Titus

LATE MISSISSIPPIAN AMMONOID PALEONTOLOGY AND BIOSTRATIGRAPHY OF THE ANTLER FORELAND BASIN

Utah Geological Survey Bulletin 131

PALEONTOLOGY SERIES, VOLUME 2

LATE MISSISSIPPIAN (ARNSBERGIAN STAGE-E2 CHRONOZONE) AMMONOID PALEONTOLOGY AND BIOSTRATIGRAPHY OF THE ANTLER FORELAND BASIN, CALIFORNIA, NEVADA, UTAH

by
Alan L. Titus

Photos by author

Large photo: Calcareous concretion with abundant *Eosyngastrioceras hesperium* (Miller and Furnish) topotypes, the most common Arnsbergian ammonoid in the Antler foreland, Trough Springs Canyon, Nevada.

Two small photos: Two views of *Stenoglaphyrites intermedium* n. sp. from the Sheep Range, Clark County, Nevada.

BULLETIN 131
UTAH GEOLOGICAL SURVEY
a division of
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ISBN 1-55791-649-7

BULLETIN 131
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UTAH GEOLOGICAL SURVEY

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FORWARD

The science of paleontology has been vital to Utah and surrounding areas since the middle of the nineteenth century. Museums, universities, and government agencies around the world have amassed important collections of Utah fossils. Many of those collections have been pivotal to the overall geologic history of our planet, and more particularly Utah and the western states. More directly, these fossils have played important roles in our understanding of past life on land and in the sea. Scientific interest in Utah's fossils spans the realm of disciplines of natural history: stratigraphy, sedimentology, paleogeography, geochronology, evolution, historical geology, geochemistry, structural geology, taphonomy, biogeochemistry, taxonomy, paleoecology, anatomy, functional anatomy, biomechanics, animal behavior, genetics and more.

Public interest in paleontology in the past two decades has soared with the rise in popularity of dinosaurs, vast improvements in technology, blockbuster museum displays, and spectacular media productions. Nevertheless, the hard work of paleontology, conducted by paleontologists, continues with ever-increasing intensity. Our need to disseminate technical information about Utah's fossil heritage continues to grow. The Utah Geological Survey Paleontology Series serves to partially satisfy that need.

One of the most important functions of paleontology in the earth sciences is time correlation of rock strata using taxonomic analysis of fossils in different regions. Comparisons of certain species' similarities between regions frequently allows for precise age dating and correlation of strata limited only by the presence/absence of species and the speed at which they evolved. Between their first appearance in the early/middle Devonian, approximately 390 million years B.P., and their ultimate extinction at the K-T boundary, 65 million years B.P., no other single taxonomic group is as precise or as widely useful for time correlation of strata as the ammonoid cephalopods, an extinct distant relative of the modern chambered nautilus. This is especially true for the Carboniferous Era (360-285 million years B.P.), where ammonoid change was extremely rapid for reasons that are as yet not fully known, although global climate fluctuation is probably a key driving force.

During Mississippian (Lower Carboniferous) time, a major island mountain range was thrust up in what is present-day central Nevada and eastern California. To the east of the mountain range lay a long, narrow, deep ocean basin that paralleled the mountain chain. Into this basin, known as the Antler foreland basin, untold millions of tons of sand, gravel, and mud were shed from the west creating thick deposits of marine sandstone, shale, and conglomerate. On the eastern edge of this seaway conditions were more conducive to carbonate deposition and many thick limestone deposits formed. Strata throughout this basin contain an abundant ammonoid fossil record. This record is rivaled by no other fossil group for intercontinental correlation, and yet is only just beginning to undergo intensive study. This paper is the very first of a series of comprehensive systematic studies on this extremely significant fauna which, when completed, will help to establish the Antler foreland in Utah, Nevada, and California as a global reference for Carboniferous research. Herein the paleogeographic ranges of many taxa are extended from Eurasia into North America and several new species and genera are named. This paper will serve as a benchmark work in Carboniferous ammonoid research and is an important source of information regarding this fascinating fossil group for both the public and professional geologists.

Alan L. Titus, the author of this publication, was born in Toledo, Ohio, but has spent most of his life in southern Nevada. Presently Alan is Paleontologist for the Grand Staircase-Escalante National Monument and resides in Kanab, Utah. His education includes Bachelor of Science degree from the University of Nevada Las Vegas (1990), Master of Science degree from the University of Arkansas (1992), and Ph.D. from Washington State University (1996). Alan has authored several papers and abstracts on Carboniferous ammonoid paleontology of North America and is recognized as a world authority on the subject. He is still active in Carboniferous ammonoid research and is presently conducting field studies on older (pre-Arnsbergian) Mississippian ammonoid faunas of west-central Utah.

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1 mm (millimeter) = 1/1000 cm = 0.04 inches
1 cm (centimeter) = 1000 mm = 0.4 inches
1 m (meter) = 1000 cm = 39 3/8 inches, or 3.28 feet
1 km (kilometer) = 1000 m = 0.621 mile

1 inch = 25.4 mm, or 2.54 cm
1 foot = 305 mm, or 30.5 cm
1 yard = 915 mm, or 91.5 cm
1 mile = 1.61 km

Or, use the following conversion factors:
To convert millimeters to inches: multiply by 0.039
To convert centimeters to inches: multiply by 0.394
To convert meters to feet: multiply by 3.281
To convert meters to yards: multiply by 1.094
To convert kilometers to miles: multiply by 0.621

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LATE MISSISSIPPIAN (ARNSBERGIAN STAGE-E_2 CHRONOZONE) AMMONOID PALEONTOLOGY AND BIOSTRATIGRAPHY OF THE ANTLER FORELAND BASIN; CALIFORNIA, NEVADA, UTAH

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ABSTRACT

Diverse and abundant ammonoid cephalopods of late Chesterian age (Arnsbergian Stage, E_2 chronozone) occur in the Rest Spring, Indian Springs, Scotty Wash, Chainman, and Ely formations of eastern California, southern and eastern Nevada, and west-central Utah, within the confines of the Antler foreland basin. Species of *Stenopronorites*, *Dombarocanites*, *Eumorphoceras*, *Metadimorphoceras*, *Arcanoceras*, *Delepinoceras*, *Proshumardites*, *Pericleites*, *Cravenoceras*, *Cravenoceratoides*, *Glaphyrites*, *Fayettevillea*, *Richardsonites*, *Cryptotyloceras* new genus, *Zephyroceras*, *Eosyngastrioceras* new genus, *Syngastrioceras*, *Somoholites*, *Stenoglaphyrites*, and *Euroceras* are all present in these assemblages, but many occurrences are localized geographically or stratigraphically. *Eosyngastrioceras* and *Cryptotyloceras* are North American endemics. The remaining genera also are widespread in Eurasia and North Africa, making global correlations possible. The dominant species in the study area is a North American endemic, *Eosyngastrioceras hesperium* (Miller and Furnish).

