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THE AMMONOID FAMILY GIRTYOCERATIDAE IN THE SOUTHERN MIDCONTINENT

by

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The Ammonoid Family Girtyoceratidae in the Southern Midcontinent

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ABSTRACT

In Upper Mississippian (Chesterian) strata, representatives of the ammonoid family Girtyoceratidae are some of the more common and stratigraphically useful goniatites. *Eumorphoceras,* the zone fossil for lower Namurian (upper Chesterian) stages has been recognized in many parts of the world. Most of the confusion regarding identity and relationship of this genus can be resolved by reference to various growth stages in the type species from Oklahoma. In general, the ancestral form *Girtyoceras* characterizes the early Chesterian (late Viséan), and *Eumorphoceras* is found almost exclusively in late Chesterian (early Namurian). Mature lenticular representatives of the two genera are similar, but several consistent features separate type species in all growth stages. Globular related forms, which occur in association with *Eumorphoceras,* are described as a new genus, *Tumulites,* with *T. varians,* new species, as type. An early Morrowan descendant of the globular form is *Arkanites,* new genus, designated as representative of a new subfamily, Arkanitinae.

INTRODUCTION

The Upper Mississippian Caney Shale of southern Oklahoma contains the type species of two genera of ammonoids which are regarded throughout the world as index fossils. Girty (1909) described the goniatites as *Adelphoceras* [*Girtyoceras*] *meslerianum* from the lower part of the Caney and *Eumorphoceras bisulcatum* from the upper part. Present understanding of these taxa has been derived to a considerable extent from material from other states (Miller and Furnish, 1940; Miller and Youngquist, 1948; Miller and others, 1949) and from western Europe (Moore, 1946). Girty's original material consisted of immature shells and there has been considerable

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uncertainty about the nature of comparable mature specimens. Large well-preserved forms now provide a view of all growth stages.

Acknowledgments.—The collections which serve as a basis for this study have been accumulated over a period of many years. Allen Graffham has been particularly helpful in providing key specimens. Associates at the State University of Iowa and the University of Arkansas have assisted in collecting and advice. Frank Stewart of Peyton Creek Phosphate Mine has taken an interest in the faunal studies and helped secure specimens. E. W. J. Moore provided comparative material from northern England and Eire.

Repositories.—The specimens described and illustrated herein are at the State University of Iowa, designated by the prefix SUI, or at the University of Arkansas, designated by the prefix UA.

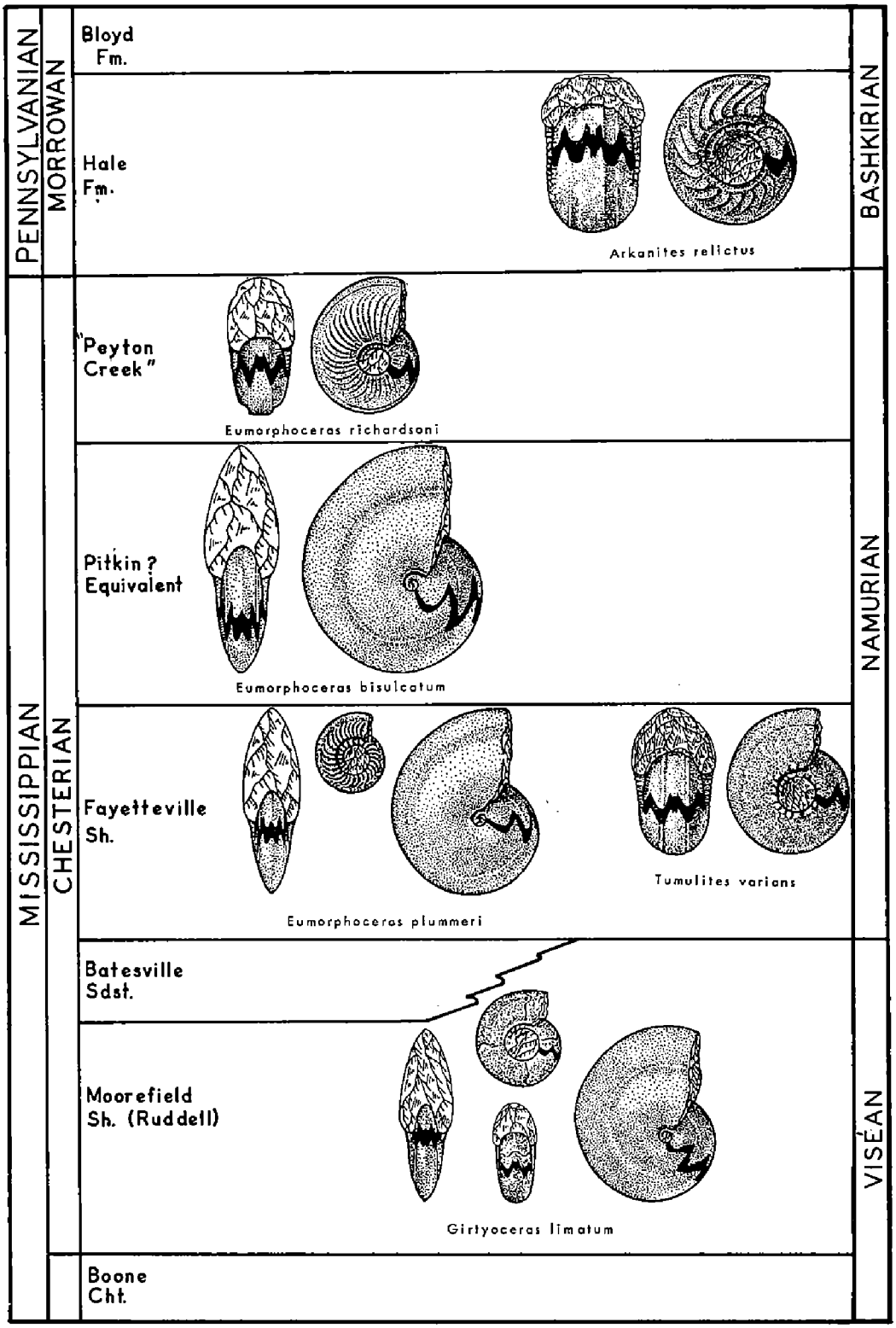
STRATIGRAPHY

Oklahoma.—The Mississippian and Pennsylvanian stratigraphy in Oklahoma is well documented. Caney Shale of the type area on the north side of the Arbuckle uplift was described by Girty and others fifty years ago. Elias (1956) has defined a series of stratigraphic units within the Mississippian of this region. His Delaware Creek and Sand Branch Members represent lower and upper parts of the Caney in earlier usage (Girty, 1909, p. 14; Miller and Furnish, 1940, p. 357). In addition, Elias' Springeran Rhoda Creek Formation should now be regarded as Mississippian, upon the basis of the goniatite fauna contained, rather than as Pennsylvanian. Correlation of these strata with the type Chesterian of southern Illinois is still somewhat obscure; much closer comparisons can be made with the goniatite zones of western Europe.

Arkansas.—Within the past few years large numbers of goniatites secured in the northern part of Arkansas have given new stratigraphic information. The status of published information makes it necessary to discuss this section in some detail.

In northern Arkansas, Mississippian rocks containing *Girtyoceras* and *Eumorphoceras* were categorized by Girty (1911, p. 5) as a black shale between two limestones and as containing a sandstone unit. The limestones are the Boone and Pitkin Formations; the sandstone is the Batesville Formation. The lower black shale unit became

known as the Moorefield Formation, lying below the Batesville Sandstone, and the Fayetteville Formation constitutes the upper part.



Text-figure 1. Stratigraphic distribution of the Girtyoceratidae in the southern Midcontinent. The Namurian-Bashkirian boundary on this chart corresponds approximately to recommended usage in the Donetz basin (Aisenverg and others, 1960).

The Moorefield and Batesville Formations crop out principally in the eastern part of the Boston Mountains. The Fayetteville and Pitkin Formations were named for outcrops in Washington County to the west, but Fayetteville strata are identifiable from the western to the eastern borders of the Boston Mountains. The western portion of this unit contains a sandstone in its upper part called the Wedington Member. Similarly, a thin but extensive bed of dark limestone, which has not been reported previously, is in the shale above the Wedington Sandstone. In the eastern part of the Boston Mountains the uppermost interval is occupied by a thick sequence (up to 300 feet) of carbonates in the form of a reef complex. The Pitkin Formation of the Boston Mountains in Washington County is essentially a few feet (20 to 30 feet) of limestone bounded above and below by unconformities. By contrast, in the eastern area, above and on the south flank of the Fayetteville reef complex, is a relatively thick sequence of sandstones, shales, limestones, and conglomerates which was referred by Easton (1942) to the Pitkin Formation.

Girty (1911, p. 5-9) recounted the "vicissitudes of nomenclature" that the Arkansas Mississippian section had undergone. He followed Williams (1900) and referred to the lower part of the Moorefield Formation as the Spring Creek Limestone. Girty (1911) described an extensive fauna from the Moorefield and also (1915) described fossils from the Batesville Formation. He regarded the area east of Searcy County as a separate province from that in Washington County, where the Moorefield was thought to be missing. Earlier, he had published a preliminary report (1910, p. 189) on the Fayetteville fauna obtained from "A rather persistent calcareous bed at the very base of the formation. . ." The Fayetteville report included 108 new generic and specific names for which the types are still not illustrated. In the western province, Girty related the limestone from which the fossils were recovered to the Fayetteville Formation, seemingly because a few patches of thin sandstone separate this limestone from the underlying Boone Formation. He supposed that the sandstone was equivalent to the Batesville Formation (1911, p. 6) and that, therefore, the immediately overlying strata belonged in the Fayetteville Formation. Except for lithologic similarity, no evidence that this sandstone is a Batesville correlative is known.

Gordon (1944) divided the Moorefield Formation into two units, restricting the term Moorefield to the lower or "Spring Creek"

portion with a *Goniatites crenistria* fauna. The upper part he proposed to name Ruddell Shale. He stated (p. 1634) that a close relationship exists between the faunas of the Ruddell Shale and the Batesville Sandstone and that there is no ". . .noticeable break in the sequence of goniatite assemblages. . ." In a practical sense, it appears that restriction of the Moorefield and introduction of Ruddell serves no useful purpose, and we prefer to retain the name Moorefield in its original sense.

