p. 71.

Type Description: "Carapace short and high for genus, moderately oblique; nodes of average diameter, low and evenly convex, sulcus rather shallow; frill of the widest-frilled form of medium width and not very convex, not confluent with the general surface of the valves at any point,

but separated all along by a slight depression. On the smaller specimen, the frill is replaced by a row of short tubercles. Surface finely granular. Measurements of the holotype: Length 1.09 mm., height 0.73 mm.

Type Level: Upper Pennsylvanian, middle Virgilian, Shawnee group, Deer Creek formation, in shaly beds overlying Ervine Creek limestone member.

Type Locality: Locality 18, railroad cut near Kansas River, just west of the Shawnee-Douglas County line crossing Highway 10, Shawnee County, Kansas.

Discussion: Some small denticles are along the post-erodorsal margin; these are not mentioned in the type description. In other respects the Bennett shale specimen agrees.

Dimensions of the figured specimen are: length 1.10 mm. and height 0.77 mm.

One specimen of H. cushmani was identified. It was in a dusky yellow, calcareous, mud-shale in a road cut along Riley County road 911, west of Deep Creek (measured section 10-1).

HOLLINELLA DIGITATA Kellett, 1929

(Plate 11, Figures 14 and 15)

HOLLINELLA DIGITATA Kellett, 1929 (Ellis and Messina, 1953, Vol. 2)

Type Reference: Kellett, B., "The ostracode genus Hollinella, expansion of the genus and description of some Carboniferous species." Jour. Pal., Austin, Texas, 1929, vol. 3, no. 2, p. 209.

Type Description: "Only females have been found. A number of well preserved specimens of Hollinella digitata were found about four miles from the locality of those described by Ulrich and Bassler. Complete specimens bear a medium to long, thick spine terminating the anterior of the frill and extending obliquely to perpendicularly away from the valve. In one specimen this spine is so much developed as to be sickle-shaped and about one-half the length of the valve. Hollinella digitata has also the marginal structure described in the above Hollinellas (Hollinella crassamarginata Kellett, H. emaciata (Ulrich

and Bassler) (Beyrichia? emaciata, 1906), H. gibbosa Kellett, H. nevensis Kellett and H. shawnensis Kellett). The cardinal spines on the right valve are extremely well developed, the anterior one usually the larger, with the hinge line not altogether straight but sloping slightly up in front of the anterior node to the cardinal spine. The difference in the convexity of the frills noted in the original description would seem, after studying the other Kansas Hollinas (see Hollinella Coryell, emend. Kellett, 1929), to be due to sex rather than to age. The frill of the non-productive female is wide, and at the post-dorsal angle flat and arising close to the edge of the valve, but it is not convex, while that of the productive female is extremely convex posteriorly and cuts obliquely across the post-ventral angle.

Length	1.12 mm.
Height	0.60 mm.

Type Level: Lower Permian, uppermost part of the Council Grove group, top of the Garrison shale. Occurs also in the Cottonwood Falls limestone, underlying the Garrison in the Council Grove group (locality 44), and in the basal part of the Chase group, Wreford limestone, overlying the Garrison (locality 43). Ulrich and Bassler's specimens from the "Cottonwood shale" (= Florena shale member of the Garrison formation).

Type Locality: Locality 68a, along Highway 50S, 2 1/2 miles west of Cottonwood Falls, Chase County, Kansas. Found also at locality 43, along Highway 40, opposite Soldier's Monument, Camp Funston, Geary County, and at locality 44, along Highway 40, at Ogden, Riley County; both in Kansas. Ulrich and Bassler's specimens from 2 miles east of Cottonwood Falls, Chase County, Kansas.

Discussion: The hinge line of some specimens does not slope up before the anterior node as described by Kellett. All other characteristics of those specimens collected agree in general with the H. digitata type description. No non-productive H. digitata females were identified.

Measurements of the figured specimens are:

	Length	Height
Plate II Figure 15	1.13 mm.	0.65 mm.
Plate II Figure 14	1.04 mm.	0.71 mm.

The figured specimens of H. digitata were in a dusky yellow, calcareous, mud-shale in a road cut along Riley County road 911, west of Deep Creek (measured section no. 10-1).

HOLLINELLA EMACIATA Ulrich and Bassler

(Plate 11, Figure 16)

HOLLINELLA EMACIATA Ulrich and Bassler (Cooper, 1946, p. 91)

Beyrichia? emaciata Ulrich and Bassler, 1906, U. S. Nat. Museum Proc., vol. 30, p. 157, pl. 1, fig. 6; Wreford limestone, Kansas.

Hollina emaciata Ulrich and Bassler, 1908, U. S. Nat. Museum Proc., vol. 35, p. 315.

Hollinella emaciata, Kellett, 1929, Jour. Paleontology, vol. 3, p. 202, pl. 25, figs. 1a-c; Cottonwood and Ft. Riley formations, Kansas.

Carapace subtrapeziform; hinge fairly short; frill narrow, outer rim thickened; anterior node large, flat, upper edge even with hinge line; posterior node small, low, and indistinct, especially on posteroventral margin where it merges imperceptibly with the shell surface; surface pitted, anterior surface and edge spinose.

Length, 1.08 mm.; height 0.57 mm.; width, 0.51 mm.

Discussion: The author identified only one specimen of H. emaciata. There are three points of discrepancy between the specimen found and the description given by Cooper: the anterior node is slightly below the hinge line; the anterior edge is not spinose; and the specimen is larger. The size modification may be because of the writer's specimen being slightly crushed.

Measurements of the figured specimen are: length 1.20 mm., and 0.46 mm.

The figured specimen was in a medium gray, argillaceous, limestone along the north bank of Mill Creek six miles south of Alma, Wabaunsee Co., Kansas, (measured section no. 13-2).

HOLLINELLA GIBBOSA Kellett, 1929

(Plate 11, Figures 11 and 12)

HOLLINELLA GIBBOSA Kellett, 1929 (Ellis and Messina, 1953, Vol. 2)

Type Reference: Kellett, B., "The ostracode genus Hollinella, expansion of the genus and description of some Carboniferous species." Jour. Pal., Austin, Texas, 1929, vol. 3, no. 2, p. 207.

Type Description: "Female. - Carapace semiovate to rhomboidal, length about twice the height, anterior end slightly rounded, posterior obliquely truncate dorsally and rounding below into the ventral margin. Marginal and hinge structure typical of the genus. An even row of minute beads bordering the beveling on the left valve. Cardinal spines on right valve prominent. Sulcus behind center of hinge line rather short and wide. Anterior node set up above the general surface of the valve, bulbous and somewhat constricted at the base. Posterior node of a small diameter but often well raised above the posterior surface of the valve--somewhat inflated. Ridge beneath the sulcus having a slight to a prominent curve, and sometimes quite gibbous, especially on those forms occurring near the top of the Pennsylvanian. Generally, convexity of the valve not great. Frill on non-productive female fairly wide and beginning with an elevated spine which rises about three-fourths of the way down the anterior margin at a little distance from the edge of the valve, the frill continuing downward and backward so that at the posteroventral angle it follows the edge of the valve closely. On a closed carapace the frills diverge anteriorly but become almost parallel at the postero-ventral angle. The wider frill of the productive female is posteriorly set up on the valve at a little distance from the margin, and is very convex. A depression occurs along the junction of the frill with the valve. On both female forms the frill widens at the postero-ventral angle and then narrows suddenly, dying out before it reaches the hinge line.

Anterior margin bordered by a few short irregular spines. Surface finely granular, granules extending up on the frill. A few very short papillae on anterior node and in front of it, sometimes arranged in a diagonal line running backward.

Hollinella gibbosa is very closely related to Hollinella bassleri (Knight) (Hollina bassleri, 1928), as the species is enlarged above (see Hollinella Coryell, emend. Kellett, 1929), but Hollinella bassleri is more tumid and slopes more toward the dorsal and ventral margins, with the anterior

node on the ventral slope instead of being nearly level as is that of Hollinella gibbosa. The nodes, especially the posterior, are less globular and restricted at the base than those of Hollinella gibbosa. The frill of Hollinella bassleri is of more even width and is wider posteriorly, extends farther up toward the inge line both anteriorly and posteriorly, is more elevated, especially at the postero-ventral angle, and is less convex on the productive female.

	Productive female		Non-productive female	Male
	Large	Medium		
Length	1.36 mm.	1.24 mm.	1.18 mm.	1.12 mm.
Height	0.89 mm.	0.72 mm.	0.63 mm.	0.63 mm.

Type Level: Holotype from Lower Permian, Council Grove group, Americus? limestone.

Type Locality: Holotype from locality 40, road cut at foot of hill about 1 mile west of Belvue, Wamego County, Kansas.

Discussion: All specimens of H. gibbosa agree in general with the type description. The one non-productive female (Fig. 11) identified has a highly elevated spine approximately 3/4 of the way down the anterior margin. This writer identified some frilless forms, assumed to be males or the young, with the H. gibbosa females.

The dimensions of the figured specimens are:

	Length	Height
Plate II Figure 11	1.11 mm.	0.72 mm.
Plate II Figure 12	1.10 mm.	0.65 mm.

The figured specimens were in an olive-gray, calcareous, mudstone along the north side of a Chicago Rock Island and Union Pacific Railroad cut in Manhattan, Riley County, Kansas (measured section no. 2-1).

HOLLINELLA MOOREI Cooper

(Plate 11, Figure 13)

HOLLINELLA MOOREI Cooper (Cooper, 1946, p. 94)

Basslerina regularis Moore, 1929, Denison Univ. Jour. Sci. Lab. vol. 24, p. 108, pl. 6, fig. 3; pl. 8, figs. 7, 8, 15; Grahm group, Texas.

Hollinella bassleri Coryell and Billings, 1932 (not Knight), Am. Midland Naturalist, vol. 13, p. 185, pl. 18, fig. 4; Wayland shale, Texas.

Carapace large, slightly flat, somewhat elongate, with little forward "swing"; hinge almost as long as shell; anterior node large, hemispherical, standing slightly above hinge line; posterior node one-fifth to one-fourth as large, low, and inconspicuous; surface coarsely punctate, devoid of spinelets except near anterior margin and an occasional one near hinge line; flange relatively narrow, flaring terminated by large blunt spine.

Length, 1.10 mm.; height, 0.60 mm. Shumway zone, locality 112.

Discussion: Only one H. moorei specimen, larger than the form described by Cooper, was identified. The anterior margin is missing; therefore, certain of its characteristics could not be observed in this study.

The measurements of the figured specimen are: length greater than 1.02 mm. and height 0.69 mm.

The broken specimen of H. moorei was in a light olive-gray, calcareous, mud-shale in a road cut along Riley County road 911, west of Deep Creek (measured section no. 10-2).

Superfamily KIRKBYACEA Ulrich & Bassler, 1906

Family KIRKBYIDAE Ulrich & Bassler, 1906

Genus KIRKBYA Jones, 1859

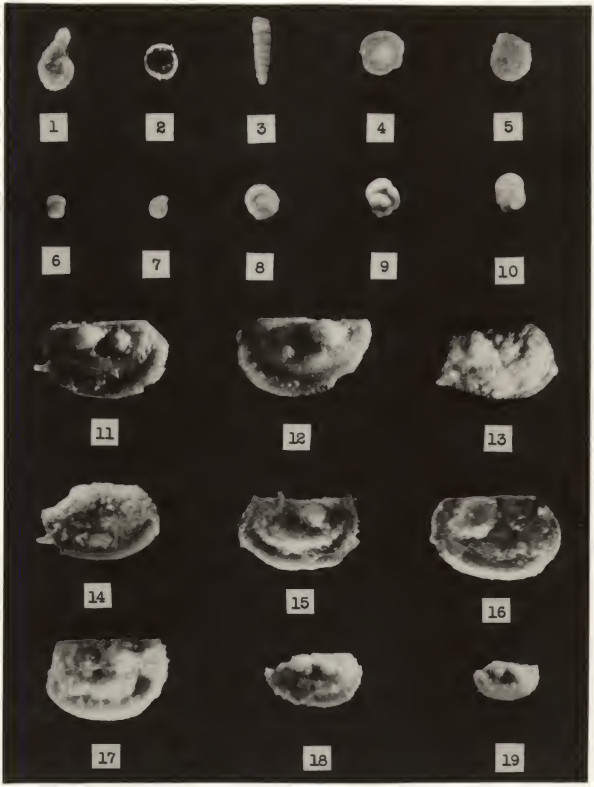
KIRKBYA Jones, 1859 (Benson and others, 1961, p. Q164)

EXPLANATION OF PLATE II

(All specimens 30x.)

Fig. 1. Ammobaculites stormi Cushman and Waters; side view. (p. 16)
Fig. 2. Ammodiscus semiconstrictus Waters; side view. (p. 14)
Fig. 3. Bdelloidina (?) permica Elias; side view. (p. 24)
Fig. 4. Tetrataxis corona Cushman and Waters; dorsal view. (p. 23)
Fig. 5. Staffela ciscoensis Harlton; side view. (p. 17)
Fig. 6. Staffela keytei Roth and Skinner; apertural view. Apertural and side views the same specimen. (p. 18)
Fig. 7. Staffela keytei Roth and Skinner; side view. (p. 18)
Fig. 8. Globivalvulina ovata Cushman and Waters; dorsal view. (p. 22)
Fig. 9. Globivalvulina biserialis Cushman and Waters; dorsal view. (p. 20)
Fig. 10. Globivalvulina cora Harlton; dorsal view. (p. 21)
Fig. 11. Hollinella gibbosa Kellett; lateral view, left valve, anterior end to the left. (p. 32)
Fig. 12. Hollinella gibbosa Kellett; lateral view, right valve, anterior end to the right. (p. 32)
Fig. 13. Hollinella moorei Cooper n. sp; lateral view, left valve, anterior end to the left. Portion of anterior end missing. (p. 34)
Fig. 14. Hollinella digitata Kellett; lateral view, left valve, anterior end to the left. (p. 29)
Fig. 15. Hollinella digitata Kellett; lateral view, right valve, anterior end to the right. (p. 29)
Fig. 16. Hollinella emaciata (Ulrich and Bassler); lateral view, left valve, anterior end to the left. (p. 31)
Fig. 17. Hollinella cushmani Kellett; lateral view, right valve, anterior end to the right. (p. 28)
Fig. 18. Hollina bassleri Knight; lateral view, left valve, anterior end to the left. (p. 27)
Fig. 19. Hollina bassleri Knight; lateral view, right valve, anterior end to the right. (p. 27)

PLATE II



Elongate, greatest length at or near dorsal margin; posterior cardinal angle acute; lateral surface evenly convex or with posterior shoulder; 2 marginal rims. L. Miss. - M. Perm.

KIRKBYA CANYONENSIS Harlton, 1929

(Plate III, Figure 1)

KIRKBYA CANYONENSIS Harlton, 1929 (Ellis and Messina, 1954, Vol. 5)

Type Reference: Harlton, B. H., "Pennsylvanian Ostracoda from Menard County, Texas." Texas Univ. (Bur. Econ. Geol.), Bull., Austin, Texas, 1929, no. 2901, p. 153.

Type Description: "This species has the same general characteristics as Kirkbya knighti Harlton and differs in the presence of the ventro-anterior node, which is not developed in Kirkbya knighti. Length 0.76 mm.; height 0.4 mm.; thickness 0.36 mm."

Type Level: Upper Pennsylvanian, Missourian, upper part of the Canyon series; marly shale and limestone, highly fossiliferous.

Type Locality: Loc. 2, outcrop on the south side of the San Saba River valley, about 3 miles west-northwest of Hext, eastern Menard County, central Texas.

KIRKBYA VALIDA Kellett, 1933

(Plate III, Figure 2)

KIRKBYA VALIDA Kellett, 1933 (Ellis and Messina, 1953, Vol. 3)

Type Reference: Kellett, B., "Ostracodes of the Upper Pennsylvanian and the Lower Permian strata of Kansas; I - The Aparchitidae, Beyrichiidae, Glyptopleuridae, Kloedenellidae; Kirkbyidae, and Youngiellidae." Jour. Pal., Menasha, Wis., 1933, vol. 7, no. 1, p. 86.

