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PENNSYLVANIAN SPIRIFERACEA AND SPIRIFERINACEA OF KANSAS

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ABSTRACT

Punctospirifer kentuckyensis, Spirifer rockymontanus, S. opimus, S. occiduus, Neospirifer dunbari, N. dunbari alatus, N. dunbari gibbosus, N. cameratus, N. latus, N. latus lateralis, N. kansasensis, N. texanus, and *N. goreii* were observed to be the only spiriferoid brachiopods occurring in the Pennsylvanian System of Kansas, and the ranges of all have been extended beyond previously known limits. A new subspecies, *N. latus lateralis,* confined to the Lansing Group, Upper Missourian, is herein proposed.

The internal structures of all species encountered in this study have been examined in serial sections, and several new structures were observed. Also, similarities of internal structures of *S. rockymontanus, S. occiduus,* and *N. dunbari,* and of *S. opimus* and remaining Neospirifers has lead the author to suspect a polyphyletic origin for *Neospirifer.*

A study of the plication patterns of *Neospirifer* has shown that the pattern of branching on the fold and sulcus is reliable for species identification. Because word descriptions for these patterns are rather lengthy, a shorthand system for describing them was developed.

INTRODUCTION

PREVIOUS STUDIES

Species of spire-bearing Pennsylvanian brachiopods from the Mid-Continent region have been described by MORTON (1836), HALL (1852, 1858), MARCOU (1858), SWALLOW (1860, 1867), MEEK (1872), BEEDE & ROGERS (1908), BEEDE (1909), MATHER (1915), GIRTY (1915, 1920, 1927, 1929-34), DUNBAR & CONDRA (1932), and KING (1933). BEEDE & ROGERS (1908) and BEEDE (1909) did early work on fossils of the upper Paleozoic of Kansas. Both included only a single species of *Spirifer* and one of *Punctospirifer.* The former work is primarily a stratigraphic paleontologic paper giving the stratigraphic range of fossil invertebrates and vertebrates known from the Coal Measures at that time. The latter paper, supplemental to the former, contains descriptions of fossil invertebrates known to occur in the Coal Measures of Kansas.

DUNBAR & CONDRA's (1932) monographic work on "Brachiopods of the Pennsylvanian System in Nebraska" was the first thorough treatment of Pennsylvanian brachiopods in the Mid-Continent region. All of the known Pennsylvanian brachiopods of Nebraska and surrounding states were described, illustrated, and listed according to stratigraphic occurrence down to formational levels. No attempt was made to record occurrences in smaller stratigraphic units.

PRESENT STUDY

The purpose of this paper is to describe as accurately as possible the Pennsylvanian spire-bearing brachiopods of Kansas and to determine their stratigraphic ranges.

By combining the available museum collections with specimens collected in the field by me, an attempt has been made to obtain representative samples from every member. Owing to the scarcity of some spire-bearing brachiopods and to the relative barrenness of rocks of some formations, however, this was not possible.

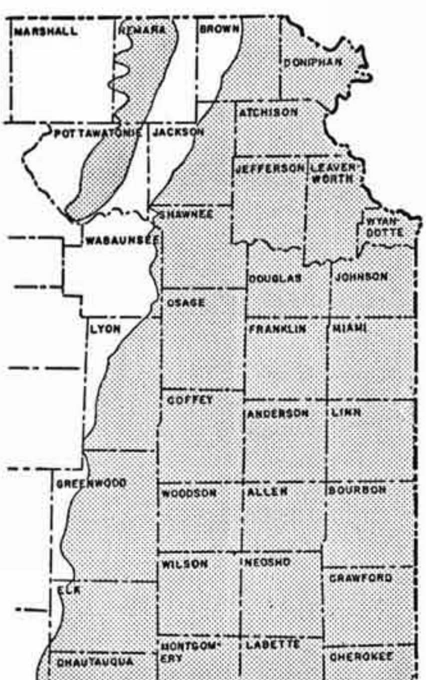

FIG. 1. Outcrop map of Pennsylvanian rocks (stippled area) in Kansas (after Moore and others, 1951).

AREA STUDIED

With exception of a few square miles in the southeast corner, Pennsylvanian strata crop out in the extreme eastern part of Kansas and have a general northeast-southwest strike (Fig. 1). Figures 2 and 3 provide a columnar section showing their stratigraphic classification.

MATERIAL STUDIED

Most fossils used in this study are from collections of the University of Kansas Department of Geology Paleontological Museum. In addition, I collected materials from stratigraphic units not represented in the museum collections and supplemented collections from other units. Field collecting was started in the spring of 1961 and continued through the summer and fall of that year. Altogether, approximately three months were spent collecting specimens.

All illustrated specimens, both hypotypes and holotypes are catalogued and deposited in the University of Kansas Museum of Invertebrate Paleontology (UKMIP) and bear catalogue numbers 500,001 to 500,0028.

METHODS OF STUDY

Because most specimens were collected from limestone, it was necessary to remove considerable amounts of matrix to permit measurement and identification. Chemical and mechanical aids were used in order to clean the specimens thoroughly. To clean specimens in a shale or shaly limestone matrix, potassium hydroxide pellets were either placed directly on the matrix or dissolved in water and boiled with the specimen for various lengths of times. Dissecting needles, dental tools, a small rotary drill, and a vibrotool, however, proved to be more useful in removing the matrix from most specimens.

In order to facilitate the identification of specimens, measurements were taken with a vernier caliper and a contact goniometer. Width, length, thickness, and angle of the fold, sulcus, and pedicle opening were recorded. Frequency distribution curves and scattergrams were plotted, but in general the data proved to be insufficient for delimiting evolutionary trends.

After each species had been identified and photographed, serial sections were made and the internal structures sketched by means of a camera lucida. Before sketching, each specimen was heated to redness over a bunsen flame, and allowed to cool in the air. The application of heat calcines the shell and makes it clearly distinguishable from the matrix. After the specimens cooled, they were mounted in blocks of plaster so that the posterior part of the lateral commissure was perpendicular to the plane of sectioning. Transverse sections were obtained by grinding the specimen with 600 powder on a glass plate.

ACKNOWLEDGMENTS

In the course of this study, numerous individuals helped me. Sincere thanks are extended to Dr. C. W. PITRAT for guidance, assistance, and encouragement rendered throughout this project. Dr. J. M. JEWETT was extremely helpful in providing information on stratigraphy, localities, and presentation, as well as providing time for consultation in the field, and in reading the manuscript critically. Dr. R. H. KING helped in providing information on collecting localities and museum material, as well as in reading the manuscript critically. The State Geological Survey of Kansas generously financed part of this study. RONALD W. WEST, MILO E. WYNN, GEORGE L. COLEMAN, STANTON M. BALL, LEAMAN H. HARRIS, and THOMAS L. THOMPSON, then graduate students of the Department of Geology, were helpful in field assistance and in critical, thought-provoking discussions of the problems that arose. Finally, I express appreciation to Dr. R. C. MOORE and ROGER B. WILLIAMS for improvements of the text and figures.

PENNSYLVANIAN STRATIGRAPHY AND FAUNAL SUMMARY

The data presented here and on following pages have been taken mainly from papers written by ABERNATHY (1937), BOWSHER & JEWETT (1943), BRONSON (1957), MOORE (1932, 1936, 1937, 1959), MOORE and others (1951), and MUDGE (1957).

In Kansas, Pennsylvanian rocks rest unconformably on older rocks, principally on the eroded surface of Mississippian beds. Rocks of Desmoinesian age and younger are exposed. At the top of the Pennsylvanian System, a local discontinuity in sedimentation is present, which seems to coincide with faunal and lithologic changes. In most of the outcrop area, however, there is no physical evidence of disconformity.

Epeirogenic movement gave these rocks a gentle westward dip of 20 to 25 feet per mile before burial under Mesozoic sediments. Seemingly, peneplanation preceded burial, as shown by the concordant summits of numerous present-day northeast-southwest escarpments in the eastern part of the state, where the Mesozoic cover, if formerly present, has been removed.

Pennsylvanian and Lower Permian strata are characterized by cyclic deposits of marine and nonmarine rocks and by the persistency of the rock units even though many of them have a thickness of only 0.2 to 2 feet. These and other facts testify that at the time of accumulation of sediment the environments were nearly identical over an extremely large area at any one time, and the changes in the sedimentary environments recurred in a relatively consistent asymmetrical sequence, each individual cycle or cyclothemic deposit being characterized by lithologic and paleontologic features.

DESMOINESIAN STAGE

Cherokee Group.—The Cherokee Group includes two large units, the Krebs Formation in the lower part and the Cabaniss Formation in the upper part, the thickness of this group ranging from 400 to 450 feet. Gray to blue-gray clayey shale and silty micaceous shale is present at several horizons. Sandstone, sandy shale, and coal also occur, but very little limestone. Most of the sandstone bodies are erratic and occur as channel fillings and bar deposits (Fig. 2).

Because shale is the dominant rock type, the outcrop area is a lowland plain on which exposures are few.

Marine fossils are rare, except in the scattered limestone beds that commonly occur above coal beds. An example of such limestone is the Verdigris Limestone, which is very fossiliferous and is the most important limestone in this group. It is approximately in the middle of the Cabaniss Formation.

Marmaton Group.—The Marmaton Group includes beds from the base of the Fort Scott Limestone to the top of the Holdenville Shale, and is more calcareous and more dominantly marine than the underlying Cherokee Group (Fig. 2). It consists of alternating layers of limestone and shale but includes some persistent coal beds and some sandstone. The thickness is approximately 250 feet.

Formations of the Marmaton Group, in ascending order, are called Fort Scott Limestone, Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, Nowata Shale, Lenapah Limestone, and Holdenville Shale.

MISSOURIAN STAGE

Pleasanton Group.—The Pleasanton Group includes beds above a recognized disconformity separating Desmoinesian from Missourian rocks and below the Hertha Limestone and has a thickness of approximately 70 to 150 feet. It consists mainly of clastic rocks—yellow, gray, and dark-gray to black clayey shale and micaceous sandstone—but includes limestone and coal. The thin, fossiliferous Checkerboard Limestone near the base is not definitely identified except in southern Kansas. The Hepler Sandstone, at the base of the group, is a persistent, brown to gray, sheetlike deposit which overlies the regional disconformity at the base of the Missourian Stage. Other units of this group are unnamed (Fig. 2).

Kansas City Group.—The Kansas City Group includes all beds from the base of the Hertha

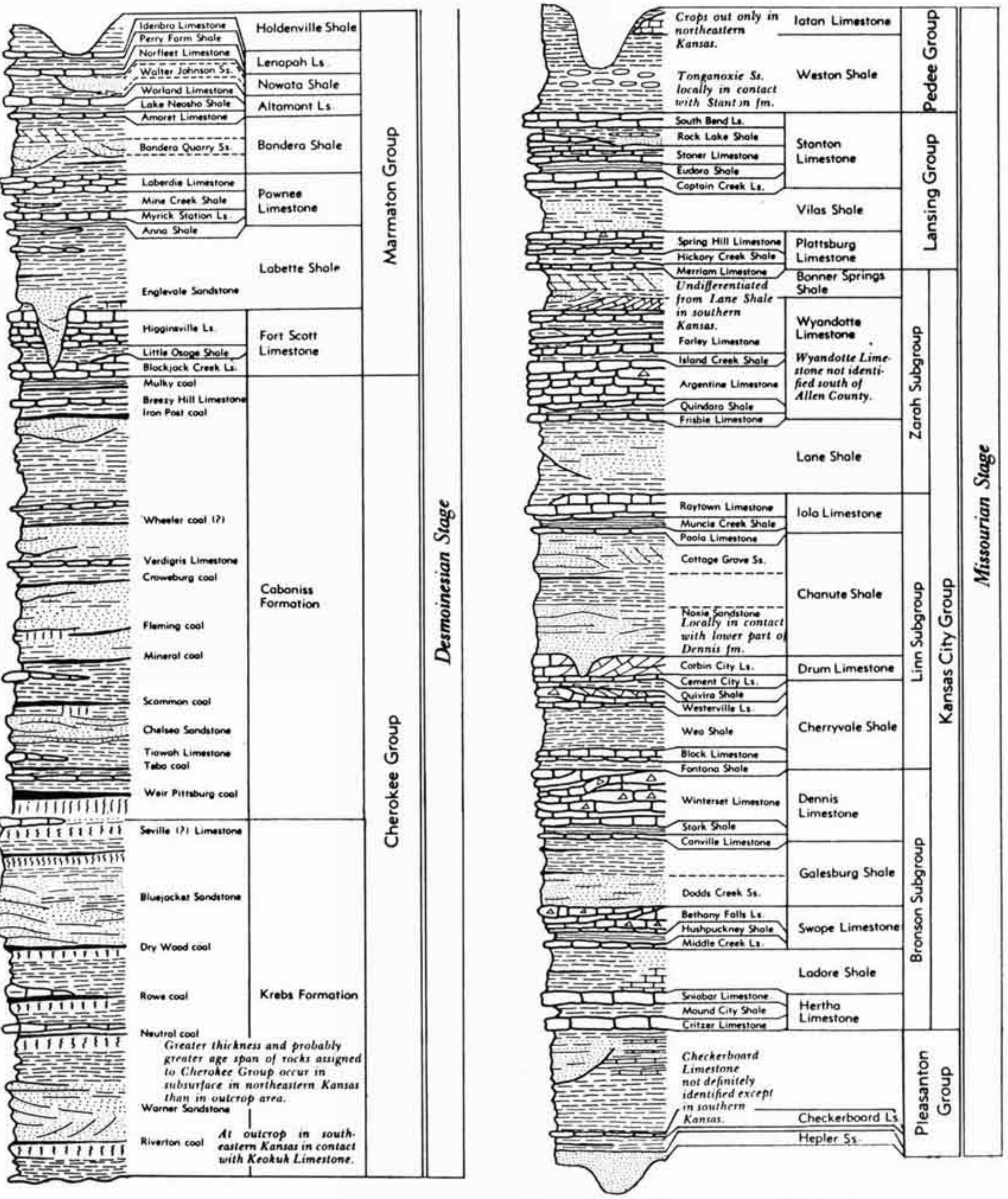

FIG. 2. Desmoinesian and Missourian rocks in Kansas (from Jewett, 1959).

Limestone to the top of the Bonner Springs Shale and consists of major limestone and shale units, each representing individual sedimentation cycles or important lithologic elements of cycles, the chief distinguishing features being the prominence of limestone. This group is divided into three subgroups, which, in ascending order, are called Bronson, Linn, and Zarah (Fig. 2).

The Bronson Subgroup has a thickness of 85 to 175 feet and is characterized, except in southern Kansas where the Galesburg and Ladore Shales are thick and limestone units are thin or absent, by the dominance of limestone that forms escarpments, whereas the Linn Subgroup has a predominance of shales, persistent limestone, and locally much sandstone and has an average thickness of 110 feet. The Zarah Subgroup has an average thickness of 100 feet and consists of prominent limestone units.

Lansing Group.—The Lansing Group has an average thickness of 85 feet and includes strata from the base of the Plattsburg to the top of the Stanton Limestones. It consists of these two limestones and the thin Vilas Shale between them. Because this shale unit is thin, the group as a whole is a fairly compact sequence, which stands

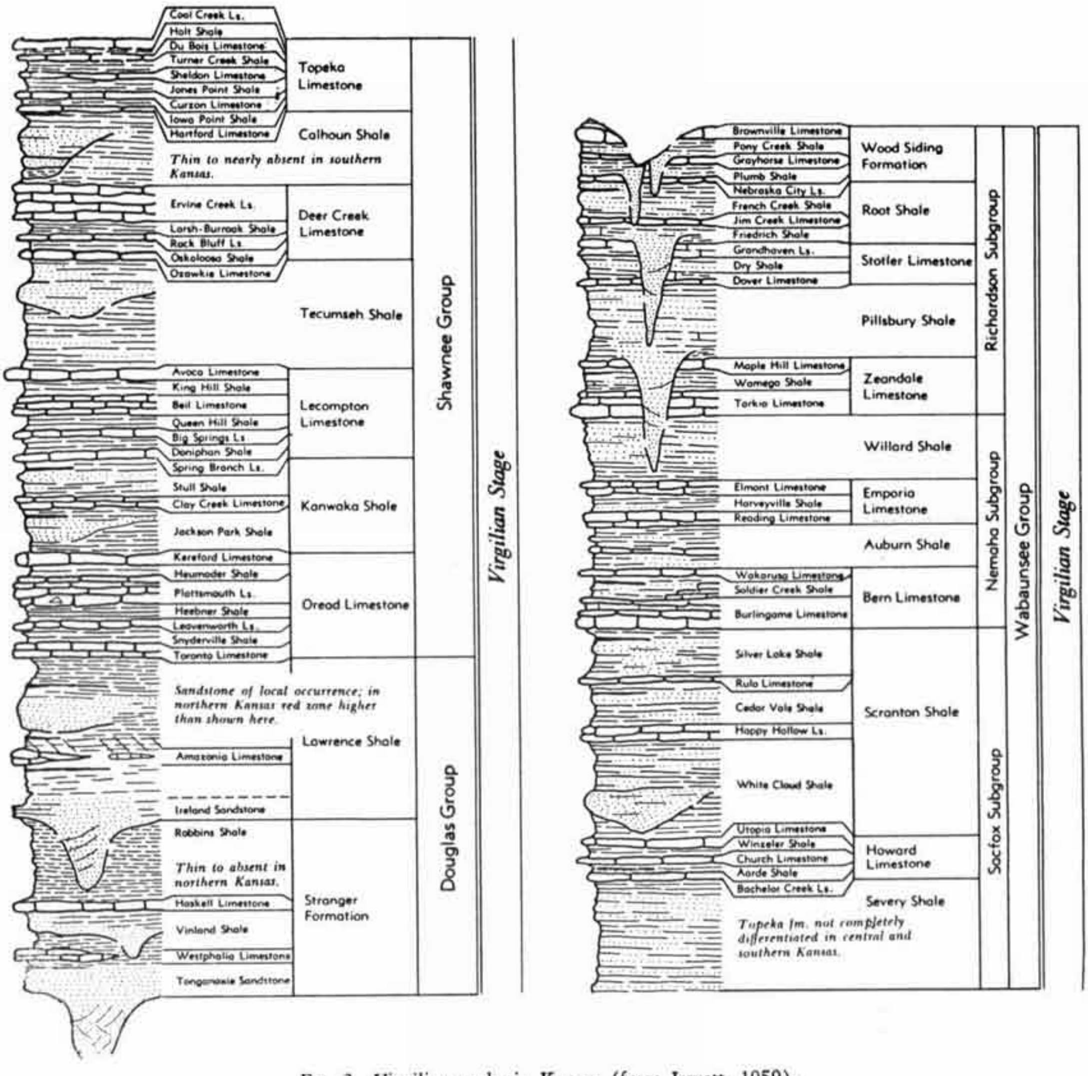

FIG. 3. Virgilian rocks in Kansas (from Jewett, 1959).

out as a distinct, persistent, escarpment-forming unit that can be easily traced across Kansas (Fig. 2).