The Fayetteville Formation poses no problems of identity beyond the association of the upper limestone units. The thick calcareous beds of the eastern part of the Boston Mountains may or may not be correlative of the Wedington Sandstone or the overlying limestone bed in the western part. The shale units below and above the Wedington Sandstone appear to contain a closely similar goniatite assemblage; in addition, those in the lower part of the formation in the Batesville area are specifically identical. Few goniatites have been recovered from the calcareous portion or the overlying reef complex.

Above the Fayetteville reef complex is the sequence of beds referred by Easton (1942) to the Pitkin Formation. In the lower part of Easton's Pitkin section in the Leslie area, Arkansas, is 30 to 40 feet of gray limestone containing numerous *Archimedes*; it lies on darker, somewhat finer grained calcareous rock without *Archimedes*. The contact is not readily apparent because the beds are lithologically similar, but for our purposes in this study the Fayetteville and overlying formations have been provisionally separated at this level. Presence or absence of *Archimedes* serves as a practical horizon indicator. Although *Archimedes* is abundant in the Pitkin Formation, it also occurs in the Fayetteville and older rocks. Absence of the genus in the provisional Fayetteville section is thus inconclusive evidence for a correlation. Possibly much of the section above the Fayetteville black shale in Searcy County is equivalent to the Fayetteville Formation farther west.

Above the provisional top of the Fayetteville in the vicinity of Leslie, the gray *Archimedes* limestone is about 40 feet thick. It is succeeded by 30 to 40 feet of calcareous shale, which is overlain by 6 feet of limestone containing numerous large *Eumorphoceras bisulcatum* and *Cravenoceras richardsonianum*. *Tumulites* and some other Fayetteville cephalopod genera have not been recovered from the post-Fayetteville strata in the Leslie area.

Above the *Eumorphoceras bisulcatum* limestone is about 120 feet of shale, sandstone, and limestone which contains an extensive assemblage of uppermost Mississippian mollusks, including numerous goniatites. Of these latter, *Eumorphoceras* is represented by *E. richardsoni,* new species, which is considerably evolved beyond *E. bisulcatum.* The genus *Delepinoceras* (Furnish, Quinn, and McCaleb, 1964) as well as species of *Anthracoceras, Cravenoceras,* and other forms, occur throughout this section (Quinn, 1963, p. 26-28). The shale is terminated at the top by beds of conglomerate and thin limestone lenses containing many *Archimedes.* Informally, we have referred to the upper shale unit as the "Peyton Creek beds" and have recognized a lower *Eumorphoceras bisulcatum* horizon and a higher *Eumorphoceras richardsoni* horizon. Sandstones and shales above the conglomerates are seemingly devoid of fossils but are similar in appearance to deposits of the Atoka Formation. Farther south, in the Clinton area, beds containing goniatites of Morrowan and Winslow age crop out beneath the Atoka-like section. We postulate that earliest Pennsylvanian strata may pinch out against the south flank of the reef complex and that the entire Lower Pennsylvanian sequence was overlapped by younger deposits.

Earliest Pennsylvanian strata in Washington County belong to the Cane Hill Member of the Hale Formation. These beds lie unconformably upon the Pitkin Formation, which is of Late Mississippian age. One or two specimens of the actinocerid cephalopod *Rayonnoceras solidiforme* Croneis have been recovered from Pitkin Limestone, and Gordon (1953, p. 1427) reported the occurrence of *Cravenoceras richardsonianum.* These species are not known to occur in Pennsylvanian rocks but are abundant in the underlying Fayetteville Formation. Some of the other cephalopods earlier reported from the Pitkin are now believed to have been collected from younger strata (Quinn, 1963). Abundant ammonoids do occur in the Pitkin at Braggs Mountain, northeastern Oklahoma.

The Cane Hill Member of the Early Pennsylvanian Hale Formation contains an extensive assemblage of goniatites closely related to those of the Prairie Grove Member and almost totally distinct from any known in the Leslie-Peyton Creek area.

SYSTEMATIC DESCRIPTIONS

Family GIRTYOCERATIDAE Wedekind, 1918

The family Girtyoceratidae is characterized by discoidal and lenticular conchs, which have major changes during ontogenetic development. It has prominent features of shell sculpture, particularly in early growth stages. Growth lamellae show a biconvex pattern, and some have prominent ventrolateral salients. In association with apertural projections are lateral sulci developed to some degree. In general, the umbilicus is moderately large but tends to become smaller during growth.

The suture is basically of the goniatitid stock with eight divisions. In thinly lenticular forms the lobes become attenuate and the saddles angular. All representatives have a prominently divided broad ventral lobe.

The family characterizes Chesterian strata in America; that is, the upper Viséan and lower Namurian of Europe. In addition, younger genera are known from the lower Morrowan in America and the Bashkirian of Eurasia. Also, some forms from middle Viséan rocks in Europe apparently belong here.

As the Girtyoceratidae was defined by Ruzhencev (1962), it contained two subfamilies: Girtyoceratinae and Baschkiritinae. A new subfamily, Arkanitinae, is herein added. The baschkiritins, constituted of the two genera, *Baschkirites* (Librovitch, 1957) and *Hudsonoceras* (Moore, 1946), are distinguished by spiral ornament, a thinly discoidal conch, small umbilici, and a broad ventral lobe. The Baschkiritinae represent late Namurian-early Bashkirian descendants of the Girtyoceratinae. In Arkansas, *Baschkirites* has been found in Prairie Grove Member of the Hale Formation (lower Morrowan).

The family Girtyoceratidae is believed to have been derived from earlier Goniatitina, possibly *Beyrichoceras*. The family also probably served as an important stem for several branches of later goniatites, for example, Reticuloceratidae and Goniolobоceratidae.

Subfamily GIRTYOCERATINAE Wedekind, 1918

Only two genera, *Girtyoceras* and *Eumorphoceras,* are included in this taxon, according to our interpretation. In each the inner

volutions of the shell are moderately evolute and ornamented, but the mature whorls are relatively smooth and lenticular. The two genera appear to represent stable evolution throughout the Chesterian. No pronounced difference appears in characters, and strata near the important Viséan-Namurian boundary contain intermediate representatives of *Girtyoceras* and *Eumorphoceras.*

According to Bisat (1952, p. 164-165) the genus *Sagittoceras* Hind, 1918, as well as several other Viséan forms related to *Girtyoceras* and *Beyrichoceras,* deserve to be recognized as independent genera. Also, *Sagittoceras* is stated (Bisat, 1952, p. 171) to characterize beds with *Goniatites crenistria* of the lower Bollandian (zones B_2 and P_1), whereas *Girtyoceras* occurs in upper Bollandian (P_2). We were unable to utilize Bisat's criteria in interpreting the collections available to us.

Advanced representatives of *Girtyoceras,* such as *G. limatum,* have been differentiated by Ruzhencev (1960, p. 204) as the subgenus *Sulcogirtyoceras.* A group of species with characters somewhat intermediate between *Girtyoceras* and *Eumorphoceras* could fall in this category. From a practical standpoint, a distinction of the two genera is already so difficult that many species cannot be assigned from published accounts.

Genus *GIRTYOCERAS* Wedekind, 1918

Type species.—*Adelphoceras meslerianum* Girty, 1909.

Adelphoceras Girty, 1909, p. 64-66.

Girtyoceras Wedekind, 1918, p. 140; Miller and Furnish, 1940, p. 363-364; Moore, 1946, p. 397; Pareyn, 1962, p. 116-117; Ruzhencev, 1962, p. 368.

Sulcogirtyoceras Ruzhencev, 1960, p. 204.

The type of *Girtyoceras* is from the lower Chesterian Delaware Creek Member of the Caney Shale. A more advanced species, *G. limatum*, is found in the Moorefield Shale of northern Arkansas. *G. meslerianum* is associated with the characteristic late Viséan goniatites, whereas *G. limatum* is found with a *Goniatites-Cravenoceras* assemblage which appears to represent a transitional Viséan-Namurian fauna. The genus is known from many localities in North America, Europe, and North Africa.

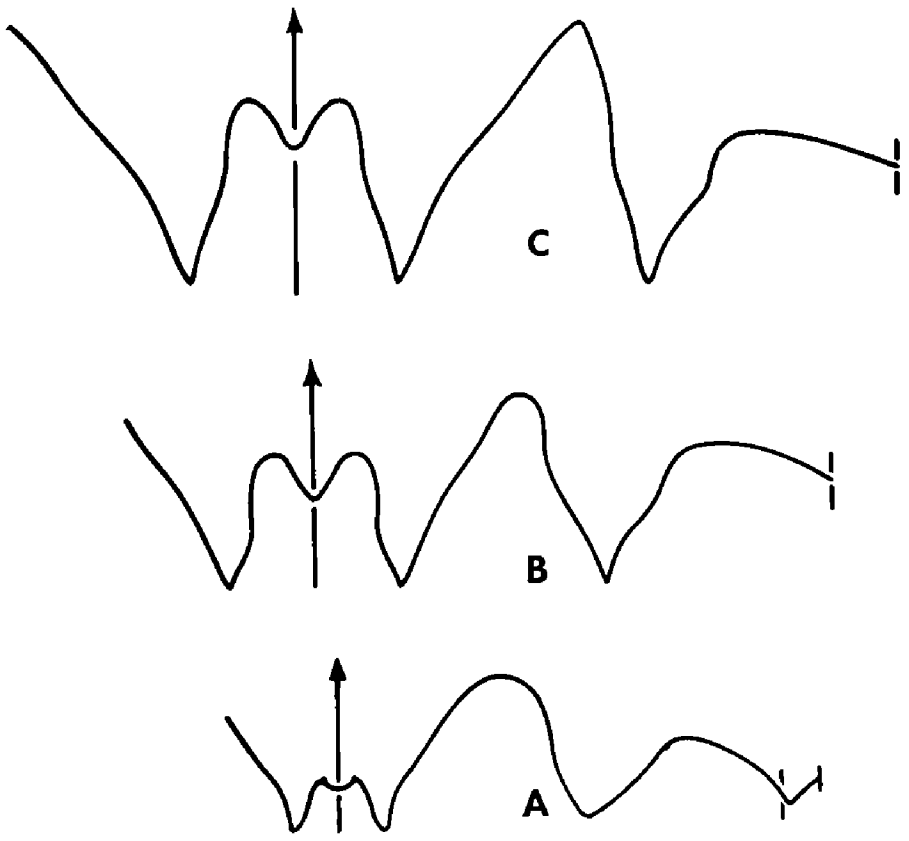
The genera *Sagittoceras* Hind and *Dryochoceras* Morgan were suppressed as synonyms of *Girtyoceras* by Miller and Furnish (1940, p. 363-364). *Adelphoceras* is a homonym.