Type Description: Carapace short and somewhat inflated. The smaller of the two left valves found shows a tooth at the anterior cardinal angle; the posterior angle of this valve is somewhat broken. There is a distinct but rounded antero-dorsal shoulder. The greatest thickness of the valve, however, is in the center and not at the anterior shoulder. An outer flange, and an inner flange of moderate width, which is set well up on the sloping side of the valve so that the outer one is partially visible

in side view without tilting. Pit small and elongate oval. Measurements of the holotype: Length 1.03 mm.; height 0.55 mm.

Occurring with Kirkbya valida were other specimens of the genus, somewhat distorted and apparently more elongate. These unidentifiable specimens may belong to another species or they may be conspecific, in which case the holotype is the shortest variation of the species. Kirkbya valida is very similar in side view and arrangement of the flanges to Kirkbya clarocarinata Knight, but Kirkbya valida is less inflated, has a much more prominent anterior shoulder, a wider inner flange, is smaller and has a small elongate oval instead of the similar species described by Roth, its length being less than twice its height.

Type Level: Lower Permian, Wolfcampian, Council Grove group, Elmdale formation; in very carbonaceous, fossiliferous shale overlying massive buff limestone.

Type Locality: Locality 64, cut where road bends about halfway up the hill, near the Cottonwood River bridge, east of Elmdale, Chase County, Kansas.

Discussion: Some specimens of K. valida are more elongated than the holotype. All other points of the type description coincided almost exactly with the specimens collected.

The measurements of the figured specimen are: Length 0.81 mm., and height 0.40 mm.

The figured specimen was in a pale olive calcareous, mud-shale in a road cut at the intersection of Highway 99 and Interstate Highway 70, Wabaunsee Co., Kansas (measured section no. 12-3).

Family AMPHISSITIDAE Knight, 1928

Genus AMPHISSITES Girty, 1910

AMPHISSITES Girty, 1910 (Benson and others, 1961 p. Q165)

(*A. rugosus) (=Albanella Harris & Lalicker, 1932; Binodella Bradfield, 1935; ?Ectodemites Cooper, 1941). Median node flanked laterally by carinae which may or may not superpose elongate nodes, and which are connected

by dorsal carina subparallel to and joining hinge near cardinal angles; with terminal dentition and 2 marginal rims. M. Dev. - M. Perm.

AMPHISSITES CENTRONOTUS Ulrich and Bassler, 1906

(Plate III, Figure 7)

AMPHISSITES CENTRONOTUS Ulrich and Bassler, 1906 (Ulrich and Bassler, 1906, p. 159)

Carapace oblong subquadrate, with thick flattened edges, a long, straight back, and rather sharp cardinal angles, the posterior angle the less sharp of the two. Valves with a prominent large rounded node situated very near the middle of the dorsal half. On either side of this a smaller elevation surmounted by a thin curved vertical ridge in old examples. The marginal ridge, which likewise is well developed only in old specimens, is directly over the hinge but runs more or less within the free edges. Test reticulated, the pattern moderately fine. Free margins, ridges, and surface ornament all arranged more or less obviously in a concentric manner. "Pit" of moderate size though readily distinguished from the meshes of the surface ornament, situated at the base of the median node and very near the center of the valve.

Measurements: length, .82 mm.; height, .50 mm.; thickness, .50 mm.

Discussion: The specimens agreed comparatively well with the description of A. centronotus given by Ulrich and Bassler.

The measurements of the figured specimen are: length 0.86 mm., height 0.48 mm., width o.46 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale in a road cut along Riley County road 911, west of Deep Creek (measured section no. 10-1).

AMPHISSITES CENTRONOTUS ELONGATUS Payne, 1937

(Plate III, Figure 8)

AMPHISSITES CENTRONOTUS ELONGATUS Payne, 1937 (Cooper, 1946, p. 98)

Amphissites centronotus elongatus Payne 1937, Jour. Paleontology, vol. 11, p. 280, pl. 38, figs. 2a-c; Hayden Branch formation, Indiana.

Carapace elongate, dorsal and ventral margins parallel, ends rounded, inner and outer carina tenuous, complete around free margins, parallel along ventral margin; ventical carina distinct though low and thin, very long, about equidistant between edge of medial node and inner carinae; node circular, of medium size, and slightly forward of center; pit ovate, axis inclined anteriorly; surface marked by irregular reticulations of small to medium size.

Length, 0.82 mm.; height, 0.41 mm.; width, o.45 mm.

A. centronotus elongatus differs from A. centronotus by its unusual length (form ratio of 1.9 or greater).

Discussion: Some specimens of A. centronotus elongatus are slightly larger than the measurements given by Payne. The specimens agreed with all other points of the type description.

Dimensions of the figured specimen are: length 0.61 mm., and height o.31 mm.

The figured specimen was collected from a dusky yellow calcareous mud-shale in a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

AMPHISSITES PINGUIS Ulrich and Bassler, 1906

(Plate III, Figures 3 and 4)

AMPHISSITES PINGUIS Ulrich and Bassler, 1906 (Kellett, 1933, p.94)

Kirkbya pinguis Ulrich and Bassler, 1906, Proc. U. S. Nat. Mus., vol. 30, p. 159, pl. 11, figs. 13-15; Cottonwood shales, 2 miles east of Cottonwood Falls, Kansas.

Amphissites pinguis Ulrich and Bassler, Delo, 1931, Washington Univ. (St. Louis) Studies--n. ser.; Science and Techn.--no. 5, p. 46, pl. 4, figs. 7a-c. Wood Oil Company, Ranson No. 1 well, Hamilton County, Kansas.

Amphissites gregeri Delo, 1931, ibid., p. 48, pl. 4, figs. 8a-c. Wood Oil Company, Ranson No. 1 well, Hamilton County, Kansas.

Cythere? haworthi Ulrich and Bassler, 1906, ibid., p. 160, pl. 11, fig. 12. Cottonwood shales, 2 miles east of Cottonwood Falls, Kansas.

Carapace sub-rectangular, short, thick and with rounded corners, antero-cardinal angle more oblique than the post-cardinal angle. Hinge-line impressed. A narrow non-reticulate border around the free edges. Outer flange represented, except at the posterior where it is absent, by a thin raised line inside the non-reticulate border. Surface smoothly curved, broken only by an antero-cardinal shoulder which has an abrupt anterior face but rounds smoothly into the surface behind it. Central node fairly large, but very low and ill defined. The small elongate kirkbyan pit, pointing obliquely upward toward the front is impressed on the lower side of and slightly anterior to the central node. Surface neatly reticulated.

Measurements of the holotype are: length 0.80 mm., height 0.48 mm., and width 0.38 mm.

Discussion: The nodes and anterior cardinal shoulders of A. pinguis are more distinct and the carapace is less inflated in the young than in the adult forms. These characteristics agreed with the descriptions of A. pinguis collected by Kellett, (1933, p. 94). The author's specimens of A. pinguis agreed with all other points of the type description.

Measurements of the figured specimen are: length 0.86 mm., height 0.48, and thickness 0.46 mm.

The figured specimen of A. pinguis was in a pale olive, calcareous, mud-shale in a stream bank along Mill Creek, six miles south of Alma, Kansas (measured section no. 13-1).

AMPHISSITES SIMPLICISSIMUS Knight, 1928

(Plate III, Figures 5 and 6)

AMPHISSITES SIMPLICISSIMUS Knight, 1928 (Ellis and Messina, 1953, Vol. 1)

Type Reference: Knight, J. B., "Some Pennsylvanian ostracodes from the Henrietta formation of eastern Missouri; Part I." Jour. Pal., Bridgewater, Mass., 1928, vol. 2, no. 3, p. 266.

Type Description: Form suboblong with rounded, almost semi-circular ends so nearly alike that it is impossible to tell one from the other. The angles at the junctures of the ends with the straight hinge-line obscure and alike, without a uniformly more distinct angle at either end. Ventral line straight and very similar to dorsal, except that it joins the ends more smoothly. Dorsal view narrowly suboblong, with parallel sides and bluntly rounded ends. Valves slightly unequal, the left being rabbetted on its inner edge around the free margins to take the edge of the other. There is a narrow, smooth margin, widest on the left valve, which passes completely around the valves. No sulci, nodes or flanges are developed, except that the antero-dorsal region is slightly wider than the post-dorsal, which slopes to the dorsum more flatly. The surface of the valves except on the margins is, typically, obscurely reticulated, though the reticulations may be in part or almost entirely lacking, being in such examples either undeveloped or exfoliated. A circular Kirkbyan pit or muscle spot of about the diameter of two reticulation pits and not impressed below the surface is located at the center of each valve. Short spinelets arise irregularly from the points of juncture of the meshes of the reticulations or may be absent from non-development or exfoliation. These are often most prominent next to the ventral and end margins and may be homologous with the carinate outer flange of some Amphissitidae. Attempts to discover other linear arrangements of spinelets over the surface of the valve were unsuccessful.

The average dimensions of several specimens are:

Length	0.65 mm.
Height	0.36 mm.
Width	0.25 mm.

Type Level: Pennsylvanian, Desmoinesian, Henrietta group, upper Fort Scott Limestone, in shale partings.

Type Locality: Locality 38 (exposure in south bank of creek east of Price Road and south of Ladue Road, just east of Ladue village, St. Louis County, Missouri; fide Knight, 1928, Jour. Pal., vol. 2, no. 4, p. 337).

Discussion: All the specimens of A. simplicissimus agreed with the type description. They are all clearly reticulated

and have spinose or show a few spines. Both types are about equal in abundance. A. simplicissimus is referable to the genus Roundyella according to Bradfield (Ellis and Messina, 1952, Roundyella bellatula, vol. 4). Ellis and Messina (1952, Vol. 2) still assign this species to the genus Amphissites; the author follows this assignment.

Measurements of the figured specimen are: length 0.67 mm., height 0.39 mm., and width 0.25 mm.

The figured specimen was in a dusky yellow, mottled pale olive, calcareous, claystone in a stream bank along Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-6).

Genus KEGELITES Coryell and Booth, 1933

(Plate III, Figure 9)

KEGELITES Coryell and Booth, 1933 (Benson and others, 1961, p. Q165)

> Pro Girtyites Coryell and Booth, 1933 (non Wedekind, 1914) (*Girtyites spinosus Coryell and Booth, 1933) (=Kirkbyites Johnsoh, 1936). Like Amphissites, without dorsal carina or anterior node; posterior node trending toward cardinal angle, projecting above hinge line. M. Miss. - M. Perm.

Discussion: The carapace is small, equivalved, subquadrate, with the greatest height at the posterior 1/3. The greatest thickness is 1/3 from the posterior border. Anterior and posterior borders are subrounded, dorsal border slightly concave, ventral border straight and nearly parallel to dorsal border. Corners subrounded. The greatest length near mid-height. The hinge line is short and straight.

Lateral surface reticulated with the reticulations radially arranged. A low spherical medial node on left valve; a low slightly elongated medial node on right valve. A posterior sulcus is parallel to the posterior border on the right valve. Just below the node on the right valve is a small kirkbyan pit. On the left valve a posterior node projects slightly above the hinge line; a shallow medial sulcus separates the two nodes. The posterior node is absent on the right valve. Along the free border of both valves is a smooth marginal ridge.

The specimen's only disagreement with the type generic description is the posterior node on the right valve was poorly developed and inconspicuous.

Dimensions of the complete carapace are: length 0.58 mm., height 0.43 mm., and width 0.22 mm.

Only one of the form above was identified. No species description could be found by the author which fits the specimen. The specimen is similar to Amphissites rothi (Ellis and Messina, 1952, vol. 4), but differs mainly in having a poorly defined anterior node. It also differs from A. rothi by having an elevated area in the anteroventral portion of the shell.

This specimen may represent a new species. However, the writer hesitates to erect a new species based on a single specimen. A study of the common characteristics and the variations of several specimens are needed before a new specie can be assigned.

The specimen of Kegelites sp. was in a light olive-gray,

calcareous mud-shale along Riley County road 911, west of Deep Creek. (Measured section no. 10-3.)

Suborder KLOEDENELLOCOPINA Scott, n. suborder, 1961

Superfamily PARAPARCHITACEA Scott, 1959

Family PARAPARCHITIDAE Scott, 1959

Genus PARAPARCHITES Ulrich and Bassler, 1906

PARAPARCHITES Ulrich and Bassler, 1906 (Benson and others, 1961, p. Q194)

(*P. humerosus) (=Antiparaparchites Coryell and Rogatz, 1932; Ardmorea Bradfield, 1935; Coelonella Stewart, 1936; Microcoelonella Coryell and Sohn, 1938). Subovate to elongate-ovate, smooth except for postero-dorsal spine in a few species; LV usually overlapping RV along free margin; hinge channeled; cardinal teeth poorly to well defined on exterior at cardinal points; greatest height medial or forward, greatest width medial in males, posterior in females, forward swing pronounced in some species. Dimorphism generally but not invariably observable. Valves may appear double-or triple-layered, owing to retention of molts. L. Dev. - M. Perm.

PARAPARCHITES HUMEROSUS Ulrich and Bassler, 1906

(Plate III, Figures 10 and 11)

PARAPARCHITES HUMEROSUS Ulrich and Bassler, 1906 (Ellis and Messina, 1952, Vol. 1)

Type Reference: Ulrich, E. O., and R. S. Bassler, "New American Paleozoic Ostracoda; Notes and descriptions of Upper Carboniferous genera and species." U. S. Nat. Mus., Proc., Washington, D. C., 1906, vol. 30, no. 1446, p. 151.

Type Description: "Length of large example 1.8 mm.; height of same 1.25 mm.; thickness of same 1.05 mm. Carapace subovate, with the outline slightly angulated in the antero-dorsal region; surface rather strongly convex, with greatest thickness near middle of valves. Left valve with dorsal edge straighter than in right valve, the edge in the latter being convex in outline and thickened so that it projects above the hinge line of the left valve. Ventral edge of carapace thick and slightly channeled on each side of the constant line between the valves.

Type Level: Not designated. Levels given: Lower Permian, Council Grove group, Elmdale formation and Chase group, Wreford formation, in yellow shales in limestone (Reece); Permo-Carboniferous, dark shaly limestone (Ballinger).

Type Locality: Not designated. Localities given: Manhattan, Riley County, and six miles west of Reece, Greenwood County, Kansas; Mustang Creek, east of Ballinger, Runnels County, Texas. Abundant; Texas specimens generally a little smaller.

Discussion: Only one specimen of P. humerosus was identified. It is smaller than the form described by Ulrich and Bassler. The greatest thickness of the specimen is slightly posterior to mid-length.

Measurements of the figured specimen are: length 1.21 mm., height 0.87 mm., and width 0.68 mm.

The P. humerosus specimen was in a moderate yellow-brown, calcareous, clay-shale in a stream bank along Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-9).

Order POLOCOPIDA, Muller, 1894

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIACEA Sars, 1888

Family BAIRDIIDAE Sars, 1888

Genus BAIRDIA McCoy, 1844

BAIRDIA McCoy, 1844 (Benson and others, 1961, p. Q202)

(*B. curtus) (=Nesidea Costa, 1849; Morrisitina Gibson, 1955 (pro Morrisites Gibson, 1955, non Buckman, 1921); Acratinella Schneider, 1956).

Carapace postly elongate fusiform in lateral view, with broadly arched dorsum that becomes concave terminally, especially at the rear; venter centrally straight but curved upward terminally so that extremities are nearly at

mid-height, anterior end generally higher and better rounded than the posterior, which generally is acuminate; in dorsal view, lateral outlines symmetrically convex and extremities acuminate; surface of valves smooth, punctate, or rarely with protuberances; LV larger than RV, mostly overreaching it around entire margin and overlapping it, especially ventrally, around contact margin. Short ridge-and-groove hingement commonly marked by prominent cardinal angles, especially in RV; contact margins complex, with wide duplicature, vestibule, and associated structures; adductor-muscle scar pattern of several discrete spots (21, 43, 53). Ord. - Rec.

BAIRDIA BEEDEI Ulrich and Bassler, 1906

(Plate III, Figures 12 and 13)

BAIRDIA BEEDEI Ulrich and Bassler, 1906 (Ellis and Messina, 1952, Vol. 1)

Type Reference: Ulrich, E. O., and R. S. Bassler, "New American Paleozoic Ostracoda; Notes and descriptions of Upper Carboniferous genera and species." U. S. Nat. Mus., Proc., Washington, D. C., 1906, vol. 30, no. 1446, p. 161.