Pedee Group.—The Pedee Group has an average thickness of approximately 90 feet and includes all strata lying above the Stanton Limestone and below the disconformity that defines the top of the Missourian Stage. It contains the Weston Shale below and the Iatan Limestone above and is characterized chiefly by clastic rocks similar to those in the overlying Douglas Group. The Iatan Limestone has been identified only in northeastern Kansas and neighboring parts of Missouri and Iowa and in many places the Weston Shale is also absent or very thin.

VIRGILIAN STAGE

Douglas Group.—The Douglas Group is the lowermost part of the Virgilian Stage, has an average thickness of 250 feet, and extends from a disconformity at the base of the Stranger Formation to the top of the Lawrence Shale. It includes only these two formations and consists predominantly of thick deposits of massive, cross-bedded sandstone, shaly sandstone, and sandy shale but includes layers of coal and conglomerate (Fig. 3).

Shawnee Group.—The Shawnee Group occurs approximately in the middle third of the Virgilian Stage, has a thickness of approximately 250 feet, and includes all units from the base of the Oread Limestone to the top of the Topeka Limestone. It is characterized by well-developed marine cycles consisting of prominent thick limestone beds alternating with shale.

Formations of the Shawnee Group, in ascending order, are called Oread Limestone, Kanwaka Shale, Lecompton Limestone, Tecumseh Shale, Deer Creek Limestone, Calhoun Shale, and Topeka Limestone (Fig. 3).

Wabaunsee Group.—The Wabaunsee Group forms the upper third of the Virgilian Stage, has a thickness of approximately 500 feet, and includes all beds above the top of the Topeka Limestone and below the base of the Onaga Shale in the Permian System.

It is distinguished from the underlying Shawnee Group by a different type of cyclothem. Gray and brown alternating shales are the predominant lithology, constituting more than half of each of the cycles present. The limestones are very persistent and uniformly thin, the average thickness of individual members being approximately 2 feet.

Because of the cyclic succession of alternating marine and nonmarine units, the Wabaunsee Group has been divided into three subgroups, which in ascending order are called Sacfox, Nemaha, and Richardson. The lower unit contains beds of shale, sandstone, and coal and a few intervening limestone beds, whereas the other two units contain limestone and intervening shale that represent the medial part of each cyclothem.

Formations of the Wabaunsee Group, in ascending order, are called Severy Shale, Howard Limestone, Scranton Shale, Bern Limestone, Auburn Shale, Emporia Limestone, Willard Shale, Zeandale Limestone, Pillsbury Shale, Stotler Limestone, Root Shale, and Wood Siding Formation (Fig. 3).

FAUNAL SUMMARY

The local ranges, in the Pennsylvanian of Kansas, are presented for all known species of the families Spiriferidae and Punctospiriferidae (Table 1, p. 33).

Dunbar & Condra (1932) found *Punctospirifer kentuckyensis* to occur throughout the Pennsylvanian System in Nebraska and Kansas. This was confirmed by my observations.

Spirifer rockymontanus, *S. opimus*, and *S. occiduus* were found by me only in the Cherokee Group in Kansas. Dunbar & Condra (1932) did not record *S. rockymontanus* from Nebraska, but occurrences reported in New Mexico, Colorado, Oklahoma, and Ohio led them to regard this species as confined to Cherokee rocks. Dunbar & Condra (1932) stated that *S. opimus* is restricted to the upper part of the Cherokee Group, but I have established extension of its range downward to include the entire group in Kansas. *S. occiduus*, according to Dunbar & Condra (1932), is absent above the Fort Scott Limestone, the basal unit of the Marmaton Group. In the present study, this species was not noted above the Cherokee Group in Kansas.

The known ranges of all Pennsylvanian species of *Neospirifer* occurring in Kansas have been extended. Dunbar & Condra (1932) found *N. dunbari* from beds as old as the Fort Scott Limestone and as young as the Council Grove Group of the Permian System. I collected this species from the Cabaniss Formation of the Cherokee Group also, an earlier occurrence than noted by DUNBAR & CONDRA. The record of ranges of the subspecies of *N. dunbari alatus* and *N. dunbari gibbosus* has been altered so as to include beds from lower Missourian to upper Virgilian, rather than from middle Missourian to upper Missourian for the former, and from upper Missourian to lower Virgilian for the latter as reported by DUNBAR & CONDRA (1932).

Neospirifer cameratus was reported by DUNBAR & CONDRA (1932) from the upper part of the Cherokee Group. In addition, individuals similar to and possibly belonging to this species are found in lower Cherokee beds and in the Kansas City Group. This species was noted throughout the Cherokee Group in the present study, but was not found above it.

The range of *Neospirifer latus* (DUNBAR & CONDRA, 1932) was regarded as extending from the Cherryvale Shale to the Vilas Shale, both late Missourian in age, but was noted from beds near the base of the Missourian to the top of the Virgilian by me. The subspecies *N. latus lateralis* (proposed herein) is confined to the Lansing Group.

DUNBAR & CONDRA (1932) stated that *Neospirifer kansasensis* ranges from the Emporia Limestone (upper Virgilian) to the Council Grove Group (middle Wolfcampian). The lower limit now is altered slightly to include the Auburn Shale.

Neospirifer texanus was not found in Nebraska by DUNBAR & CONDRA (1932) but was reported by them as common in the Lenapah Limestone in Oklahoma. I collected one specimen of *N. texanus* from the Lenapah Limestone in Kansas.

Neospirifer goreii, thought by DUNBAR & CONDRA (1932) to be confined to the Morrowan, was found as high as the Cabaniss Formation of the Cherokee Group in Kansas.

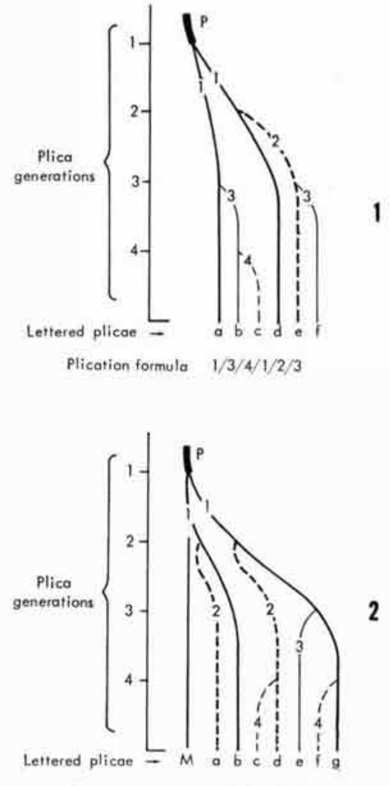

FIG. 4. Diagrammatic construction of plication patterns in *Neospirifer dunbari* showing mode of distinguishing successive plica generations and recording them as plication formulas. *1*. Fold. *2*. Sulcus. [Explanation: *P*. denotes primary plica extending from beak to first bifurcation; *M* denotes mid-line unbranched plica which originates independently of primary or other plicae.]

PLICATION PATTERNS IN NEOSPIRIFER

METHODS OF ANALYSIS

Proceeding laterally right from the mid-line of the fold of *Neospirifer dunbari*, for example, successive plicae along the anterior margin may be lettered in sequence (*a, b, c,* etc.) and then each can be designated by a number that records its order of generation. Let the plica originating at the beak and extending to the first bifurcation be termed *P* (for primary). This bifurcation marks the first order of generation of derived (or secondary) plicae and both the inner and outer of the two branches may be distinguished as belonging to plica generation 1 (Fig. 4,*1*). A second bifurcation of the outer plica occurs in *N. dunbari* not far forward from its origin, whereas the inner plica remains unbranched at this stage of shell growth. The position of the second bifurcation is defined as marking a second-order of plica generation, the inner branch being distinguished as extension of the parent (first-order) plica and the outer branch as the daughter (second order) plica. Interpreted in this way, the branching pattern is exotomous. Following additional shell growth, the daughter plica of the outer first-order parent plica becomes bifurcated, thus marking a third order of plica generation, the inner branch being considered as the continuation of the second-order parent plica and the outer branch as the third-order plica (daughter of daughter, hence granddaughter). At the same stage of shell growth the admedian first-order plica also bifurcates, the inner branch being construed as continuation of the parent and the outer branch as another third-order plica. This latter plica branches again, defining a fourth order of plica generation (Fig. 4,*1*), but the third-order plica at the outer edge of the fold remains unbranched. Along the anterior margin of the fold the successive plicae *a-f* can be numbered according to their respective plica generation orders as 1, 3, 4, 1, 2, 3, or given as a plication formula written F (for fold) 1/3/4/1/2/3.

In other species of *Neospirifer* both the relative positions and sequences of successive plica generations are found to differ, and thus the various patterns are useful for taxonomic identifications. In *N. latus*, for example, the admedian first-order plica gives rise to a second-order plica, whereas intermediate and outer first-order plicae do not (Fig. 5,*3*). In *N. kansasensis* both admedian and outer first-order plicae are parents of second-order plicae; the former gives rise to a third-order plica but the latter only to a fourth-order daughter plica (Fig. 5,*4*).

The generations of plicae in the sulcus of *Neospirifer* can be determined in similar manner, but differences are introduced by the occurrence in all species of an unbranched median plica (designated as *M*) which does not reach to the beak and by a branching pattern of the plicae interpreted as endotomous. Thus, in the sulcus of *N. dunbari*, for example, bifurcation of the primary *(P)* plica produces inner and outer first-order plicae, both of which give rise to daughter second-order plicae on their admedian sides, that of the former remaining undivided but that of the latter bifurcating to produce a fourth-order plica (Fig. 4,*2*). Also, the outer first-order plica gives off branches consisting of third- and fourth-order plicae.

Plication patterns of the sulci of other species, like those of the folds, exhibit easily determined differences which are sufficiently constant within each species to have diagnostic value.

Characteristics of the plication patterns of Pennsylvanian-Permian species of *Neospirifer* are summarized in following short descriptions and accompanied by statement of their plication formulae.

PLICATION PATTERNS OF SPECIES

NEOSPIRIFER DUNBARI

The bifurcation patterns described in this section for *Neospirifer dunbari* and other species are found in Figures 5 and 6, and can be easily diagrammed in the manner shown in Figure 4,*1* and 4,*2*.

The dorsal fold (Fig. 5,*6*) begins as a simple plication, which almost immediately divides into four. At approximately 7 mm. forward from the beak, the outermost plicae branch exotomously to form new outer plications which, along with the two innermost plicae, branch exotomously again at approximately 10 mm. A further subdivision may take place on the first-formed outermost plications at about 15 mm. to give a total of twelve.

The sinus (Fig. 6,*6*) begins as a simple furrow bounded on each side by a plication. Almost immediately, a median plication *(M)* arises and remains undivided throughout the length of the shell. At 2 mm. forward from the beak, the lateral bounding plications branch endotomously, giving rise to plicae adjacent to the median rib. At approximately 8 mm. the bounding plications and those adjacent to the median rib branch in the above manner, giving rise to nine plications. The bounding plications again branch at about 13 mm. to give 11 plicae, and at approximately 18 mm. the bounding plications and the plicae formed from it at the 8-mm. mark branch endotomously to give a total of 15.

Plication formulas. F: 1/3/4/1/2/3.
S: M/2/1/4/2/3/4/1.

NEOSPIRIFER CAMERATUS

The fold (Fig. 5,*1*) begins as a simple plication, which almost immediately divides into four. At approximately 7 mm. forward from the beak, each of these four plications branches exotomously

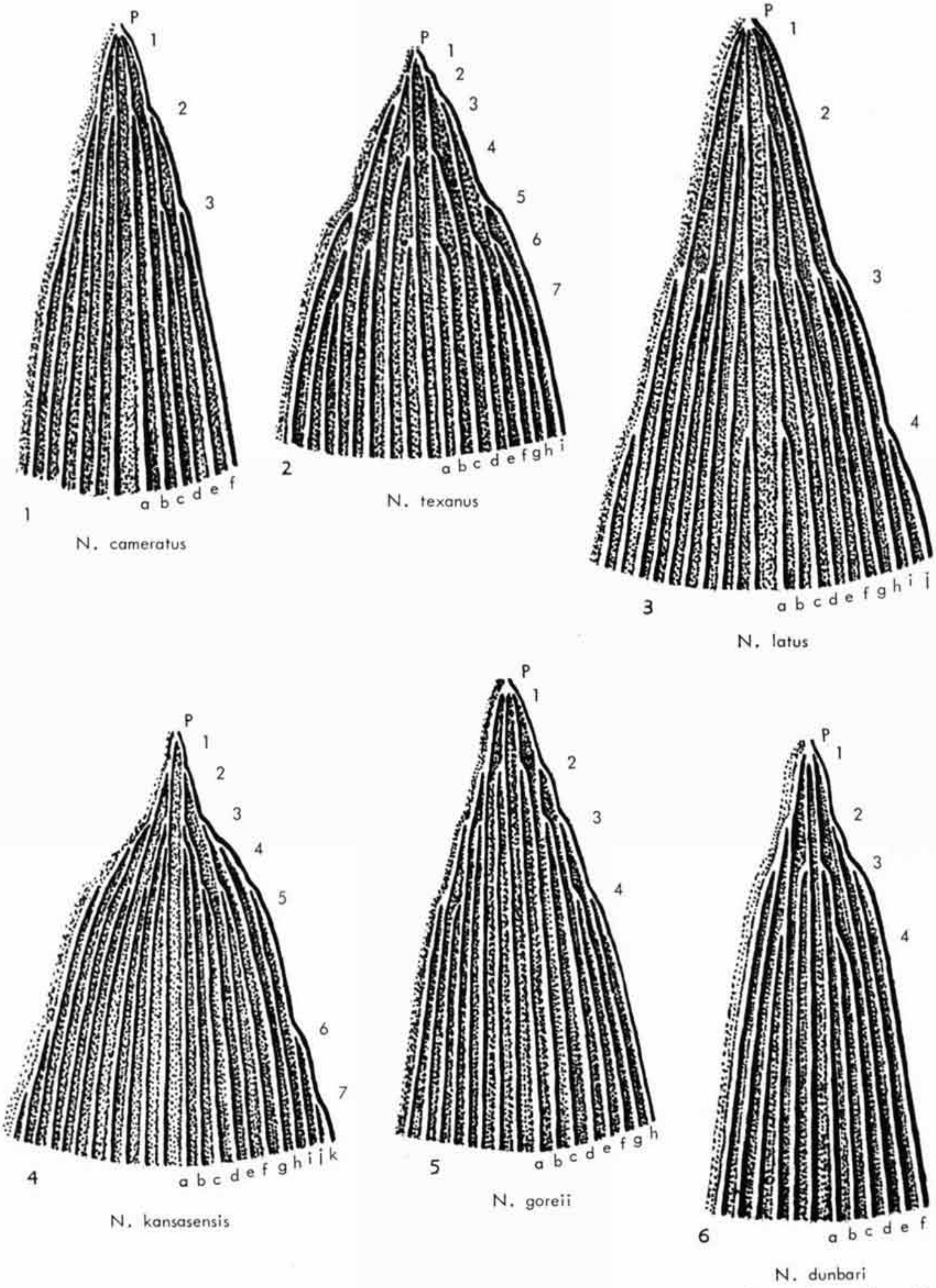

FIG. 5. Plication patterns on folds of various species of *Neospirifer* showing number and positions of successive plica generations.

to give eight; at about 14 mm. the first- and second-formed outermost plication divide to give a total of 12 on the fold.

The sulcus (Fig. 6,*1*) begins as a simple furrow bounded on each side by a plication. Almost immediately a median *(M)* plication arises and remains simple throughout the length of the shell. At approximately 3 mm. forward from the beak, the lateral bounding plications branch endotomously giving rise to plicae adjacent to the median plication. Endotomous branching of the bounding plications is repeated at about 6 mm. and 13 mm. from the beak to give nine plications. At about 18 mm. the lateral bounding plications and those adjacent to the median plication branch endotomously, giving a total of 13 plications on the sinus.

Plication formulas. F: 1/2/1/3/2/3.
S: M/4/1/2/3/4/1.