Girtyoceras meslerianum (Girty), 1909

Text-figures 2A-C, 3A; plate 1, figures 4-6; plate 2, figures 8, 9

Adelphoceras meslerianum Girty, 1909, p. 66-67, pl. 12, figs. 1-3c.
Girtyoceras meslerianum Wedekind, 1918, p. 140; Miller and Furnish, 1940, p. 367-368, pl. 47, figs. 1-5, pl. 48, figs. 1-3; Miller and Youngquist, 1948 [part], p. 667, pl. 100, figs. 22-24 [not pl. 94, figs. 10, 11].

Numerous specimens from the lower part of the Caney Shale of the type area in Oklahoma are available for study. One of the larger conchs is septate but has a diameter of slightly more than 80 mm, a height of 46 mm, a width about 20 mm, and an umbilical diameter of 8 mm. Another fragmental body chamber is about 120 mm in diameter. In immature specimens the conch is widely



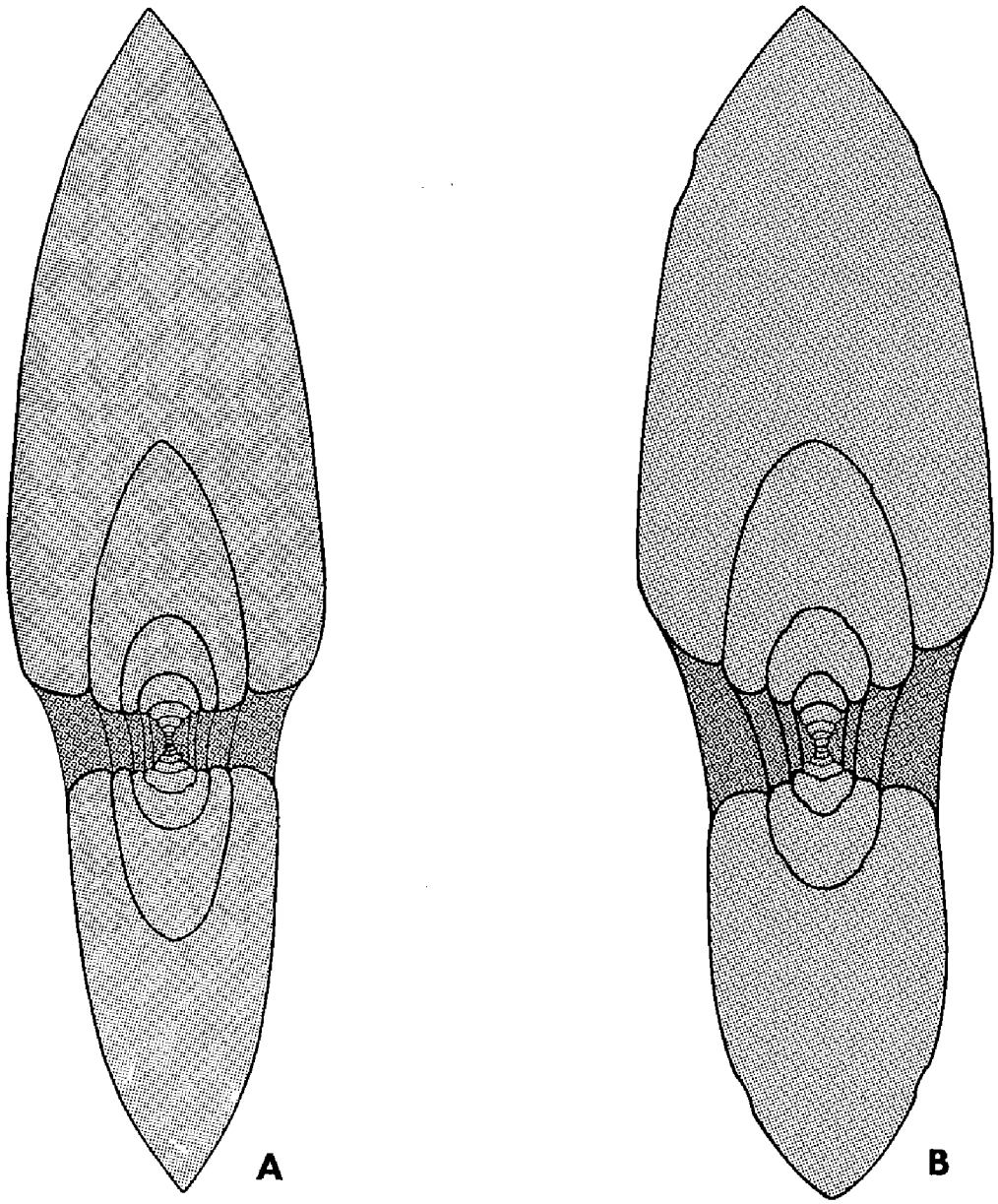
Text-figure 2. Diagrammatic representation of sutural ontogeny in *Girtyoceras meslerianum* (Girty), based on specimens from the Delaware Creek Member of the Caney Shale, southern Oklahoma.

A. Immature specimen (SUI 6976) at a diameter of 10 mm, x5; from about 6 miles south-southeast of Ada, Pontotoc County (sec. 1, T. 2 N., R. 6 E.).

B. Immature specimen (SUI 11519) at a diameter of 33 mm, x2; from about 15 miles southeast of Ada (sec. 12, T. 1 N., R. 7 E.).

C. Mature specimen (SUI 10932) at a diameter of 81 mm, x1.25; from Coal County, north of Wapanucka (sec. 22, T. 1 S., R. 8 E.).

umbilicate and subdiscoidal, with a rounded venter; the periphery becomes sharply angular at about 25 mm diameter (text-fig. 3A). Immature specimens retain prominent transverse constrictions, but these disappear at about 25 mm diameter and are not discernible on larger specimens. The test has fine sinuous biconvex transverse



Text-figure 3. Diagrammatic cross sections of mature *Girtyoceras meslerianum* (Girty) and *Eumorphoceras bisulcatum* Girty.

A. *G. meslerianum* (SUI 10932), x1.25; from the Delaware Creek Member of the Caney Formation, north of Wapanucka (sec. 22, T. 1 S., R. 8 E.), Coal County, Oklahoma.

B. *E. bisulcatum* (SUI 11532), x1.5; from a post-Fayetteville limestone, possibly the Pitkin equivalent, 1 mile east of Leslie on State Highway 66 (S central sec. 23, T. 14 N., R. 15 W.), Searcy County, Arkansas.

lirae. Several larger specimens, in which the test is preserved, have a serrated ventral keel.

The suture pattern of *G. meslerianum* (text-fig. 2) changes to a considerable degree throughout ontogeny. In different specimens referred to this species it is similar, at a given diameter. The broad ventral lobe with sloping sides is characteristic.

Remarks.—None of the North American *Girtyoceras meslerianum* collections available to us ranges through a local succession, and the exact age relationships are not certain. The various specimens which we have examined from different areas show a reasonably high degree of similarity in shape, shell sculpture, and suture patterns. There are slight differences; for example, those known from West Texas have appreciably wider conchs (W/D=0.50 versus 0.43 at 15 to 20 mm diameter) than are typical of *G. meslerianum*. Also, the specimens from Montana appear to be dwarfed in that they portray early mature characteristics at a diameter of only 12 mm. In each case mechanical adjustments occur in sutural detail.

Moore (1946) recognized nine new species, plus four "forms," in northern England and referred additional described species to *Girtyoceras*. We cannot evaluate his taxonomic treatment on the basis of published information.

Occurrence.—All specimens examined are apparently of early Chesterian (late Viséan) age. Girty's type is from the *Goniatites multistriatus* zone of the Delaware Creek Member of the Caney Shale in sec. 14, T. 2 S., R. 7 E., northwest of Wapanucka, Johnston County, Oklahoma. Previously undescribed material is now available from this same stratigraphic unit a few miles to the north and northeast. Also, specimens are available from the Helms Formation of Sierra Diablo, Culberson County, West Texas. In addition, representatives of this species have been described from the Heath Formation of Montana, Barnett Formation of central Texas, Floyd Shale of Georgia, and White Pine Shale of Nevada, as well as from European localities.

Girtyoceras limatum (Miller and Faber), 1892

Text-figure 6A; plate 2, figures 1-3; plate 3, figure 7

Goniatites limatus Miller and Faber, 1892, p. 166-167, pl. 6, figs. 8, 9.
Adelphoceras meslerianum? Girty, 1915, p. 131-132.
?*Eumorphoceras Burhennei* Brüning, 1923, p. 265.

shape in mature-type *Eumorphoceras* and *Girtyoceras* (text-figs. 2A-C, 3A-B, 4A-C).