Five ammonoid-based biozones are established herein for Arnsbergian equivalents of the Antler foreland. These are, in ascending order, the *Eumorphoceras paucinodum*, *Eumorphoceras rotuliforme*, *Eumorphoceras girtyi*, *Cravenoceratoides nititoides*, and *Delepinoceras thalassoide* biozones. The above zonation represents the highest resolution system ever developed for latest Mississippian strata of North America. When integrated with faunal zonations based on conodonts, calcareous foraminifers, and gastropods, the ammonoid record provides a basis for extremely high-resolution continent-wide correlations. On a global scale, the Antler foreland zonation is presently excelled only by the extremely precise European zonation, which is based mostly on short-lived endemic taxa and difficult to correlate with other regions on a zone-for-zone basis. Antler foreland assemblages contain elements of North American, European, and Asian faunas and are readily correlated with successions in Britain, Germany, Ireland, Poland, Spain, the Czech Republic, Kazakhstania, Uzbekistania, Algeria, and China. The *Eumorphoceras paucinodum* and *E. rotuliforme* biozones are here viewed as equivalent to the E_2a of the standard western European succession, while the *E. girtyi* and *Ct. nititoides* biozones equate with the E_2b, and the *D. thalassoide* correlates roughly with the E_2c. Revisions to previous intercontinental correlations made herein necessitate reinterpretation of the global eustatic and climatic record, which is beyond the scope of this paper.

INTRODUCTION

The Antler orogenic belt formed by compressional and transpressional strain during Devonian and Mississippian time and stretches some 2500 km from the Canadian Arctic to southern California (Eisbacher, 1983). To the east of its southern end lies a group of discreet foreland and backbulge basins (Silberling and others, 1995) that collectively make up what is referred to as the Antler foreland basin (figure 1). The Antler foreland basin (AFB), among other things, is unique in the Western Hemisphere because it contains an unrivaled early to mid-Carboniferous biostratigraphic record replete with rich ammonoid cephalopod assemblages. In fact, the Late Mississippian-Early Pennsylvanian succession of the AFB is so good that a section in Arrow Canyon, southern Nevada, was recently designated the Global Mid-Carboniferous Boundary Stratotype (Lane, 1995). In spite of the importance of the region to global Carboniferous geology, many of the biostratigraphically critical ammonoid assemblages remain undescribed even though they are abundant and easily recovered. Other important groups with lower biostratigraphic resolution such as conodonts and foraminifers have been extensively studied and form the basis for most previously made correlations (Webster, 1969; Dunn, 1965, 1970; Tynan, 1980; Wardlaw, 1984; Baesemann and Lane, 1985; Brenckle, 1973; Poole and Sandberg, 1991).

As part of an ongoing effort to assess the significance of this ammonoid fauna, I amassed a stratigraphically controlled collection of 10,000+ Meramecian and Chesterian (Viséan through Namurian A Series of Europe) ammonoids from California, Nevada, and Utah, where upper Mississippian assemblages are particularly abundant. Initial evaluation of these collections made it clear that many new taxa were present, mandating systematic description. Additional material of this age and from this region has been collected by personnel of the U. S. Geological Survey (USGS) in con-

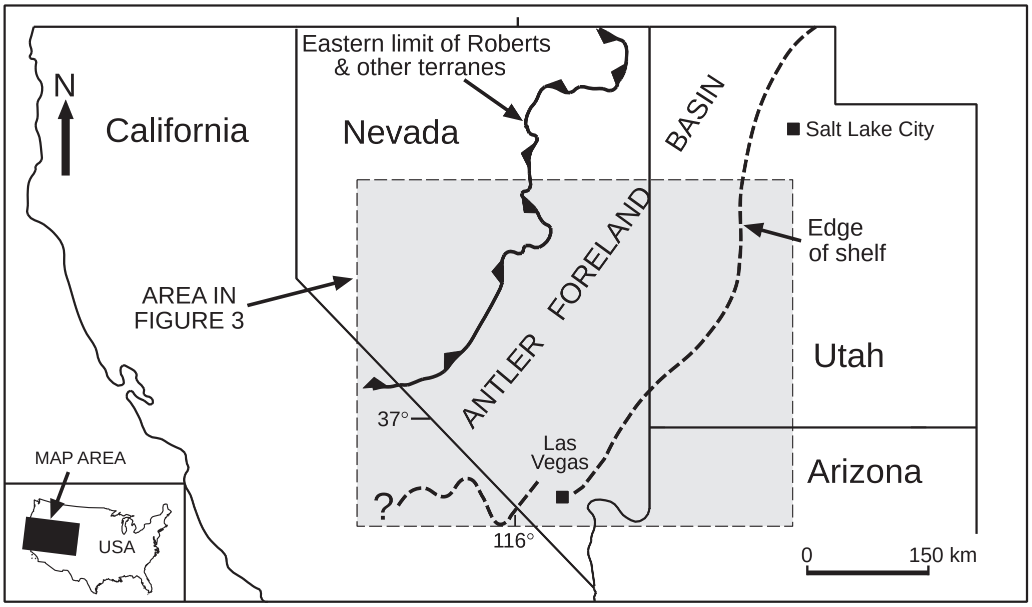


Figure 1. Reference map showing southern portion of the Mississippian Antler foreland basin and location of the study area. Modified from Silberling and others (1995).

junction with mapping efforts, and supports similar conclusions. Together, these collections represent one of the most diverse and complete Late Mississippian ammonoid successions in the world. Study of this remarkable record is challenging long-held ideas about Carboniferous biostratigraphy, paleogeography, and eustacy.

Because of the sheer number of specimens and taxa involved, systematic description of these collections is being done on a stage-by-stage basis. This paper covers assemblages of latest Chesterian (late-early, and late Elvirian Stage) age, which are exactly time equivalent to the Arnsbergian Stage (E_2 Ammonoid Chronozone) of Western Europe (figure 2). Latest Mississippian-Early Pennsylvanian assemblages of the *Homoceras* and *Cancelloceras* genozones (latest Elvirian-late Halian) have been described in Titus and Manger (in press) and Titus (1997a) respectively, while older material will be treated in future publications.

Arnsbergian is used subsequently throughout this report in preference to the North American Elvirian Stage because the type section of the latter, which is located in the Illinois basin, is unconformity bounded, completely lacks ammonoids, and cannot be reliably correlated with areas outside of the United States mid-continent. Similar problems exist with correlating other Mississippian stage and series defined in and around the Illinois basin (see Webster, 1997 for discussion of problems with the Kinderhook-Osage series boundary). In contrast, the Arnsbergian can be unequivocally related to ammonoid-bearing strata found in the western United States and elsewhere.

The Arnsbergian derives its name from the Arnsberg Forest region of western Germany (Schmidt, 1934). Because of poor exposures and incomplete biostratigraphic records in Germany, conceptually the stage is now tied to localities in the Craven basin, England, and Slieve Anierin, Ireland (Yates, 1962; Riley, 1987) where thick marine clastic sections have yielded a nearly continuous middle Mississippian to Early Pennsylvanian ammonoid record. The lower stage boundary with the underlying Pendleian is marked by the first appearance of the ammonoid *Eumorphoceras grassingtonense* Dunham and Stubblefield, 1945, while the upper stage boundary (the base of the overlying Chokierian Stage) is placed at the first appearance of the genus *Isohomoceras*, which at one time defined the base of the Pennsylvanian. Ammonoids of this interval are widespread through the paleotropical-subtropical belt and are extensively utilized for high-resolution correlation.