NEOSPIRIFER LATUS

The fold (Fig. 5,*3*) begins as a simple plication, which seems to split almost immediately into six. At approximately 8 mm. forward from the beak, the innermost plicae branch exotomously, giving eight plications. At approximately 20 mm. from the beak, all the previously formed plicae branch exotomously to give a total of 16. A further subdivision make take place on the innermost and on the outermost plicae at about 32 mm. to give a total of 20.

The sulcus (Fig. 6,*3*) begins as a simple furrow bounded on each side by a plication. Almost immediately a median plication *(M)* forms, and at the same time, the lateral bounding plications branch endotomously. Endotomous branching again occurs on the bounding plications 7 mm. from the beak. At approximately 11 mm., the first-formed plicae and the bounding plications divide to give 11. At about 15 mm., the bounding plicae again branch, and at approximately 20 mm. the second-formed plications divide. Final endotomic branching occurs on the bounding plications on the first- and third-formed plications at approximately 27 mm. to give a total of 21.

Plication formulas. F: 1/4/3/2/3/1/3/1/3/4.
S: M/3/6/1/5/2/6/3/4/6/1.

NEOSPIRIFER KANSASENSIS

The fold (Fig. 5,*4*) begins as a simple plication, which almost immediately bifurcates. At approximately 3 mm. forward from the beak, these first-formed plicae branch exotomously to form new outer plications, which along with the innermost plications branch exotomously again at 7 mm. to give eight. At about 9 mm. the innermost and newly formed outermost plications again divide in the same manner. At approximately 12 mm. the newly formed outermost plications, the second-formed outermost plications, and the plicae that branched from the first-formed outermost plications at the 7-mm. mark all divide to give 18 plicae. At 23 mm. the last or fifth-formed outermost plicae divide to give a total of 20 plications on the fold. Depending on the size of the specimen, additional branching may take place on the outermost plicae approximately at 30 mm., increasing the total number of plications on the fold to 22.

The sulcus (Fig. 6,*4*) begins as a simple furrow bounded on each side by a plication. Almost immediately a median plication *(M)* arises and remains undivided throughout the length of the shell. At the same point, the bounding plications branch endotomously to give rise to the first-formed innermost plicae. At about 5 mm. forward from the beak, the bounding plications again divide endotomously. At approximately 7 mm., the first-formed innermost plicae branch endotomously so that the newly formed plicae are now adjacent to the median rib. At about 10 mm. from the beak, the lateral bounding plications again branch, and, at approximately 16 mm. the innermost plicae, the first- and second-formed branches of the bounding plications, and the bounding plications themselves branch to give 19 plicae. At approximately 25 mm. the third-formed plicae from the bounding plications divide. The third-formed innermost plications branch at about 29 mm. to give a total of 23.

Plication formulas.
F: 1/4/3/5/2/5/3/4/5/6/7.
S: M/7/5/3/5/1/5/2/6/4/5/1.

NEOSPIRIFER TEXANUS

The fold (Fig. 5,*2*) begins as a simple plication, which almost immediately bifurcates. At approximately 2 mm. forward from the beak, these first-formed plications branch exotomously. At about 4 mm. from the beak, branching occurs on the second-formed plications, and at approximately 8 mm. the first-formed plicae again branch to

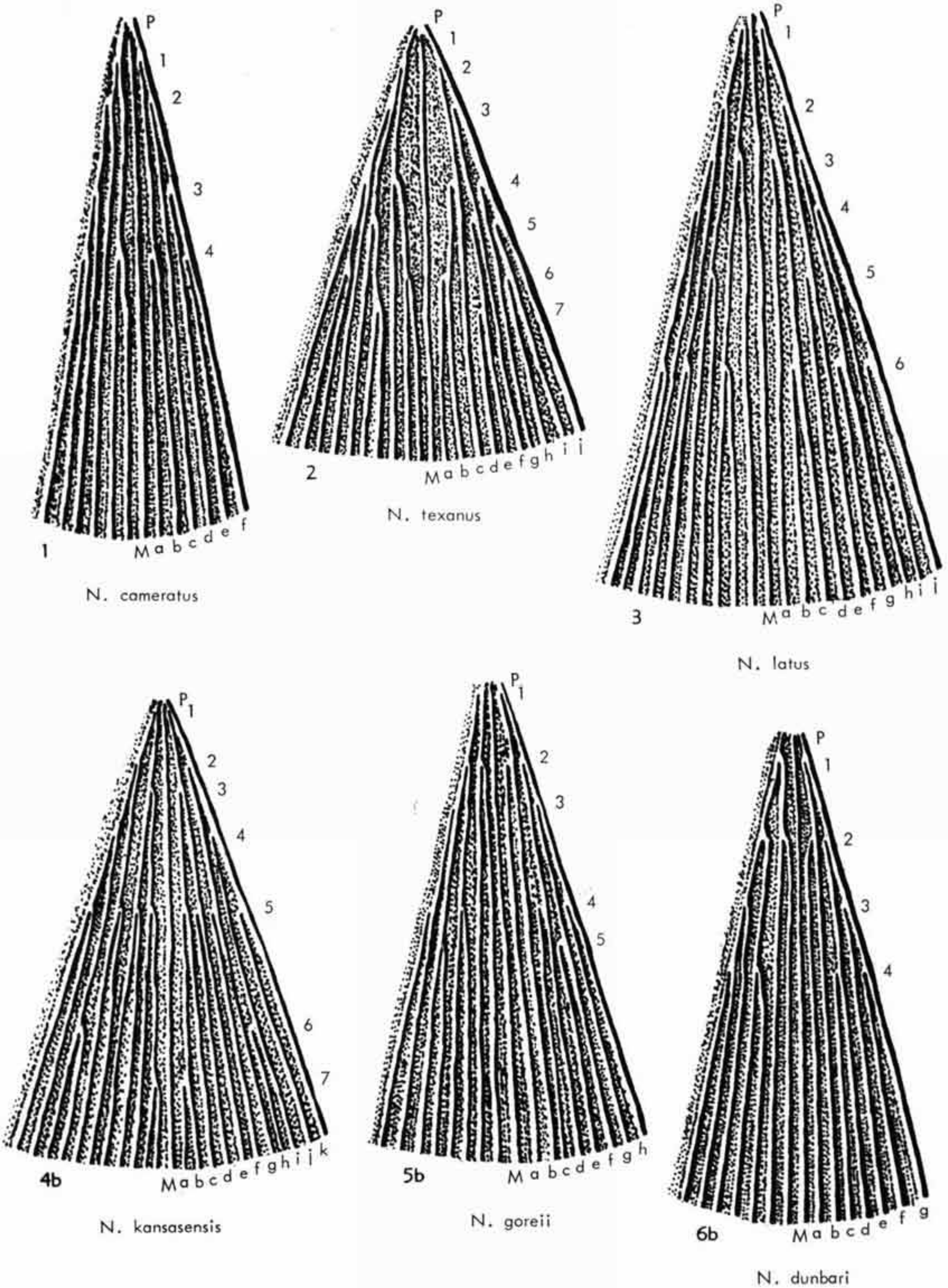

Fig. 6. Plication patterns on sulci of various species of *Neospirifer* showing number and positions of successive plica generations.

give eight. At 12 mm., the bounding plication splits. At about 15 mm., the first-, second-, and third-formed plications branch exotomously to give a total of 16. A further subdivision takes place on the third-formed plicae at about 19 mm. to raise the total to 18.

The sulcus (Fig. 6,*2*), which begins as a simple furrow, is bounded on each side by a plication. At approximately 3 mm. forward from the beak, a low inconspicuous median plication *(M)* arises, and, at the same point the lateral bounding plications branch endotomously. The lateral plications again divide at about 6 mm. from the beak. At about 12 mm. the bounding plications and the first-formed plications branch endotomously, giving rise to a new set of plicae that are adjacent to the median rib. At approximately 15 mm. the second- and third-formed bounding plications divide endotomously. The third-formed bounding plications and those that are adjacent to the median rib divide at about 19 mm., giving 19 plications on the sulcus. At approximately 22 mm. an additional subdivision may occur on the fourth plication outward from the median rib, which develops from the second-formed plicae at the 15-mm. mark to give a total of 21.

Plication formulas.
F: 1/6/4/2/6/3/7/6/5.
S: M/6/4/2/7/5/3/4/6/5/1.

NEOSPIRIFER GOREII

The fold (Fig. 5,*5*) begins as a simple plication, which almost immediately divides into four. At about 7 mm. forward from the beak, these four plicae branch exotomously. At approximately 11 mm., the first-formed outer plications and the newly formed outer plications again branch exotomously to give a total of 12. A further subdivision may take place on the two outermost plicae at about 17 mm. to give 16 plications.

The sulcus (Fig. 6,*5*) begins as a simple furrow bounded on each side by a plication. Almost immediately a median plication *(M)* arises and remains undivided throughout the length of the shell, and at the same point, the lateral bounding plications branch endotomously. At about 6 mm. forward from the beak, these newly formed plications and the bounding plications branch endotomously. Branching again occurs on the bounding plications at about 9 mm. At approximately 17 mm. the second-formed branches off the bounding plications and the bounding plications themselves divide to give 13. An additional subdivision may occur on the third-formed plications off the bounding plications at about 20 mm. to give a total of 15.

Plication formulas. F: 1/2/1/3/2/4/3/4.
S: M/2/1/4/2/5/3/4/1.

SYSTEMATIC DESCRIPTIONS

Superfamily SPIRIFERINACEA Davidson, 1884

Family SPIRIFERINIDAE Davidson, 1884

Genus PUNCTOSPIRIFER North, 1920

Description.—Shell of spiriferoid contour, widest at or near hinge line, which extends into slightly rounded to angular cardinal extremities. Beak of brachial valve not prominent, slightly arched and incurved over long narrow interarea; dorsal fold well developed, mesially flattened. Beak of pedicle valve very prominent, small, pointed, strongly arched and slightly incurved over moderately high, longitudinally concave cardinal area; sinus well-defined, mesially flattened.

Explanation of Figure 7 (all ×1 except as stated otherwise).

1. *Punctospirifer kentuckyensis* (Shumard), Deer Creek Limestone, Osage Co.; *1a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,010); *1e*, ventral view of alate form (KUMIP 500,001); *1f-g*, dorsal and side views of gibbous form, ×2 (KUMIP 500,003).
2. *Neospirifer goreii* (Mather), Verdigris Limestone Member, Cabaniss Formation, Labette Co.; *2a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,019).
3. *Neospirifer kansasensis* (Swallow), Auburn Shale, Shawnee Co.; *3a-d*, dorsal, ventral, side and anterior views (KUMIP 500,007).
4. *Neospirifer latus lateralis* (Spencer), n. subsp.; Spring Hill Limestone Member, Plattsburg Limestone, Linn Co., *4a-b*, dorsal and side views of holotype (KUMIP 500,028); *4c-d*, Spring Hill Limestone Member, Plattsburg Limestone, Wilson Co., ventral and dorsal views (KUMIP 500,004).

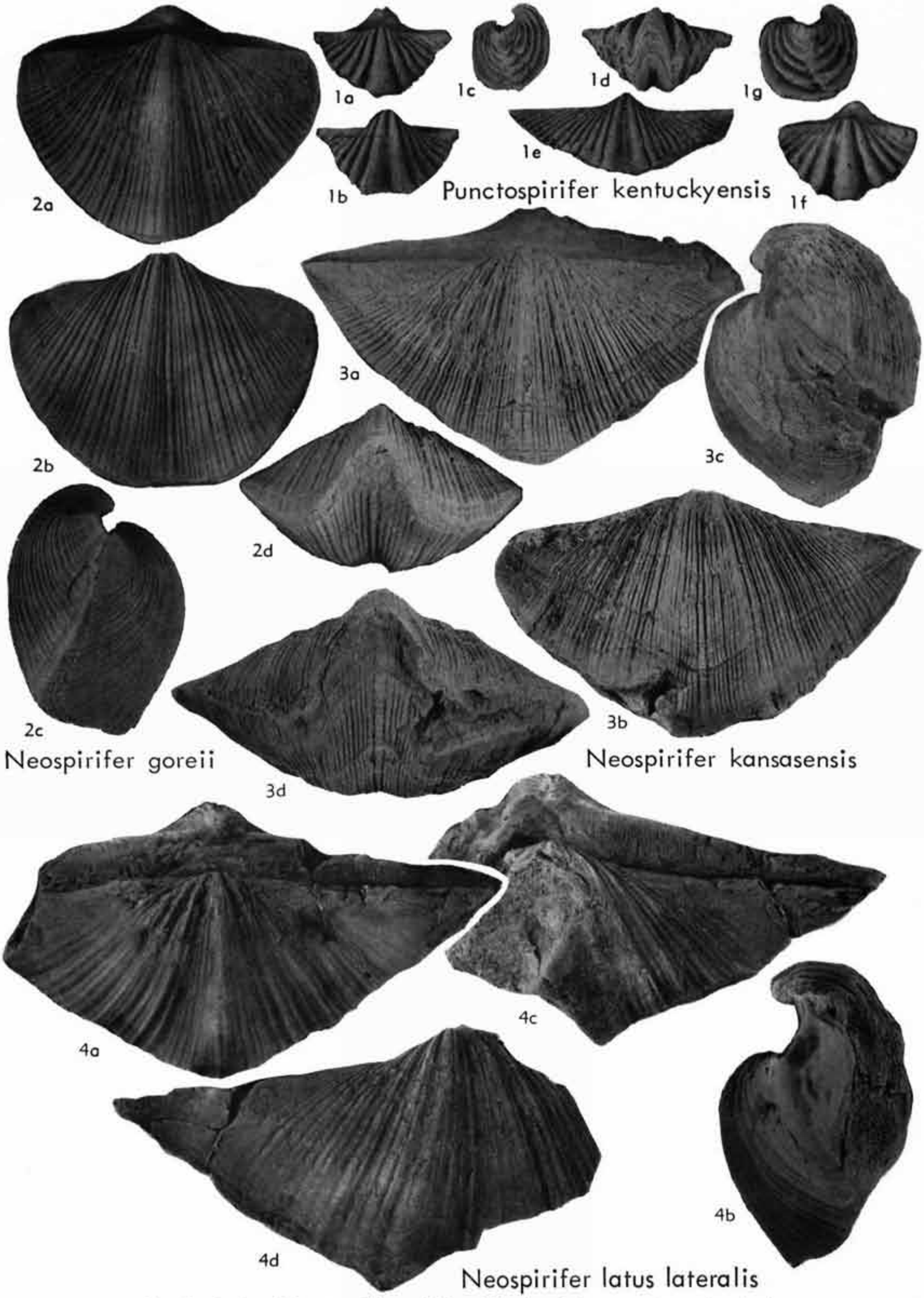

FIG. 7. Species of *Punctospirifer* and *Neospirifer* (see facing page for explanation).

Lateral slopes bear simple, rounded plications, separated by rounded troughs. Surface covered with fine, regularly spaced, imbricating lamellae. Shell coarsely punctate.

Pedicle valve interior has median septum and hinge teeth supported by strong, slightly diverging dental lamellae. Brachial valve has cruralium supported by median septum; cardinal process a nub with teeth. Crural lamellae appear as small flanges beneath palintrope. Spiralia large, laterally directed.

Discussion.—D'ORBIGNY, in 1847, established the genus *Spiriferina* from the Lower Jurassic for certain spiriferoid species having punctate shells.

NORTH, in 1920, showed that this genus contained two groups. The first, represented by the Jurassic type species, has a narrow, subangular fold and sulcus, which differ from the lateral plications only in size. The surface has imbricating lamellae, which are few and widely spaced over the posterior part of the shell but more crowded anteriorly. The cardinal area is defined only by a pair of lines diverging from the beak, outside of which the shell gradually curves into the lateral slopes. The jugum is a simple transverse band.

The second group has the fold and sinus flattened and wider than the lateral plications, the surface covered by closely spaced, lamellose growth lines, and the cardinal area clearly separated from the lateral slopes by an abrupt angle in the shell. This second group is especially characteristic of the late Paleozoic. For this second group, NORTH erected the genus *Punctospirifer*, choosing a Lower Carboniferous British form, which he named *P. scabricosta*, as the type species.

NORTH also stated that *Punctospirifer* has a slender, V-shaped jugum, the apex of which is directed ventrally and posteriorly. Neither DUNBAR & CONDRA nor I have observed this particular structure in the numerous specimens sectioned.

Type species.—Punctospirifer scabricosta North.

PUNCTOSPIRIFER KENTUCKYENSIS Shumard

Figures 7,*1*; 8

Spirifer octoplicata? HALL (*non* SOWERBY), 1852, p. 409, pl. 4, 4a,b.

Spirifer kentuckyensis SHUMARD, 1855, p. 203.

Spiriferina kentuckyensis MEEK, 1872, p. 185, v. 6, fig. 3a-d, pl. 8, fig. 11a,b.

Punctospirifer kentuckyensis DUNBAR & CONDRA, 1932, p. 351, pl. 38, fig. 1-5.

Description.—Shell small, spiriferoid in contour, biconvex to gibbous, semicircular to subtriangular in outline, generally wider than long, greatest width at hinge, which extends into acutely pointed cardinal extremities; in specimens having shorter hinge line, cardinal extremities are approximately square or rounded. Width, length, and thickness of an average specimen 1.6 cm., 0.9 cm., and 0.8 cm., respectively.

Beak of brachial valve not prominent, scarcely rising and incurving over long, narrow interarea; fold narrow and flat-topped; in later growth stages developing narrow depression along mid-line.