The ventral lobe of the suture in *Girtyoceras* is relatively wider throughout ontogeny than that of *Eumorphoceras,* the first lateral saddle is also lower and more nearly symmetrical in *Girtyoceras,* and the first lateral lobe is similar in both genera but with slight variations. The conch shape in *Eumorphoceras* and *Girtyoceras* follows roughly the same ontogenetic pattern, from a rounded form with a moderately open umbilicus to an angular form with a proportionally smaller umbilicus (text-fig. 3); however, significant differences are discernible between the two. In *Eumorphoceras,* the umbilicus is somewhat larger at all comparable ontogenetic stages; in *Girtyoceras,* sharp ventral angularity of the conch appears at an earlier growth stage. As mentioned elsewhere, immature specimens may be distinguished by the prominent lateral ribs in *Eumorphoceras* compared with prominent transverse constrictions and absence of ribs in *Girtyoceras.* Shallow constrictions may occur in *Eumorphoceras.*

Differentiation of *Eumorphoceras* and *Girtyoceras* on the basis of conch shape and ornamentation has caused confusion. The two genera are gradational and probably formed a direct line of evolution. Moore (1946) presented the most critical analysis of the Girtyoceratidae; in essence, he placed reliance on differences in the immature conchs recognized by Girty's (1909) original definitions. He also had a good general concept of the radical ontogenetic changes in conch form. On the basis of additional material representing the type species of *Eumorphoceras* and *Girtyoceras,* we can verify most of Moore's conclusions as well as add positive criteria for all growth stages. Conch shape and ornament are sufficiently distinctive to serve as secondary bases for identification, but large shells are closely similar. Intermediate forms found in uppermost Viséan and lowermost Namurian (Bisat, 1950) must rather arbitrarily be assigned to one genus or the other. Many of the described forms based on crushed specimens or impressions are clearly referable to *Eumorphoceras* in an immature stage; others cannot be assessed. Moreover, our observations indicate that even segments of the sutures at all stages in the type species of the two genera can be differentiated and that this character should be considered the primary basis for definition. For example, although Miller and Young-

quist (1948) and Youngquist (1949) regarded all Late Mississippian large lenticular forms as *Girtyoceras,* their published illustrations are usually sufficient to place the specimens generically. Notably, none of the occurrences reported by Miller and Youngquist actually involved these two genera in direct association.

Stratigraphically, *Eumorphoceras* is restricted in common occurrence to the *Eumorphoceras*-zone (E) or early Namurian Pendleian-Arnsbergian stages in western Europe. This genus occurs throughout middle and upper Chesterian strata in North America. Representatives from Oklahoma, Arkansas, Georgia, central Texas, West Texas, Nevada, western Germany, and northern England are available to us for study. The ultimate vertical range of the genus *Eumorphoceras* may be represented by *E. richardsoni,* new species, of the Peyton Creek beds, well above strata containing *E. bisulcatum.* The descendants, Arkanitinae, new subfamily, and Reticuloceratidae, are found characteristically in younger rocks.

Eumorphoceras bisulcatum Girty, 1909

Text-figures 3B, 4A-C; plate 1, figures 1, 2; plate 2, figures 4, 5; plate 3, figure 1

Eumorphoceras bisulcatum Girty, 1909, p. 68-70, pl. 11, figs. 15-15c, 17-19a [not 16-16b]; Moore, 1946, p. 430-432, pl. 22, fig. 3, pl. 23, fig. 7, pl. 25, figs. 5a-5d, pl. 27, figs. 1, 2; Miller and Youngquist, 1948, p. 662-665, pl. 100, figs. 9-17; Currie, 1954, p. 582-583, pl. 4, figs. 5-7; Elias, 1956, p. 130, pl. 6, fig. 6; Yates, 1962, p. 381-386, pl. 52, figs. 3-5; pl. 53, figs. 1-5, pl. 54, figs. 1-7, pl. 55, fig. 5.

Girtyoceras meslerianum Miller and Youngquist, 1948, p. 667-669, pl. 94, figs. 10, 11; Youngquist, 1949, p. 302-303, pl. 58, fig. 18.

About two hundred well-preserved large specimens of *Eumorphoceras bisulcatum* have been collected in Searcy County, Arkansas, from the middle part of a unit possibly occupying the stratigraphic position of the Pitkin Formation. Also 15 specimens of various sizes were secured recently from the upper part of the Caney Shale, at the type Sand Branch Member near Frisco, Pontotoc County, Oklahoma, several miles north of Girty's type locality for *E. bisulcatum.* One of the Oklahoma specimens and most of the Arkansas specimens are mature; that is, of nearly 100-mm diameter. These large specimens have been compared to the small-size type material of Girty by exposing the inner whorls and in polished cross sections.

A representative large specimen of *E. bisulcatum* from the Leslie locality is completely septate and has a conch diameter of 120 mm, a conch height of 66 mm, a width of 37 mm, and an umbilical diameter of 15 mm. The diameter of the body chamber would have been as much as 200 mm. The conch is subdiscoidal in immature specimens and lenticular at maturity (text-fig. 3B). The immature specimens have prominent lateral ribs becoming indistinguishable at an early intermediate stage, 25 to 30 mm. Deep narrow ventrolateral grooves, developed at 5 to 10 mm, become broader with increase in size, but retain their position at about the first lateral saddle. The test is rarely preserved, but, where present, it has fine, biconvex growth lines traversing the shell. The extremely thin shell in large specimens perhaps accounts for rarity of their preservation.

The single large Caney Shale (Sand Branch) specimen is a slightly distorted fragment of a whorl more than 100 mm in diameter, with a conch height of 50 mm and a width of 35 mm. Sutures are clearly visible and part of the inner whorls can be examined in section. In all respects this specimen appears to be identical with those from the Leslie locality.

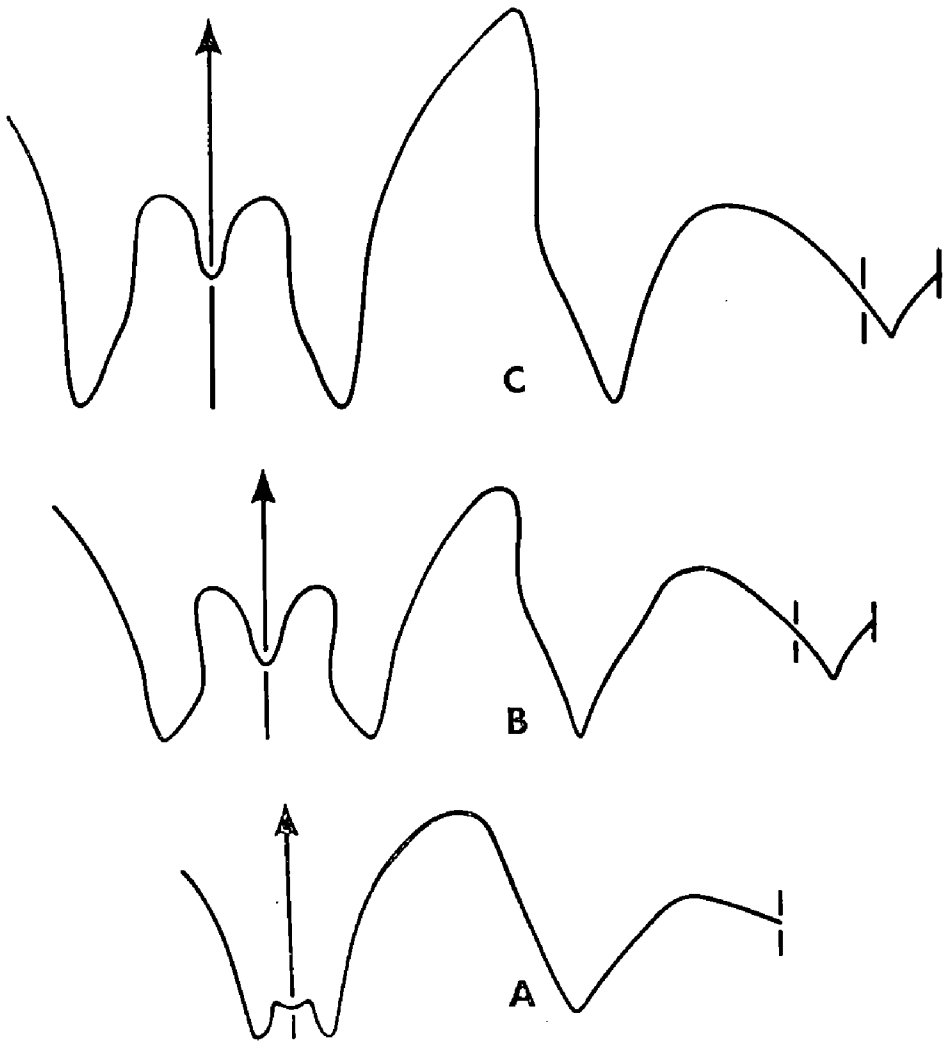
Remarks.—The specimens of *E. bisulcatum* at maturity present characteristics other than those noted by Girty in his description of the type. Comparison of ontogenetic stages shows that his small specimens are conspecific with the larger ones now available for study.

Occurrence.—The greater portion of material described here was collected from a stratigraphic unit lying above the Fayetteville Formation (which may or may not be equivalent to the Pitkin Formation), SE¼ sec. 23, T. 14 N., R. 15 W., one mile east of Leslie, Searcy County, Arkansas. Since the discovery of this locality in 1960, several hundred specimens of *E. bisulcatum* have been secured. All growth stages are represented, but many shells are 50 to 100 mm in diameter.

E. bisulcatum has been described from middle Chesterian deposits throughout North America; it is also widely known throughout Europe and in North Africa in beds of early Namurian age. The holotype of the species was found on Sandy Creek, sec. 36, T. 2 S., R. 8 W., south of Wapanucka in Johnston County, Oklahoma. At a distance of about 25 miles to the north-northwest

in Pontotoc County southeast of Ada and in the vicinity of Frisco, numerous immature specimens have been secured from the Sand Branch Member of the Caney Shale, sec. 8, T. 2 N., R. 7 E., west of Clear Boggy Creek.

Another locality previously unreported for this species is in the Chinati Mountains of Presidio County, West Texas. Cecil Rix collected two specimens, 20 mm and 70 mm in diameter, in association with abundant *Cravenoceras hesperium* Miller and



Text-figure 4. Diagrammatic representation of the sutural ontogeny of *Eumorphoceras bisulcatum* Girty, from a post-Fayetteville limestone unit possibly equivalent to the Pitkin Formation, 1 mile east of Leslie, Searcy County, Arkansas (S central sec. 23, T. 14 N., R. 15 W.).

A. Immature specimen (SUI 11533), at a diameter of about 12 mm, x5.
B. Immature specimen (SUI 11523), at a diameter of 33 mm, x2.25.
C. Mature specimen (SUI 11614), at a diameter of 118 mm, x0.75.

Furnish and rare *Eogonioloboceras burmai* (Miller and Downs). This locality represents type Cieneguita Formation and is the same horizon and locality mentioned by Miller (1945, p. 343). The fossils were secured from nodular limestones south of the Cieneguita ranch road, 2.5 miles west of U. S. Highway 67, about 5 miles north of Shafter. The fossils occur about 25 feet above the base of the section where Middle Pennsylvanian fusulinids are known to occur some 200 feet higher. The genus *Eogoniolobocerας* is a rare element in our upper Chesterian collections. In addition to central and western Texas, this fossil has been found in the Fayetteville Shale of Washington County, Arkansas, and in the lower part of the Pitkin Limestone of Muskogee County, Oklahoma.