Type Description: "Length 1.22 mm.; height 0.75 mm.; thickness 0.52 mm. Carapace thick, short, subrhomboidal in outline, lanceolate in edge views, the point of greatest thickness being near the middle; overlapping dorsal edge of left valve thick, the ventral overlap also rather wide; posterior extremity bluntly acuminate, the dorsal half of the outline nearly straight in the left valve and barely concave in the right valve, the lower half arching broadly into the ventral margin; anterior extremity less acuminate than the posterior, the outline being rounded in the lower half, nearly straight in the upper half, and abruptly bent about the mid-height. Valves unequal, the left much the larger, and the middle part of its dorsal outline distinctly convex, while the corresponding part of the right valve is sufficiently straightened to form obtuse angles at the ends of the hinge. Surface of both valves evenly convex and smooth.

"The writers have a large number of specimens of Bairdia, apparently representing six or seven species, procured mainly from Upper Carboniferous rocks in the Mississippi Valley and Texas. Although these have not yet been subjected to critical study, it is believed that Bairdia beedei occurs in some of the lots. However, pending careful comparisons, it would be unwise to attempt giving either the stratigraphic or the geographic distri-

EXPLANATION OF PLATE III

(All specimens 30x.)

Fig. 1. Kirkbya canyonensis Harlton; lateral view, right valve, posterior end to right. (p. 36)

Fig. 2. Kirkbya valida Kellett; lateral view, left valve, posterior end to the left. (p. 36)

Fig. 3. Amphissites pinguis (Ulrich and Bassler); lateral view, left valve, posterior end to the right. Lateral and dorsal views the same specimen. (p. 39)

Fig. 4. Amphissites pinguis (Ulrich and Bassler); dorsal view, posterior end to the left. (p. 39)

Fig. 5. Amphissites simplicissimus (Knight); lateral view, left valve, posterior end to right. Lateral and dorsal views the same. (p. 40)

Fig. 6. Amphissites simplicissimus (Knight); dorsal view, posterior end to the right. (p. 40)

Fig. 7. Amphissites centronotus (Ulrich and Bassler); lateral view, left valve, posterior end to the right. (p. 38)

Fig. 8. Amphissites centronotus elongatus Payne; lateral view, left valve, posterior end to the left. (p. 38)

Fig. 9. Kegelites sp. Coryell and Booth; lateral view, left valve, posterior end to the right. (p. 42)

Fig. 10. Paraparchites humerosus Ulrich and Bassler; lateral view, left valve, anterior end to the left. Lateral and dorsal views the same specimen. (p. 44)

Fig. 11. Paraparchites humerosus Ulrich and Bassler; dorsal view, anterior end to the left. (p. 44)

Fig. 12. Bairdia beedei Ulrich and Bassler; lateral view, right valve, anterior end to right. Lateral and dorsal views the same specimen. (p. 46)

Fig. 13. Bairdia beedei Ulrich and Bassler; dorsal view, anterior end to right. (p. 46)

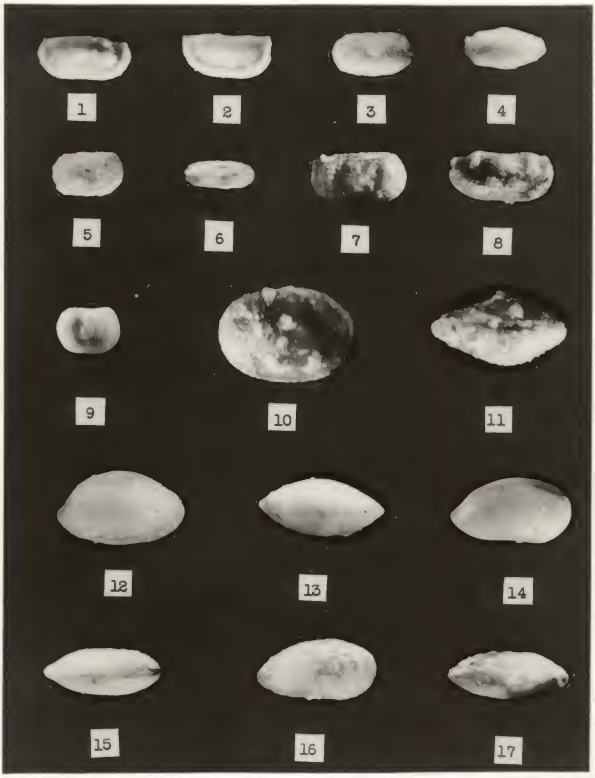
Fig. 14. Bairdia florenaensis Upson; lateral view, right valve, anterior end to the right. Lateral and dorsal views the same specimen. (p. 49)

Fig. 15. Bairdia florenaensis Upson; dorsal view, anterior end to right. (p. 49)

Fig. 16. Bairdia folgeri Kellett, lateral view, right valve, anterior end to the right; lateral and dorsal views the same specimen. (p. 50)

Fig. 17. Bairdia folgeri Kellett; dorsal view, anterior end to left. (p. 50)

PLATE III



bution of the species."

Type Level: Lower Permian, Council Grove group, Cottonwood formation; shale.

Type Locality: Two miles east of Cottonwood Falls, Chase County, Kansas.

Discussion: The specimens of B. beedei agreed in general with tye type description. The form in Plate III, Figure 12 is slightly concave above the posterior beak. The others agreed with Ulrich's and Bassler's description; they have a straight postero-dorsal slope.

Measurements of the figured specimen are: length 1.08 mm., height 0.68 mm., and thickness 0.52 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale in a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

BAIRDIA EISSENSIS Upson, 1933

(Plate IV, Figure 3)

BAIRDIA EISSENSIS Upson, 1933 (Ellis and Messina, 1955, Vol. 7)

Type Reference: Upson, M. E., "The Ostracoda of the Big Blue series in Nebraska," Geol. Survey Bull., Lincoln, Nebr., 1933, ser. 2, no. 8, p. 20.

Type Description: "Carapace subrhomboidal in outline; tumid; dorsal margin arched, posterior slope longer of the two and slightly convex; ventral margin broadly convex with central portion nearly straight; anterior extremity evenly rounded, occupying the lower three-fifths of the carapace; posterior extremity bluntly pointed with a slight tendency to curve upward; dorsal profile lanceolate, greatest thickness central; left valve the larger, overlapping the right dorsal and ventral margins, most conspicuous along center of ventral margin and on dorsal angle; surface smooth. Length 1.42 mm.; height 0.586 mm.; thickness 0.576 mm.

Type Level: Lower Permian, lower Wolfcampian, upper

part of the Council Grove group, lower part of the Garrison formation, base of the middle zone of the Eiss limestone member; in shale.

Type Locality: Road cut along the Kansas-Nebraska line, at the southeast corner of the SE¼ sec. 34, T. 1 N., R. 13 E., Richardson County, southeastern Nebraska.

Discussion: Some specimens of B. eissensis are nearly straight in the central portion of the arched dorsal margin. Many of the specimens are smaller than those described by Upson. In all other points the Bennett shale specimens are in agreement with Upson's description.

Dimensions of the figured specimen are: length 1.37 mm., height 0.73 mm. and width .51 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale along a road cut on the west side of Riley County road 911, west of Deep Creek (measured section no. 10-1).

BAIRDIA FLORENAENSIS Upson, 1933

(Plate III, Figures 14 and 15)

BAIRDIA FLORENAENSIS Upson, 1933 (Ellis and Messina, 1955, Vol.7)

Type Reference: Upson, M. E., "The Ostracoda of the Big Blue series in Nebraska." Nebraska, Geol. Survey Bull., Lincoln, Nebr., 1933, ser. 2, no. 8, p. 22.

Type Description: "Carapace sub-oblong in lateral view; dorsal margin broadly arched, curvature most pronounced over anterior end of hinge, posterior slope long, convex, lower third steeply inclined; anterior slope convex; hinge line short, depressed, located mainly in posterior half; ventral margin usually straight but often concave medially; inclined posteriorly from region of anteroventral angle; posterior extremity bluntly acuminate, located below median line; anterior extremity broadly rounded, most pronounced dorsally; greatest height about one-third length of shell from anterior end; ventral profile elongate, extremities thick, greatest thickness in median two-thirds; left valve the larger, strongly overlapping the right on anterior dorsal slope and along ventral median third, remaining

overlap of free margin slight; surface smooth. Length 1.212 mm.; height 0.60 mm.; thickness 0.45 mm.

Type Level: Lower Permian, lower Wolfcampian, upper part of the Council Grove group, lower part of the Garrison formation, base of the Florena shale member. Occurs also in the lower Wolfcampian, lower part of the Putnam group, Santa Anna Branch formation; in shale (Texas).

Type Locality: Road cut along the south line of the SW¼ sec. 34, T. 1 N., R. 14 E., Richardson County, southeastern Nebraska. Found also in north-central Texas (abundant).

Discussion: Many specimens are smaller than the measurements given in the type description. These are probably immature forms.

Measurements of the figured specimen are: length 1.08 mm., height 0.59 mm., and width 0.43 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale along a road cut on Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

BAIRDIA FOLGERI Kellett, 1934

(Plate III, Figures 16 and 17)

BAIRDIA FOLGERI Kellett, 1934 (Ellis and Messina, 1954, Vol. 7)

Type Reference: Kellett, B., "Ostracodes from the Upper Pennsylvanian and the Lower Permian strata of Kansas; II - The genus Bairdia." Jour. Pal., Menasha, Wis., 1934, vol. 8, no. 2, p. 136.

Type Description: Bairdia folgeri is characterized by the curved and somewhat inflated outline in dorsal view. It very closely resembles Bairdia florenaensis Upson in lateral view, but in dorsal view it is more inflated and the sides less straight. The dorsum of Bairdia folgeri is less sharply arched than that of Bairdia oklahomaensis Harlton, and the posterior more acuminate. (See also Bairdia chaseae Kellett, 1934.)

Type Level: Upper Pennsylvanian, upper Virgilian, lower part of the Wabaunsee group; holotype, paratypes, and young specimen from the Howard formation.

Type Locality: Holotype, paratypes and young specimen from locality 25 (brick plant cut in field north of Gage Park, Topeka, Shawnee County, Kansas; fide Kellett, 1933, Jour. Pal., Vol. 7, no. 1, p. 106).

Discussion: All the author's specimens of B. folgeri adhered closely to the type description.

The specimens of B. folgeri and B. florenaensis are very similar. In lateral view they are alike. Their height, length and general outlines are the same. The only difference is in dorsal view; the carapace of B. folgeri is more inflated and the sides are more curved than B. florenaensis. Intermediate forms are very difficult to identify. It is the opinion of this author that B. folgeri and B. florenaensis should be assigned to one species.

Kellett (Ellis and Messina, 1953, Bairdia chasae, vol. 4) believes that the shorter and more inflated form, B. folgeri, is the female and the more elongated form, B. florenaensis, is the male of the same species. This author agrees with Kellett's view.

Measurements of the figured specimen of B. folgeri are: length 1.08 mm., height 0.54 mm., and width 0.44 mm.

The figured specimen was in a dusky yellow mottled dark gray, calcareous, mud-shale along a stream bank on the north side of Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-4).

BAIRDIA MARMOREA Kellett, 1934

(Plate IV, Figures 1 and 2)

BAIRDIA MARMOREA Kellett, 1934 (Ellis and Messina, 1954, Vol. 4)

Type Reference: Kellett, B., "Ostracodes from the Upper Pennsylvanian and the Lower Permian strata of Kansas; II - The genus Bairdia." Jour. Pal., Menasha, Wis., 1934, vol. 8, no. 2, pp. 127, 125.

Type Description: "Carapace rather small; in lateral view anterior end narrowly rounded and slightly above the mid-height of the valve; posterior end pointed and slightly below the mid-height; dorsal and ventral margins evenly arched; greatest height slightly anterior to the center; in dorsal view ends evenly tapered; dorsal line of contact of the valves very slightly if at all depressed and straight in the central part rather than arched.

Type Level: Lower Permian, Wolfcampian, lower part of the Chase group, Wreford formation; three limestone beds, the lowermost one very cherty and overlain by yellow shale. Occurs in deep well samples as low as the Upper Pennsylvanian, lower Missourian; occurs in surface samples ranging from the Wakarusa limestone (Upper Pennsylvanian, upper Virgilian, Wabaunsee group) to the Winfield limestone (Lower Permian, upper Wolfcampian, top of the Chase group).

Type Locality: Locality 57 (low outcrop along a north-south road, north of District No. 17 school, between Lincolnville and Elmdale and only a few miles from the latter, in Chase County, Kansas; fide Kellett, 1933, Jour. Pal., vol. 7, no. 1, p. 107).

Discussion: All specimens of B. marmorea agreed with all points of Kellett's description. B. marmorea can be distinguished from B. Beedei by its more tapering form in both lateral and dorsal views (Ellis and Messina, 1953, B. marmorea, vol. 4).

Measurements of the figured specimen are: length 1.03 mm., height 0.59 mm., and width 0.45 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale in a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

BAIRDIA NEBRASKENSIS Upson, 1933

(Plate IV, Figures 7 and 8)

BAIRDIA NEBRASKENSIS Upson, 1933 (Ellis and Messina, 1955, Vol. 7)

Type Reference: Upson, M. E., "The Ostracoda of the Big Blue series in Nebraska." Nebraska, Geol. Survey, Bull., Lincoln, Nebr., 1933, ser. 2, no. 8, p. 18.

Type Description: "Carapace small, elongate, length about two and one-half times the height; dorsal margin arched, posterior slope long and straight, anterior slope slightly convex; ventral margin concave on posterior half of median third; anterior extremity broadly rounded, nearly as broad as maximum width of shall; posterior extremity bluntly pointed; greatest height over dorsal angle; dorsal view lanceolate, thickest centrally; left valve larger, moderately overlapping the right dorsally and along ventral median third. Surface smooth. Length 1.14 mm.; height 0.525 mm.; thickness 0.374 mm.

Type Level: Lower Permian, upper Wolfcampian, lower part of the Chase group, lower part of the Wreford formation, upper part of the Threemile limestone member (formerly called Fourmile limestone member); in a shale seam.

Type Locality: Road cut 3½ miles southeast of Randolph, Riley County, northeastern Kansas.

Discussion: A few postero-dorsal margins of the B. nebraskensis specimens are straight to slightly concave; however, most of the specimens have a straight margin. Some specimens disagree with the type description in having a subrectangular shape. These specimens have a straight to slightly convex dorsal margin and a straight ventral margin.

Measurements of the figured specimen are: length 1.06 mm., height 0.45 mm., and width o.31 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale from a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-1).

BAIRDIA REUSSIANA Kirkby, 1858

(Plate IV, Figures 5 and 6)

BAIRDIA REUSSIANA Kirkby, 1958 (Kellett, 1934, p. 132)

Carapace elongate tapering; anterior beak broad and blunt with rather square corners; posterior beak high and blunt; greatest height anterior to the center; antero-dorsal slope in side view slightly depressed; apparent overlap narrow.

Measurements: length 1.34 mm., height .61 mm., and thickness .41 mm.

Discussion: Some specimens of B. reussiana collected by the author are slightly more elongated than the forms described by Kellett (1934, p. 132). All other points of the author's specimens fit the type description.

Measurements of the figured specimen are: length 1.30 mm., height 0.65 mm. and width o.40 mm.

The figured specimen was in a light olive gray, mottled medium gray, calcareous, mud-shale near the intersection of Kansan Highway 99 and Interstate Highway 70 in Wabaunsee Co., Kansas (measured section no. 12-4).

BAIRDIA SEMINALIS Knight, 1928

(Plate IV, Figure 9)

BAIRDIA SEMINALIS Knight, 1928 (Ellis and Messina, 1953, Vol. 2)

Type Reference: Knight, J. B., "Some Pennsylvanian octracodes from the Henrietta formation of eastern Missouri; Part II." Jour. Pal., Bridgewater, Mass., 1928, vol. 2, no. 4, p. 320.