Beak of pedicle valve elevated and incurved over high, flat cardinal area, which is almost at right angles to plane of valve margins; sulcus steep-sided and deep, being narrow in posterior part of shell and gradually expanded anteriorly; narrow elevated ridge along mid-line.

Lateral slopes bear 5 to 13 narrow, rounded, plications on each side of fold or sulcus; plications separated by rounded troughs. Commonly there are 5 to 7 plications, the greater number occurring in more alate forms. Only first 3 plications radiate from beak area, others being added consecutively along hinge line as shell grows larger.

Surface marked by fine regularly spaced, imbricating lamellae, 4 to 8 in space of 1 mm.; surface coarsely punctate.

Pedicle valve interior (Fig. 8) has strong hinge teeth supported by high, abruptly terminating dental lamellae; median septum beginning at apex of shell persists through about one-third of shell length. Brachial valve with cruralium supported by hollow dorsal median septum; cardinal process a small rounded nub rising in center from back edge of inner hinge plate and containing 7 to 10 teeth in comblike structure along outer edge. Crural lamellae appear as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to front of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 5 to 7 volutions.

Discussion.—Some discrepancies between internal structures illustrated by DUNBAR & CONDRA (1932, p. 353, fig. 2) and those found by me need to be reported. DUNBAR & CONDRA illustrated a cardinal process without teeth, whereas teeth were found to be present in every specimen sec-

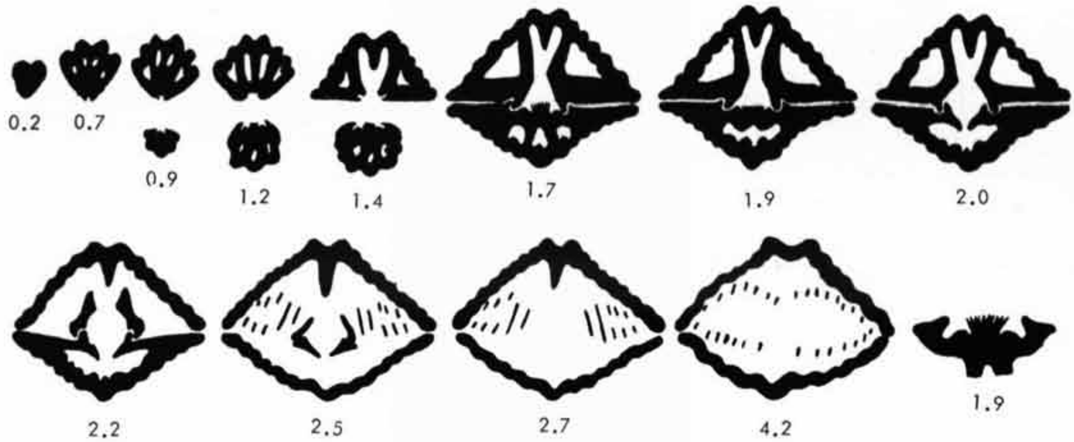

FIG. 8. Serial transverse sections of *Punctospirifer kentuckyensis* SHUMARD. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×3, except the last (lower right) which shows cardinal process, ×15.

tioned in the present study. Also, DUNBAR & CONDRA indicated a solid dorsal median septum, but this structure is hollow in all of my specimens.

Occurrence.—Both DUNBAR & CONDRA and I have found this species to be widely distributed throughout the Pennsylvanian section and into the Permian of Kansas, Nebraska, and Missouri.

Hypotypes.—KUMIP nos. 500,001, 500,003, 500,010.

Superfamily SPIRIFERACEA King, 1846

Family SPIRIFERIDAE King, 1846

Genus SPIRIFER Sowerby, 1814

Description.—Shells of spiriferoid contour, fold, sulcus, and lateral slopes simply plicate. Ventral beak very prominent, strongly arched and incurved over a well-defined interarea. Dorsal beak not prominent, slightly elevated, and incurved over a narrow interarea. Surface covered with fine, closely spaced, concentric lirae and very fine radial lirae.

Internally, dental sockets are long and subconical, bounded by heavy, curved socket plates, which arise from sides of valve, curving inward and upward around socket and becoming fused at their inner edges against their crural lamellae. Crural lamellae united under beak, forming narrow, sloping hinge plate, which becomes vertical anteriorly, not reaching floor of valve but hanging pendent and flangelike below contact with socket plates. Cardinal process a broad, low boss having comblike structure. Dental lamellae strong, slightly diverging to vertical septa, commonly enveloped in callus-like thickening of shell beneath palintrope.

Discussion.—The type species of *Spirifer* is a Lower Carboniferous British species, the distinctive generic features of which are simple ribs closely alike on fold, sulcus, and lateral slopes, and a fine grill-like surface sculpture.

Type species.—*Conchyliolithus (Anomia) striatus* MARTIN, 1793.

SPIRIFER ROCKYMONTANUS Marcou

Figures 9,2; 10

Spirifer rocky-montani MARCOU, 1858, p. 50, pl. 7, fig. 4c,d,e, (*non* fig. 4,4a,b).

Spirifer rockymontanus GIRTY, 1903, p. 383, pl. 6, fig. 5-7c.

Description.—Shell small, highly biconvex, length nearly equal to width, greatest at or near hinge, which extends into obtusely angular to somewhat rounded cardinal extremities. Width, length, and thickness of an average specimen 1.7 cm., 1.5 cm., and 1.3 cm., respectively.

Beak of brachial valve not prominent, slightly elevated, and incurved over narrow interarea; fold well-defined, becoming subtriangular toward anterior, beginning as simple narrow plication, which almost immediately bifurcates; at approximately 2 mm. forward from beak, first-formed plications bifurcate, outer pair of which divide at approximately 6 mm. from beak to give total of 6 plications on fold. On large shells, last-formed plicae may divide at about 8 mm. from beak, giving total of 8.

Pedicle-valve beak strongly arched and incurved over concave, moderately large, long, triangular interarea. At apex of beak, sulcus is narrow and unplicated, lying between two prominent plications; at approximately 2 mm. forward from beak, median plication *(M)* arises and remains undivided throughout length of shell, and at some place, lateral bounding plications split into 3, innermost on inside of sulcus and outermost forming 2nd plication on lateral slopes; at 9 mm. bounding plication bifurcates to give total of 5 plications in sulcus.

Lateral slopes bearing 9 to 12 small, subangular plications on each side of fold or sulcus, first 2 joining near beak and others radiating from umbo.

Surface marked by fine radial lirae and equally spaced, fine concentric growth lines, intersection of which forms small nodes.

Pedicle valve interior (Fig. 10) has moderately strong hinge teeth supported by abruptly terminating dental lamellae, persisting only short distance beyond umbo and very short, persistent, nublike median septum. Brachial valve with cruralium supported by solid dorsal median septum; cardinal process a small comblike structure containing 14 to 17 teeth on inner hinge plate; crural lamellae appear as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 6 to 9 volutions.

Discussion.—Girty (1903, p. 384) observed that Marcou's original figures apparently included two distinct species, the smaller of which he designated as type. Mather (1915, p. 184) overlooked Girty's choice and invalidly designated Marcou's larger specimen as type. Since Girty has priority by 12 years, his designation must be accepted.

Occurrence.—Specimens were found near the top of the Cabaniss Formation in the Cherokee Group in southern Crawford County, Kansas, and Dunbar & Condra (1932, p. 319) noted the species in the Pumpkin Creek Limestone Member of the Dornick Hills Formation near Berwyn, Oklahoma, and in the upper part of the Pottsville Formation of Ohio. Like *S. opimus* and *S. occiduus*, this species is confined to the lower part of the Pennsylvanian System and is not known to occur above the Cherokee Group.

Hypotypes.—KUMIP nos. 500,011, 500,021.

SPIRIFER OPIMUS Hall

Figures 9,*1*; 11

Spirifer opimus Hall, 1858, p. 711, pl. 28, fig. 1a,b; Mather, 1915, p. 185, pl. 12, fig. 7-7c.

Description.—Shell small and gibbous, highly biconvex, length nearly equal to width, greatest width at or near hinge, cardinal extremities slightly rounded or square. Width, length, and thickness 1.5 cm., 1.3 cm., and 1.1 cm., respectively.

Beak of brachial valve slightly elevated and incurved over narrow interarea; fold well defined and rounded, beginning as simple plication, which almost immediately bifurcates; at approximately 4 mm. forward from beak, each plication splits to give total of 4 on fold, middle 2 plicae being stronger than lateral ones, and separated by well-defined grooves.

Pedicle-valve beak strongly arched and incurved over slightly concave, equilaterally triangular interarea. At apex of beak, sulcus is narrow and unplicated, lying between 2 prominent plications; almost immediately a median plication *(M)* arises and remains undivided throughout length of shell; at approximately 3 mm. forward from beak, bounding plications split into 3, innermost lying on inside of sulcus to give total of 3, and outermost forming 2nd plication on lateral slopes.

Lateral slopes bearing 8 to 10 rounded plica-

Explanation of Figure 9 (all ×1 except as stated otherwise).

1. Spirifer opimus (Hall), Mineral Coal Cap, Cabaniss Formation, Crawford Co., *1a-b*, dorsal and side views, ×2 (KUMIP 500,006); *1c-f*, Verdigris Limestone Member, Cabaniss Formation, Crawford Co., dorsal, ventral, side, and anterior views (KUMIP 500,012).

2. Spirifer rockymontanus (Marcou), Mineral Coal Cap, Cabaniss Formation, Crawford Co.; *2a-d*, dorsal, ventral, side, and anterior views, ×2 (KUMIP 500,011); *2e*, dorsal view, ×2 (KUMIP 500,021).

3. Spirifer occiduus (Sadlick), Verdigris Limestone Member, Cabaniss Formation, Labette Co.; *3a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,013); *3e*, ventral view (KUMIP 500,002).

4. Neospirifer cameratus (Morton), Mineral Coal caprock, Cabaniss Formation, Crawford Co.; *4a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,015); *4e*, ventral view (KUMIP 500,025).

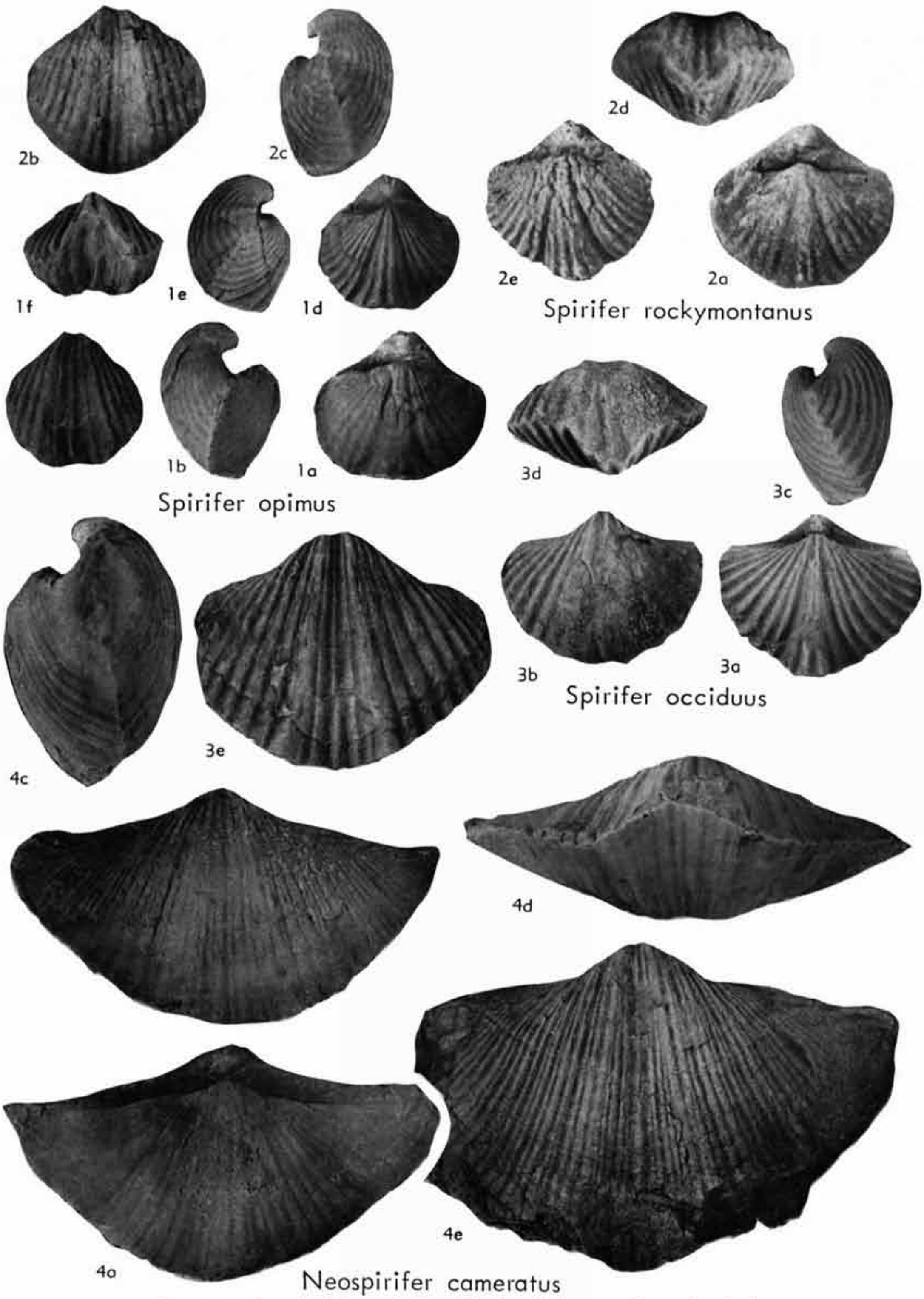

FIG. 9. Species of *Spirifer* and *Neospirifer* (see facing page for explanation).

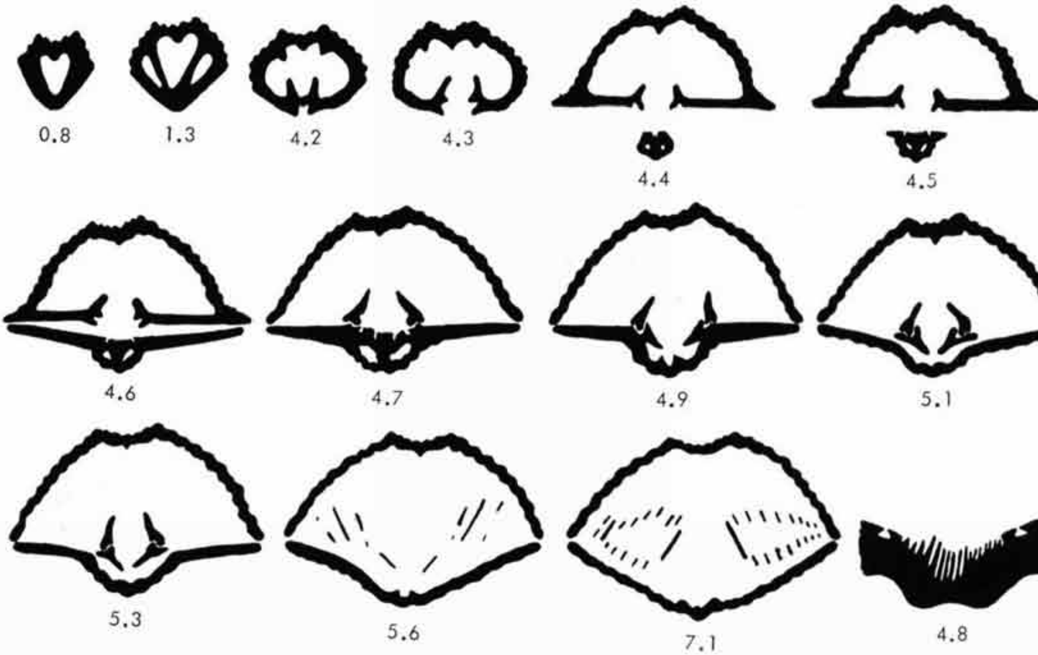

FIG. 10. Serial transverse sections of *Spirifer rockymontanus* MARCOU. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×3, except the last (lower right) which shows the cardinal process, ×15.

tions on each side of fold or sulcus, 1st 2 joining near beak and others radiating outward from umbo.

Surface marked by imbricating, lamellose growth lines and fine radiating striae.

Pedicle-valve interior (Fig. 11) with very small, persistent median septum and strong hinge teeth supported by high persistent dental lamellae, which converge dorsally to about middle of pedicle valve and then bend sharply laterally to hinge teeth. Brachial valve with unsupported cruralium; cardinal process a small, comblike structure containing 9 to 12 teeth on inner hinge plate; crural lamellae appear as small flanges beneath palintrope.

Discussion.—In many ways, *Spirifer opimus* resembles *S. occiduus*, having similar plications and surface sculpture. It differs from *S. occiduus* in being rotund and gibbous in outline and in having an equilaterally triangular cardinal area, whereas *S. occiduus* is much more transverse, has a low ventral beak, and a lower but longer cardinal area. Internally, the persistence and shape of the dental lamellae, the absence of a dorsal median septum, and the number of teeth on the comblike cardinal process characterize *S. opimus*.

Because of the state of preservation, primary lamellae of the spiralia could not be observed in specimens available for study.

Occurrence.—Specimens were found near the top of the Cabaniss Formation of the Cherokee Group, and DUNBAR & CONDRA (1932, p. 323) reported the species in the upper part of the Cherokee Group. It also occurs in the Kendrick Shale Member of the Pottsville Formation in Kentucky and in the Glenn Group near Woodford, Oklahoma. Therefore, it seems that this species is confined to the lower part of the Pennsylvanian System.