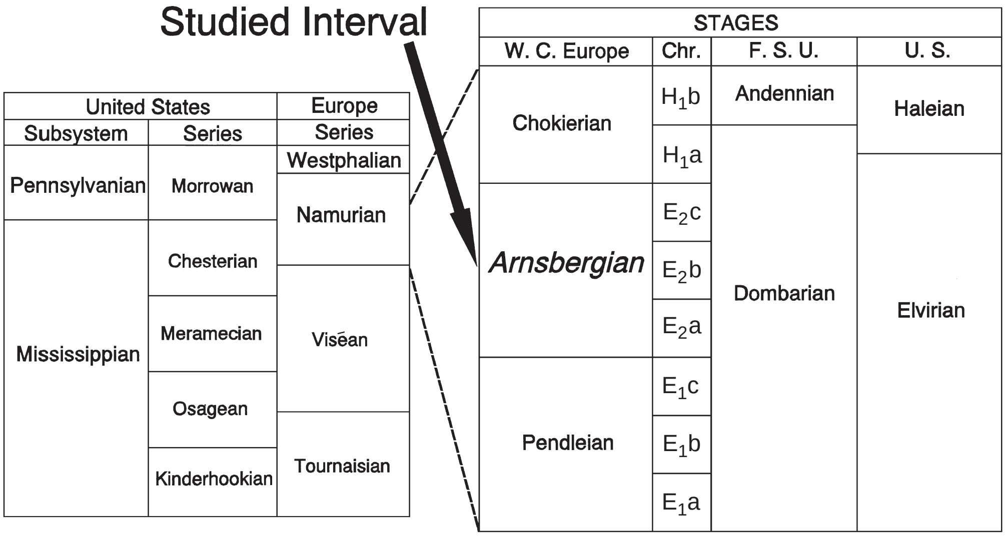


Figure 2. Correlation of United States, European, and former Soviet Union mid-Carboniferous chronosratigraphic units showing interval treated in this study (Arnsbergian). WC, west-central; Chr, Chronozone; FSU, former Soviet Union; US, United States.

PREVIOUS WORK

California

The only previously published systematic paper on Arnsbergian-age ammonoids from California was by Gordon (1964). Most of the material described in that work represents an early Arnsbergian assemblage from the Rest Spring Shale type section that had been collected and listed by J. F. McAllister (1952). Also described by Gordon (1964) were smaller collections of late Arnsbergian ammonoids from the Cerro Gordo Pipeline Trail locality (from the Rest Spring Shale) that were originally identified by G. H. Girty (listed in Knopf, 1918). Additional material from the Cerro Gordo Pipeline Trail locality collected by Merriam (1963) was also studied. My reinterpretation of this work yields the following changes:

From the basal portion of the Rest Spring Shale, Rest Spring, California:

Gordon (1964)	**This Report**
Anthracoceras macallisteri Gordon	*Arcanoceras macallisteri* (Gordon)
Eumorphoceras paucinodum Gordon	no change
Delepinoceras californicum Gordon	no change
Cravenoceras hesperium Miller and Furnish	*Eosyngastrioceras hesperium* (Miller and Furnish)
Cravenoceras hesperium (part)	*Eosyngastrioceras quadratum* n. gen. n. sp.
Cravenoceras inyoense Gordon	*Fayettevillea inyoense* (Gordon)

From slightly higher in the Rest Spring Shale, Rest Spring, California:

Gordon (1964)	**This Report**
Cravenoceras merriami Youngquist	*Stenoglaphyrites intermedius* n. sp.

From the lower portion of the Rest Spring Shale, Cerro Gordo Pipeline Trail, California:

Gordon (1964)	**This Report**
Eumorphoceras bisulcatum Girty	no change
Dombarocanites masoni	no change
Cravenoceratoides sp., cf. *C. nititoides*	*Cravenoceratoides nititoides* (Bisat)

Montana

A single Arnsbergian ammonoid collected from the Amsden Formation was illustrated and described by Gordon and Yochelson (1975, plate 2, figures 33-35). This report is significant in that it is the only documented occurrence of a North American *Cravenoceratoides* outside of southeastern California. The specimen was left in open nomenclature, however, it is here referred to *C. macrocephalum* (Frech), which in Europe is confined to lower-middle Arnsbergian strata (Schwarzbach, 1937).

Cox (1986) listed a small ammonoid assemblage from the Bear Gulch Limestone (identified by W. B. Saunders) that is probably middle to late Arnsbergian in age. All the original diagnoses are accepted here.

Nevada

The first report on Arnsbergian ammonoids from Nevada was published by A. K. Miller and W. M. Furnish (1940). The subject of that paper was two small collections of ammonoids from the "White Pine Shale" that were made by J. Fox, a private collector living in Shoshone, Nevada. One of the lots was from the Egan Range, Lincoln County, Nevada in the Trough Springs Canyon region, while the other was from "Johns Hollow," southern part of the Snake Range, White Pine County, Nevada. All of the specimens studied served as types for new species, with *Cravenoceras hesperium* being from the first locality and *Cravenoceras nevadense* and *Anthracoceras*(?) *colubrellus* from the second. The precise location of Miller and Furnish's Johns Hollow locality is not known and attempts to locate it by both M. Gordon, Jr. and myself have failed. However, forms very close to, if not identical with, *C. nevadense* and *A.*(?) *colubrellus* occur in a middle Arnsbergian assemblage that I collected in the White Pine Range, demonstrating that Miller and Furnish's *Cravenoceras nevadense*-*Anthracoceras*(?) *colubrellus* assemblage is actually middle Arnsbergian in age. *Cravenoceras nevadense* was referred to *Glaphyrites* by Ruzhencev and Bogoslovskaya (1971b). *Anthracoceras*(?) *colubrellus* is herein referred to *Stenoglaphyrites*.

The type locality for *Cravenoceras hesperium* is in the southern part of the Egan Range (Miller and Furnish, 1940). Although the description is not precise in the original paper, I have relocated the stratigraphic interval that yielded the types. It is a relatively thin, highly fossiliferous, calcareous, concretionary horizon less than ten meters above the lowest quartz arenite unit in the Scotty Wash Formation. Two collections made for this study from localities in the Trough Springs area are almost certainly from near where the original type lot was secured. The assemblage is distinctly Arnsbergian and the new collections contain *Eumorphoceras rotuliforme* Ruan. Reassessment yields the following changes:

From the "White Pine Shale" (Scotty Wash Formation of this paper) of east-central Nevada:

Miller and Furnish (1940)	**This Report**
Cravenoceras hesperium Miller and Furnish	*Eosyngastrioceras hesperium* (Miller and Furnish)
Anthracoceras? *colubrellus* Miller and Furnish	*Stenoglaphyrites colubrellus* (Miller and Furnish)
Cravenoceras nevadense Miller and Furnish	*Glaphyrites nevadensis* (Miller and Furnish)

In the late 1940s through the early 1950s, W. Youngquist published a series of papers on Carboniferous ammonoids from the eastern Great Basin (Youngquist, 1949a, 1949b, 1951; Miller and others, 1949, Miller and others, 1952). These papers describe early Namurian ammonoids from the "White Pine Shale" from several localities in Lincoln, Nye, and White Pine Counties, Nevada, and one latest Viséan fauna from the Confusion Range, Millard County, Utah. After reviewing these papers and the original collections they were based upon, I have concluded that much of Youngquist's material was Pendleian in age. Arnsbergian ammonoids are present only in the collection made at Johns Hollow, located 2.4 km east of the trail up Murphy Wash in the southern part of the Snake Range and approximately in the SE$^{1}/_{4}$ section 2, T. 10 N., R. 68 E., White Pine County. According to Youngquist (1949a, p. 278), Mr. J. Fox of Shoshone, Nevada, claimed this locality was near the one that yielded Miller and Furnish's (1940) types of *C. nevadense* and *A.*(?) *colubrellus*. However, Youngquist's collections do not contain either of these species, and his material was obtained from a lower horizon. My examination of Youngquist's collections also revealed that his Johns Hollow Arnsbergian material is contaminated with specimens of the Pendleian goniatitid *Paracravenoceras barnettense* (Plummer and Scott). On the basis of the latter's unique preservation and matrix they were accidentally introduced from his Duckwater collection. The following applies only to unequivocal Arnsbergian material illustrated by Youngquist (1949a).