Type description: Outline of the larger valve suboval, the entire carapace having a seed-like aspect. Dorsal outline roundly curved, slightly flattened on the antero-dorsal, and less so on the post-dorsal slope. No angulation over the post-dorsal end of the hinge. Posterior beak bluntly angular but not conspicuous. Ventral outline roundly and gently curved for its posterior three-quarters and more abruptly upward to the somewhat more sharply rounded anterior end. Outline, when viewed from above, broadly lanceolate and gently convex, the broadest point being about midway. The outline of the smaller valve is considerably narrower and suboblong. The hinge line is comparatively

short, being about 55 percent of the total length. The dorsal margin of the right valve is flatly arched with a backward slope along the hinge, with a steeply rounded post-dorsal, and more gradual antero-dorsal slope. The anterior end is somewhat drawn out. The overlap of the left valve is rather pronounced, particularly along the dorsal line. It is even more conspicuous than usual ventrally. The produced anterior end of the right valve, however, extends forward almost as far as that of the left.

The dimensions of the two specimens are:

Length	0.75 mm.	0.78 mm.
Height of the left valve	0.48 mm.	0.53 mm.
Width	0.35 mm.	-

Type Level: Pennsylvanian, Desmoinesian, Henrietta group, upper Fort Scott limestone, in shale partings.

Type Locality: Locality 38, exposure in south bank of creek east of Price Road and south of Ladue Road, just east of Ladue village, St. Louis County, Missouri.

Discussion: The specimens of B. seminalis are slightly larger than the type specimen described by Knight. All other points of the description agreed with those given in the type description.

The measurements of the figured specimen are: length 0.98 mm., and height 0.67 mm.

The figured specimen of B. seminalis was in a dusky yellow, mottled pale olive, calcareous, mudstone along the north bank of Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-4).

Genus BYTHOCYPRIS Brady, 1880

BYTHOCYPRIS Brady, 1880 (Benson and others, 1961, p. Q205)

(*B. reniformis (Bairdia bosquetiana Brady, 1866)). Carapace reniform in lateral view, with straighter venter and more rounded dorsum and extremities; mostly lacking angulation and asymmetry of Bairdia, but with similar overlap and overreach, ridge-and-groove hinge, duplicature, vestibule, and associated structures, including muscle scar

(53). (Many modern species are defined partly on the basis of soft parts, whereas numerous Paleozoic species do not exhibit the muscle scar and marginal structure of Recent Bairdia and other Bairdiidae. Altogether, the genus is in an unsatisfactory condition, nearly all Paleozoic species being doubtfully assigned to it.) ?L. Ord., Rec.

BYTHOCYPRIS PEDIFORMIS Knight, 1928

(Plate IV, Figures 10 and 11)

BYTHOCYPRIS PEDIFORMIS Knight, 1928 (Ellis and Messina, 1953, Vol. 2)

Type Reference: Knight, J. B., "Some Pennsylvanian ostracodes from the Henrietta formation of eastern Missouri; Part II." Jour. Pal., Bridgewater, Mass., 1928, vol. 2, no. 4, pp. 326, 328.

Type Description: Outline suggesting roughly the imprint of a broad moccasined human foot, the anterior margin forming the heel and the post-ventral beak the great toe. Posterior and dorsal margin form an unbroken curve from the posterior beak, which is in line with the ventral margin, to just anterior to the centrally located highest point, where the curve flattens very slightly and then curves roundly out to a short radius around the end. The curve of the anterior end meets that of the ventral margin smoothly, and that of the ventral margin itself is straight to very slightly concave for its anterior three-fifths, then, proceeding posteriorly, shows a slight convexity a little behind the middle, after which it proceeds nearly straight to the beak. The beak is almost blunt pointed and gives the appearance of pointing downward. The left valve is larger, extending beyond and overlapping the right a small amount all around, more ventrally than elsewhere. The surface is smooth. The dorsal aspect is narrow ovate, heavier posteriorly and rather fine anteriorly.

Dimensions of two individuals are:

Length	0.65 mm.	0.61 mm.
Height	0.36 mm.	0.36 mm.
Width	-	0.22 mm.

Type Level: Pennsylvanian, Desmoinesian, Henrietta group, upper Fort Scott limestone, in shale partings. Not very abundant.

Type Locality: Not designated.

Discussion: The specimens collected by the writer are smaller than the forms described by Knight. In all other points, the specimens collected agree with the type description.

Dimensions of the figured specimen are: length 0.54 mm., height 0.28 mm., and width 0.20 mm.

The figured specimen of B. pediformis was in a medium gray limestone along a stream bank of Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-2).

Superfamily CYPRIDACEA Baird, 1845

Family CYPRIDACEA Uncertain

Genus CARBONITA Strand, 1928

CARBONITA Strand, 1928 (Benson and others, 1961, p. Q247)

(Pro Carbonia Jones, 1870 (non Robineau-Desvoidy, 1863)) (*Carbonia agnes Jones, 1870).

Small, elongate, subquadrate, moderately convex, thickest posteriorly; hinge margin straight to slightly convex; venter slightly sinuous, ends rounded, anterior margin slightly narrower; small raised ridge near anteroventral margin; RV overlapping LV along free margins but LV extending slightly beyond RV dorsally; surface smooth or pitted. (Fresh-water, ?marine.) ?L. Carb., Penn. (U. Carb.) - Perm.

CARBONITA (?) TUMIDA Upson, 1933

CARBONITA (?) TUMIDA Upson, 1933 (Kellett, 1935, p. 160)

Bythocypris tumidus Upson, 1933, Neb. Geol. Survey, Bull. 8, (2), p. 24, pl. 2, figs. 11a-c. Stearns shale, Lower Permian, Kansas. Type examined.

Carapace very tumid posteriorly in dorsal view, the posterior end rounded and the anterior end pointed and sometimes slightly compressed; a short marginal ridge at the antero-ventral corner, anterior extremity of the venter somewhat compressed and ridge-like but venter flattened at the center and just in front of the center.

CARBONITA (?) TUMIDA VAR. MAGNA Upson, 1933

(Plate IV, Figures 12 and 13)

CARBONITA (?) TUMIDA VAR. MAGNA Upson, 1933 (Kellett, 1935, p.161)

Bythocypris tumidus var. magnus Upson, 1933, Neb. Geol. Survey, Bull. 8, (2), pp. 24-25, pl. 2, figs. 13a-b. Stearns shale, Lower Permian, Kansas. Type explained.

This variety is less tumid and on the average smaller than C. tumida.

Measurements of specimen:

Figs.	Length	Height	Width
11a,b	0.68 mm.	0.39 mm.	

Discussion: All the specimens of C. (?) tumida var. magna agreed with the description given by Kellett (1935, p. 161).

Measurements of the figured specimen are: length 0.64 mm., height 0.38 mm., width 0.34 mm.

The figured specimen was in a light olive gray, mottled black, calcareous, clay-shale from a road cut along Interstate Highway 70, three miles east of Paxico, Wabaunsee Co., Kansas (measured section no. 7-3).

Superfamily CYTHERACEA Baird, 1850

Family BYTHOCYTHERIDAE Sars, 1926

Genus MONOCERATINA Roth, 1928

MONOCERATINA Roth, 1928 (Benson and others, 1961, p. Q268)

(*M. ventrale (sic)) (=Bythocytheremorpha Madelstam, 1958).

Typically elongate, with long, straight dorsal margin terminating in caudal process; median sulcus extending from dorsal margin to near center of valve, commonly surrounded by crescentic lobe which may bear one or more thornlike spines. Hinge modified lophodont, dominated by long median ridge in LV which in some species has a swollen posterior extremity; anterior element of RV reduced or

absent; posterior element of RV a short swollen ridge; abductor-muscle scars of Paleozoic forms in arcuate group of 5, with 2 antennal scars in front (some post-Paleozoic species assigned to genus have only 4 adductor scars). Dev. - Rec.

MONOCERATINA BRADFIELDI Cooper, 1935

(Plate IV, Figure 16)

MONOCERATINA BRADFIELDI Cooper, 1935 (Cooper, 1946, p. 39)

Monoceratina n. sp. Bradfield, 1935, Bull. Am. Paleontology, vol. 22, p. 77, pl. 1, figs. 16-18, 20; Deese group, Okla.

Carapace small, elongate, lateral outline subrectangular; hinge line long, straight, ends subequally rounded; ventral margin convex, depressed areas medially and anteriorly broad and very shallow; ventral spine short, widely flaring at base, joining an inflated portion of posterior half of shell; posterior end unusually wide; surface punctate.

Length, 0.50 mm; height, 0.25 mm.; width, 0.22 mm.

Discussion: The anterior end, past the ventral spine, is missing in the two M. bradfieldi specimens found. One specimen has a greater height and the ventral margin is more convex than the form described by Cooper.

Dimensions of the figured specimen are: length (broken) 0.50 mm., and height 0.35 mm.

The figured specimen of M. bradfieldi was in a dusky yellow, calcareous, mud-shale in a road cut along Interstate Highway 70, six miles east of Paxico, Kansas (measured section no. 7-1).

MONOCERATINA LEWISI Harris and Lalicker, 1932

(Plate IV, Figures 14 and 15)

MONOCERATINA LEWISI Harris and Lalicker, 1932 (Ellis and Messina, 1953, Vol. 3)

Type Reference: Harris, R. W., and C. G. Lalicker, "New Upper Carboniferous Ostracoda from Oklahoma and Kansas."

EXPLANATION OF PLATE IV

(All specimens 30x.)

Fig. 1. Bairdia marmorea Kellett; lateral view, right valve, anterior end to the right. Lateral and dorsal views the same specimen. (p. 51)

Fig. 2. Bairdia marmorea Kellett; dorsal view, anterior end to the right. (p. 51)

Fig. 3. Bairdia eissensis Upson; lateral view, right valve, anterior end to the right. Lateral and dorsal view the same specimen. (p. 48)

Fig. 4. Bairdia eissensis Upson; dorsal view, anterior end to the right. (p. 48)

Fig. 5. Bairdia reussiana Kirkby; lateral view, right valve, anterior end to the right. Lateral and dorsal views the same specimen. (p. 53)

Fig. 6. Bairdia reussiana Kirkby; dorsal view, anterior end to the right. (p. 53)

Fig. 7. Bairdia nebraskensis Upson; lateral view, right valve, anterior end to the right. Lateral and dorsal views the same specimen. (p. 52)

Fig. 8. Bairdia nebraskensis Upson; dorsal view, anterior end to the right. (p. 52)

Fig. 9. Bairdia seminalis Knight; lateral view, left valve, anterior end to the left. (p. 54)

Fig. 10. Bythocypris pediformis Knight; lateral view, right valve, anterior end to the left. Lateral and dorsal views the same specimen. (p. 54)

Fig. 11. Bythocypris pediformis Knight; dorsal view, anterior end to left. (p. 54)

Fig. 12. Carbonita (?) tumida var. magna (Upson); lateral view, left valve, anterior end to the left. Lateral and dorsal views the same specimen. (p. 58)

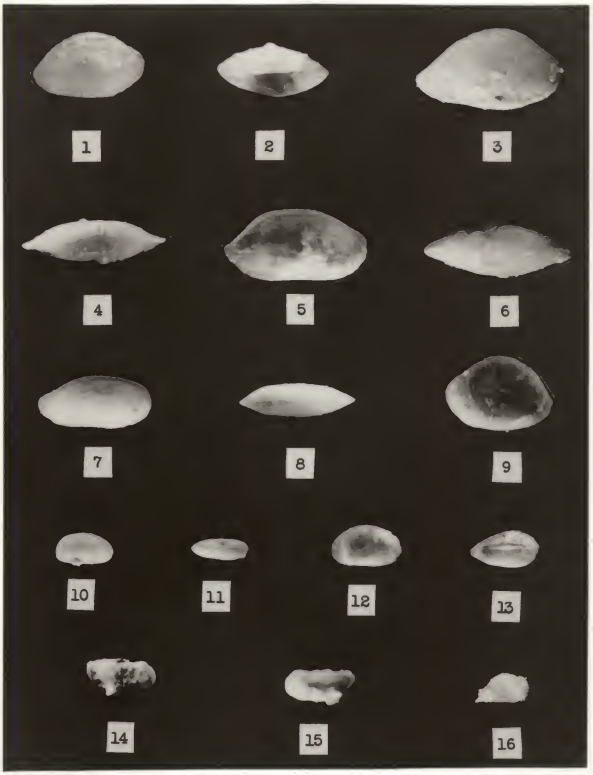
Fig. 13. Carbonita (?) tumida var. magna (Upson); dorsal view, anterior end to the left. (p. 58)

Fig. 14. Monoceratina lewisi Harris and Lalicker; lateral view, left valve, anterior end to right. (p. 60)

Fig. 15. Monoceratina lewisi Harris and Lalicker; lateral view, right valve, anterior end to the left. (p. 60)

Fig. 16. Monoceratina bradfieldi Cooper n. sp.; lateral view, left valve, anterior end to right. Portion of posterior end is missing. (p. 59)

PLATE IV



Amer. Midland Nat., Notre Dame, Ind., 1932, vol. 13, no. 6, p. 398.

Type Description: Carapace elongate, tumid; maximum eight median; hinge line straight, slightly upturned at anterior end; anterior extremity acutely pointed; posterior extremity rounded, distinctly protruding backward; prominent forward-projecting spine located antero-centrally on ventral margin; inflated node slightly behind center and below the median line; minute tubercle located at the post-dorsal angle and set off anteriorly by a slight incision; shallow sulcus posterior to center; free margin depressed, flange-like posteriorly and especially anteriorly; surface punctate. Length 0.67 mm.; height 0.32 mm.

Type Level: Lower Permian, Wolfcampian, Chase group, Fort Riley formation; limestone.

Type Locality: Eight miles southeast of Towanda, Butler County, Kansas.

Discussion: The nodes of M. lewisi are generally inconspicuous. The anterior end of the specimens are narrowly rounded to nearly pointed.

Measurements of the figured specimens are:

	Length	Height
Plate IV Figure 14	0.63 mm.	0.30 mm.
Plate IV Figure 15	0.64 mm.	0.28 mm.

The figured specimens were in an olive-gray to dusky yellow, calcareous, mud-shale in a stream bank along one branch of McDowell's Creek, south of Riley County road 901 (measured section no. 11-5).

Suborder METACOPINA Sylvester-Bradley, n. suborder, 1961

Superfamily HEALDIACEA Harlton, 1933

Family HEALDIIDAE Harlton, 1933

Genus HEALDIA Roundy, 1926

HEALDIA Roundy, 1926 (Benson and others, p. Q361)

Carapace generally subtriangular in lateral view, with angularly arched dorsum venter nearly straight, anterior

border mostly broadly rounded and posterior end commonly truncate; greatest thickness posterior, producing cuneate appearance in dorsal view; surface of each valve generally smooth and posteriorly sculptured with either a sickle-shaped to straight, vertical ridge or shoulder, or 1 or 2 backward-pointing spines, or both; LV larger than RV, with overlap and overreach of LV over RV but overlap commonly reduced or lacking in hinge area located posterodorsally. Hinge and contact margins consisting of groove or depressed shoulder in LV into which fits edge of RV, which also is grooved or beveled marginally; dorsal elements of articulation of each valve commonly crenulated transversely in numerous, minute toothlets and grooves extending through and beyond hinge area; adductor muscle scar circular, with numerous aggregate spots arranged in concentric rings or rows (121, 299, 82). Dev. - Perm.

HEALDIA SIMPLEX Roundy, 1926

(Plate V, Figures 1 and 2)

HEALDIA SIMPLEX Roundy, 1926 (Kellett, p. 142)

Healdia simplex Roundy, 1926, U. S. Geol. Survey, Prof. Paper 146, p. 8, pl. 1, figs. 11a-c;

Healdia absentia Coryell and Billings, 1932, Am. Midland Nat., vol. 13, p. 179, pl. 17, fig. 13; Wayland shale, Texas.

Carapace medium sized for the genus, moderately thick, dorsal margin angled at the center, ventral margin straight or slightly concave, ends of about even height and broadly rounded, the postdorsal slope flattened with the valves meeting evenly, spines on adult molts absent or only faintly indicated. Measurements of the specimens: length 0.67 mm., height 0.43 mm; length 0.59 mm., height 0.35 mm., width 0.30 mm.