Hypotypes.—KUMIP nos. 500,006, 500,012.

SPIRIFER OCCIDUUS Sadlick

Figures 9,*3*; 12

Spirifer boonensis SWALLOW, 1860, p. 646.
Spirifer boonensis? GIRTY, 1903, p. 381, pl. 6, fig. 1-3.—MORNINGSTAR, 1922, p. 186, fig. 21-25.
Spirifer opimus HALL var. *occidentalis* GIRTY, 1927, p. 433, pl. 27, fig. 28-31.
Spirifer occidentalis DUNBAR & CONDRA, 1932, p. 322, pl. 41, fig. 12-16.
Spirifer occiduus SADLICK, 1960, p. 1210.

Description.—Shell small to moderately large, biconvex, transverse, greatest width at hinge line,

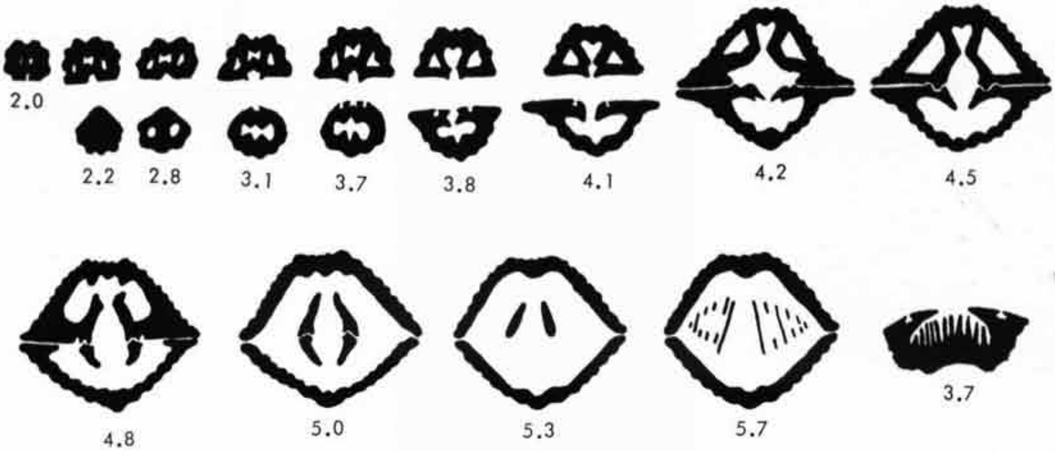

Fig. 11. Serial transverse sections of *Spirifer opimus* Hall. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×3, except the last (lower right) which shows cardinal process, ×15.

which extends into slightly angular to square cardinal extremities. Width, length, and thickness 3.2 cm., 2.0 cm., and 1.7 cm., respectively.

Beak of brachial valve not prominent, scarcely rising and incurving over long, narrow interarea. Dorsal fold moderately high and rounded, beginning as a simple plication which bifurcates approximately 3 mm. forward from beak, 2 newly formed plications bifurcating at about 5 mm. to give 4. If 6 plications are present, a 3rd, but less prominent, bifurcation from the outer pair occurs at about 7 mm.

Pedicle-valve beak prominent, strongly arched and incurved over long, moderately low interarea. This valve has 3 to 5 plications in rounded sulcus, which is unplicated and narrow near beak, and bounded by 2 prominent plications; at approximately 2 mm. forward from beak, a median plication arises and at same place, lateral bounding plications split into 3, inner lying inside sinus to give a total of 3, and outer forming 2nd plication on lateral slopes. If 5 plications occur, bounding plications again divide at about 8 mm. from beak.

Lateral slopes containing 11 to 13 rounded plications on each side of fold or sulcus, 1st 2 joining near beak and rest radiating from umbo.

Surface marked by fine radial striae and fine, equally spaced, concentric growth lines, the intersection of which forms small nodes.

Pedicle valve interior (Fig. 12) has a very weak median septum and strong hinge teeth supported by moderately high, persistent dental lamellae. Brachial valve interior has cruralium supported by solid median septum; cardinal process a fine comblike structure containing 17 to 20 teeth on inner hinge plate. Crural lamellae appear as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to front of shell before curving ventrally and posteriorly and giving rise to simple spiral coils of 5 to 7 volutions.

Discussion.—Kindle (1908) gave the name *Spirifer occidentalis* to a brachiopod in the Jefferson Limestone near Princeton, Montana. Girty (1927) overlooked this publication and introduced the name *S. occidentalis* for a so-called variety (subspecies) of *Spirifer opimus* Hall. In 1932 Dunbar & Condra elevated this to specific rank, and since then, it has been known as *Spirifer occidentalis* Girty. Sadlick (1960) found that this was a homonym of *Spirifer occidentalis* Kindle (1908) and proposed that Girty's species be called *Spirifer occiduus*.

According to Dunbar & Condra (1932, p. 325), this species closely resembles *Spirifer matheri*, but the latter ". . . has finer more angular plications and has seven to nine instead of three or rarely five plications in the sinus and eight rather than four or occasionally six on the fold. Moreover, dichotomy of the plications is rather common on the lateral slopes of *S. matheri* and is scarcely seen except in the first pair of lateral ribs in *S. occidentalis*."

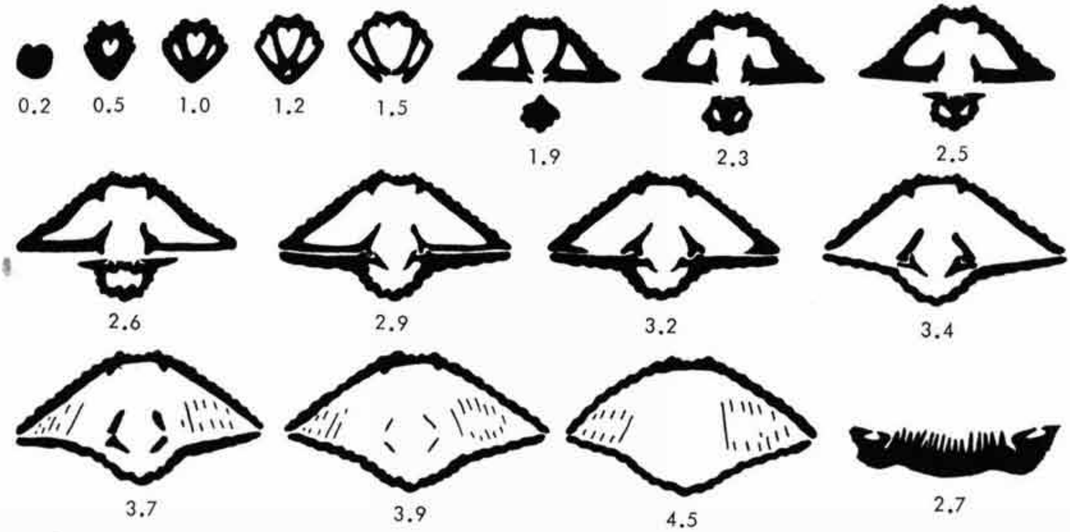

FIG. 12. Serial transverse sections of *Spirifer occiduus* SADLICK. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×3, except the last (lower right) which shows cardinal process, ×15.

Occurrence.—This species is confined to the lower part of the Pennsylvanian System. Specimens were found near the top of the Cabaniss Formation in the Cherokee Group. DUNBAR & CONDRA (1932, p. 326), found a single specimen in the lower part of the Fort Scott Limestone 2 miles west of Chelsea, Oklahoma. However, I have not found it anywhere above the Cabaniss Formation in Kansas.

Hypotypes.—KUMIP 500,002, 500,013.

Genus NEOSPIRIFER Fredricks, 1919

Description.—Shell small, of spiriferoid contour, normally subtriangular in outline, greatest width at hinge, which extends into acute to bluntly angular cardinal extremities. Beak of brachial valve not prominent, scarcely rising and incurving over a low, linear interarea; dorsal fold well developed, narrow, subangular. Beak of pedicle valve prominent, strongly arched and incurved over high, linear interarea; sinus well defined, narrow, subangular. Lateral slopes marked by unequal, subangular, bifurcating plications, main rib of each bundle being more pronounced than rest, especially on younger part of shell. Minute surface sculpture of fine, closely spaced, radial lirae and concentric lines, intersection of which forms delicate grill.

Pedicle valve interior with heavy callus commonly filling unbonal region; hinge teeth supported by dental lamellate. Brachial valve with cruralium, which may be unsupported or supported by dorsal median septum; cardinal process a broad, low, comblike structure; dental sockets long and conical, partly closed along their upper side.

Discussion.—According to DUNBAR & CONDRA,

Explanation of Figure 13 (all ×1).

1. *Neospirifer texanus* (MEEK), Norfleet Limestone Member, Lenapah Limestone, Bourbon Co.; *1a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,018).
2. *Neospirifer dunbari alatus* (DUNBAR & CONDRA), Beil Limestone Member, Lecompton Limestone, Shawnee Co., *2a*, ventral view of immature shell (KUMIP 500,022); *2b-e*, Spring Hill Limestone Member, Plattsburg Limestone, Coffey Co., dorsal, ventral, side, and anterior views (KUMIP 500,009).
3. *Neospirifer dunbari dunbari* (KING), Plattsmouth Limestone Member, Oread Limestone, Douglas Co., *3a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,014); *3e*, Beil Limestone Member, Lecompton Limestone, Osage Co., dorsal view (KUMIP 500,028).
4. *Neospirifer dunbari gibbosus* (DUNBAR & CONDRA), Plattsmouth Limestone Member, Oread Limestone, Douglas Co., *4a-d*, dorsal, ventral, side, and anterior views (KUMIP 500,027); *4e-f*, Frisbie Limestone Member, Wyandotte Limestone, Wyandotte Co., dorsal and side views (KUMIP 500,026).

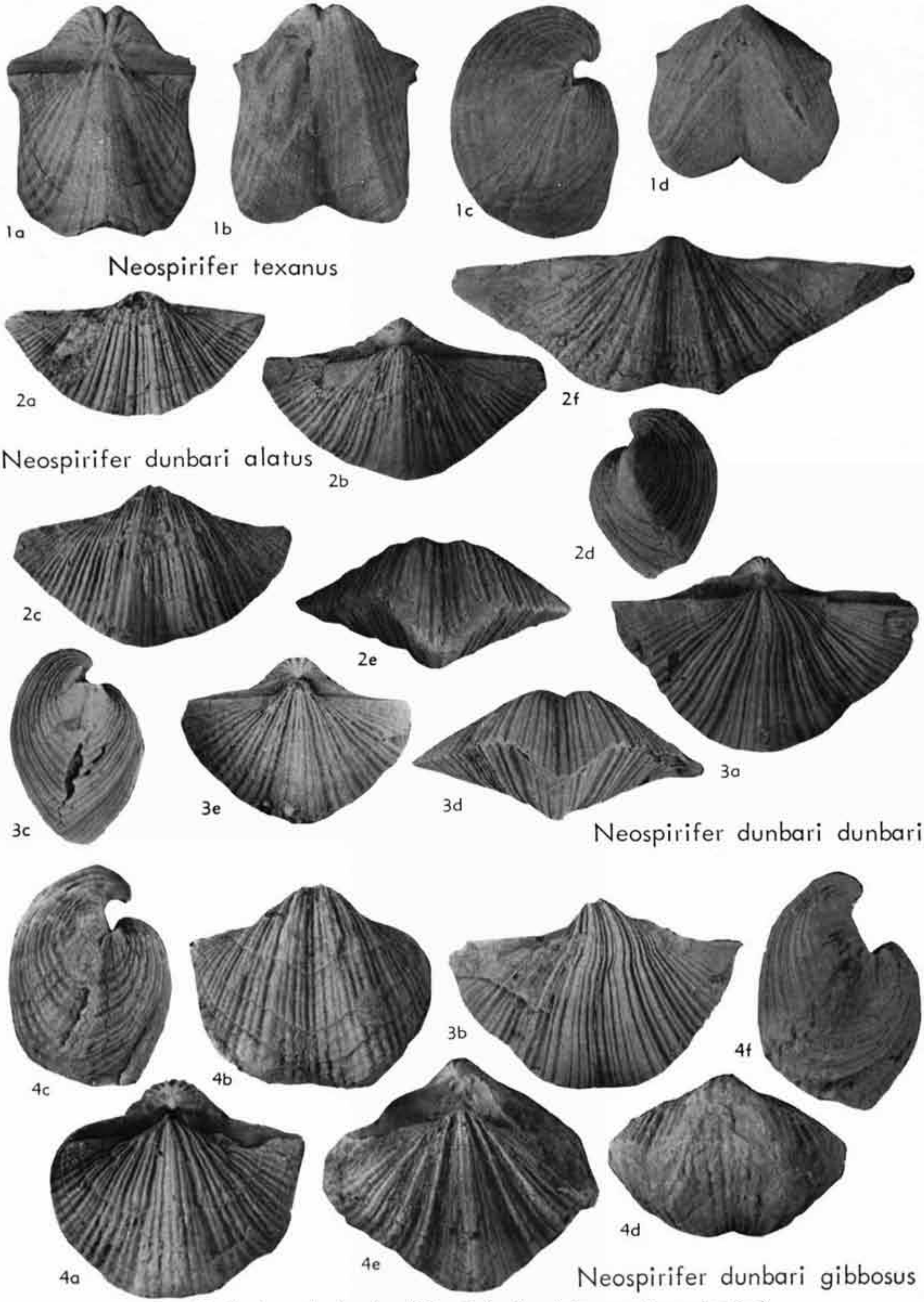

Fig. 13. Species and subspecies of *Neospirifer* (see facing page for explanation).

Splitting of the ribs makes its first appearance in certain species of the *S. striatus* group early in the Lower Carboniferous, as in *S. pikei, S. rowleyi, S. grimesi, S. gregeri,* and others, but the gathering of the ribs into prominent, elevated fascicles began with the Upper Carboniferous.

After the extinction of the simply ribbed Spirifer in the early part of the Pennsylvanian Period, those forms having bundled plications became dominant, and continued into the Permian Period. From this group, FREDRICKS chose *Spirifer fasciger* KEYSERLING as the type species of *Neospirifer*.

Studies of the internal structure of *Spirifer* and *Neospirifer* lend some support to the notion that the latter arose polyphyletically. *Spirifer opimus* and all species of *Neospirifer* examined in this study, except *N. dunbari* have certain characteristics in common: 1) absence of dorsal median septum; 2) presence of long, persistent dental lamellae; and 3) cardinal process confined by overhanging outer hinge plate.

The *Spirifer occiduus-S. rockymontanus* stock and *Neospirifer dunbari*, however, have similar internal structures very different from the above: 1) dorsal median septum present; 2) fairly short dental lamellae; 3) cardinal process little confined by the outer hinge plate.

Type species.—Spirifer fasciger KEYSERLING.

NEOSPIRIFER DUNBARI DUNBARI King

Figures 13,*3*; 14

Spirifer triplicata HALL, 1852, p. 410.——GIRTY, 1920, p. 645, pl. 54, fig. 22.

Spirifer cameratus auctores *(partim)*.

Neospirifer triplicatus DUNBAR & CONDRA, 1932, p. 328, pl. 39, fig. 5, pl. 41, fig. 1-6.

Neospirifer dunbari KING, 1933, p. 441.

Description.—Shell medium to large, biconvex, subtriangular in outline, greatest width at hinge, which extends into acute to bluntly angular cardinal extremities. Width, length, and thickness of an average specimen 4.3 cm., 2.8 cm., and 1.7 cm., respectively. In exceptionally large shells, width, length, and thickness, 6 cm., 5 cm., and 3 cm., respectively.

Beak of brachial valve not prominent, scarcely rising and incurving over low, linear interarea; dorsal fold high, narrow, rounded, and steep sided, beginning as simple plication, which divides and redivides to give a total of 12 plications.

Pedicle valve slightly more convex, beak very prominent, strongly arched, and incurved over high, linear interarea, which has a height of 1/10 to 1/12 as great as length of hinge. Pedicle opening has an apical angle of 60° to 75° and seems to be open or partly filled with internal callus. Sulcus moderately low, steep sided, and subangular, beginning as a simple furrow bounded on each side by plications and containing a total of 13 plications; margins subtend an angle of 20° to 24°.

Formula of plication generation of fold and sulcus: F: 1/3/4/1/2/3. S: M/2/1/4/2/3/4/1.

Lateral slopes bear 19 to 25 subangular, unequal plications on each side of fold or sulcus, 1st 2 lateral bundles containing 3 plicae and 3rd containing 2.

Surface sculpture of fine, closely spaced radial lirae and concentric lines, 15 of which occupy space of 1 mm. on average.

Pedicle valve interior (Fig. 14) with moderately strong hinge teeth supported by very abruptly terminated dental lamellae persisting only slightly beyond umbo, with shallow cavity bounded on each side by short extensions of shell material in place of median septum. Brachial valve with cruralium supported by solid, abruptly terminated dorsal median septum; cardinal process a small comblike structure containing maximum of 18 teeth on inner hinge plate. Crural lamellae appear as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 15 volutions.

Discussion.—Because of the subdued fasciculation of *Neospirifer dunbari* in the Cherokee Group, this species can be confused with *N. cameratus*. The angularity of the fold and sulcus and of the plications, and the pattern of branching on the fold and sulcus are good external aids in identification. Internally, the presence of a dorsal median septum, the degree of development of the articulating mechanism, and the number of teeth on the cardinal process are diagnostic criteria.

The name *Spirifer triplicatus* was given by HALL, and the species came to be regarded as identical with MORTON's poorly defined *S. cameratus*. SHUMARD (1855) called attention to the fact that this name was preoccupied, for KUTORGA (1842) had described a form that he called *Spirifer triplicata*.