From the "White Pine Shale" of the southern Snake Range:

Youngquist (1949a)	**This Report**
Cravenoceras hesperium Miller and Furnish	*Eosyngastrioceras hesperium* (Miller and Furnish)
Eumorphoceras bisulcatum Girty	?*Eumorphoceras girtyi* Elias

The next description of Arnsbergian ammonoids from Nevada was by Webster and Lane (1967). These authors reported a small, but significant Late Mississippian ammonoid faunule from the Indian Springs Formation at a locality in central Clark County, Nevada, known as “Apex” in reference to a nearby railroad siding. In addition, several poorly preserved ammonoids (phosphatized internal molds) were reported from the widespread “marker conglomerate” unit which is stratigraphically just below the Apex ammonoid bed. One new taxon, *Syngastrioceras walkeri* Webster and Lane, was described along with *Cravenoceras* sp., *Pronorites* sp., and some nautiloid taxa. Reassessment yields the following changes:

From an ammonoid-bearing lens in the lower part of the Indian Springs Formation:

Webster and Lane (1967)	**This Report**
Syngastrioceras walkeri Webster and Lane	*Somoholites walkeri* (Webster and Lane)
Cravenoceras sp.	*Syngastrioceras websteri* n. sp.
Pronorites sp.	*Stenopronorites* sp., cf. *S. uralensis* (Karpinsky)

The following year Gordon and Poole (1968) illustrated another small but significant faunule from Unit J of the Eleana Formation (now referred to the Scotty Wash Formation), Northern Syncline Ridge, Nye County, Nevada. The following taxa were illustrated in this report:

From a concretionary interval in the “top of the Eleana Formation”:

Gordon and Poole (1968)	**This Report**
Eumorphoceras sp., cf. *E. bisulcatum* Girty	*Eumorphoceras girtyi* Elias
Cravenoceras hesperium Miller and Furnish	*Syngastrioceras websteri* n. sp.
Cravenoceras merriami Youngquist	*Euroceras nyense* n. sp.
Syngastrioceras sp.	*Syngastrioceras websteri* n. sp.

More recently, Titus (1992) and Titus and others (1997) figured middle and late Arnsbergian assemblages from the Test Site Region. The first of these, from the north end of Syncline Ridge, was collected from the same locality that yielded Gordon and Poole’s Late Mississippian assemblage. The second came from the highest exposed shale portion of the Scotty Wash Formation at the south end of Syncline Ridge, which has also yielded *Homoceras* zone ammonoids of Early Pennsylvanian age. Review of both these reports yields the following changes:

From the Scotty Wash Formation, Syncline Ridge area, Nye County, Nevada:

North Syncline Ridge

Original Identification	**This Report**
Eumorphoceras sp., cf. *E. bisulcatum* Girty	*Eumorphoceras girtyi* Elias
Syngastrioceras oblatum (Miller and Moore)	*Eosyngastrioceras inexpectans* n. sp.
Euroceras sp., cf. *E. ellipsoidale* Ruzhencev and Bogoslovskaya	*Euroceras nyense* n. sp.
Zephyroceras sp.	*Zephyroceras friscoense* (Miller and Owen)
Richardsonites sp.	*Richardsonites richardsonianus* (Girty)

South Syncline Ridge

Original Identification	**This Report**
Delepinoceras thalassoide (Delepine)	no change
Zephyroceras sp., cf. *Z. friscoense* (Miller and Owen)	*Zephyroceras friscoense* (Miller and Owen)

Utah

The first comprehensive biostratigraphic study on Chesterian ammonoids of the Great Basin was published by Gordon and others (1957). Recently Sadlick (1995) published a discussion of Chesterian Chainman ammonoid biostratigraphy using the zonal system established by Gordon (1970) which is discussed at length below under biostratigraphy. Both of these studies were largely based on collections made in western Utah. In spite of this, no Arnsbergian ammonoid faunas have been previously systematically described or illustrated from Utah.

Miscellaneous

In addition to the above, the following publications contain faunal lists that include Arnsbergian ammonoids: Knopf (1918), McAllister (1952), Drewes (1967), Merriam (1963), Ross (1966), Tschanz and Pampeyan (1970), Sadlick (1965; 1995), Gordon (1970), and Webster and others (1984). Although important as records of ammonoid occurrences, these works are limited in their biostratigraphic and taxonomic value as no illustrations were given in the original publication and their nomenclature is obsolete. Because the original collections that form the basis of these reports have not been examined, they are not reassessed.

LIMITS OF THE STUDY AREA AND METHODS

The material described herein comes from 91 field collections (appendix B) made at 20 general localities scattered over west-central Utah, eastern and southern Nevada, and eastern California (figure 3). Although Late Mississippian strata are discontinuously exposed throughout the study area, most of the collecting localities are located along three generally east-west-trending transects. The northernmost transect includes localities (from east to west) from western Millard County, Utah, and northern Lincoln, and southern White Pine Counties, Nevada (figure 3: localities 15-20). The second transect is located entirely in southern Nevada (localities 4-13). From east to west this includes localities in southern Lincoln, northern Clark, and southeastern Nye Counties. The third transect is located entirely within Inyo County, California (localities 1-3).

Whenever possible or practical, a measured or measured composite section was made for each ammonoid yielding locality (appendix A), although frequently local structure and/or cover precluded this. Collections were then made along strike and keyed to marker horizons within the measured or composite section. Only in situ and loose specimens with a high degree of stratigraphic control were collected. Specimens were then prepared, sorted by taxonomic affinity, measured, described, and photographed. Comparison with established taxa was facilitated by examination of material illustrated in the literature or reposited in various institutions.

PHYSICAL STRATIGRAPHY

West-Central Utah

Late Chesterian AFB fill is mostly represented by the Chainman Shale (or Formation) in western Millard and Juab Counties, Utah (Webster and others, 1984). In this region, the Chainman Formation was further divided by Sadlick (1995) into formal members, the highest three of which, from oldest to youngest, are the Camp Canyon, Willow Gap Limestone, and Jensen Siltstone Members (figure 4). Good summaries of the lithologic character of these members are found in Sadlick (1995) and Webster and others (1984). Ammonoid data indicate that the Viséan-Namurian boundary, based on the first appearance of the cravenoceratid *Emstites*, is in the Camp Canyon Member throughout western Millard County (Titus, unpublished data).