Discussion: Short spines are either present or absent on the H. simplex specimens collected from the Bennett shale. The spines were faintly indicated on most of the specimens.

Dimensions of the figured specimen are: length 0.54 mm., height 0.34 mm., and width 0.26 mm.

The figured specimen of H. simplex was in an olive gray, calcareous, clay-shale in a railroad cut at Manhattan, Riley Co.,

Kansas (measured section no. 2-3).

?Family CAVELLINIDAE Egorov, 1950

Genus CAVELLINA Coryell, 1928

CAVELLINA Coryell, 1928 (Benson and others, 1961, p. Q369)

(*C. puchella) (=?Cavellinella Bradfield, 1935; Alvenus Hamilton, 1942 (erroneous original spelling), Alveus Hamilton, 1942).

Carapace oblong to ovate in lateral view, dorsum moderately arched, venter slightly concave to convex, ends rounded, with posteroventer and anterodorsal extremities slightly to moderately truncated. Subovate in dorsal view, posterior end thicker than anterior, especially pronounced in female. Surface smooth; contact margin of right valve grooved along inner edge so as to receive edge of smaller left valve which may be more subangular than right valve marginally. Sexual dimorphism expressed by shorter, higher, and thicker carapace of females especially in posterior part, where inner body cavity is more fully developed than in male. Some species show tendency to develop shallow muscle-scar pit (as in Sulcella) and posterior rim or ridge (as in Birdsallella, Paracavellina). ? Sil., Dev. - Penn., Perm.

CAVELLINA CORYELLI Croneis and Gale, 1939

(Plate V, Figures 7 and 8)

CAVELLINA CORYELLI Croneis and Gale, 1939 (Ellis and Messina, 1954, Vol. 5)

Type Reference: Croneis, C., and A. S. Gale, Jr., "New ostracodes from the Golconda formation." Denison Univ., Sci. Lab., Jour., Granville, Ohio, 1939, vol. 33 (1938), art. 5, p. 292.

Type Description: Carapace subovate, medium sized; right valve overlaps the left completely, most prominently along dorsum, less markedly at the venter, least at the ends. Postero- and anterodorsal slopes about equal in length and curvature, both being only slightly convex. Greatest angularities in outline are at ends, about mid-carapace height anteriorly, and about three-fifths shell height above venter posteriorly. Postero-ventral slope steep, slightly convex, rounds smoothly into venter. From anterior end the carapace gradually swells to high point in postercentral area, from which point it rounds, at first gradually and then more steeply, to posterior margin. Posterior and ventral slopes of carapace steeper than anterior and dorsal slopes, respectively. Dimensions of type speci-

men: length 0.83 mm.; height 0.52 mm.; thickness 0.32 mm.

Remarks: This species is somewhat similar to Cavellina nebrascensis (Geinitz) (Cythere nebrascensis, 1866), from the Permian Elmdale formation of Kansas. In the latter, however, the dorsal slopes are less steep, and dorsal and ventral overlaps are more nearly equal than in Cavellina coryelli.

Type Level: Upper Mississippian, lower Chesterian, Homberg group, Golconda formation; gray or bluish, commonly crystalline limestone interbedded with more or less sandy shale.

Type Locality: Road cut near Douglas School, Hardin County, southern Illinois.

Discussion: One specimen of C. coryelli is slightly more elongated than the holotype described by Croneis and Gale. The posterodorsal slope of the specimens is somewhat longer and less convex than the C. coryelli holotype.

Dimensions of the figured specimen are: length 0.85 mm., height 0.46 mm., and width 0.28 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale in a road cut along a county road, west of Deep Creek, Wabaunsee Co., Kansas (measured section no. 10-1).

CAVELLINA EDMISTONAE Harris and Lalicker, 1932

(Plate V, Figures 5 and 6)

CAVELLINA EDMISTONAE Harris and Lalicker, 1932 (Kellett, 1935, p. 147)

Sansabelloides edmistoni Harris and Lalicker, 1932, Am. Midland Nat., vol. 13, p. 402, pl. 37, fig. 5. Garrison shale formation, Permian, Kansas. Type examined.

Cavellina winfieldensis Upson, 1933, Neb. Geol. Survey, (2) Bull. 8, pp. 14, 15, pl. 2, figs. 8a, b. Gage shale, Permian, Nebraska. Type examined.

Cavellina subpulchella Upson (not Coryell), 1933, Neb. Geol. Survey, (2), Bull. 8, pl. 2, figs. 7a-c. Eiss limestone, Permian, Nebraska. Type examined.

Cytherella ovate Upson (not Roemer), 1933, Neb. Geol. Survey, (2), Bull. 8, pp. 15, 16, pl. 2, figs. 9a-b. Eiss limestone, Nebraska. Type examined.

Carapace very small for species of this genus, adults in lateral view rather short and the ends broadly rounded, dorsum slightly arched, venter straight to slightly convex; dorsal overlap narrow, widest at the anterior; posterior third of the interior of the female valves slightly depressed and set off by a low vertical ridge from the rest of the valve; females also show characteristic posterior inflation in dorsal view; the young and rare adults show a shallow central pit located just above the median line; surface smooth. Measurements of the figured specimen: fig. 6a, length 0.73 mm., height 0.42 mm., width 0.27 mm.

Discussion: Some of the specimens are smaller than those described by Kellett (1935, p. 147). All other points of the author's specimens fit the type description.

The measurements of the figured specimen are: length 0.65 mm., height 0.40 mm., and width 0.21 mm.

The figured specimen was in a dusky yellow, calcareous, mud-shale in a road cut on Riley county 911 west of Deep Creek (measured section no. 10-1).

CAVELLINA ELLIPTICALIS Hamilton, 1942

(Plate V, Figures 11 and 12)

CAVELLINA ELLIPTICALIS Hamilton, 1942 (Ellis and Messina, 1955, Vol. 7)

Type Reference: Hamilton, I. B., "Ostracodes from the Upper Permian of Texas." Jour. Pal., Tulsa, Okla., 1942, vol. 16, no. 6, p. 717.

Type Description: Subelliptical in lateral view; dorsal margin gently arched; anterior evenly and bluntly rounded, posterior more sharply rounded, with rather prominent beak well above midheight; ventral margin slightly concave, rounding sharply into posterior, gently into the anterior extremity; right valve overlaps left all around, less conspicuous at extremities; maximum length midway between dorsum and venter; maximum height just behind middle; maximum thickness in posterior third; surface smooth; sides in

dorsal view converge gently to anterior, abruptly into thickened posterior; hinge line sinuate in anterior third; dorsal margin of right valve raised into broad ridge.

Measurements. - Holotype: Length 0.90 mm.; height 0.50 mm.; thickness 0.40 mm.

Type Level: Lower Permian, basal Guadalupian, base of the Word formation; in irregular lenses of fine-grained dark brown to black bituminous limestone in platy siliceous shale, underlying the Word no. 1 limestone and overlying the siliceous shales at the top of the Leonard formation. Rare.

Type Locality: A southwest-northeast-trending scarp immediately north of the former Old Word Ranch house (now marked by a sheep corral and water tank), which stood 370 yards west of benchmark 5652, in the Glass Mountains, 14 miles N. 26° E. from Marathon, Brewster County, Texas.

Discussion: The ventral margin of the specimens found is straight. In some forms the hinge lines do not appear to be sinuated in the anterior third as described by Hamilton.

Measurements of the figured specimens are: length 0.94 mm., height 0.50 mm., and width 0.35 mm.

The measured specimen was in a pale olive, calcareous mudshale along a stream bank of Mill Creek, six miles south of Alma, Wabaunsee Co., Kansas (measured section no. 13-4).

CAVELLINA FOOTEI Coryell and Booth, 1933

(Plate V, Figures 3 and 4)

CAVELLINA FOOTEI Coryell and Booth, 1933 (Cooper, 1946, p. 72)

Cytherella footei Coryell and Booth, 1933, Am. Midland Naturalist, vol. 14, p. 270, pl. 4, fig. 11; Wayland shale, Texas.

Carapace small, tumid, ovate in lateral outline; dorsal and ventral margins strongly convex; ends rounded, posteroventral truncation faint; overlap greatest in centrodorsal and ventral areas, diminishing towards ends, very faint around anterior end; greatest height central; greatest thickness posterior; surface, granulose.

Length, 0.72 mm.; height, 0.49 mm.; width, 0.34 mm.

Discussion: All specimens of C. footei are smaller than the measurements given by Coryell and Booth. C. footei differed by being granular, from other Cavellina species found in the Bennett shale.

Measurements of the figured specimen are: length .40 mm., height 0.26 mm., and thickness o.20 mm.

The measured specimen was in a pale olive, calcareous, mud-shale in a road cut at the intersection of Highway 99 and Interstate Highway 70, Wabaunsee Co., Kansas (measured section no. 12-1).

CAVELLINA NEBRASCENSIS (Geinitz), emend. Lalicker, 1935

(Plate V, Figures 9 and 10)

CAVELLINA NEBRASCENSIS Geinitz, emend. Lalicker, 1935 (Ellis and Messina, 1954, Vol. 4)

Synonymy: Cythere nebrascensis Geinitz, 1866, Verh. (Nova Acta) K. Leop.-Carol. Deutsch. Akad. Naturf., Vol. 33 (1867) p. 2, pl. 1, fig. 2. - Meek, 1872, in Hayden, U. S. Geol. Survey Nebraska, Final Rept., p. 237, pl. 11, fig. 33. - Keyes, 1888, Proc. Acad. Nat. Sci. Philadelphia, p. 243. - White, 1891, U. S. Geol. Survey Bull. 77, p. 30, pl. 4, fig. 20. - Weller, 1898, ibid., Bull. 153, p. 211.

(Cytheropsis) nebrascensis (Geinitz). - Miller, 1889, North American Geol. and Pal., p. 541.

Cavellina nebrascensis (Geinitz). - Kellett, 1935, Jour. Pal., vol. 9, no. 2, p. 146, pl. 18, fig. 1.

Type Reference: Lalicker, C. G., "Cavellina nebrascensis (Geinitz). Jour. Pal., Menasha, Wis., 1935, vol. 9, no. 8, p. 744.

Type Description: (See Cythere nebrascensis Geinitz, 1866.)

(Lalicker, 1935, op. cit., p. 744): Geinitz (1866, loc. cit.), in his work on the Carboniferous and Permian of

EXPLANATION OF PLATE V

(All specimens 30x.)

Fig. 1. Healdia simplex Roundy; lateral view, right valve, anterior end to right. Lateral and dorsal views the same specimen. (p. 62)

Fig. 2. Healdia simplex Roundy; dorsal view, anterior end to the left. (p. 62)

Fig. 3. Cavellina footei (Coryell and Booth); lateral view, left valve, posterior end to the right. Lateral and dorsal views same specimen. (p. 66)

Fig. 4. Cavellina footei (Coryell and Booth); dorsal view, anterior end to the right. (p. 66)

Fig. 5. Cavellina edmistonae (Harris and Lalicker); lateral view, left valve, anterior end to the left. Lateral and dorsal views the same specimen. (p. 64)

Fig. 6. Cavellina edmistonae (Harris and Lalicker); dorsal view, posterior end to the right. (p. 64)

Fig. 7. Cavellina coryelli Croneis and Gale; lateral view, left valve, anterior end to the left. Lateral and dorsal views same specimen. (p. 63)

Fig. 8. Cavellina coryelli Croneis and Gale; dorsal view, anterior end to the left. (p. 63)

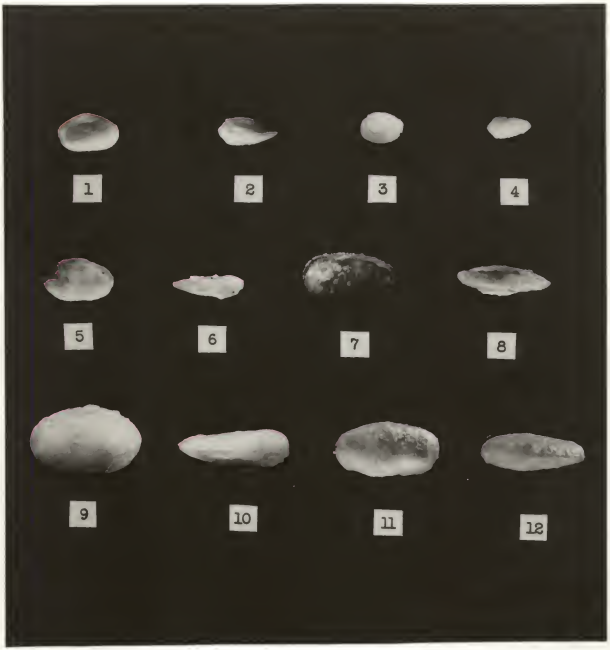
Fig. 9. Cavellina nebrascensis (Geinitz); lateral view, left valve, posterior end to the right. Lateral and dorsal views the same specimen. (p. 67)

Fig. 10. Cavellina nebrascensis (Geinitz); dorsal view, posterior end to the right. (p. 67)

Fig. 11. Cavellina ellipticalis Hamilton; lateral view, left valve, anterior end to the left. Lateral and dorsal views the same specimen. (p. 65)

Fig. 12. Cavellina ellipticalis Hamilton; dorsal view, anterior end to the right. (p. 65)

PLATE V



Nebraska, described one new ostracode, which is of importance to workers on ostracodes in the Mid-Continent region. The types are deposited in the Museum of Comparative Zoology, Cambridge, Massachusetts. Unfortunately, the holotype is a crushed form and does not show the characteristics of the species as well as hypotypes from the same slab of rock. This species is common at Nebraska City, Nebraska, and is probably widespread throughout the Mid-Continent region.

Carapace suboval in lateral view; greatest height slightly posterior to the center; dorsal border evenly convex; posterior end more sharply rounded than the anterior, slightly angled just above the median line; ventral border less convex than the dorsal, and meeting the posterior end in a blunt angle; anterior end broadly rounded; dorsal and ventral overlaps of the right valve strong, most prominent dorsally slightly anterior to the center, and ventrally at the center; surface smooth.

Length of holotype 1.16 mm.; height 0.74 mm.; thickness 0.40 mm. (crushed). Length of figured hypotype (tf. 3) 1.12 mm.; height 0.75 mm.; thickness 0.50 mm.

Type Level: Holotype (tfs. 1-2) and figured hypotype (tf. 3) from the Upper Pennsylvanian, upper Virgilian, upper part of the Wabaunsee group at about the horizon of the Tarkio limestone; in the same slab of rock. (See also Cythere nebrascensis Geinitz, 1866.)

Type Locality: Holotype (tfs. 1-2) and figured hypotype (tf. 3) from near the top of the bluff, above the old steamboat landing, on the west bank of the Missouri River at Nebraska City, Otoe County, Nebraska. (See also Cythere nebrascensis Geinitz, 1866.)

Discussion: The posterior and anterior ends of a few C. nebrascensis specimens are smaller than sizes given by Lalicker; they are also more wedge-shaped than the larger forms. Most of these are immature forms. A posterior ridge was on the smallest specimen.

According to Kellett (Ellis and Messina, 1953, Cavellina fittsi, vol. 4) C. nebrascensis is very similar to B. fittsi; however, one distinction is that the latter has a thicker overlap than the former. The young are indistinguishable in that

they are both wedge shaped and have posterior ridges.

The measurements of the figured specimen are: length 1.02 mm., height 0.64 mm., and width 0.35 mm.

The figured specimen was in a pale olive, calcareous, mud-shale in a road cut at the intersection of Highway 99 and Interstate Highway 70, Wabaunsee Co., Kansas (measured section no. 12-3).

DISTRIBUTION AND PALEOECOLOGY OF OSTRACODA, FORAMINIFERA AND OTHER FOSSILS IN THE BENNETT SHALE

Ostracoda

Ostracodes are present in almost all lithotopes in the Bennett shale. They are most abundant in the more calcareous facies, which characteristically make up in the upper unit of the Bennett shale. The grayer shales had the least variety of ostracodes, and the black shales rarely contained ostracodes.

The black shales, which contain few fossils, seem to indicate an environment that lacked circulation and had a limited supply of oxygen (Twenhofel, 1950, p. 370). Specks of pyrite or marcasite occur in the dark gray and black shales; this may indicate the presence of toxic sulfides during deposition. Variations from different shades of gray to black probably indicate the amount of marine water circulation; the darker the color, the poorer the circulation (McCrone, 1961).