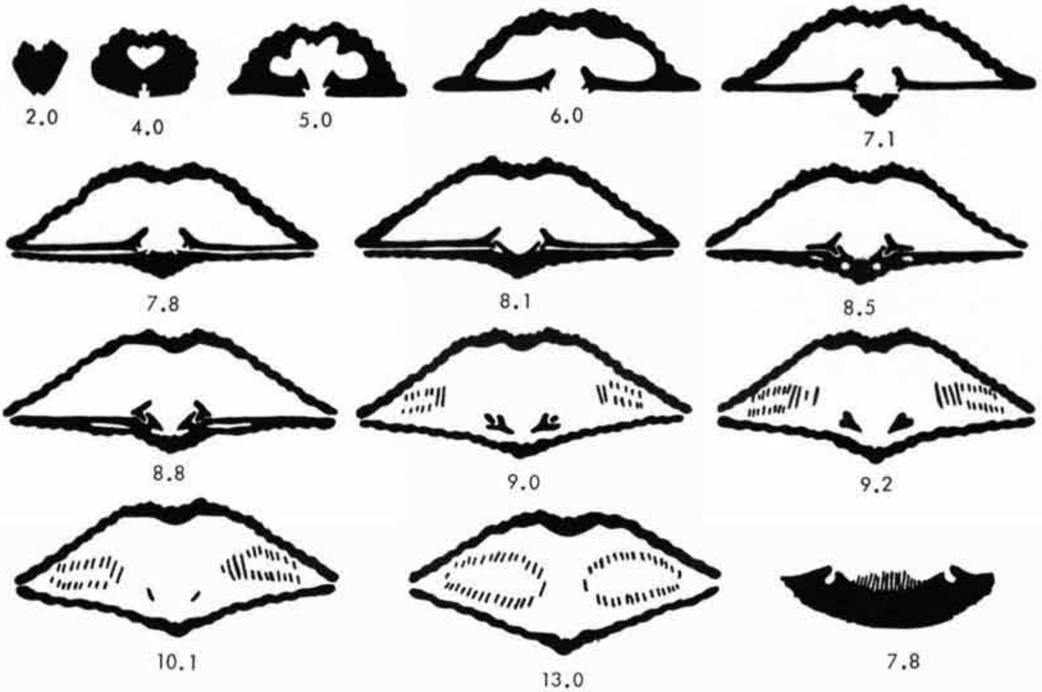

FIG. 14. Serial transverse sections of *Neospirifer dunbari dunbari* KING. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×1.5, except the last (lower right) which shows cardinal process, ×8.

In 1920, GIRTY showed that HALL's species was distinct and valid; hence, he took it out of synonomy with *Spirifer cameratus* MORTON and reestablished it under HALL's name.

DUNBAR & CONDRA (1932) placed HALL's species in the genus *Neospirifer* of FREDRICKS but did not suggest a new name. KING (1933) proposed the name *Neospirifer dunbari* for the species originally named *Spirifer triplicatus* by HALL.

Occurrence.—This species is very common and widespread and seems to be the most conservative and longest ranging of all the Pennsylvanian species of *Neospirifer*. Both DUNBAR & CONDRA and I have found it to range throughout the entire Pennsylvanian System exposed in Kansas and into the Permian.

Hypotypes.—KUMIP nos. 500,014, 500,020.

NEOSPIRIFER DUNBARI ALATUS
Dunbar & Condra

Figure 13, 2

Neospirifer triplicatus var. *alatus* DUNBAR & CONDRA, 1932, p. 332, pl. 38, fig. 11-12.

Description.—Shell biconvex, very transverse, subtriangular in outline, greatest width at hinge line, which extends into extremely acute cardinal extremities; width, length, and thickness of an average specimen 5.6 cm., 2.5 cm., and 2.0 cm., respectively; but, depending on shell maturity, width may range between 4 and 9 cm. In other respects, this subspecies agrees closely with *N. dunbari dunbari*, except that on ears are 4 to 10 subangular plications that do not reach beak.

Discussion.—*Neospirifer kansasensis*, occurring in the upper part of the Pennsylvanian System, has a similar alate form, but differs from *N. dunbari alatus* in that it has less fasciculation and finer, more numerous plications.

Occurrence.—DUNBAR & CONDRA described a holotype from the Plattsburg Limestone at Louisville, Nebraska, and indicated that the subspecies ranges from the Dennis Limestone of the Kansas City Group to the Deer Creek Limestone of the Shawnee Group. Specimens were collected by me from rocks occurring above and below these units; hence, the range is here extended to include the Critzer Limestone Member of the Hertha Limestone below and the Aarde Shale Member of the Howard Limestone above the range previously recognized.

Hypotypes.—KUMIP nos. 500,009, 500,022, 500,023, 500,024.

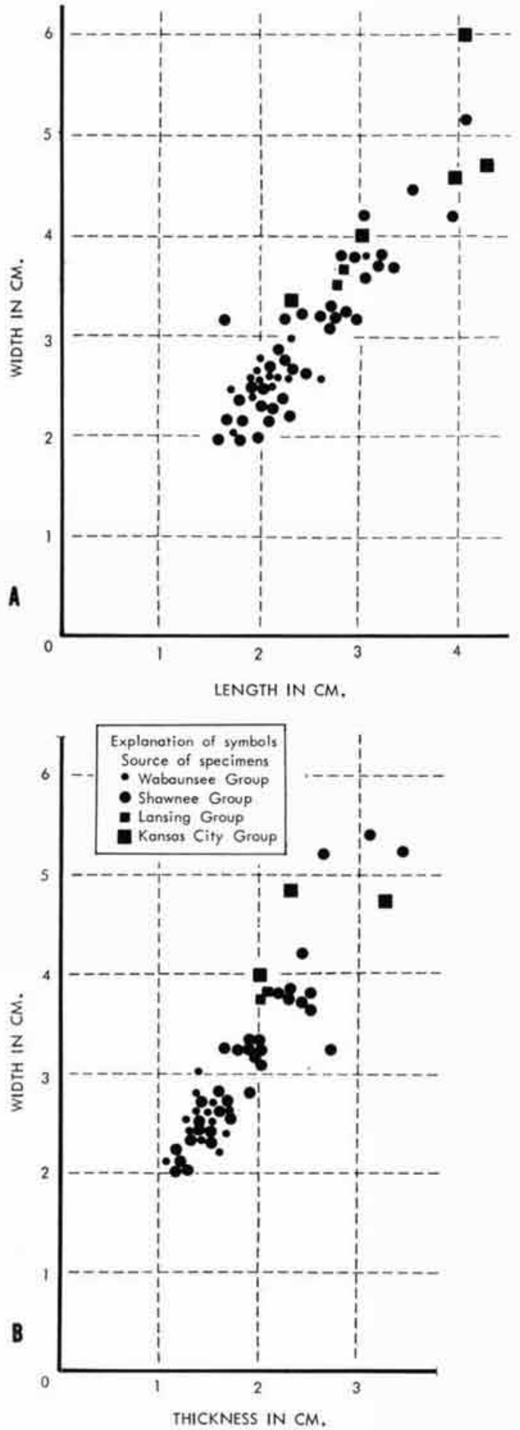

FIG. 15. Decrease in size of *Neospirifer dunbari gibbosus* associated with increasingly higher stratigraphic position, using (A) length-width ratio per specimen, and (B) width-thickness ratio per specimen.

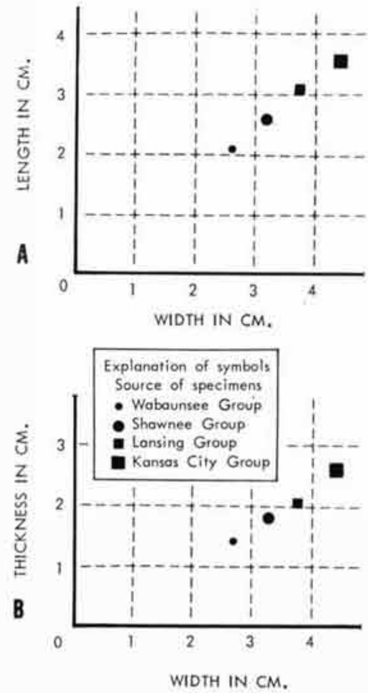

FIG. 16. Decrease in size of *Neospirifer dunbari gibbosus* associated with increasingly higher stratigraphic position, using (A) averaged length-width ratio of all specimens per group and (B) averaged width-thickness ratio of all specimens per group.

NEOSPIRIFER DUNBARI GIBBOSUS Dunbar & Condra

Figure 13, *4*

Neospirifer triplicatus var. *gibbosus* DUNBAR & CONDRA, 1932, p. 333, pl. 38, fig. 14-15.

Description.—Shell strongly biconvex, short hinged, subcircular in outline; width of shell only slightly greater than length, so that cardinal extremities are bluntly angular; width, length, and thickness of an average specimen 3.1 cm., 2.4 cm., and 2.0 cm., respectively. Ventral cardinal area triangular rather than rectangular and may attain a height of 8 mm.; pedicle-valve beak large and strongly arched above the hinge line.

Discussion.—A similar form was briefly described by SWALLOW as *Spirifer cameratus* var. *percrassus*. It was said to have a hinge line shorter than the width of the shell and to differ from *S. cameratus* in having a smaller cardinal area. Because SWALLOW's types were lost in a fire and because *Neospirifer dunbari gibbosus* has an exceptionally large rather than a small cardinal area, it seems best to regard it as a distinct subspecies.

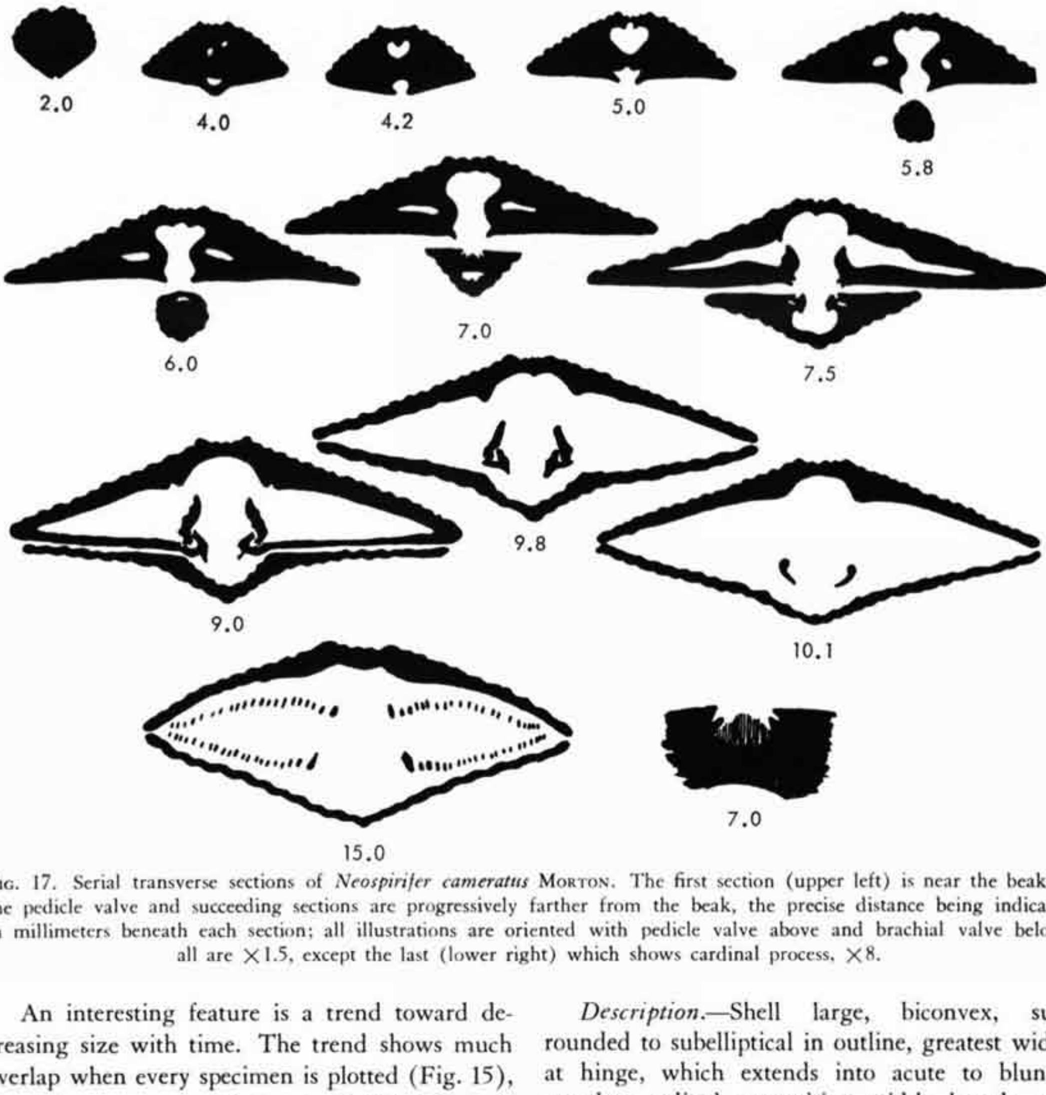

FIG. 17. Serial transverse sections of *Neospirifer cameratus* MORTON. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×1.5, except the last (lower right) which shows cardinal process, ×8.

An interesting feature is a trend toward decreasing size with time. The trend shows much overlap when every specimen is plotted (Fig. 15), but when average valves are plotted for each group, the trend becomes clear (Fig. 16).

Occurrence.—DUNBAR & CONDRA assigned to this subspecies a range from the Iatan Limestone to the Deer Creek Limestone. Specimens collected by me from strata above and below these units extend the range from the Winterset Limestone Member of the Dennis Limestone to the top of the Howard Limestone.

Hypotypes.—KUMIP nos. 500,026, 500,027.

NEOSPIRIFER CAMERATUS Morton

Figures 9,4; 17

Spirifer cameratus MORTON, 1836, p. 150, pl. 2, fig. 3.—GIRTY, 1920, p. 645; 1927, pl. 27, fig. 24-27.

Neospirifer cameratus DUNBAR & CONDRA, 1932, p. 334, pl. 39, fig. 4, 6-9b.

Description.—Shell large, biconvex, subrounded to subelliptical in outline, greatest width at hinge, which extends into acute to bluntly angular cardinal extremities; width, length, and thickness of an average specimen 5.2 cm., 3.1 cm., and 1.5 cm., respectively.

Beak of brachial valve fairly prominent, strongly arched and incurved over low, linear interarea; dorsal fold low, rounded to slightly angular, beginning as a simple plication, which divides and redivides to give total of 12 plications.

Beak of pedicle valve prominent, strongly arched and incurved over high, linear interarea, which has a height of 1/10 to 1/12 as great as length of hinge line; sulcus low and rounded, beginning as a simple furrow bounded on each side by a plication and containing total of 11 plications; margins subtend an angle of about 24°.

Formula of fold and sulcus plication generation: F: 1/2/1/3/2/3. S: M/2/1/4/2/3/4/1.

Lateral slopes have 25 to 30 low, broadly rounded, equal plications on each side of fold or sulcus, 1st 3 lateral bundles containing 3 plicae each.

Surface sculpture consists of fine radial lirae and concentric growth lines.

Pedicle valve interior (Fig. 17) with moderately strong hinge teeth supported by moderately high, thick, abruptly terminated dental lamellae; near umbonal region, small nublike median septum is present, giving way almost immediately to cavity bounded on each side by small rounded extensions of shell material. Brachial valve with unsupported cruralium; cardinal process a small comblike structure containing maximum of 22 teeth on inner hinge plate. Crural lamellae hang down as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to spiral coils of 16 volutions.

Discussion.—The internal skeletal structure of *Neospirifer cameratus* is very similar to that of *N. kansasensis* but differs from this species in that the cardinal process of *N. cameratus* is more compact and is enclosed by the hinge plate; also the teeth and sockets seem to be more convoluted, thereby having more interlocking points of hingement than *N. kansasensis.*

Occurrence.—The type of this species is from the basal part of the Alleghany Formation of Ohio. Specimens were collected from various horizons in the Cabaniss Formation of the Cherokee Group, and the top of this formation seems to be the upper limit of the range.

Hypotypes.—KUMIP nos. 500,015, 500,025.

NEOSPIRIFER LATUS LATUS
Dunbar & Condra

Figures 18,*1*; 19

Neospirifer latus Dunbar & Condra, 1932, p. 336, pl. 40, fig. 1-5.

Description.—Shell very large, robust, biconvex, semicircular in outline, greatest width at hinge, which extends into acute, at early maturity, to bluntly angular to rounded cardinal extremities; width, length, and thickness of an average specimen 6.8 cm., 4.3 cm., and 2.3 cm., respectively.

Beak of brachial valve fairly prominent, scarcely rising, but strongly incurving, over very low, linear interarea; dorsal fold broad and low, beginning as simple plication, which divides and redivides to form total of 16 to 20 plications. Pedicle valve slightly more convex, beak very prominent, strongly arched and incurved over high, linear interarea. Apical angle of pedicle opening 60° to 75°. Sulcus low and broad, beginning as simple furrow bounded on each side by plications and containing total of 15 to 19 plications; subtends angle of 28° to 30°.

Formula of plication generation of fold and sulcus: F: 1/4/3/2/3/1/3/1/3/4.
S: M/3/6/1/5/2/6/3/4/6/1.

Lateral slopes bear 28 to 37 subangular, unequal plications on each side of fold or sulcus, 1st 3 lateral bundles containing 4, 5, or 6 ribs each.