At their respective type localities, the Willow Gap Limestone Member is predominantly a distinctive shallow-water carbonate grainstone and oolitic shoal facies, while the Jensen Siltstone Member is an alternating clastic-carbonate unit that becomes progressively more carbonate-rich upsection. Previously, the lower Arnsbergian was equated with Mamet's Foraminiferal Biozone 18 (for example, Gordon and Yochelson, 1987), and thus with at least the upper portion of the Willow Gap Limestone Member (Sadlick, 1995). However, at locality TWG (figure 3), the Willow Gap Limestone Member is Pendleian in age from top to bottom (see discussion under foraminiferal biostratigraphy) and its contact with the overlying Jensen Siltstone Member is a disconformity where late Pendleian to middle Arnsbergian strata are missing (figure 4). Contrary to Sadlick (1965; 1995) and Webster and others (1984), who suggested that the Willow Gap Limestone Member is age equivalent to the lower portion of the type Jensen Siltstone Member, ammonoid-based correlations indicate that the Willow Gap Limestone Member has its equivalent in the middle of Sadlick's Camp Canyon Member at Jensen Wash (figure 3, locality 18). Willow Gap Limestone Member-type lithologies (grainstones) are not developed at Jensen Wash because deposition occurred in deeper water. Based on ammonoid correlations reported herein, the base of the Jensen Siltstone Member is older at its type locality than it is at Willow Gap, and thus chronostratigraphically correlates into the Jensen-Willow Gap disconformity at Willow Gap in the northern Confusion Range (figure 3, locality TWG). As a result, the lower and middle Arnsbergian is represented by the Jensen Siltstone Member throughout most of western Millard County, where it overlies the Camp Canyon Member to the west and the Willow Gap Limestone Member to the east. Although Sadlick (1995) extended the term Jensen Siltstone Member to most of eastern Nevada, the western limit of Jensen-type lithologies is considered herein to be near the Nevada-Utah border. The Foote Ranch (figure 3, locality 19) and Snake Range (not shown) sections contain a higher volume of quartz arenites than sections farther east in Utah and could just as easily be referred to the Scotty Wash Formation. Consequently, all of the ammonoids described herein from this region are from the Jensen Siltstone Member/Scotty Wash units and the Ely Limestone

East-Central Nevada

In southern and eastern White Pine, and northern Lincoln Counties, ammonoid-based correlations indicate that the Pendleian-Arnsbergian boundary coincides approximately with the lowest level at which massive monocrystalline quartz arenites occur in the "Newark Valley Sequence" of Trexler and Cashman (1991). Overlying strata consist largely of deltaic mudstones, siltstones and sandstones that grade upsection into more carbonate-rich units. The appearance of craton-derived, non-cherty quartz arenites is a key marker horizon for correlation within the AFB, and in the White Pine Range they can be demonstrated to overlie the chert-rich arenites and conglomerates of the Hamilton Canyon and Diamond Peak Formations.

A variety of conflicting formational names have been applied to this sequence (Webster and others, 1984; Sadlick, 1995). The term Diamond Peak Formation (=Diamond Peak Quartzite of Hague, 1883), as used by Nolan and others (1956), would encompass this largely chert-free uppermost portion of the AFB clastic sequence. The Diamond Peak Formation is here restricted from use for the largely chert-free sequence because the type section of the Diamond Peak Formation contains significant amounts of chert pebble conglomerate and chert arenites in its lower portion. Furthermore, the conglomeratic facies, which is most characteristic of the Diamond Peak Formation, is not found outside of western White Pine and northernmost Nye Counties. This conglomeratic sequence was referred to the

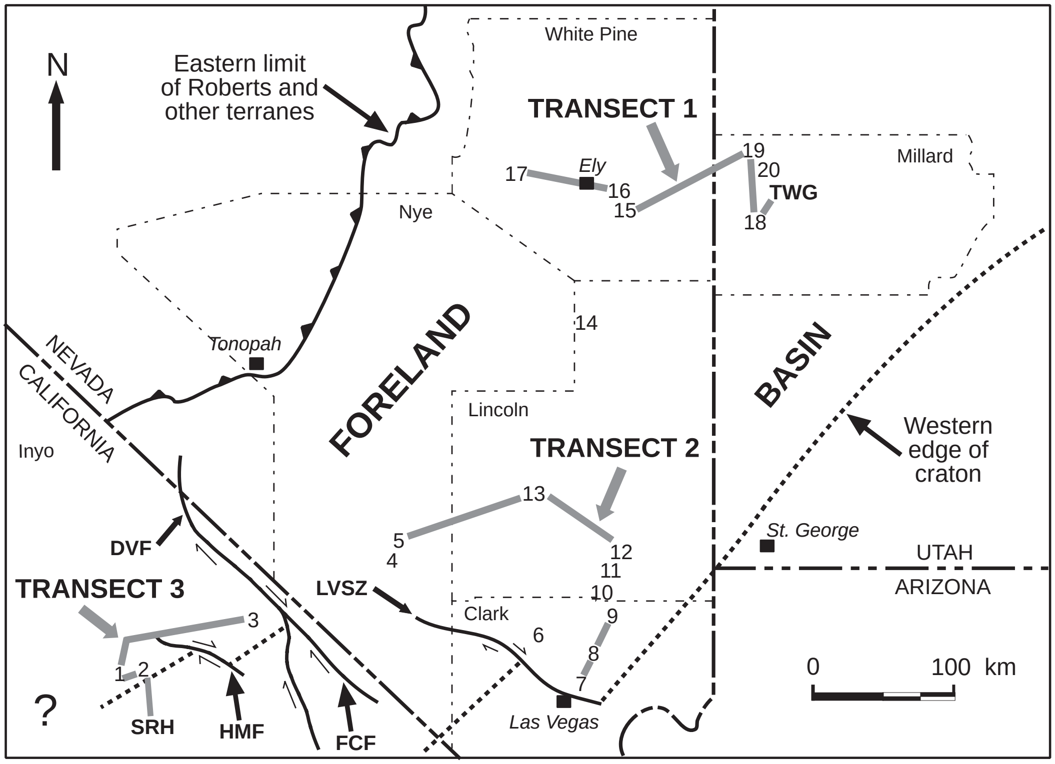


Figure 3. *Map of study area showing general location of field collections and selected structures. Transects in figures 4-6 shown as stippled bars. SRH, Santa Rosa Hills; DVF, Death Valley fault; HMF, Hunter Mountain fault; FCF, Furnace Creek fault; LVSV, Las Vegas shear zone. Locality numbers are keyed to appendix A.*

Donner Member of the Chainman Formation by Sadlick (1995), but probably should be retained in the Diamond Peak Formation as modified herein, which has priority. It is further proposed here that the Diamond Peak Formation be restricted to intervals characterized by chert pebble conglomerates and chert litharenites.

The term Illipah Formation was coined by Christiansen (1951) for the same stratigraphic interval referred to the Diamond Peak Formation by Nolan and others (1956), and therefore would encompass the interval under present consideration. However, Illipah Formation is considered redundant by most later workers (Sadlick, 1960) and has largely been abandoned. The Hamilton Canyon Formation (Langenheim, 1962), originally proposed as the uppermost member of the White Pine Group, can be excluded from use for the monocrystalline quartz-rich arenite sequence (as in Webster and others, 1984) because at its type section it is stratigraphically below the Diamond Peak Formation conglomerates and characterized by chert-rich arenites.

The type section for the Scotty Wash Formation of Westgate and Knopf (1932) consists of at least 151 m of mudstone with interbedded monocrystalline quartz arenites that overlie the Chainman Shale (referred to the Peers Spring Formation by Westgate and Knopf, 1932) and underlie the Ely Limestone, which is typical for the Arnsbergian of eastern Nevada. Although Westgate and Knopf (1932) thought the formation was almost all quartz arenite, both sections described by them (Fairview Range and Dutch John Mountain) are mostly covered with sandstone float. As was pointed out by Sadlick (1995), the Scotty Wash Formation is predominantly mudstone at its type section. The term Scotty Wash Formation seems most appropriate for the monocrystalline quartz arenite-mudstone sequence in eastern Nevada for the following reasons:

1. The base of the formation can be consistently recognized based on the first appearance of noncherty arenites.
2. The lithologic sequence throughout the region is very similar.
3. Many of the sand units can be correlated over wide areas.
4. The name has priority.