Eumorphoceras plummeri Miller and Youngquist, 1948

Text-figure 5; plate 1, figure 3; plate 3, figure 8

Eumorphoceras plummeri Miller and Youngquist, 1948, p. 665-667, pl. 100, figs. 1-4, 20, 21.

Eumorphoceras (*Edmooroceras*) *plummeri* Elias, 1956 [part], p. 132-133, pl. 6, fig. 8.

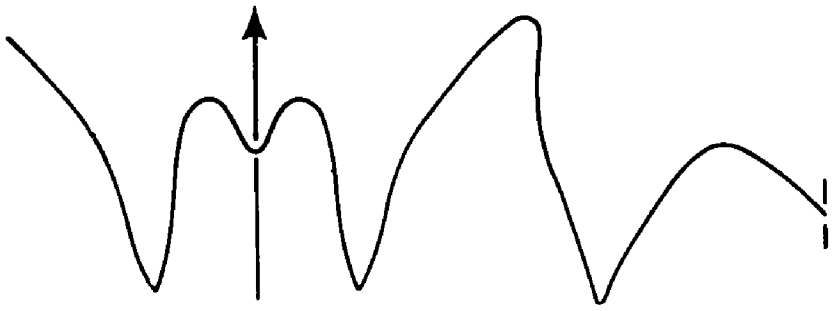
Numerous specimens of *E. plummeri* have been collected from the Fayetteville Formation throughout northern Arkansas; about 100 specimens less than 10 mm in diameter have been found near Batesville, Independence County. The four largest specimens are from near Fayetteville, Washington County, and two have a diameter of about 110 mm. Two smaller mature individuals have a diameter of 80 mm, a conch height of 45 mm, a width of about 20 mm, and an umbilical diameter of 8 mm. The conch shape varies from subdiscoidal with a rounded venter in immature specimens (about 15 mm) to lenticular with an angular venter at maturity (greater than 30 mm). Immature specimens, of which about a dozen have been collected at Fayetteville, exhibit the typical *Eumorphoceras* feature of heavy ribbing, but lose this sculpture in the mature forms. Ornamentation is that of type *Eumorphoceras* with sinuous transverse ribs and a ventrolateral groove in the immature forms to a wide lateral sulcus in the otherwise smooth mature forms. The grooves are in the position of the first lateral saddle.

Remarks.—According to our interpretation, *Eumorphoceras plummeri* differs from typical *E. bisulcatum* in that the prongs of the ventral lobe are more nearly symmetrical (text-figs. 4c, 5), the umbilicus is slightly smaller at similar conch diameters, and the whorl cross section is more compressed. Fayetteville specimens identified as *E. plummeri* appear to represent an earlier phylogenetic stage but certainly have strong affinity with *E. bisulcatum*.

Miller and Youngquist (1948, p. 666) stated unequivocally that other species of *Eumorphoceras* occur in direct association with *E. plummeri*. These authors designated the thinner whorls as being the primary basis for differentiation from *E. bisulcatum*. Elias (1956, p. 132) gave the flattened venter and angular umbilical shoulders as major distinctions. Elias' interpretation thus contradicts the original definition, but his species *E. goddardense* is apparently identical with his interpretation of *E. plummeri*. None of the type specimens of these several species is a mature shell.

Occurrence.—The holotype of *E. plummeri* was described from the Barnett Shale about 2.5 miles south-southeast of San Saba, San Saba County, central Texas. Other specimens studied by Plummer and Scott (1937), Miller and Youngquist (1948), and Elias (1956) were all from this general locality. The extensive synonymy published by Miller and Youngquist (1948, p. 665-666) is apparently nothing more than a recognition that many of the published references to *E. bisulcatum* and related species cannot be assigned with certainty.

Arkansas specimens referred to *E. plummeri* have been collected from the Fayetteville Shale in the beds of Hickory Creek southwest



Text-figure 5. Suture of *Eumorphoceras plummeri* Miller and Youngquist, UA L-84-H-4, at a diameter of about 75 mm, x1.25, from the Fayetteville Formation, bed of Town Branch, Fayetteville, Washington County, Arkansas.

of Fayetteville, sec. 13, T. 15 N., R. 31 W., and Town Branch in the southwestern part of Fayetteville sec. 17, T. 16 N., R. 30 W., Washington County; and from natural exposures of Fayetteville Shale south of State Highway 14 about 5 miles southeast of Rosie, SW¼ sec. 26, T. 12 N., R. 5 W., Independence County.

Eumorphoceras richardsoni McCaleb, Quinn, and Furnish, new species

Plate 3, figures 5, 6

The new species *E. richardsoni* is represented by three specimens from the Peyton Creek area, south of Leslie, Searcy County, Arkansas; the largest is designated the holotype. This type is 28 mm in diameter, has a conch height of 13 mm, and an umbilical diameter of 7 mm. The conch is subdiscoidal, and the venter is flat but becomes subrounded in the more nearly mature portion in excess of 20 mm diameter. Thirty-five prominent ribs extend across the flank to the ventrolateral sulcus, then become fine lirae. Growth lines form broad lateral sinuses, prominent ventrolateral salients, and a deep rounded ventral sinus.

None of the available specimens has the entire suture clearly visible, but the holotype is terminated adorally by a septum. At a diameter of 25 to 30 mm, the suture is similar to typical *Eumorphoceras* but more advanced than comparable-sized *E. bisulcatum;* that is, the lobes show relatively high relief.

Remarks.—Eumorphoceras richardsoni can be differentiated from *E. bisulcatum* by the conch shape; *E. richardsoni* is wider and has a more strongly flattened venter. Also, the ribs of *E. richardsoni* are more prominent and numerous than those of *E. bisulcatum* at a diameter of 20 to 30 mm. The umbilical diameter of *E. richardsoni* is proportionately twice that of *E. bisulcatum.*

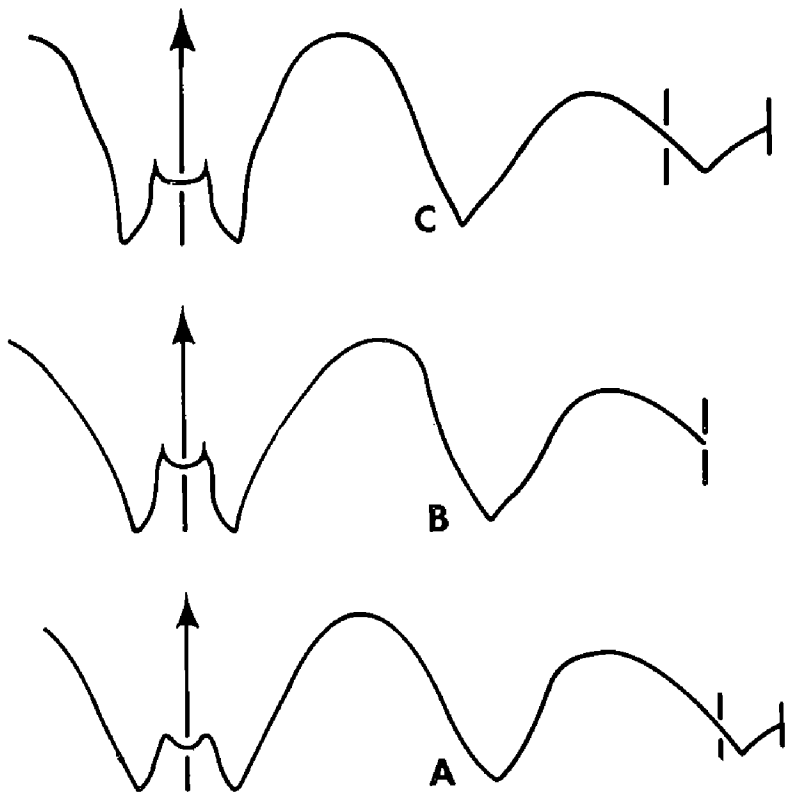
The venter of *E. goddardense* (Elias, 1956, p. 131) is strongly flattened at a diameter of about 10 mm but not to the same degree as in *E. richardsoni.* The types of *E. richardsoni* show a distinctly concave venter from 7 to 17 mm diameter, with angular ventrolateral margins. Presumably *E. richardsoni* and all other species of the genus developed an angular venter and lenticular conch form in the fully mature growth stages. Schmidt (1925) has been the only previous author to illustrate diagrammatic cross sections of fully

mature shells in the genus; for example, a reconstruction of *E. coronula* Roemer from Letmathe, Sauerland, northwestern Germany.

The specific name is in honor of Keith Richardson, who found the holotype.

Occurrence.—The type locality of *Eumorphoceras richardsoni* is 5 miles south of Leslie, Searcy County, Arkansas, but in the northern part of Van Buren County, sec. 12, T. 13 N., R. 15 W., along U. S. Highway 65, half a mile south of the Peyton Creek bridge. Weathered-free goniatites are secured on the shale slope of the highway cut.

Types.—Holotype, UA L-114-1; plaster replicas, SUI 11537; paratypes, SUI 11538.



Text-figure 6. Sutures of *Girtyoceras limatum* (Miller and Faber) and *Tumulites varians*, new genus, new species, x5, from Upper Mississippian of northern Arkansas.

A. Immature specimen of *G. limatum* (SUI 11522), at a diameter of 14 mm, from the Moorefield Formation, near Batesville (NW¼ sec. 29, T. 13 N., R. 5 W.), Independence County.

B. Holotype of *T. varians* (UA L-119-TB-5) at a diameter of 15 mm; from the Fayetteville Formation, bed of Town Branch, Washington County.

C. Paratype of *T. varians* (UA L-119-TB-7) at a diameter of 14 mm; from the Fayetteville Formation, bed of Town Branch, Washington County.

Subfamily ARKANITINAE, McCaleb, Quinn, and Furnish, new subfamily

As a general rule Carboniferous ammonoids show little indication of provincial distribution. An exception is represented in the subfamily Arkanitinae, which is found in local abundance. *Arkanites relictus* has been secured literally by the thousands within one ledge at a single Arkansas locality; rarely elsewhere in the same general region. A few associated goniatites, such as *Baschkirites* sp., also occur. In somewhat similar fashion, the goniatites which occur in the Fayetteville Shale in northern Arkansas can be found by the thousands as small pyritized shells; the most common species is a representative of this subfamily, *Tumulites varians,* new species. Other occurrences of *Tumulites* are uncertain.