Pedicle valve interior (Fig. 19) has strong hinge teeth supported by thick, relatively persistent, high, abruptly terminating dental lamellae, and has small, bluntly pointed median septum giving way to shallow cavity bounded on each side by small protrusions of shell material. Brachial valve with small, massive, unsupported cruralium; cardinal process a small comblike structure containing maximum of 32 teeth on inner hinge plate. Crural lamellae occur as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 22 volutions.

Discussion.—The large size, robust form, coarse bundling of ribs, pattern of branching on fold and sulcus, and internal structure are distinctive features of this species.

Occurrence.—Dunbar & Condra (1932, p. 337) indicated that *Neospirifer latus* is confined to the Kansas City and Lansing Groups, but I have collected specimens from strata ranging up into the Brownville Limestone Member

Explanation of Figure 18 (all ×1).

1. Neospirifer latus latus (Dunbar & Condra), *1a-b*, Winterset Limestone Member, Dennis Limestone, Linn Co., ventral and dorsal views (KUMIP 500,006); *1c*, Spring Hill Limestone Member, Plattsburg Limestone, Coffey Co., ventral view of immature form (KUMIP 500,008); *1d-g*, Critzer Limestone Member, Hertha Limestone, Bourbon Co., dorsal, ventral, side, and anterior views (KUMIP 500,016).

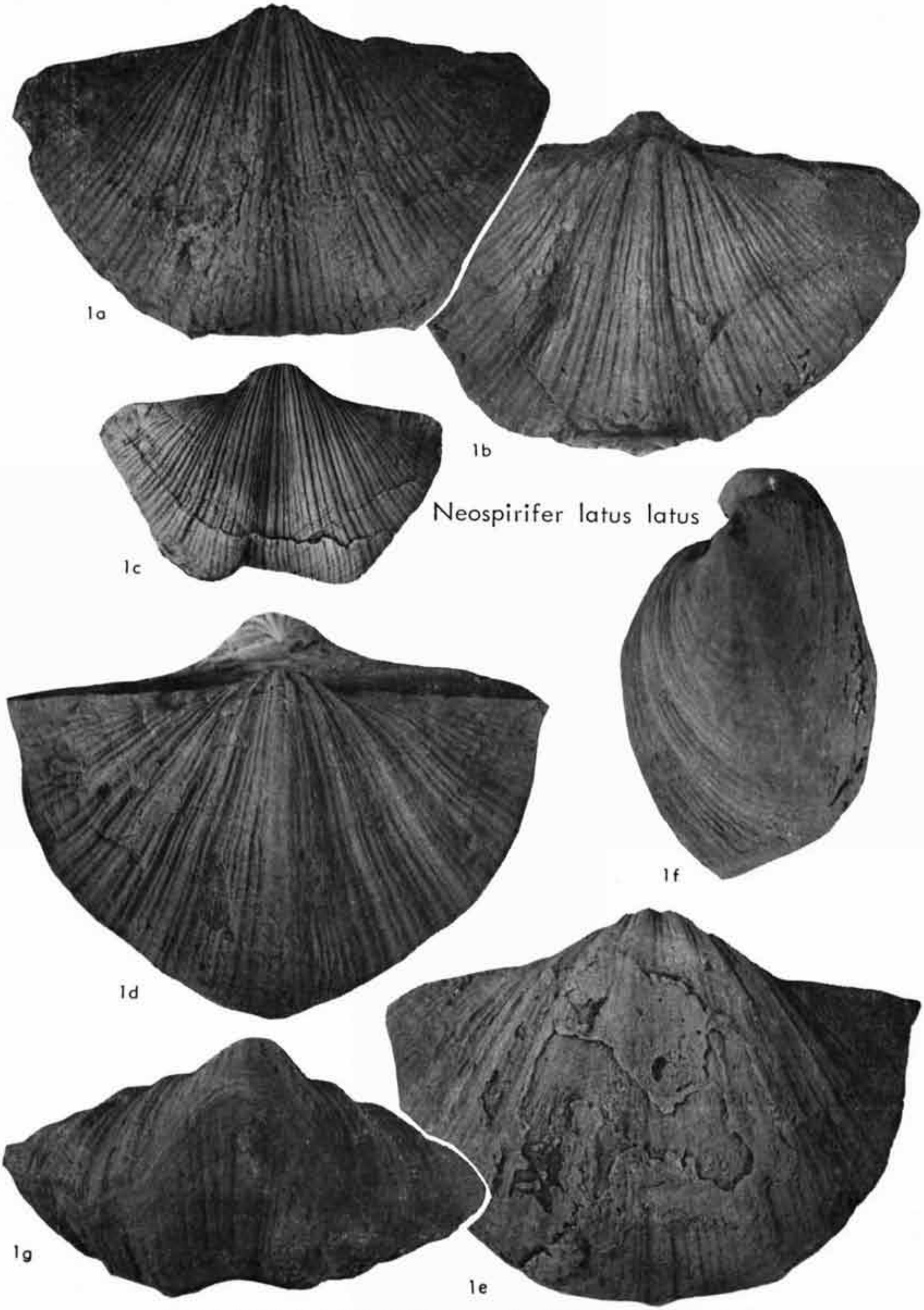

FIG. 18. *Neospirifer latus latus* from Kansas (see facing page for explanation).

of the Wood Siding Formation, which defines the upper limit of the range as presently known.

Hypotypes.—KUMIP nos. 500,005, 500,008, 500,016.

NEOSPIRIFER LATUS LATERALIS Spencer, new subspecies

Figure 7,*4*

Description.—Shell large, robust, biconvex, very transverse, subtriangular in outline, greatest width at hinge, which extends into extremely acute cardinal extremities; width, length, and thickness of an average specimen 8.1 cm., 4.1 cm., and 2.1 cm., respectively. Plications subangular except in sinus, where they seem to be flatter. In all other respects, this subspecies is similar to *Neospirifer latus latus.*

Discussion.—The characteristics that distinguish this alate form from similar forms of *Neospirifer kansasensis* and *N. dunbari alatus* are the pattern of branching on the fold and sulcus, the very high interarea, the angle that the sinus subtends, the number of plications on the lateral slopes, the extreme transverse and robust form.

Occurrence.—The holotype was found near the base of the Plattsburg Limestone in the Ross Quarry, one mile southeast of Ottawa, Kansas. Other specimens were collected from the top of the Stanton Limestone at an abandoned quarry northeast of Middleton, Kansas, and from the top of the Wyandotte Limestone south of DeSoto, Kansas. No specimens were observed above or below this sequence; the known range extends from the Farley Limestone Member of the Wyandotte Limestone to the South Bend Limestone Member of the Stanton Limestone.

Holotype.—KUMIP nos. 500,004, 500,028.

NEOSPIRIFER KANSASENSIS Swallow

Figures 7,*3*; 20

Spirifer camerata var. *kansasensis* SWALLOW, 1876, p. 409.
Neospirifer kansasensis DUNBAR & CONDRA, 1932, p. 335, pl. 40, fig. 6-8.

Description.—Shell medium to large, biconvex, subtriangular in outline, greatest width at hinge, which extends into acute to bluntly angular cardinal extremities. Width, length, and thickness of average specimen 5.5 cm., 3.2 cm., and 2.0 cm., respectively.

Beak of brachial valve not prominent, scarcely rising, and incurving over low linear interarea; dorsal fold high, narrow, subangular to rounded, and steep-sided, beginning as simple plication, which divides and redivides to form total of 20 to 22 plications on fold.

Beak of pedicle valve very prominent, strongly arched and incurved over high, linear interarea. Apical angle of pedicle opening 65° to 70°; opening seems to be clear or partly filled with internal callus. Sulcus low, rounded to subangular; slopes moderately inclined, beginning as simple furrow bounded on each side by plications and containing total of 19 to 21 plications; margins subtend angle of 28° to 30°.

Formulas of plication generation of fold and sulcus. F: 1/4/3/5/2/5/3/4/5/6/7.
S: M/7/5/3/5/1/5/2/6/4/5/1.

Lateral slopes bear 40 to 45 fine, angular, strongly fasciculated plications on each side of fold or sulcus, 1st 2 or 3 lateral bundles containing 3, 4, or 5 plications each.

Pedicle valve interior (Fig. 20) has very short, bluntly pointed median septum and strong hinge teeth supported by moderately high, strong, persistent, but abruptly terminating dental lamellae. Brachial valve with unsupported cruralium; cardinal process a small comblike structure containing maximum of 22 teeth on inner hinge plate; crural lamellae hang down as flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 12 volutions.

Discussion.—*Neospirifer kansasensis* has the general form of *N. dunbari* but differs from that species in that the division occurs repeatedly during growth, causing plications to be finer and more numerous. Also the fold and sulcus tend to be more sharply angular, the shells are shorter and more transverse, and the pattern of branching on the fold and sulcus is different than in *N. dunbari.* Internally, the arrangement of the articulating mechanism and the number of teeth on the cardinal process aid in differentiation of these two species. The internal structure of *N. kansasensis* is very similar to that of *N. cameratus,* but the species is distinguished from the latter on the

FIG. 19. Serial transverse sections of *Neospirifer latus* DUNBAR & CONDRA. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×1.5, except the last (lower left) which shows cardinal process, ×8.

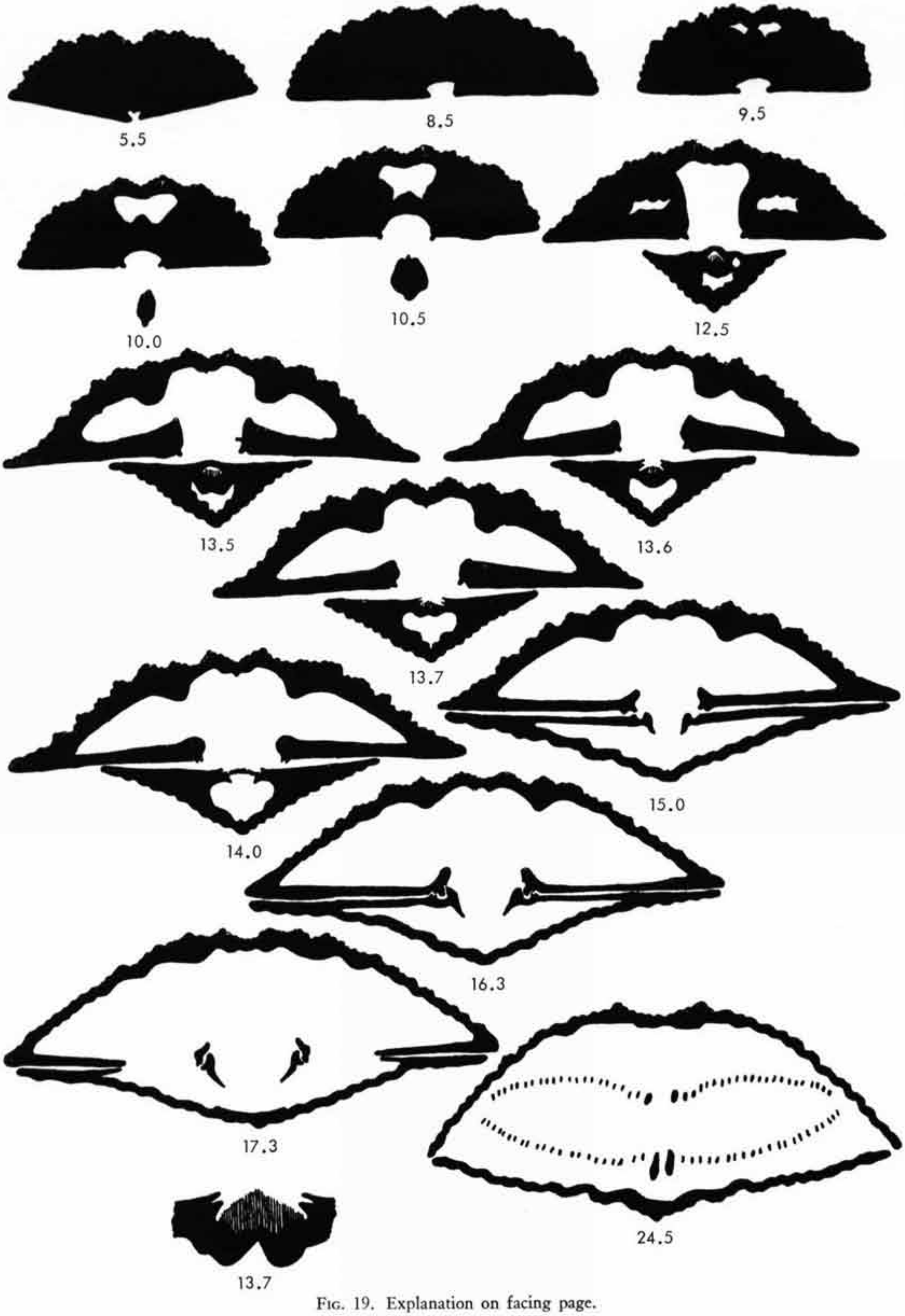

FIG. 19. Explanation on facing page.

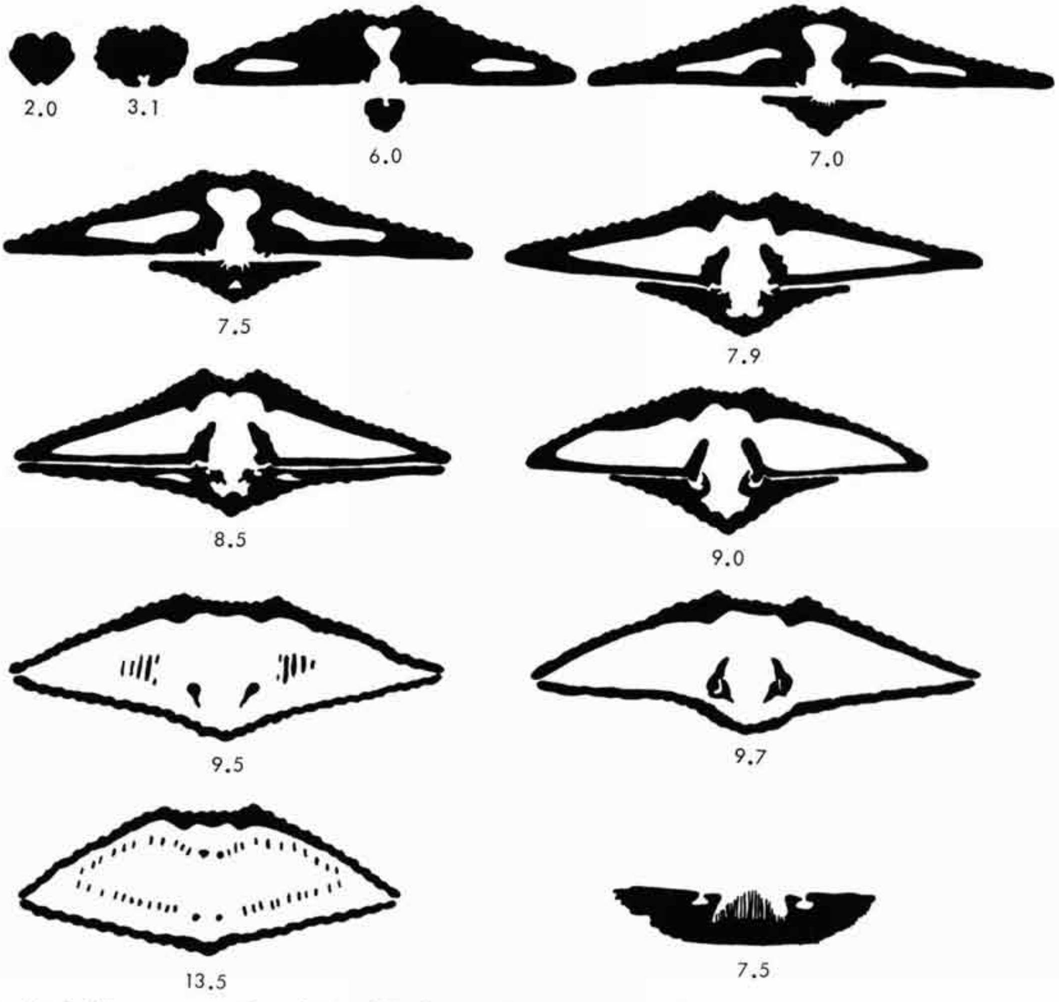

FIG. 20. Serial transverse sections of *Neospirifer kansasensis* SWALLOW. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×1.5, except the last (lower right) which shows cardinal process, ×15.

basis of the number of plications on the lateral slopes and the pattern of branching on the fold and sulcus.

Occurrence.—This species first appears in the Auburn Shale of the Wabaunsee Group and continues into the lower part of the Permian System. According to DUNBAR & CONDRA (1932, p. 338), this species dies out in the Wreford Limestone of the Permian System in Nebraska.

Hypotypes.—KUMIP nos. 500,007, 500,017.

NEOSPIRIFER TEXANUS Meek

Figures 13,*1*; 21

Spirifer (Trigonotreta) texanus MEEK, 1871, p. 179.

Neospirifer texanus DUNBAR & CONDRA, 1932, p. 341, pl. 38, fig. 6-10.

Description.—Shell medium sized, extremely biconvex, subquadrate to subovate in outline, greatest width anterior to mid-length; length greater than width. Hinge line short, and extending into obtusely angular cardinal extremities, which do not project beyond lateral slopes in more gibbous specimens. Width, length, and thickness 2.5 cm., 3.0 cm., and 2.2 cm., respectively.