Recently, J. Trexler (oral communication, 1995) and R. Crosby (written communication, 1995) of the University of Nevada-Reno came to some of the same conclusions while remapping and remeasuring the type Hamilton Canyon section.

Sadlick (1995) extended the use of the Jensen Siltstone Member of the Chainman Formation to most of eastern Nevada, including the White Pine Range. In the same paper, the term Scotty Wash Formation was restricted geographically to its type locality. This usage of the Jensen Siltstone Member displaced the Scotty Wash Formation in eastern Nevada. However, the type section of the Jensen Siltstone Member does not contain the thick, pure quartz arenites characteristic of most time equivalent sections in Nevada (Sadlick, 1995, p. 19). The Jensen Siltstone Member, as the name implies, contains a higher proportion of finer-grained clastics. Accordingly, the Scotty Wash Formation, which has priority, is here applied throughout eastern Nevada and the Jensen Siltstone Member is restricted to west-central Utah (figure 4).

The Ely Limestone, which overlies both the Scotty Wash Formation and the Jensen Siltstone Member, is predominantly a shallow-water carbonate grainstone facies. It is, with the exception of a single poorly preserved specimen recovered from locality 19 (figure 3), devoid of ammonoids. Age constraints on the age of the Ely Limestone are derived mostly from conodont data, and indicate that the base of the formation coincides roughly with the base of the Lower *Rachistognathus muricatus* Biozone. Consequently, throughout southern White Pine County and western Millard County the latest Arnsbergian (E_2c) is within the lowermost portion of the Ely Limestone (Titus and others,

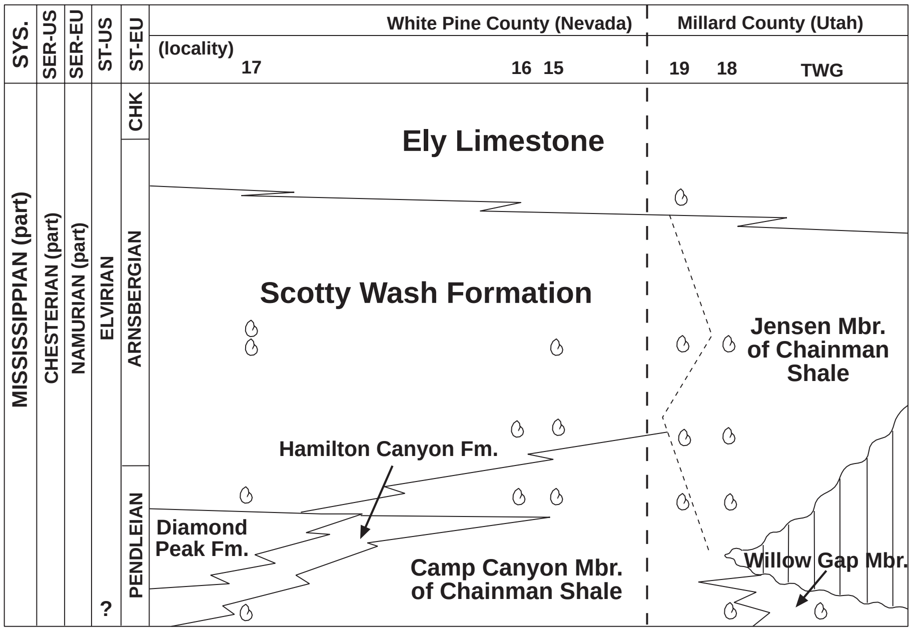


Figure 4. *Generalized architectural and chronostratigraphic framework of Pendleian and Arnsbergian lithostratigraphic units along Transect 1. Measured or collected sections are indicated by numbers and are keyed to figure 2 and appendix A. Sampled ammonoid horizons indicated by shell symbol. No absolute thickness implied due to distortion of units along the time axis. Distance between localities is schematic. Abbreviations are as follows: SYS, system; SER-US, United States Series; SER-EU, European Series; ST-US, United States Stages; ST-EU, European Stages; TWG, type locality for Willow Gap Limestone Member.*

1997), although this is poorly constrained in the White Pine Range (figure 3, locality 17).

Southern Nevada

In southern Nevada, the base of the Namurian (Mamet Foraminiferal Biozone 17 equivalent) occurs in the middle portion of the Battleship Wash Formation at localities on the margin of the AFB (Brenckle, 1973), and within the Chainman Shale at more basinal localities. At the eastern margin of the AFB (figure 3, localities 6-11) the Arnsbergian is represented by the Indian Springs and Bird Spring Formations (Webster, 1969; Webster and others, 1984). There the time and stratigraphic relationships between Namurian units are analogous to those observed at the Willow Gap-Skunk Spring area in Utah. The Indian Springs Formation, a close lithologic and chronostratigraphic analog of the Jensen Siltstone Member, disconformably overlies the Battleship Wash Formation, the upper portion of which is also early Pendleian in age (figure 5). Similarly, the lower portion of the Bird Spring Limestone, which contains Lower *Rachistognathus muricatus* Biozone conodonts and conformably overlies the Indian Springs Formation, resembles the lower portion of the Ely Limestone.

In the southern portion of Lincoln County, a marked thickness contrast occurs across the “hingeline” of Webster (1969), with thinning of the Arnsbergian to the southeast. As a result, at Kane Springs Wash (figure 3, locality 12) the clastic section is much thicker than at other nearby areas located to the south (localities 7-11). The entire Arnsbergian clastic section at Kane Springs Wash has been referred to the Chainman Shale and Indian Spring formations, with the base of the latter being defined arbitrarily as one of the middle quartz arenite units (Webster and Lane, 1967; Webster, 1969).

Historically the term Indian Springs has been applied mostly to thin Arnsbergian-age clastic sections sandwiched between the Battleship Wash or Monte Cristo Formations and the overlying Bird Spring Formation, all of which are predominantly carbonate. Use of the name Indian Springs Formation has also largely been confined to east of the hingeline (Rich, 1963; Dunn, 1965), with the Kane Springs Wash section an exception. In addition, the Kane Springs Wash section contains four prominent quartz arenites that are atypical for the Indian Springs Formation, but characteristic of the Scotty Wash Formation. For consistency, the use of Indian Springs Formation is herein restricted to the region south and east of the “hingeline” where sections lack both the multiple Scotty Wash-type monocrystalline quartz arenites and a “Chainman Shale” interval (figure 5). The Kane Springs black shale interval is herein referred to the Camp Canyon Member of the Chainman Shale, while the interval from the first quartz arenite to the overlying Bird Spring Formation is referred to the Scotty Wash Formation. Use of either Ely Limestone or Bird Spring Formation is equally justifiable in this area. Sections in the western parts of Lincoln County (locality 13) are typical of Scotty Wash Formation-Ely Limestone sections farther north.

In the southern part of Nye County (figure 3, localities 4-5), the Pendleian portion of the Chainman Shale is extremely thick, and the Viséan-Namurian boundary has never been precisely located because of a lack of diagnostic fossils. The Scotty Wash Formation, which was referred to the informal quartzite subunit of Unit J of the Eleana Formation (Hoover and Morrison, 1980), has been demonstrated by Titus and others (1997) to be, in part, the age equivalent of the lower portion of the Ely and Bird Spring Limestones farther east (figure 5). Since its upper portion contains Early Pennsylvanian ammonoids in this area, here the Arnsbergian is entirely within the Scotty Wash Formation.