The lighter and more calcareous sediments, in which ostracodes were most abundant, probably indicates clearing of the

water, and a return to more normal marine conditions.

The few fossils present in the black shales were probably swept in by currents and died when introduced to the toxic conditions. Ostracodes favored the clearer, freely circulating marine water; the greatest variety and numbers were found in the lighter colored, more calcareous shales and mudstones.

The genus Amphissites generally was restricted to the calcareous gray mudstones, to the dusky yellow mud-shales and mudstones, and to the argillaceous limestone facies in the upper unit of the Bennett shale (Table 1). One species, A. pinguis, seemed to be less restricted to these facies than the others. It was present in some places in olive-gray or gray mud-shales in the lower unit of the Bennett shale. The species of the genus were not always in the same lithology in different areas. Individual species probably were controlled more by plant population, food source, and salinity of the water than by the type of sediments deposited.

The genus Kirkbya is rare in the Bennett shale, and is restricted to the dark yellow mud-shales and mudstones, which may indicate that it favored more normal marine conditions. Kirkbya canyonensis and K. valida are the only species occurring together at one locality. These species may become more abundant south of this area where the Bennett shales become more calcareous (Jewett and O'Connor, 1952, p. 344).

Several species of Hollinella occur in the Bennett shale. These are confined to gray mudstones and marl, dusky yellow mud-

shale, and gray limestone lithotopes. All the Hollinella species are rare and none was found in more than one or two places.

Cavellina also was limited to the more calcareous facies of the Bennett shale. The lithotopes in which they are present consist of gray limestone, dark gray marl, pale olive or olive-gray mud-shale and a dusky yellow mud-shale.

Cavellina nebrascensis was the most abundant species identified. It forms a biofacies at the top of the upper unit in the southern part of the area of investigation (measured sections 6, 7, 12, and 13). The C. nebrascensis biofacies is in all the lithotopes mentioned above. Carapaces representing both young and adults are abundant. This species must have been more adapted to the different lithotopes in which it was found than any other species of Cavellina or any other ostracode genera. All other species of Cavellina are represented in at least one of the lithotopes of the C. nebrascensis biofacies, but none can be traced from one lithotope to another.

Bairdia is more abundant and occurs over a wider range of lithologies than any other ostracode genus. It occurs in lithotopes ranging from olive-gray to dark gray mudstones and mud-shales to dusky yellow limestone, mudstones and mud-shales. This probably indicates that it adapted to several environments ranging from toxic to normal marine conditions. Even so, its greatest numbers occur in light calcareous sediments indicating Bairdia had a tendency to favor the more normal marine conditions.

The two species that lived under the most varied marine

conditions and are also the most abundant are B. florenaensis and B. folgeri. All other species were more restricted to the lighter, more calcareous sediments.

Bythocypris seems to have adapted to a variety of environments. Only one species, B. pediformis, was present in only one or two localities (Table 1). A few specimens were present in the darker shale facies, but the species is more often present in a dusky yellow mud-shale and a medium-gray limestone facies.

Carbonita is rare in the Bennett shale. According to Swain (Benson and others, 1961, p. 249), it lived under fresh water and possibly marine conditions. The only species, C. tumida var. magna, commonly was found in an olive-black and/or olive-gray mud-shale at two localities (measured section no. 5 and 7). More rarely it is in a dusky yellow mudstone from another locality (Table 1). This genus probably was adapted to the toxic conditions in the lower unit of the Bennett shale. It is probable that C. tumida var. magna lived under brackish conditions, because Orbiculoidea is also present with this species.

Healdia is seldom present in the Bennett shale. Only one species, H. simplex, was identified. A swarm of H. simplex was present in an olive-gray clay shale (Table 1) at Manhattan. This may have represented a mass mortality. However, it seems more likely that they thrived in this locality, as they rarely occur outside this area. Only one other specimen was identified in an olive marl at section 12 (Plate VII, Figure 1).

Monoceratina was identified in several lithotopes. The lithofacies ranged from gray mudstones and olive-gray mud-shales to dusky yellow mud-shales and an olive marl. M. lewisi and M. bradfieldi were collected. Only two specimens of M. lewisi were present, along with M. bradfieldi, in a dusky yellow mud-shale at section 7 (Plate VII, Figure 2). This environment must have been well suited to ostracode life as the majority of Bennett shale ostracoda genera and species were identified at this locality in the dusky yellow mud-shale. Other fossils in abundance in the dusky yellow mud-shale are fusulinids and other foraminifera; brachiopods, including Neospirifer; echinoids; and gastropods. Dunbar stated (1957, vol. 2, p. 753) that fusulinids lived in clear, warm, shallow water. Neospirifer, described by Lowenstam (McCrone, 1961, p. 108) from geochemical data, lived in marine waters around 75° F. It seems that ostracodes abounded in somewhat similar conditions.

M. bradfieldi occurs not only in the dusky yellow calcareous shale but in other types of lithologies. It more commonly is in gray mudstones and olive-gray mud-shales in the Manhattan area. M. bradfieldi, apparently favored the slightly toxic and less circulated marine waters.

Only one specimen of each was found representing Hollina, Kegelites, and Paraparchites (Table 1). These probably never were abundant during Bennett time.

Foraminifera

Foraminifera occur in several different lithofacies. They

Table. Distribution and abundance of Ostracoda and Foraminifera in the Bennett shale.

Measured Sections	1			2					3			4		5			6		7			8			9		10					11						12				13								
Lithologic Divisions	1	2	3	1	2	3	4	5	1	2	3	1	2	1	2	3	1	2	1	2	3	1	2	3	1	2	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6	7	8	9
Ostracoda																																																		
Amphissites centronotus		C		C		R			R										C								C		R							R					R					C	R			C
Amphissites centronotus elongatus																			R								R		R														R		R	R				R
Amphissites pinguis	R	R		R	R	R													A										C							C		R	R	R		C		C	R	R	R			R
Amphissites simplicissimus																			A								A											R		R		R		R		R	R			
Bairdia beedei		R		R															A								A				C										R	R	R	R	R	R				R
Bairdia eissensis																			R								C		R									R		R							R			
Bairdia florenaensis		C	R	C	R	C			C		R								C		R			R			R	R	C	R	C				A		C	R		R	R				R	R	R		R	C
Bairdia folgeri		C		C		C			C										C	R							C			R					A												R		R	A
Bairdia marmorea	R	C																	R								R				R												R		R					
Bairdia nebraskensis									R								C		A		R						A	R													R				R	R				
Bairdia reusseana						R																					C				R										R									
Bairdia seminalis																			R																										R					
Bythocypris pediformis			R	R					R		R																								C		R		R				C							R
Carbonita (?) tumid var. magna															R						C																								R					
Cavellina coryelli																											R				R																			
Cavellina edmistonae																											R												R											
Cavellina ellipticalis		R																									R																		C					
Cavellina footei																																						A												
Cavellina nebrascensis																	C		C																			A	A	A		A	A	A	R					
Healdia simplex						A																																												
Hollina beasleri																																						R		R										
Hollinella cushmani																											R																							
Hollinella digitata																											C														R									
Hollinella emaciata																																											R							
Hollinella gibbosa				C															R																								R							
Hollinella mooresi																												R																						
Kegelites sp.																													R																					
Kirkbya canyonensis																			R								R																			R				
Kirkbya valida																																						R		R						C				
Monoceratina bradfieldi																			R																															
Monoceratina lewisi				R					R										R																C	A			R											
Paraparchites numerosus																																																		R
Foraminifera																																																		
Ammobaculites stormi		R						R																																										
Ammodiscus semiconstrictus	R				R		R																													C														
Bdelloidina (?) permica																			R																															
Globivalvulina biserialis																																			R							R		R						
Globivalvulina cora		R				C																					C	R							R	C		A	A	A		C	A	C	C					
Globivalvulina ovata																			R										R									C		C		C		C	C					
Staffella siscoensis																			R																															
Staffella keytei																			R																															
Tetrataxis corona		R		R		R	R												C								R	R	C							R	R								R					

are most abundant and have the greatest variety in the calcareous sediments. Those in the darker sediments are, in general, more coarsely arenaceous than those in the lighter calcareous sediments. Foraminifera in the lighter calcareous sediments are either finely arenaceous or have a hyaline texture.

Ammobaculites stormi seldom is found in the Bennett shale. The rare specimens of A. stormi were identified in an olive-gray mudstone and a yellow-brown mud-shale in the Manhattan area. Bandy (1960, p. 8) stated that present day Ammobaculites may be the dominant foraminifera found in brackish water. It seems possible that the species A. stormi may have lived in a brackish habitat, indicated by the gray mudstone.

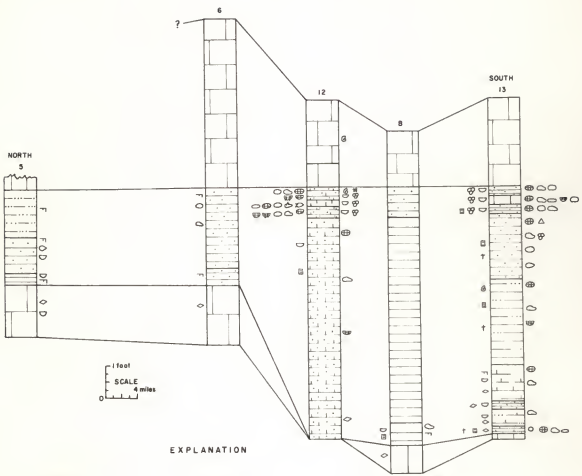
Ammodiscus semiconstrictus also was confined to the Manhattan area (Plate VII, Figure 1). It seems to be restricted to the darker shales, ranging from olive-gray to black. This form may have been pelagic, living at the surface where oxygen was more plentiful than living at the bottom in a reducing environment.

Globivalvulina is generally restricted to the more calcareous sediments. The number of Globivalvulina increase in the southern part of the area of investigation, where the Bennett shale is composed mainly of olive-gray or dusky yellow mud-shales and mudstones, and a single bed of limestone or marl. Three species of Globivalvulina were found, G. biserialis, G. cora and G. ovata. G. cora and G. ovata are most common and widely distributed (Table 1).

EXPLANATION OF PLATE VI

Columnar sections and paleontology of the Red Eagle limestone in Pottawatomie and Wabaunsee Counties. Locations of columnar sections given in Plate I.

PLATE VI



LIMESTONE
MARL
CLAYSTONE
CLAYSTONE, VERY CALCAREOUS
MUDSTONE
MUDSTONE, VERY CALCAREOUS
SILTSTONE
CLAY-SHALE
CLAY-SHALE, VERY CALCAREOUS

MUD-SHALE
MUD-SHALE, VERY CALCAREOUS
COVERED

▲ PELECYPODS
BRACHIOPODS
† ECHINOIDS
CONODONTS
BRYOZOANS
CRINOIDS
◇ FUSULINIDS
△ TETRATAXIS
♭ AMMOBACULITES
GASTROPODS

AMMODISCUS
GLOBIVALVULINA
BOELLOIDINA
STAFFELA
KIRKBYA
AMPHISITES
BAIROIA
CAVELLINA
CARBONITA
HEALDIA
BYTHOCYPRIS
MONOCERATINA
HOLLINELLA
HOLLINA
PARAPARCHITES

EXPLANATION OF PLATE VII

Fig. 1. Columnar sections and paleontology of the Red Eagle limestone in Riley County. Locations of columnar sections in Plate I.

Fig. 2. Columnar sections and paleontology of the Red Eagle limestone in Riley and Wabaunsee Counties. Locations of columnar sections in Plate I.

PLATE VII

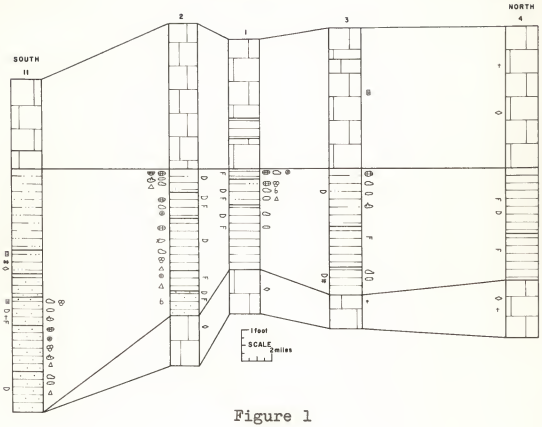


Figure 1

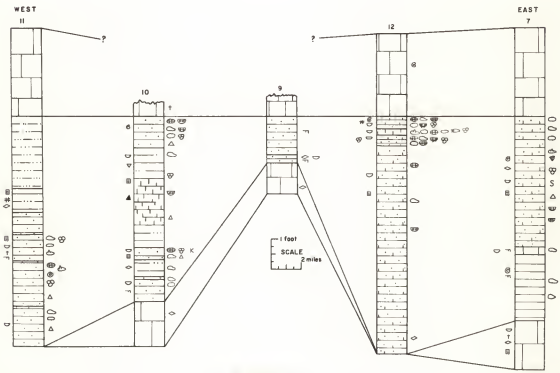


Figure 2

Tetrataxis corona occurs in several lithologies but never is abundant. It was identified most commonly in a dusky yellow mudshale at section 7 and in an olive-gray mud-shale at section 10.

The genera Bdelloidina and Staffela were identified at only one locality. This was at section 7 in a dusky yellow mudshale. This shale, as mentioned before, probably was deposited in a clear, shallow water environment.

Bdelloidina permica was the only Bdelloidina species identified. This is an attached form (Elias, 1950, p. 302) which usually attaches itself to hard surfaces, generally the shells and spines of other animals. The specimen found in the Bennett shale was not attached.

Staffela ciscoensis and S. keytei were the only two species of Stafella found. Two specimens of S. ciscoensis and one of S. keytei were located in a dusky yellow mud-shale in measured section 7 (Plate VII, Fig. 2).

Other fusulinids (besides Staffela) are the small fusiform types. Only a very few forms are more than 2 millimeters in length. These are confined near the base of the Bennett shale at section 12 in a dusky yellow, very calcareous, mud-shale.

All the fusulinids are confined to gray marls, limestones and mudstones, and to dusky yellow mud-shales. An exception is at section 9 where they are present in abundance in an olive-gray to black shale. This probably represents a mass mortality in places where the fusulinids were swept into an environment

which was toxic.

Other Fossils in the Bennett Shale

Conodonts are characteristic of the lower dark shale unit in the Bennett shale. They almost always were in every lithology representing this unit from the black and dark gray shales to the dusky yellow mud-shales and mudstones (Plates VI and VII) since they are in a variety of lithologies, they probably were independent of bottom conditions and were pelagic as mentioned by Hass (1962, p. W4).

Conodonts and fusulinids form a somewhat rare assemblage at section 9. As Muller (1962, p. W87) stated, conodonts occur rarely in fusulinid-bearing limestones. The conodont-fusulinid assemblage was not in a limestone but in an olive-gray to black shale. Muller did not mention them together in other lithologies. Orbiculoidea also was in the conodont-fusulinid assemblage.

Orbiculoidea is another characteristic fossil in the lower unit of the Bennett shale. They are most common in the dark shales but often are present in the more calcareous dusky mud-shales and the upper unit limestones. This indicates they were adapted to several environments but flourished best under low oxygen and poorly circulated marine water.

Marginifera is present only in the Manhattan area, in measured sections 1, 2, 3, 10 and 11. It is restricted to olive-gray mud-shale and mudstones. The Marginifera appear to have been best adapted to the semi-toxic conditions of the mudstones and mud-shales in this area.

CONCLUSION

The Bennett shale is composed of two parts, the upper more calcareous sediments and the lower unit, composed of dark shales. The lithofacies of the upper unit range from dusky yellow mud-shales and mudstones to medium gray marls, mudstones and limestones. The lower unit, composed of dominantly olive-gray to black marine shales, becomes more calcareous and grades into dusky yellow mud-shale and mudstone facies in the southern part of the area of investigation.

The lower, darker shales apparently represent toxic and euxinic conditions present during early deposition of the Bennett shale. Toward the south these conditions gradually changed to less toxic conditions and the water became better circulated. The dusky yellow, more calcareous sediments of the upper unit represent clearer, better circulated marine waters.