The subfamily Arkanitinae is characterized by broad whorls and a globular to subdiscoidal conch. Lateral ribs or umbilical nodes persist throughout all growth stages observed. The growth lamellae indicate prominent ventrolateral salients, in association with pronounced sulci.

The sutures in representatives of this subfamily are typically closer to gastrioceratids than to goniatitids; that is, the large ventral lobe in *Arkanites* has prongs subequal to the secondary saddle and roughly half the area of the deep lateral lobe. In the older *Tumulites* this sutural feature is somewhat intermediate. Apparently this subfamily is characterized by prochoanitic siphuncular foramina. However, the gradational nature with associated *Eumorphoceras* in the Upper Mississippian indicates close relationship.

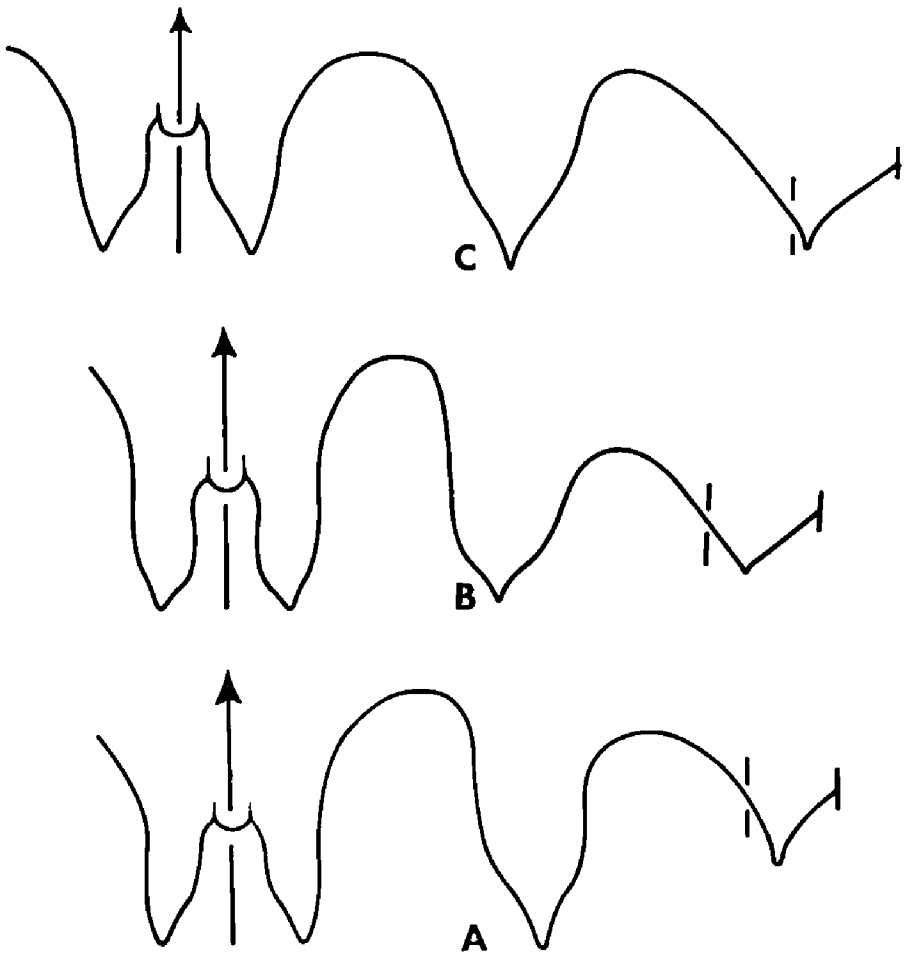
The distinctive broad rounded whorls of the Arkanitinae persist into the mature stage. Portions of the body chamber are retained on the larger shells. Thus, mature specimens in this subfamily resemble inner volutions of ancestral *Eumorphoceras.*

Genus *ARKANITES* McCaleb, Quinn, and Furnish, new genus

Type species.—*Eumorphoceras relictum* Quinn, McCaleb, and Webb, 1962.

This genus *Arkanites* is based primarily on a study of several thousand specimens of a single species from the Morrowan Hale

Formation of northern Arkansas. Available data in the type species indicate that the conch is variable in shape; the range of height/width ratio is about 0.35 to 0.65 in conchs 25 to 30 mm in diameter (text-fig. 8A, B). The holotype of *A. relictus* (UA L-63-BM, 1) is 22.5 mm in diameter; additional fully septate specimens from the type locality up to 45 mm in diameter have been secured. The whorls tend generally to be broadly rounded, but in a few cases they are distinctly flattened ventrally or compressed markedly (text-fig. 8A, B). Ventrolateral grooves in even the largest specimens are broad, deep, and bordered by ridges. The umbilical diameter is somewhat variable also, as this measure is a function of conch shape;



Text-figure 7. Diagrammatic representation of the sutural variation in paratypes of *Arkanites relictus* (Quinn, McCaleb, and Webb), x3, from the Prairie Grove Member of the Hale Formation at Bradshaw Mountain (SW¼ NW¼ sec. 34, T. 19 N., R. 23 W.), Carroll County, Arkansas.

A. Paratype UA L-63-BM-11, at a diameter of 25 mm.
B. Paratype UA L-63-BM-12, at a diameter of 27 mm.
C. Paratype UA L-63-BM-13, at a diameter of 40 mm.

the umbilicus is twice as large in flattened forms as in the rounded forms. Umbilical ribbing is also variable, according to shape; the flattened forms have about 21 heavy ribs with nodelike bases per whorl, whereas the rounded forms have as many as 42 finer ribs per whorl with no thickening at the base. In addition, the sutural details (text-fig. 7A-C) differ with conch shape. All differences of shape are gradational and therefore do not represent specific categories.

Although the genus *Arkanites* is closely related to *Eumorphoceras,* it is sufficiently distinct to serve as the type of a separate subfamily. It probably represents a departure from typical *Eumorphoceras* and a separate evolutionary trend from the more typical Girtyoceratinae. Ventrolateral grooves have been considered diagnostic for *Eumorphoceras* (Elias, 1956), but they are known to exist in such diverse groups as the Schistoceratidae, Clymeniaceae, and Thalassoceratidae. Collectively, ontogeny and phylogeny outweigh the value of any particular detail as criteria for establishing relationships.

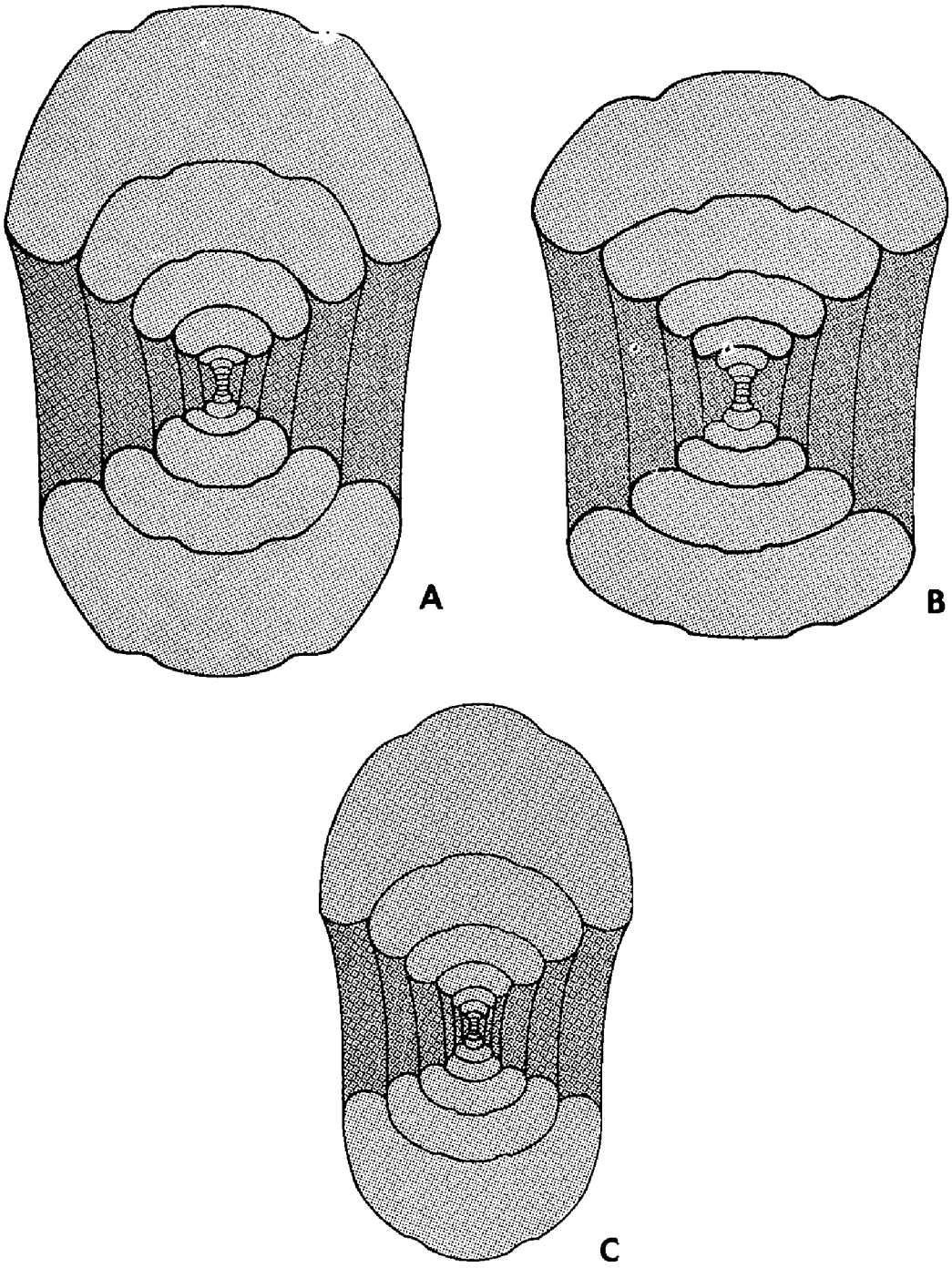
Genus *TUMULITES* McCaleb, Quinn, and Furnish, new genus

Type species.—*Tumulites varians* McCaleb, Quinn, and Furnish, new species.