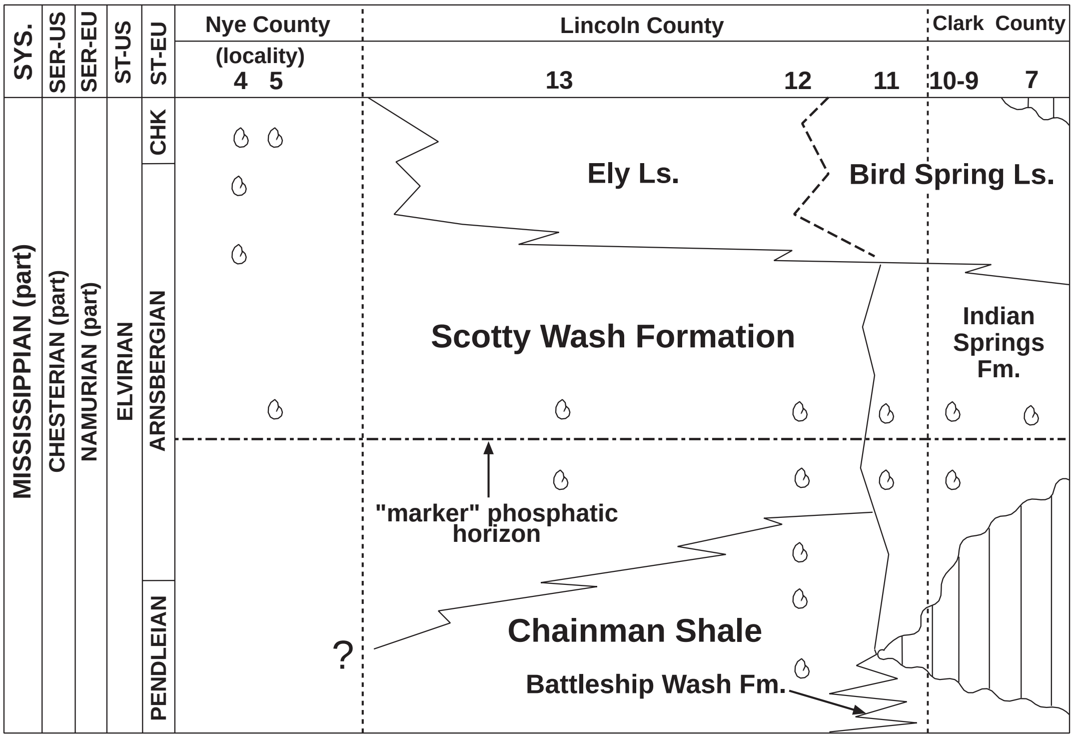


Figure 5. *Architectural and chronostratigraphic framework of Pendleian and Arnsbergian lithostratigraphic units along Transect 2. Measured or collected sections are indicated by numbers and are keyed to figure 2 and appendix A. Sampled ammonoid horizons indicated by shell symbol. No absolute thickness implied due to distortion of units along the time axis. Distance between localities is schematic. Abbreviations same as for figure 4.*

Eastern California

In the Cottonwood Mountains, California (figure 3-locality 3), the formational contact between the Rest Spring Shale and the underlying Mexican Spring Formation essentially coincides with the Pendleian-Arnsbergian boundary (figure 6) based on data presented herein. The Viséan-Namurian boundary, which lies somewhere in the upper portion of the Mexican Spring Formation, has not been located precisely due to a lack of diagnostic fossils. Immature conodont Pa elements recovered from a horizon in the upper portion of the Rest Spring Shale at its type locality are tentatively identified as *Adetognathus lautus* (Gunnell) and suggest that the Mississippian-Pennsylvanian systemic boundary is within the Rest Spring Shale. If these conodont identifications are correct, then the Arnsbergian is contained entirely within the concretionary mudstones of the Rest Spring Shale in its type region. There late Mississippian-early Pennsylvanian strata are mostly deeper water mudstones with several prominent concretionary horizons and I can detect no significant depositional break in the Pendleian to early Pennsylvanian section. Ammonoid data indicate that both the lower portion of the Rest Spring Shale and the uppermost portion of the Mexican Spring Formation, which have yielded such distinct taxa as *Delepinoceras*, *Platygoniatites*, *Eumorphoceras*, and *Fayettevillea*, are within Mamet Foraminiferal Zone (MFZ) 19. Consequently, the assignment of this interval to MFZ 16 by Stevens and others (1991) is untenable. In sections located closer to the basin margin (figure 3, localities 1-2), the uppermost portion of the Mexican Spring Formation is probably younger than at the type locality, and is even possibly early Arnsbergian in age, although this is poorly constrained. In marginal to cratonic settings such as in the Argus Range and the Darwin Plateau (not shown on figure 6), the Indian Springs Formation unconformably overlies the Santa Rosa Hills Limestone (also not shown on figure 6) of early to late Meramecian (late Viséan) age (Stevens and others, 1991).

AMMONOID FACIES AND STRATIGRAPHIC DISTRIBUTION

Locality descriptions and measured stratigraphic sections showing the horizons from which collections were made are given in appendices A and B. The AFB Arnsbergian is characterized by generally progradational, heterogeneous, somewhat cyclic sequences of mudstones, siltstones, quartz arenites, marls, limestones and minor conglomerates. Ammonoids are more abundant in the central and eastern parts of the AFB, with most of the specimens being collected from concretionary mudstone (claystone) facies. Preservation is frequently excellent. With few exceptions, the best specimens (uncrushed) were obtained from calcareous and sideritic concretions (plate 16, figure 18) that formed prior to significant sediment compaction (that is, a very early taphonomic phase). Crushed specimens occur frequently in non-concretionary fine-grained clastic facies or in lateral zones between isolated concretions. Ammonoids also occur, sometimes in local abundance, in phosphate pebble conglomerates and storm-generated quartz arenite lenses.

FAUNAL COMPOSITION

A total of 4115+ Arnsbergian ammonoids from the AFB were incorporated into this study. The fauna is dominated by the Suborder Goniatitina (99.7%). Representatives of the Suborder Prolecanitina are relatively rare (0.3%). The single most abundant species is *Eosyngastrioceras hesperium* (Miller and Furnish) (27.1% of the total specimens collected). At the generic level the most common Arnsbergian elements are, in decreasing order of abundance, *Eosyngastrioceras* (38.1%), *Stenoglaphyrites* (15.5%), *Richardsonites* (11.5%), *Glaphyrites* (10.8%), *Cryptotyloceras* (5.4%), *Syngastrioceras* (4.5%), *Euroceras* (4.2%), *Eumorphoceras* (2.5%), *Cravenoceratoides* (2.4%), *Zephyroceras* (1.4%),