Ostracodes and foraminifera thrived best in the better circulated normal marine conditions, represented by dusky yellow mud-shales, mudstones and limestones. They were seldom identified in the toxic black shales. But, ostracodes were more abundant than foraminifera in olive-gray and gray mudstones and mud-shales, indicating that the former were better adapted to the less circulated and more turbid marine conditions than the latter.

Ostracodes or foraminifera genera were not restricted to one lithology, but many were restricted to the lighter, more calcareous sediments. Only one species had a definite pattern

of occurrence. Cavellina nebrascensis forms a biofacies at the top of the upper unit in the southeastern part of the area of investigation.

Lithology does not seem to be the factor controlling foraminifera and ostracode occurrence. Probably they were more dependent on bottom conditions; as the majority of the forms were benthonic. Plant population, amount of oxygen, salinity, temperature, and the abundance of food source were probably the main factors controlling their occurrence.

The most characteristic fossils of the Bennett shale are Orbiculoidea and conodonts. In the lower unit of the Bennett shale they are invariably present. They seem to be well adapted to many environments.

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REFERENCES

Bandy, O. L. (1960), General correlation of foraminiferal structure with environment. Sess. 21st Int. Geol. Congress, Part XXII, pp. 7-19

Benson, R. H. (1961), Ecology of ostracode assemblages. Treatise on Invert. Paleo. (Q) Arthropoda: Geol. Soc. America and Univ. of Kans. Press, pp. Q56-Q63.

_____, J. M. Berdan, W. A. Van Den Bold, T. Hanai, I. Hessland, H. V. Howe, R. V. Kesling, S. A. Levinson, R. A. Reyment, R. C. Moore, H. W. Scott, R. H. Shaver, I. G. Sohn, L. E. Stover, F. M. Swain, P. C. Sylvester-Bradley, and J. Wainwright (1961), Systematic descriptions. Treatise on Invert. Paleo. (Q) Arthropoda: Geol. Soc. America and Univ. of Kans. Press, pp. Q99-Q414.

Clark, W. K. (1950), Ostracod microfaunas of the Lower Permian of Riley County, Kansas. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas, pp. 1-65.

Cooper, C. L. (1946), Pennsylvanian ostracodes of Illinois. State Geol. Sur. of Ill. Bull. 70, pp. 1-179.

Condra, G. E. (1927), The stratigraphy of the Pennsylvanian system in Nebraska. Nebraska Geol. Survey, ser. 2, Bull. 1, pp. 1-291.

Cushman, J. A. (1928), Foraminifera, their classification and economic use. Cushman Laboratory for Foraminiferal Research, pp. 1-397.

Davis, M. E. (1951), Ostracoda of the limestones of the Permian System Wolfcamp Series in Kansas. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas, pp. 1-98.

Dunbar, C. O. (1957), Fusline Foraminifera. Treatise on Marine Ecology and Paleoecology, V. 2, pp. 753-754: Geol. Soc. America Memoir 67.

Elias, M. K. (1950), Paleozoic Ptychocladia and related Foraminifera. Jour. of Paleo., V. 24, pp. 287-386.

Ellis, B. F. and A. R. Messina (1940), Catalogue of Foraminifera. American Mus. of Nat. Hist., V. 1, 3, and 25.

_____, (1952), Catalogue of Ostracoda. American Mus. of Nat. Hist., V. 1-10.

Folk, R. L. (1954), The distinction between grain size and mineral composition in sedimentary rock nomenclature. Jour. Ecol., V. 62, pp. 345-351.

Galloway, J. J. (1933), A manual of Foraminifera. Virginia: McLean Paleontological Laboratory, pp. 1-320.

Glossary of Geology and Related Sciences (1957), American Geol. Institute, pp. 1-325.

Goddard, E. N., and others (1948), Rock-color chart. Rearch council, Washington, D. C.

Harlton, H. H. (1928), Pennsylvanian Foraminifera of Oklahoma and Texas. Jour. of Paleo. V. 1, pp. 305-310

Hass, W. H. (1962), Conodonts. Treatise on Invert. Paleo. (W) Miscellanea: Geol. Soc. America and Univ. of Kans. Press, pp. W3-W5.

Kellett, B. (1935), Ostracodes of the upper Pennsylvanian and lower Permian strata of Kansas: Ill. Bairdiidae (concluded), Cytherellidae, Cyriidinidae, Entomoconchidae, Cytheridae and Cypridae. Jour of Paleo., V. 9, pp. 132-166.

Ladd, H. S. (1957), Paleoecological evidence. Treatise on Marine Ecology and Paleoecology, V. 2, pp. 31-66: Geol. Soc. America Memoir 67.

McCrone, A. W. (1961), The Red Eagle cyclothem (Lower Permian). Unpublished Ph. D. dissertation, Univ. of Kansas, Lawrence, Kansas. Michigan: University Microfilms, Inc., pp. 1-368.

Mudge, M. R., and R. H. Burton (1959), Geology of Wabaunsee County, Kansas. U. S. Geol. Survey Bull. 1068, pp. 1-210.

_____, and Beck (1949), Highway construction material and geology of Riley County, Kansas. U. S. Geol. Survey, Open Files Report.

_____, and E. L. Yochelson (1962), Stratigraphy and paleontology of the uppermost Pennsylvanian and Permian rocks in Kansas. Geol. Sur. Prof. Paper 323, pp. 1-213.

Muller, K. J. (1962), Taxonomy, evolution and ecology of conodonts. Treatise on Invert. Paleo. (W) Miscellanea: Geol. Soc. Am. and Univ. of Kans. Press, pp. W83-W91.

Roth, R. and J. Skinner (1930), The fauna of the McCoy Formation, Pennsylvanian, of Colorado. Jour. of Paleo., V. 4, sup. 1, pp. 332-352.

Scott, G. R., F. W. Foster, and C. F. Crumpton. (1959), Geology and construction-material resources of Pottawatomie County, Kansas. U. S. Geol. Survey Bull. 1060-C, pp. 1-178.

Twenhofel, W. H. (1950), Principles of sedimentation. New York: McGraw-Hill, pp. 1-673.

APPENDIX

Descriptions of Measured Sections

Measured Section No. 1

West side of U. S. 24 spur along a road cut in the SE¼ SW¼ SW¼ sec. 13, T. 10 S., R. 7 E., Riley Co., Kansas.

	Approximate thickness, feet
Howe limestone:	
Limestone, soft, massive; yellow-gray, weathers gray-yellow and irregular, limonite stained	2.5
Shale, clayey, calcareous; pale yellow, weathers pale yellow; laminated; limonite stained	.7
Limestone, soft, massive; gray-yellow, weathers yellow-gray, and irregular	.9
Thickness of Howe limestone	4.1
Bennett shale:	
(1) Shale, clayey, calcareous; dark gray, weathers medium gray; laminated; Orbiculoidea sp.; Conodonts; straight blade, arched bar, and simple cone types; Amphissites pinguis, Bairdia marmorea and Ammodiscus semiconstrictus	.3
(2) Mudstone, slightly calcareous; light olive-gray, weathers light olive-gray and irregular; Composita sp., Dictyoclostus sp., Marginifera sp.; straight blade conodonts; crinoid columnals, echinoid spines, Amphissites centronotus, Amphissites pinguis, Bairdia beedei, Bairdia florenaensis, Bairdia folgeri, Bairdia marmorea, Cavellina ellipticalis, Ammobaculites stormi, Globivalvulina cora, Tetrataxis corona, and fossil fragments	.8
(3) Shale, clayey, slightly calcareous; olive-black, weathers medium dark gray; laminated; Composita sp., Dictyoclostus sp., Marginifera sp., Orbiculoidea sp., Bairdia florenaensis; Bythocypris pediformis; conodonts: straight blade and simple cone types. Orbiculoidea sp. is the only megascopic fossil present in the lower 15 inches	2.1
Thickness of Bennett shale	3.2

Glenrock limestone:
Limestone, hard, dense; yellow-gray, weathers gray-yellow; limonite stained; fusulinids and brachiopod fragments 1.4

Thickness of Glenrock limestone 1.4

Total thickness of the Red Eagle limestone 8.7

Measured Section No. 2

North side of the Chicago Rock Island and Pacific Railroad in a cut on the NW¼ SW¼ NE¼ sec. 24, T. 10 S., R. 7 E., Riley Co., Kansas.

Howe limestone:
Limestone, soft, massive; yellow-gray, weathers gray-yellow and irregular 4.2

Thickness of Howe limestone 4.2

Bennett shale:
(1) Mudstone, slightly calcareous; olive-gray, weathers green-gray and irregular; limonite stained; Composita sp., crinoid columnals, Derbyia sp., Dictyoclostus sp., Amphissites centronotus, Amphissites pinguis, Bairdia beedei, Bairdia florenaensis, Bairdia folgeri, Bythocypris pediformis, Hollinella gibbosa, Monoceratina lewisi, Tetrataxis corona . . .7
(2) Shale, clayey; black, weathers dark gray; laminated; Orbiculoidea sp., straight blade and simple cone conodonts, Amphissites pinguis, Bairdia florensaensis, Ammodiscus semiconstrictus 8
(3) Shale, clayey, calcareous; olive-gray, weathers olive-gray; laminated; Dictyoclostus sp., Marginifera sp., Composita sp., Amphissites centronotus, Amphissites pinguis, Bairdia florenaensis, Bairdia folgeri, Bairdia reussiana, Healdia simplex, Globivalvulina cora, Tetrataxis corona 1.7
(4) Shale, clayey, slightly calcareous; black to black mottled yellow-gray, weathers dark gray; laminated; Ammodiscus semiconstrictus, Tetrataxis corona 7
(5) Shale, muddy, calcareous; medium yellow-brown with a few black laminae, weathers pale yellow-brown; laminated; Orbiculoidea sp., Ambocoelia sp., straight bar and simple cone conodonts, Ammobaculites stormi .7

Thickness of Bennett shale 4.6

Glenrock limestone:
Limestone, hard, dense; yellow-gray, weathers gray-yellow and blocky, limonite stained; Fusulinids . . 1.6

Thickness of Glenrock limestone 1.6

Total thickness of the Red Eagle limestone 10.4

Measured Section No. 3

West side of K-13 road in a cut along the northeast side of Bluemont Hill, Manhattan in the SW¼ SE¼ SE¼ sec. 7, T. 10 S., R. 8 E., Riley Co., Kansas.

Howe limestone:
Limestone, soft, massive; yellow-gray, weathers pale yellow-brown and irregular 1.0
Limestone, soft, massive; gray-orange, weathers pale yellow-brown; Crinoids 3.5

Thickness of Howe limestone 4.5

Bennett shale:
(1) Mudstone, calcareous; dusky yellow to olive-gray, weathers pale gray-yellow to green-gray and irregular; Composita sp., Derbyia sp., Orbiculoidea sp., Amphissites centronotus, Bairdia florenaensis, Bairdia folgeri, Bairdia nebraskensis, Bythocypris pediformis, Monoceratina lewisi, and fossil fragments 1.9
(2) Shale, clayey, slightly calcareous; black, weathers medium gray; laminated, weathers fissile; simple cone type conodont 1.3
(3) Shale, clayey, calcareous; olive-gray, weathers olive-gray; fissile; Marginifera sp., crinoid columnals, fenestrate bryozoans, Bairdia florenaensis, Bythocypris pediformis, and fossil fragments 9

Thickness of Bennett shale 4.1

Glenrock limestone:
Limestone, hard, dense; yellow-gray, weathers yellow-gray; clay nodules, limonite stained, weathers blocky; echinoid spines 1.3

Thickness of Glenrock limestone 1.3

Total thickness of the Red Eagle limestone 9.9

Measured Section No. 4

East side of Tuttle Creek spillway, south of K-13 in the NW¼ NW¼ NE¼ sec. 19, T. 10 S., R. 8 E., Pottawatomie Co., Kansas.

Howe limestone:
Limestone, soft, massive; yellow-gray, weathers gray-yellow and irregular; Fusulinids and echinoid spines 4.5

Thickness of Howe limestone 4.5

Bennett shale:
(1) Shale, clayey, calcareous; dark yellow-brown, weathers dark yellow-brown; upper eight inches limonite stained; laminated; Orbiculoidea sp.; conodonts arched blade, simple cone, straight blade and bowed bar types 2.1
(2) Shale, clayey, calcareous; dark yellow-brown to dark yellow-brown mottled brown-black, weathers dark gray; laminated, weathers fissile; Orbiculoidea sp.; conodonts: straight blade, arched blade, and simple cone types 1.5

Thickness of Bennett shale 3.6

Glenrock limestone:
Limestone, hard, dense; light gray, weathers yellow-gray and blocky; limonite stained, clay nodules; echinoid spines and fusulinids 1.9

Thickness of Glenrock limestone 1.9

Total thickness of the Red Eagle limestone 10.0

Measured Section No. 5

East side of road in a cut along county road north of Belvue, SW¼ SW¼ SW¼ sec. 16, T. 9 S., R. 11 E., Pottawatomie Co., Kansas.

Howe limestone (part):
Limestone, moderate yellow-brown, weathers light olive-gray and cavernous; two feet exposed 2.0

Thickness of exposed Howe limestone 2.0

Bennett shale:
(1) Siltstone, moderate yellow-brown, weathers moderate yellow-brown; simple cone type conodont, Carbonita (?) tumid var. magna 1.5
(2) Shale, muddy; olive-black to moderate yellow-brown, weathers olive-black to moderate yellow-brown; laminated. Orbiculoidea sp.; straight blade and simple cone conodonts 1.0
(3) Shale, clayey, slightly calcareous; dark yellow-orange to moderate yellow-brown, weathers moderate yellow-brown; laminated; straight blade and simple cone conodonts, brachiopod fragments 4

Thickness of Bennett shale 2.9

Glenrock limestone:
Limestone, hard, dense; moderate yellow-brown, weathers gray-orage to pale yellow-brown; limonite stained; weathers blocky; forms a small hillside bench; fusulinids and brachiopod fragments 1.6

Thickness of Glenrock limestone 1.6

Total thickness of the Red Eagle limestone 6.5

Measured Section No. 6

East side of road in a cut along Highway 99 in the SW¼ SE¼ NW¼ sec. 3, T. 10 S., R. 10 E., Wabaunsee Co., Kansas.

Howe limestone:
Limestone, hard, massive; moderate yellow-brown, weathers light olive-gray; weathers cellular, deeply weathered 5.1

Thickness of Howe limestone 5.1

Bennett shale:
(1) Shale, muddy, calcareous; dark yellow-brown to mottled pale green, weathers dark yellow-brown; straight blade and simple cone conodonts, Bairdia nebraskensis, Cavellina nebraskensis, and brachiopod fragments 2.4
(2) Shale, muddy, slightly calcareous; dark yellow-brown to mottled pale green; calcareous concretions; simple cone type conodont 5

Thickness of Bennett shale 2.9

Glenrock limestone:
Limestone, dense; light gray to yellow-gray, weathers light olive-gray; weathers blocky; fusulinids 1.8

Thickness of Glenrock limestone 1.8

Total thickness of the Red Eagle limestone 9.8

Measured Section No. 7

South side of road in a cut along Interstate 70, in the NW¼ NW¼ NW¼ sec. 31, T. 11 S., R. 12 E., Wabaunsee Co., Kansas.