Eumorphoceras [part] Schmidt, 1934, p. 445, 449; Demanet, 1941(?), p. 138, pl. 5, figs. 16, 17; Moore, 1946, p. 417, etc., pl. 23, fig. 2(?), pl. 24, figs. 1-2b; Currie, 1954(?), p. 583, pl. 4, fig. 7; Pareyn, 1962, p. 122, pl. 11, figs. 1-3.

The surface of the test is ornamented by a series of transverse sinuous lirae. The sculpture forms umbilical ribs, which curve to form a prominent salient at the position of the first lateral saddle and a rounded sinus across the venter. A narrow shallow ventrolateral groove is also present at the salient. Lirae are mostly bifurcated at the junction of the rib. The ribs, numbering about 16 per whorl, diminish in prominence with increase in shell size and are indistinct on the body chamber of the holotype.

In northern Arkansas, from the vicinity of Fayetteville to the region east of Batesville, black shales of the Fayetteville Formation contain an abundance of small goniatites (about 10 mm in diameter). The most common form was examined by Furnish more than



Text-figure 8. Diagrammatic cross sections of *Arkanites*, new genus, and *Tumulites*, new genus, x2.75, from northern Arkansas.

A, B. *A. relictus* (Quinn, McCaleb, and Webb), paratypes (SUI 11534, 11535), from the Prairie Grove Member of the Hale Formation, Bradshaw Mountain (SW¼ NW¼ sec. 34, T. 19 N., R. 23 W.), Carroll County.

C. *T. varians*, new species, a paratype (SUI 11536), from the Fayetteville Formation, Town Branch, Fayetteville, Washington County.

twenty-five years ago, and the general resemblance to *Eumorphoceras* was recognized. During the past few years numerous specimens have been secured, including some larger than 20 mm in diameter. These specimens show a consistent difference from the type of *Eumorphoceras,* and mature characters are so distinct that separate generic designation seems warranted.

The related *Tumulites* and *Eumorphoceras* are associated in the Fayetteville Formation. The first few volutions of these two genera show similarities in lateral view, but representatives of *Tumulites* have consistently broader whorls. Also in the suture are differences which are related to conch form (text-figs. 4A, 6A). That is, the ventral lobe of *Eumorphoceras* is proportionally narrower at all stages. No stratigraphic distinction in the occurrence of these genera is known, and they are believed to represent parallel lines of evolution from a common ancestor, *Girtyoceras.*

Tumulites varians McCaleb, Quinn, and Furnish, new species
Text-figures 6B, 6C, 8C; plate 3, figure 4; plate 4, figures 1-4

Eumorphoceras, new species (robust), Gordon, 1953, p. 1427; Quinn, McCaleb, and Webb, 1962, p. 113.

Several thousand specimens of *T. varians* have been recovered from the Fayetteville Formation at numerous localities across northern Arkansas from Fayetteville, on the west, to Batesville 200 miles eastward. This taxon is one of the more abundant in the fauna. The largest well-preserved specimen (UA L-119-TB-5), selected as holotype of the new species, is 23 mm in diameter, has a conch height of 10 mm, a conch width of 13 mm, and an umbilical diameter of 6 mm. The conch (text-fig. 8c) is broadly rounded in the mature stage, with no apparent tendency toward angularity. *T. varians* has some variation in conch shape similar to that in *Arkanites relictus;* also, the shape of the shell affects the shape of the suture as well as conch dimensions. These gradational differences are not thought to be taxonomically significant.

The suture of *T. varians* is also somewhat variable. The gradation between the two forms illustrated (text-fig. 6B, C) is considered as an infraspecific difference.

Remarks.—Tumulites can be differentiated from *Arkanites* on the basis of the suture; that of the latter (text-fig. 7A-C) has

larger, more symmetrical ventral prongs, and the first lateral lobe is acuminate instead of deeply V-shaped. Also the umbilical lobe is asymmetric in *Arkanites,* whereas in *Tumulites* it is centered on the umbilical wall. The ventrolateral grooves in *Arkanites* are deeper and wider, and are bordered by more prominent ridges. In general, the conch form is wider in *Tumulites* at comparable diameters, but the ribbing is much less prominent and is scarcely discernible at larger sizes. *Arkanites* may have evolved from *Tumulites,* but no more nearly direct connection than resemblance has been established.

Occurrence.—T. varians is known from the Fayetteville Formation (upper Chesterian) of northern Arkansas. A large number of perfectly preserved pyritized shells has been collected from the beds of Hickory Creek southwest of Fayetteville, sec. 13, T. 15 N., R. 31 W., and Town Branch in the southwestern part of Fayetteville, sec. 17, T. 16 N., R. 30 W., Washington County. These specimens were found in the shale beds in the bank or in the bed of the stream. In addition, loose specimens came from the weathered shale debris. In the eastern area of Fayetteville Shale outcrop natural exposures provided a comparable number of this species on weathered slopes south of State Highway 14, about 5 miles southeast of Rosie, SW¼ sec. 26, T. 12 N., R. 5 W., Independence County.

Types.—Holotype, UA L-119-TB-5; paratypes, SUI 11531, SUI 11536, and UA L-119-TB-6-9.

REFERENCES

AISENVERG, D. E., and others, 1960, Carboniferous stratigraphy of the Donetz basin: Congrès Avancement Etudes Stratigraphie Géologie Carbonifère, 4th, Heerlen 1960, Compte Rendu, vol. 1, p. 1-12.

BISAT, W. S., 1950, The junction faunas of the Viséan and Namurian: Leeds Geol. Assoc., Trans., vol. 6, pt. 3, p. 10-26, pls. 1, 2.

———1952, The goniatite succession at Cowdale Clough, Barnoldswick, Yorkshire: Leeds Geol. Assoc., Trans., vol. 6, pt. 4, p. 155-181, pls. 1-3.

CURRIE, E. D., 1954, Scottish Carboniferous goniatites: Royal Soc. Edinburgh, Trans., vol. 62, pt. 2, p. 527-602, pls. 1-4.

EASTON, W. H., 1942, Pitkin limestone of northern Arkansas: Ark. Geol. Survey, Bull. 8, 115 p., 12 pls.

PLATE 1

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Figure 3.	*Eumorphoceras plummeri* Miller and Youngquist. Hypotype SUI 11518, x6, from the Fayetteville Shale about 10 miles southeast of Batesville, Independence County, Arkansas.	22
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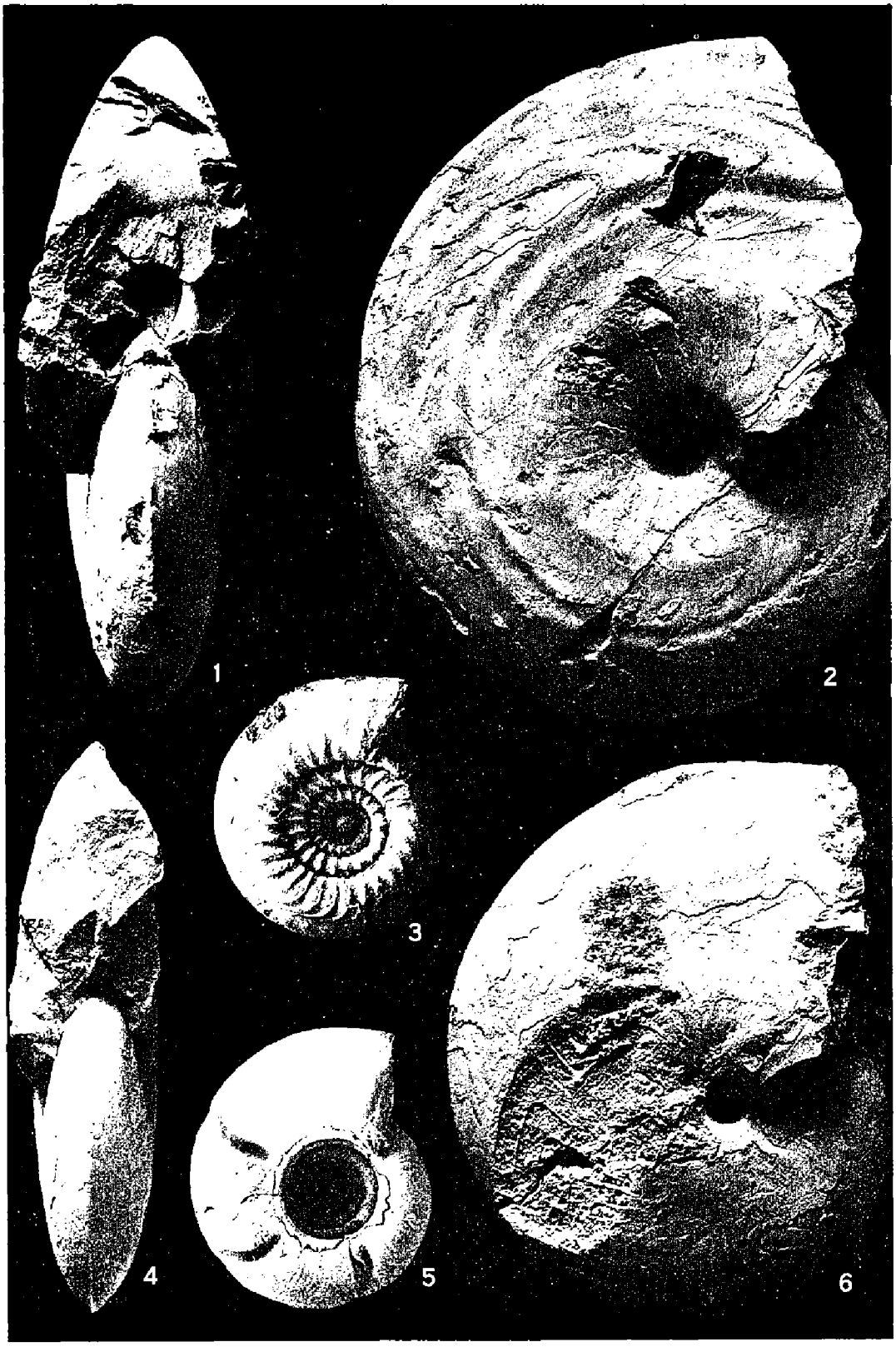
Plate 1



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Figures 1-3. *Girtyoceras limatum* (Miller and Faber). Hypotypes SUI 11521 and 11522, x3.5, from the Moorefield Shale near Batesville, Independence County, Arkansas. 15
1. From "Ruddell" type locality.
2, 3. From about 1 mile south of Moorefield.