Beak of dorsal valve not prominent, scarcely rising but strongly incurving over low linear interarea; umbonal region elevated above cardinal extremities. Dorsal fold moderately high, angular to slightly subangular, widening rapidly, and be-

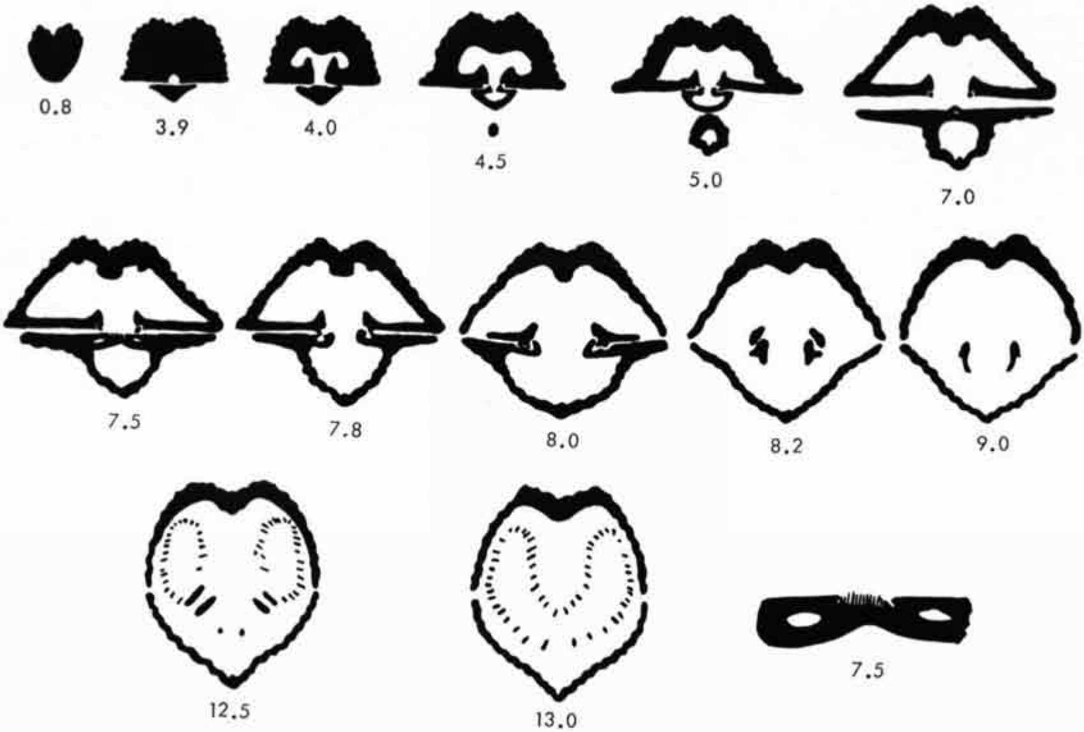

FIG. 21. Serial transverse sections of *Neospirifer texanus* MEEK. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial valve below; all are ×1.5, except the last (lower left) which shows cardinal process, ×15.

ginning as simple plication, which divides to give total of 16 to 18 plications on fold.

Pedicle valve more convex, beak very prominent, strongly arched and incurved over moderately arched interarea extending to cardinal extremities. Pedicle opening having apical opening of 60°, and distinct marginal furrows. Sinus small and angular at beak, but widening rapidly and deepening very rapidly toward anterior commisure where it makes strongly curved, triangular projection that fits into fold. Sulcus subtending angle of 35°, beginning as simple furrow bounded on each side by plications and containing total of 17 to 19 plications.

Formulas of plication generation of fold and sulcus: F: 1/6/4/2/6/3/7/6/5.
S: M/6/4/2/7/5/3/4/6/5/1.

Lateral slopes short, bearing 9 to 11 broad, low, rounded plications on each side of fold or sulcus. Fasciculation not prominent, being confined to area closest to umbo.

Minute surface markings consist of fine undulating growth lines, which become more pronounced and lamellose toward anterior margin, and fine radiating striae; regularly spaced granules, which may be bases of small spines, also present.

Pedicle valve interior (Fig. 21) with strong hinge teeth supported by very abruptly terminating dental lamellae persisting only slightly beyond umbo, and very persistant, short, knobbed median septum. Brachial valve with unsupported cruralium; cardinal process a fine comblike structure containing 15 to 18 teeth on inner hinge plate; crural lamellae appear as small flanges only after tooth and socket dentition well developed. Primary lamellae of spiralia run forward to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 14 volutions, which for 1st few turns extend laterally, then curve ventrally following outline of shell.

Discussion.—Because the beak and umbo are so strongly incurved, the earlier-formed parts of

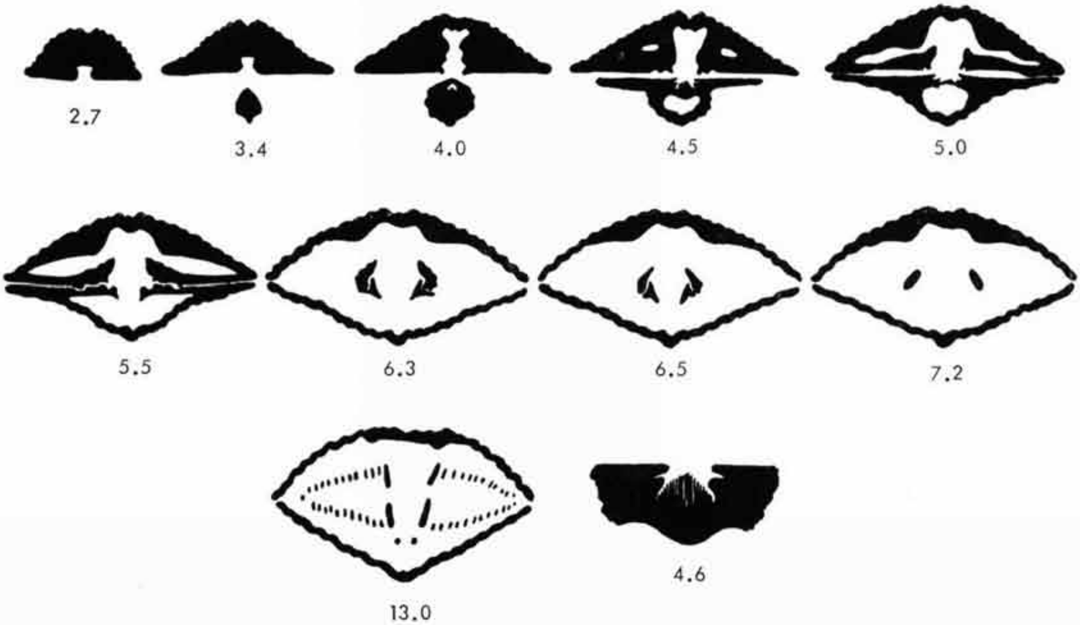

FIG. 22. Serial transverse sections of *Neospirifer goreii* MATHER. The first section (upper left) is near the beak of the pedicle valve and succeeding sections are progressively farther from the beak, the precise distance being indicated in millimeters beneath each section; all illustrations are oriented with pedicle valve above and brachial below; all are ×1.5, except the last (lower right) which shows cardinal process, ×15.

the shell were also observed in the first few serial sections.

Occurrence.—MEEK described this species from the lower part of the Cisco Series in Young County, Texas. PLUMMER & MOORE (1921) reported its occurrence in the Graford Group of the Canyon Series and in the Graham Group in the Cisco Series. It was not reported north of Texas until DUNBAR & CONDRA found that it was common in the Lenapah Limestone on the west edge of Nowata, Oklahoma, but none was found farther north, in Kansas and Nebraska. However, I have found a very good specimen in the Norfleet Limestone just northeast of Uniontown, Kansas.

Hypotype.—KUMIP no. 500,018.

NEOSPIRIFER GOREII Mather

Figures 7,2; 22

Spirifer goreii MATHER, 1915, p. 186, pl. 12, fig. 10-11a.
Neospirifer goreii DUNBAR & CONDRA, 1932, p. 341, pl. 39, fig. 1-3.

Description.—Shell medium to large, moderately to strongly biconvex, subtriangular in outline, greatest width at hinge, which extends into subrounded to bluntly angular cardinal extremities. Width, length, and thickness of an average specimen 5.4 cm., 3.4 cm., and 2.1 cm., respectively.

Beak of brachial valve inconspicuous, scarcely rising, but strongly incurving over very low, linear interarea; umbonal region strongly elevated above cardinal extremities; dorsal fold moderately high, not well defined, subangular, and steep-sided, beginning as simple plication, which divides and redivides to give total of 17 plications. Pedicle valve moderately convex, beak strongly elevated and incurved over a moderately high interarea, which has height about 0.1 as great as length of hinge line. Cardinal area gently concave and transversly striated, containing large isosceles triangular delthyrium. Sulcus moderately low, beginning as simple furrow bounded on each side by plications, and contains a total of 15 plications; margins subtend an angle of 23° to 25°.

Formulas of plication generation of fold and sulcus: F: 1/2/1/3/2/4/3/4.
S: M/2/1/4/2/5/3/4/1.

Lateral slopes bear 20 to 29 rounded, rarely bifurcating plications on each side of fold or sulcus, which grow fainter toward cardinal extremities, where they may be obsolete.

Minute surface sculpture consists of fine radial lirae and wavy, concentric growth lines.

Pedicle valve interior (Fig. 22) has moderately strong hinge teeth supported by very abruptly terminating dental lamellae, persisting only slightly beyond umbo; no observable median septum. Brachial valve has unsupported cruralium; cardinal process a small comblike structure containing 18 to 20 teeth on inner hinge plate. Crural lamellae hang down as small flanges beneath palintrope. Primary lamellae of spiralia run forward nearly to anterior end of shell before curving ventrally and posteriorly, giving rise to simple spiral coils of 13 volutions.

Discussion.—Similarities between this species and *Neospirifer cameratus* exist, but *N. goreii* can be externally differentiated from *N. cameratus* on the basis of number of plications per cm. At a distance of 2 cm. from the beak, *N. goreii* has about 12 plicae per cm. on the inner part of the lateral slopes, whereas *N. cameratus* bears 7 or 8. The two species also have different patterns of branching of plicae in the fold and sulcus. Internally, the differences between these species are not distinct enough to warrant differentiation on this basis.

Occurrence.—MATHER identified this species from the Hale and Kessler Members of Morrowan age in Arkansas and Oklahoma. Specimens were collected by me from the Krebs and Cabaniss Formations of the Cherokee Group. A specimen of doubtful identification was found in the Norfleet Limestone Member of the Lenapah Limestone, hence the upper limit of the range of this species is tentatively placed at the top of the Cherokee Group.

Hypotype.—KUMIP no. 500,019.

CONCLUSIONS

Punctospirifer kentuckyensis, Spirifer rockymontanus, S. opimus, S. occiduus, Neospirifer dunbari dunbari, N. dunbari alatus, N. dunbari gibbosus, N. cameratus, N. latus latus, N. latus lateralis, N. kansasensis, N. texanus, and *N. goreii* are spiriferoid brachiopods found in the Pennsylvanian System of Kansas, *P. kentuckyensis* ranging throughout the Pennsylvanian System, and *S. rockymontanus, S. opimus,* and *S. occiduus* are confined to the lower and middle Desmoinesian (Table 1).

The ranges of all Pennsylvanian species of *Neospirifer* described in this study have been extended. *N. dunbari dunbari* ranges from upper Desmoinesian to middle Wolfcampian, and *N. dunbari alatus, N. dunbari gibbosus,* and *N. latus latus* occur between lower Missourian and upper Virgilian. *N. latus lateralis* is confined to middle

TABLE 1. *Stratigraphic occurrence of the Spiriferacea and Spiriferinacea species in the Pennsylvanian System of Kansas.*

	a	b	c	d	e	f	g	h	i	j	k	l	m
Wood Siding Fm.	×	-	-	-	×	-	-	-	×	-	×	-	-
Root Sh.	+	-	-	-	-	-	-	-	-	-	-	-	-
Stotler Ls.	×	-	-	-	-	-	-	-	-	-	-	-	-
Pillsbury Sh.	+	-	-	-	-	-	-	-	-	-	-	-	-
Zeandale Ls.	+	-	-	-	×	-	-	-	-	-	×	-	-
Willard Sh.	+	-	-	-	+	-	-	-	-	-	-	-	-
Emporia Ls.	+	-	-	-	+	-	-	-	-	-	+	-	-
Auburn Sh.	×	-	-	-	×	-	-	-	×	-	×	-	-
Bern Ls.	×	-	-	-	×	-	-	-	-	-	-	-	-
Scranton Sh.	+	-	-	-	-	-	-	-	-	-	-	-	-
Howard Ls.	×	-	-	-	×	×	×	-	-	-	-	-	-
Severy Sh.	×	-	-	-	+	-	-	-	-	-	-	-	-
Topeka Ls.	×	-	-	-	×	×	×	-	×	-	-	-	-
Calhoun Sh.	+	-	-	-	×	-	×	-	-	-	-	-	-
Deer Creek Ls.	×	-	-	-	×	-	×	-	-	-	-	-	-
Tecumseh Sh.	-	-	-	-	×	-	×	-	-	-	-	-	-
Lecompton Ls.	×	-	-	-	×	×	×	-	×	-	-	-	-
Kanwaka Sh.	×	-	-	-	×	-	×	-	-	-	-	-	-
Oread Ls.	×	-	-	-	×	×	×	-	-	-	-	-	-
Lawrence Sh.	+	-	-	-	+	-	-	-	-	-	-	-	-
Stranger Fm	×	-	-	-	-	-	-	-	-	-	-	-	-
Iatan Ls.	+	-	-	-	+	-	-	-	-	-	-	-	-
Weston Sh.	×	-	-	-	-	-	-	-	-	-	-	-	-
Stanton Ls.	×	-	-	-	×	×	-	-	×	×	-	-	-
Vilas Sh.	×	-	-	-	-	-	-	-	-	-	-	-	-
Plattsburg Ls.	×	-	-	-	×	×	×	-	×	×	-	-	-
Bonner Springs Sh.	-	-	-	-	-	-	-	-	+	-	-	-	-
Wyandotte Ls.	×	-	-	-	×	×	×	-	+	-	-	-	-
Lane Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Iola Ls.	×	-	-	-	×	+	×	-	-	-	-	-	-
Chanute Sh.	+	-	-	-	-	-	-	-	-	-	-	-	-
Drum Ls.	×	-	-	-	×	×	×	-	-	-	-	-	-
Cherryvale Sh.	×	-	-	-	×	×	-	-	-	-	-	-	-
Dennis Ls.	×	-	-	-	×	×	×	-	×	-	-	-	-
Galesburg Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Swope Ls.	×	-	-	-	×	-	-	-	-	-	-	-	-
Ladore Sh.	×	-	-	-	-	-	-	-	-	-	-	-	-
Hertha Ls.	×	-	-	-	×	-	-	-	×	-	-	-	-
U. Pleasanton Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Checkerboard Ls.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hepler Ss.	-	-	-	-	-	-	-	-	-	-	-	-	-
Holdenville Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Lenapah Ls.	-	-	-	-	×	-	-	-	-	-	-	×	-
Nowata Sh.	+	-	-	-	-	-	-	-	-	-	-	+	-
Altamont Ls.	-	-	-	-	-	-	-	-	-	-	-	-	-
Bandera Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Pawnee Sh.	×	-	-	-	×	-	-	-	-	-	-	-	-
Labette Sh.	-	-	-	-	-	-	-	-	-	-	-	-	-
Fort Scott Ls.	×	-	-	+	×	-	-	-	-	-	-	-	-
Cabaniss Fm.	×	×	×	×	×	-	-	×	-	-	-	-	×
Krebs Fm.	×	×	×	×	-	-	-	×	-	-	-	-	×

a: Punctospirifer kentuckyensis
b: Spirifer rockymontanus
c: Spirifer opimus
d: Spirifer occiduus
e: Neospirifer dunbari dunbari
f: Neospirifer dunbari alatus
g: Neospirifer dunbari gibbosus
h: Neospirifer cameratus
i: Neospirifer latus latus
k: Neospirifer kansasensis
l: Neospirifer texanus
m: Neospirifer goreii
x: Observed by author
+: Observed by Dunbar & Condra (1932)

upper Missourian. *N. cameratus* is tentatively placed in the lower and middle Missourian, and *N. goreii* has been found from Morrowan to middle Missourian. *N. texanus* is apparently restricted to the Lenapah Limestone in Kansas, although it persisted much longer in Texas.

During the course of this study, the internal structure of all species heretofore mentioned have been examined in serial section. It has been noted that:

1) The number of teeth forming the comblike cardinal process of the genus *Spirifer* is a characteristic of specific importance.
2) The internal structure of *S. opimus* is different from those of the related forms *S. rockymontanus* and *S. occiduus*.
3) *Punctospirifer kentuckyensis* possesses a hollow dorsal median septum, and a comblike cardinal process rising off a low, rounded nub.
4) In none of the spiriferoid brachiopods examined has a jugum been observed.
5) Except for *Neospirifer dunbari* and *N. texanus*, the internal structures of the Neospirifers examined in this study are very similar, only minor variations in the articulating mechanism, cardinal process, and dental lamellae being apparent.

A special study of the plication patterns in *Neospirifer* has shown that they are reliable for species identification. Because a word description of the patterns is lengthy, a shorthand system was developed for describing them.

The close similarities of internal structures between *Spirifer occiduus, S. rockymontanus,* and *Neospirifer dunbari,* and between *S. opimus* and the other Neospirifers described in this study has led the author to suspect a polyphyletic origin of the genus *Neospirifer*.

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