Howe limestone:
Limestone, soft, massive; gray-orange, weathers very pale orange to gray-orange-pink; thin-bedded; lenticular 1.6
Limestone, soft, thin-bedded, pale orange, weathers very pale orange and porous; lenticular 3

Thickness of Howe limestone 1.9

Bennett shale:
(1) Shale, muddy, very calcareous; dusky yellow to pale yellow, weathers gray-yellow; laminated; Neospirifer sp., Naticopis sp., highly spiraled gastropods, fusulinids, crinoid columnals, echinoid plates and spines, fenestrate bryozoans, Amphissites centronotus, Amphissites centronotus elongatus, Amphissites pinguis, Amphissites simplicissimus, Bairdia beedei, Bairdia eissensis, Bairdia florenaensis, Bairdia folgeri, Bairdia marmorea, Bairdia nebraskensis, Bairdia seminalis, Cavellina nebrascensis, Hollinella gibbosa, Monoceratina bradfieldi, Monoceratina lewisi, Bdelloidina (?) permica, Globivalvulina ovata, Staffella keytei, Staffella ciscoensis, Tetrataxis corona, and Kirkbya canyonensis 4.2
(2) Limestone, argillaceous, soft; dark yellow-orange to moderate yellow-brown, weathers moderate yellow-brown; Orbiculoidea sp., echinoid spines, straight bar and simple cone conodonts, Bairdia folgeri and chitin material abundant 3
(3) Shale, clayey, calcareous; light olive-gray to mottled black, weathers yellow-gray to dark gray; laminated, weathers fissile; Naticopis sp., Maturipupa sp.; conodonts: straight bar, simple cone, and bowed bar types; fenestrate bryozoans, Bairdia florenaensis, Bairdia nebraskensis, Carbonita (?) tumid var. magna 2.2

Thickness of Bennett shale 6.7

Glenrock limestone:
Limestone, hard, dense; dusky yellow to pale yellow-orange, weathers pale yellow-orange; weathers blocky; fusulinids, crinoid columnals, and echinoid spines 1.6

Thickness of Glenrock shale 1.6

Total thickness of the Red Eagle limestone 10.1

Measured Section No. 8

North side of pasture entrance road in a cut along Mill Creek in the NE¼ NW¼ SE¼ sec. 11, T. 12 S., R. 10 E., Wabaunsee Co., Kansas.

Howe limestone:
Limestone, hard, massive; moderate yellow-brown, weathers dark yellow-orange; limonite stained 1.7

Thickness of Howe limestone 1.7

Bennett shale:
(1) Shale, muddy, slightly calcareous; dusky yellow, weathers gray-yellow; laminated; celestite geodes . 1.0
(2) Shale, clayey; slightly calcareous, medium dark gray mottled dusky yellow, weathers pale green-yellow, poorly laminated; limonite stained, calcareous concretions 6.1
(3) Shale, clay, calcareous; dark yellow-orange to moderate yellow-brown mottled medium dark gray, weathers the same; fissile; Chonetes sp., Bairdia florenaensis, straight bar and simple cone conodonts, echinoid spines and plates, crinoid columnals flattened and rounded, fenestrate bryozoans, Neospirifer (?) fragments, Orbiculoidea sp. fragments and other brachiopod fragments 7.9

Thickness of Bennett shale 7.9

Glenrock limestone:
Limestone, hard, dense; yellow-gray, weathers yellow-gray; limonite stained; fusulinids 8

Thickness of Glenrock limestone .8

Total thickness of the Red Eagle limestone 10.4

Measured Section No. 9

West side of road in a cut along a county road one-half mile north of Interstate 70 in the SW¼ SE¼ SE¼ sec. 23, T. 11 S., R. 9 E., Wabaunsee Co., Kansas.

Howe limestone (part):
Limestone, hard; gray-orange, weathers gray-orange and cavernous, limonite stained; eight inches exposed 7

Thickness of exposed Howe limestone .7

Bennett shale:
(1) Shale, silty, calcareous; dark yellow-brown to dusky yellow-brown, weathers the same; laminated; straight bar conodonts 1.3
(2) Shale, muddy, calcareous; light olive-gray with a few black laminae, weathers light olive-gray; laminated; Orbiculoidea sp., fusulinids, straight bar and simple cone conodonts, conodont and brachiopod fragments 1.5

Thickness of Bennett shale 2.8

Glenrock limestone:
Limestone, hard, dense; yellow-gray, weathers yellow-gray and blocky; limonite stained; fusulinids . . . 1.0

Thickness of Glenrock limestone 1.0

Total thickness of the Red Eagle limestone 4.5

Measured Section No. 10

West side of road in a cut along county road 911, west of Deep Creek in the NW¼ SW¼ SW¼ sec. 14, T. 11 S., R. 8 E., Riley Co., Kansas.

Howe limestone (part):
Limestone, hard; gray-yellow, weathers gray-orange and cavernous; limonite stained; five inches exposed; echinoid spines 4

Thickness of exposed Howelimestone .4

Bennett shale:
(1) Shale, muddy, calcareous; dusky yellow, weathers dusky yellow; laminated; fenestrate and twig-like bryozoans, Naticopis sp., Amphissites centronotus,

Amphissites centronotus elongatus, Amphissites simplicissimus, Bairdia beedei, Bairdia eissensis, Bairdia florenaensis, Bairdia folgeri, Bairdia marmorea, Bairdia nebraskensis, Bairdia reussiana, Cavellina coryelli, Cavellina edmistonae, Cavellina ellipticalis, Hollinella digitata, Kirkbya canyonensis, Globivalvulina cora, Tetrataxis corona . . . 1.1

(2) Mudstone to marl; mudstone, calcareous; light olive-gray, weathers medium gray, limonite stained; approximately 12 inches thick; grades vertically to marl. Marl, laminated to thin bedded; light olive-gray, weathers light olive-gray, limonite stained; resistant to weathering, 22 inches thick; grades vertically back to olive-gray mudstone, 12 inches thick; Allorisma sp., Dictyoclostus sp., echinoid spines, crinoid columnals, Bairdia florenaensis, Bairdia nebraskensis, Hollinella moorei, Healdia simplex, Globivalvulina cora, Tetrataxis corona . . 3.2

(3) Shale, muddy, calcareous; light olive-gray, weathers yellow-gray; laminated, weathers fissile; Marginifera sp., Ambocoelia sp., crinoid columnals, fenestrate and twig-like bryozoans, echinoid plates, Amphissites centronotus, Amphissites centronotus elongatus, Amphissites pinguis, Bairdia eissensis, Bairdia florenaensis, Bythocypris pediformis, Kegelites sp., Globivalvulina ovata, Tetrataxis corona, and fusulinids 4

(4) Mudstone, calcareous; light olive-gray to olive-gray, weathers yellow-gray to gray and irregular; Bairdia florenaensis, Bairdia folgeri, and fossil fragments 6

(5) Shale, muddy, calcareous; light olive-gray, weathers yellow-gray, laminated; Ambocoelia sp., Marginifera (?) sp. fragments, crinoid columnals, Bairdia beedei, Bairdia florensensis, Bairdia marmorea, Bairdia reussiana, Cavellina coryelli, straight bar conodonts and fossil fragments 8

Thickness of Bennett shale 6.1

Glenrock limestone:

Limestone, hard, dense, slightly argillaceous; yellow-gray, weathers gray-yellow, fusulinids 1.1

Thickness of Glenrock limestone 1.1

Total thickness of the Red Eagle limestone 7.6

Measured Section No. 11

In a stream bank along the east side of a branch of McDowell's Creek, south of county road 901 in the NE¼ SE¼ NW¼ sec. 12, T. 11 S., R. 7 E., Riley Co., Kansas.

Howe limestone:

Limestone, hard, massive; pale yellow-brown, weathers yellow-gray and irregular; limonite stained 2.2

Limestone, soft, massive; argillaceous; dusky yellow, weathers yellow-gray and irregular; limonite stained; not as resistant to weathering as limestone above . .6

Thickness of Howe limestone 2.8

Bennett shale:

(1) Siltstone, slightly calcareous; pale olive-gray to pale olive-gray mottled dusky yellow 2.3

(2) Mudstone, calcareous; light olive-gray, weathers yellow-gray and irregular; crinoid columnals, echinoid spines, Ambocoelia sp., Dictyoclostus sp., fusulinids 8

(3) Shale, muddy, calcareous; dark gray, weathers gray; laminated; fenestrate bryozoans, echinoid spines . . .7

(4) Shale, muddy, calcareous; dusky yellow, weathers dusky yellow; laminated; Chonetes sp., echinoid spines, crinoid columnals, straight bar conodonts, Bairdia florenaensis, Bairdia folgeri, Bythocypris pediformis, Monoceratina lewisi, Globivalvulina biserialis, Globivalvulina cora 8

(5) Shale, muddy, very calcareous; olive-gray to dusky yellow, weathers the same, laminated; echinoid spines, Amphissites centronotus, Amphissites pinguis, Monoceratina lewisi, Ammodiscus semiconstrictus, Globivalvulina cora, Tetrataxis corona, and straight bar conodonts 1.5

(6) Shale, muddy, very calcareous; dusky yellow to olive-gray, weathers same; laminated; Orbiculoidea sp., Composita sp., Marginifera sp., crinoid columnals, Bairdia florenaensis, Bythocypris pediformis, Tetrataxis corona 1.3

Thickness of Bennett shale 7.5

Glenrock limestone (missing):

Total thickness of the Red Eagle limestone 10.3

Measured Section No. 12

South side of Interstate 70 in a road cut near intersection of Highway 99 and Interstate 70, in the NW¼ NE¼ SW¼ sec. 26, T. 11 S., R. 10 E., Wabaunsee Co., Kansas.

Howe limestone:

Limestone, hard, massive; moderate yellow-brown, weathers gray-orange and cavernous, limonite stained; highly spiraled gastropods 2.1

Limestone, soft, massive, argillaceous; moderate yellow-brown, weathers gray-orange and irregular, deeply weathered 7

Thickness of Howe limestone 2.8

Bennett shale:

(1) Shale, muddy, very calcareous; pale olive-gray, weathers pale green-yellow; laminated, limonite stained; crinoid columnals, echinoid spines and plates, brachiopod fragments, Amphissites pinguis, Amphissites simplicissimus, Bairdia eissensis, Bairdia florenaensis, Cavellina footei, Cavellina nebrascensis, Hollina bassleri, Kirkbya valida, Globivalvulina cora, Globivalvulina ovata 1.0

(2) Marl; pale olive mottled dark gray; weathers same; Dictyoclostus sp., Meekella sp., crinoid columnals, echinoid spines, fenestrate bryozoans, Amphissites pinguis, Bythocypris pediformis, Cavellina edmistonae, Cavellina nebrascensis, Healdia simplex, Monoceratina lewisi, and Globivalvulina cora 2

(3) Shale, muddy, very calcareous; pale olive-gray, weathers green-yellow; laminated; echinoid spines, crinoid columnals, brachiopod fragments, fenestrate bryozoans, Amphissites simplicissimus, Amphissites pinguis, Bairdia eissensis, Bairdia florenaensis, Cavellina footei, Cavellina nebrascensis, Hollina bassleri, Kirkbya valida, Globivalvulina cora, Globivalvulina ovata 3

(4) Shale, muddy, very calcareous; light olive-gray mottled medium gray, weathers yellow-gray; laminated and irregular, fairly resistant to weathering; limonite stained; Dictyoclostus sp., Chonetes sp., Composita sp., crinoid columnals, echinoid columnals, fenestrate bryozoans, fusulinids, Amphissites centronotus, Amphissites simplicissimus, Bairdia beedei, Bairdia florenaensis, Bairdia nebraskensis, Bairdia reussiana, Hollinella digitata 6.2

Thickness of Bennett shale 7.7

Glenrock limestone (absent).

Total thickness of the Red Eagle limestone 10.5

Measured Section No. 13

North bank of Mill Creek, in a stream bank, east of county road FAS 1682, in the SE¼ SW¼ SW¼ sec. 36, T. 12 S., R. 10 E., Wabaunsee Co., Kansas.

Howe limestone:

Limestone, hard, massive; pale yellow-orange, weathers pale yellow-brown to a gray-orange and cavernous; limonite stained; fossils not apparent 2.7

Thickness of Howe limestone 2.7

Bennett Shale:

(1) Shale, muddy, calcareous; pale olive, weathers yellow-gray; fissile, weathers fissile; crinoid columnals, fenestrate bryozoans, brachiopod fragments, Amphissites pinguis, Bairdia beedei, Cavellina ellipticalis, Cavellina nebrascensis, Globivalvulina biserialis, Globivalvulina cora, Globivalvulina ovata 3

(2) Limestone, soft, argillaceous; medium gray to medium dark gray, weathers pale gray-yellow, limonite stained; echinoids spines, crinoid columnals, brachiopod fragments, Amphissites centronotus elongatus, Bairdia beedei, Bairdia marmorea, Bythocypris pediformis, Cavellina nebrascensis, Hollinella emaciata, Hollinella gibbosa, Globivalvulina ovata . .2

(3) Shale, muddy, calcareous; pale olive, weathers yellow-gray; fissile, weathers fissile; crinoid columnals, fenestrate bryozoans, brachiopod fragments, Amphissites pinguis, Bairdia beedei, Cavellina ellipticalis, Cavellina nebrascensis, Globivalvulina cora, Globivalvulina ovata, Globivalvulina biserials 3

(4) Shale, muddy, calcareous, dusky yellow mottled dark gray, weathers yellow-gray mottled medium dark gray; laminated, weathers fissile to irregular; limonite stained; Composita sp., Dictyoclostus sp. Linoproductus sp., echinoid spines, crinoid columnals, Amphissites centronotus elongatus, Amphissites pinguis, Bairdia beedei, Bairdia florenaensis, Bairdia marmorea, Bairdia nebraskensis, Carbonita tumid var. magna, Cavellina nebrascensis, Globivalvulina ovata, Globivalvulina cora, Tetrataxis corona 2.0

(5) Mudstone, calcareous; dusky yellow mottled pale olive, weathers yellow-gray and irregular; fenestrate bryozoans, crinoid columnals, echinoid spines, Amphissites centronotus, Amphissites centronotus elongatus, Amphissites pinguis, Amphissites simplicissimus, Bairdia beedei, Bairdia florenaensis, Bairdia nebraskensis, Bairdia seminalis, Kirkbya canyonensis, Kirkbya valida 2.6

(6) Claystone, very calcareous; dusky yellow mottled pale olive, weathers yellow-gray; slightly resistant to weathering; Maturipupa sp., crinoid columnals, echinoid spines, Amphissites centronotus, Amphissites pinguis, Amphissites simplicissimus, Bairdia eissensis, Bairdia florenaensis, Bairdia folgeri 1.1

(7) Shale, muddy, slightly calcareous; yellow-brown, weathers yellow-gray; laminated, weathers laminated to fissile; fusulinids rare, fenestrate bryozoans rare 2

(8) Mudstone, very calcareous; dusky yellow mottled ple olive, weathers yellow-gray and irregular, resistant to weathering; limonite stained; Bairdia florenaensis, Bairdia folgeri 5

(9) Shale, clay, very calcareous; moderate yellow-brown, weathers yellow-gray; laminated, weathers fissile; limonite stained; echinoid spines, fusulinids rare, Amphissites centronotus, Amphissites centronotus elongatus, Amphissites pinguis, Bairdia beedei, Bairdia florenaensis, Bairdia folgeri, Bythocypris pediformis 2

Thickness of Bennett shale 7.4

Glenrock limestone:

Limestone, hard, argillaceous; pale yellow-brown, weathers pale yellow-brown; lenticular; limonite stained; fossils not apparent 2

Thickness of Glenrock limestone .2

Total thickness of the Red Eagle limestone 10.3

THE DISTRIBUTION OF OSTRACODA AND FORAMINIFERA IN THE BENNETT SHALE

by

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ABSTRACT

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ABSTRACT

An investigation was made to establish a relationship between ostracodes and foraminifera and the different lithotopes in the Bennett shale. It was also believed that some characteristic fauna of the Bennett shale could be established.

Fifty samples were taken from 13 measured sections in Riley, Pottawatomie, and Wabaunsee Counties. These samples were broken down in the laboratory by hydrogen peroxide and sodium hydroxide methods; the hydrogen peroxide method was the most effective.

Twelve genera and 31 species of ostracodes and 6 genera and 9 species of foraminifera were identified from the Bennett shale. The ostracodes were more abundant and more adapted to the dark shale facies. Both ostracodes and foraminifera favored the lighter and more calcareous facies. Few ostracodes and foraminifera were present in the black toxic and euxinic shales. These were probably swept in and died when introduced to the toxic conditions.

Only one biofacie was established. Cavellina nebrascensis formed the biofacie and was present only in four measured sections in Wabaunsee County. No other genera or species of ostracodes and foraminifera formed a definite pattern of occurrence. Sedimentation seemed to be secondary in determining the occurrence of the fauna. It seemed more likely that plant life, source of food, salinity and other conditions had a more dominating effect.

Conodonts and Orbiculoidea were invariably present in the Bennett shale and are the most characteristic fauna.