Figures 4, 5. *Eumorphoceras bisulcatum* Girty. Hypotype SUI 11523, x2, from a post-Fayetteville limestone about 1 mile east of Leslie, Searcy County, Arkansas. 19

Figures 6, 7. *Eumorphoceras pseudocoronula* Bisat. Homeotype SUI 11524, x2.5, from the lower Pendleian, Lancashire, England. Donated by E. W. J. Moore.

Figures 8, 9. *Girtyoceras meslerianum* (Girty). Hypotype SUI 11525, x2.5, from Chesterian black shale in Helms Formation at the base of Sierra Diablo escarpment about 2 miles northwest of Figure-2 ranch house, Culberson County, West Texas. 13

Plate 2

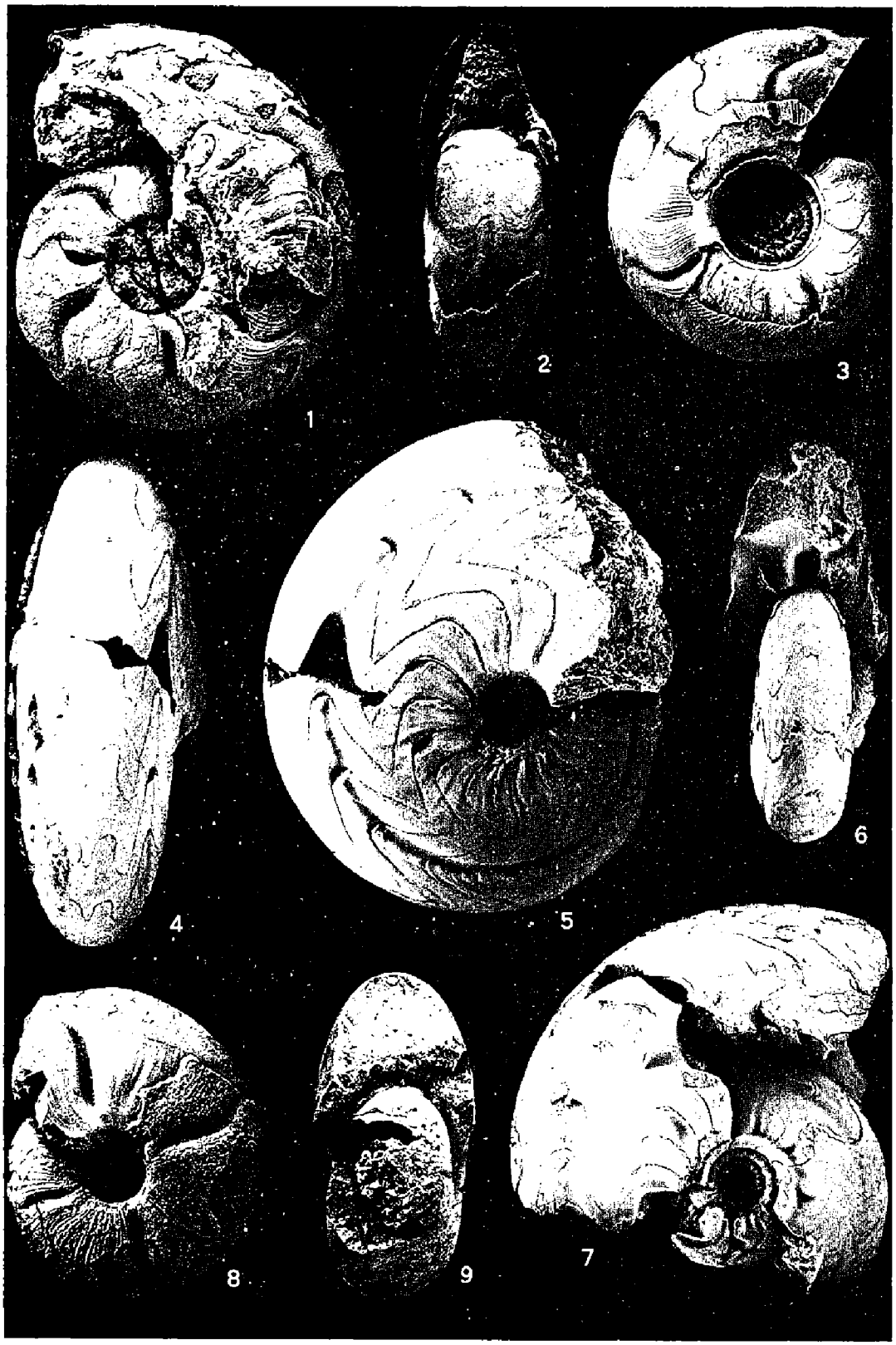

PLATE 3

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Figure 1.	*Eumorphoceras bisulcatum* Girty. Hypotype SUI 11526, x1, from Chesterian black shale in the type section of the Cieneguita Formation north of Shafter, Presidio County, West Texas.	19
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Figure 8.	*Eumorphoceras plummeri* Miller and Youngquist. Large fragmentary hypotype UA L-84-H-4, x1, from the Fayetteville Shale on Town Branch, Fayetteville, Washington County, Arkansas.	22

Plate 3

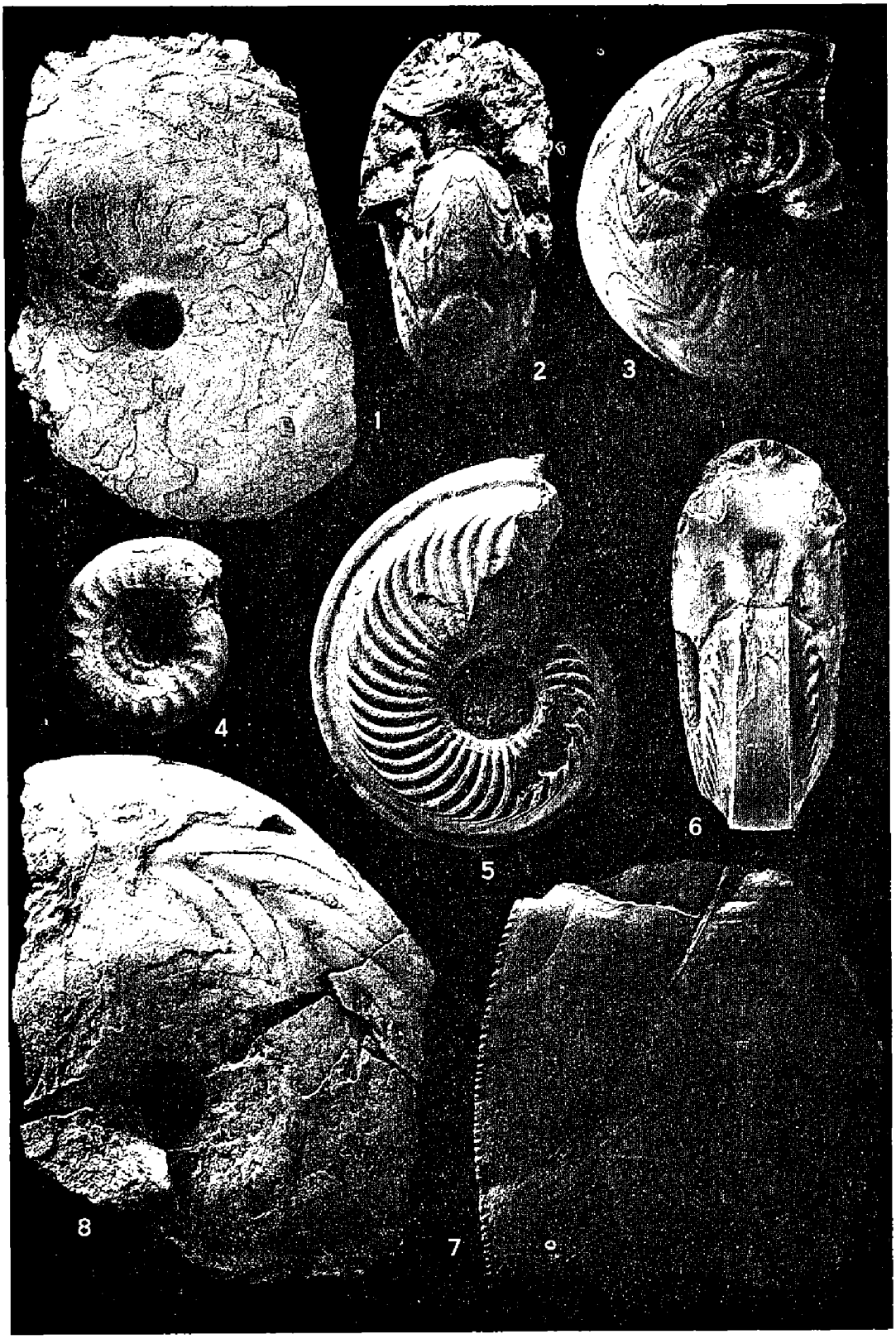

PLATE 4

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Figures 1-4. *Tumulites varians*, new genus, new species, from the Fayetteville Shale of northern Arkansas. 30

1. Holotype UA L-119-TB-5, x2.5. Ventral view; from Town Branch, Washington County.

2. Paratype UA L-119-TB-6, x3.5; from Town Branch, Washington County.

3, 4. Small paratype SUI 11531, x3.75, from about 10 miles southeast of Batesville, Indepeendence County.

Figures 5-8. *Arkanites relictus* (Quinn, McCaleb, and Webb), x1.75, from the Prairie Grove Member of the Hale Formation, Bradshaw Mountain, Carroll County, Arkansas. 26

5. Paratype UA L-63-BM-11.

6. Paratype UA L-63-BM-12.

7, 8. Paratype UA L-63-BM-13.

Plate 4