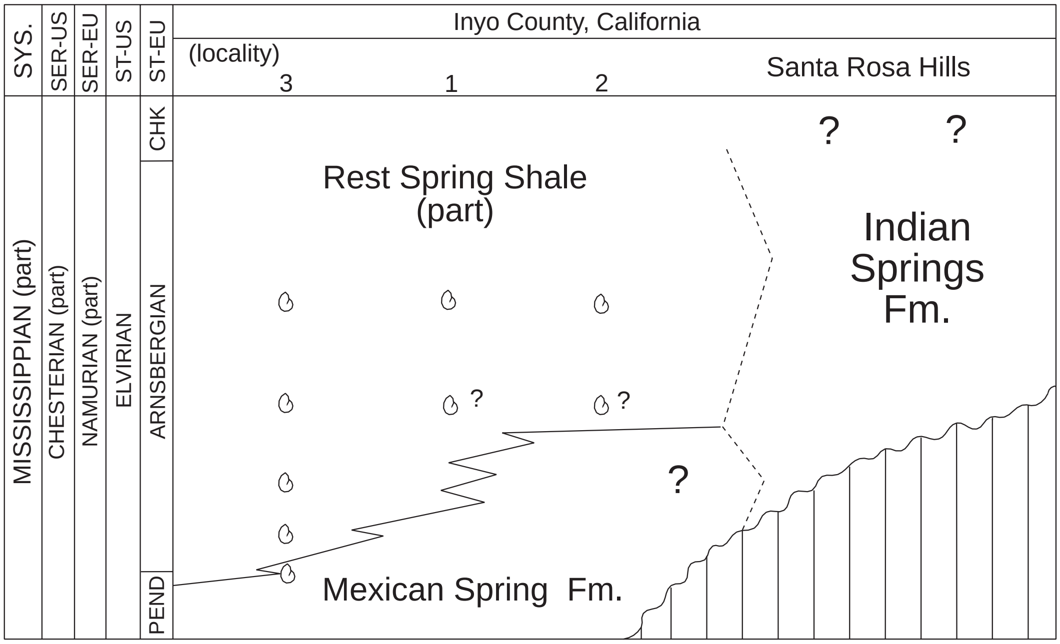


Figure 6. Architectural and chronostratigraphic framework of Pendleian and Arnsbergian lithostratigraphic units along Transect 3. Measured or collected sections are indicated by numbers and are keyed to figure 2 and appendix A. Sampled ammonoid horizons indicated by shell symbol. No absolute thickness implied due to distortion of units along the time axis. Distance between localities is schematic. Abbreviations same as for figure 4.

and *Fayettevillea* (1.3%). The following genera each represent less than one percent of the total fauna: *Dombarocanites*, *Stenopronorites*, *Metadimorphoceras*, *Arcanoceras*, *Delepinoceras*, *Pericleites*, *Proshumardites*, *Cravenoceras*, and *Somoholites*.

Cravenoceratoides is common at three localities but is unknown outside of southern California. Similarly, *Cryptotyloceras* is known only from a limited geographic area in eastern Nevada and west-central Utah. The limited geographic distributions for these genera is somewhat difficult to explain given the relatively narrow geometry of the AFB and the presumed nekto-benthic habit of ammonoids. However, nekroplanktic movement of certain species may have been fairly restricted geographically (Saunders and Spinosa, 1979). If *Cryptotyloceras* were primarily a benthic species this may partly explain its distribution. On the other hand, *Cravenoceratoides*, which has a near circum-paleotropic distribution, is absent from all but the southernmost portion of the AFB. This genus was probably intolerant of the shallow water, carbonate-rich environments that characterized the central and northern portion of the study area during most of the middle Arnsbergian. A similar explanation can also be given for the complete absence of the important late Arnsbergian index taxon, *Nuculoceras*, although barriers to faunal migration effected by climate change may also have been a factor (Titus, 1997b).

AMMONOID BIOSTRATIGRAPHY

European Standard Zonation

A total of nine ammonoid biozones (figure 7) are now recognized within the limits of the Arnsbergian Stage in western Europe, where the biostratigraphic record is exceptionally complete and well documented (Ramsbottom and others, 1979; Riley, 1987). Owing to its completeness, this succession has become the standard global reference even though the assemblages are generally of low diversity and contain endemics. Important zonal indices for the western European section include species of *Eumorphoceras*, *Cravenoceras*, *Cravenoceratoides*, and *Nuculoceras*, which are widespread in the paleotropical-subtropical belt, but may locally be rare or absent in assemblages with “proto-Tethyan” affinities dominated by *Proshumardites* and *Delepinoceras*.

In contrast to Europe, only one or two “zones” have been recognized in Arnsbergian equivalents in North Africa, Europe, Kazakhstan, Middle Asia, and China. Frequently ammonoid assemblages from this interval are lumped into the lower-resolution *Fayettevillea-Delepinoceras* Ammonoid Genozone (Ruzhencev and Bogoslovskaya, 1971a; Ramsbottom and Saunders, 1985), or, alternatively, the Upper *Eumorphoceras* (E_2) Ammonoid Genozone (Bisat, 1924; Kullmann and others, 1990), both of which are exactly equivalent to the entire Arnsbergian. Previous attempts to relate other ammonoid successions to the standard substage zonation have mostly been made by North American workers directly familiar with the European sections (for example, Saunders, 1973; Saunders and others, 1977). Such efforts are hindered by the many short-lived endemic species in the European system and inconsistent taxonomy elsewhere. However, in some cases, even when European index taxa are present, their significance has been ignored (for example, *Nuculoceras* in Ruzhencev and Bogoslovskaya, 1971a). Fortunately, *Cravenoceratoides*, *Nuculoceras*, and *Eumorphoceras* are widespread enough outside of Europe that at least some degree of substage, if not zone-for-zone, correlation can be made with most regions.

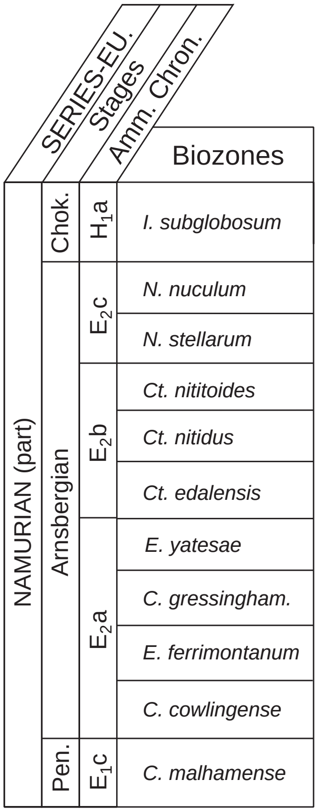


Figure 7. *Standard chronostratigraphic and high-resolution ammonoid-based biostratigraphic divisions of the western European Arnsbergian Stage and parts of adjacent stages. Modified from Riley (1987).*

Western United States

Background

The first comprehensive substage-level Chesterian ammonoid biozonation for the Great Basin region that recognized Arnsbergian equivalents was synthesized by Gordon (1970). This zonation was subsequently reproduced unchanged in Webster and others (1984), Gordon and Yochelson (1987), and Sadlick (1995). In it, three ammonoid biozones are recognized as early Namurian equivalents, which are, in ascending order, the *Paracravenoceras barnettense*, *Cravenoceras* (here referred to *Eosyngastrioceras*) *hesperium*, and *Richardsonites* (here referred to *Stenoglaphyrites*) *merriami* Biozones (figure 8). Gordon (1970) correlated the first biozone with the entire Pendleian stage (E_1), while the latter two were thought to represent the lower and middle Arnsbergian stage (E_2) respectively. The later part of the Arnsbergian was not zoned because of the rarity of ammonoids in that interval. Serious practical and nomenclatorial problems are inherent in this zonation and it is herein superceded for the following reasons.

1. The type lot of *Stenoglaphyrites merriami* (Youngquist) was collected from a horizon in the Duckwater Hills, Nevada, which I have determined is Pendleian (E_1) in age. Taxa associated with *S. merriami* at this locality include

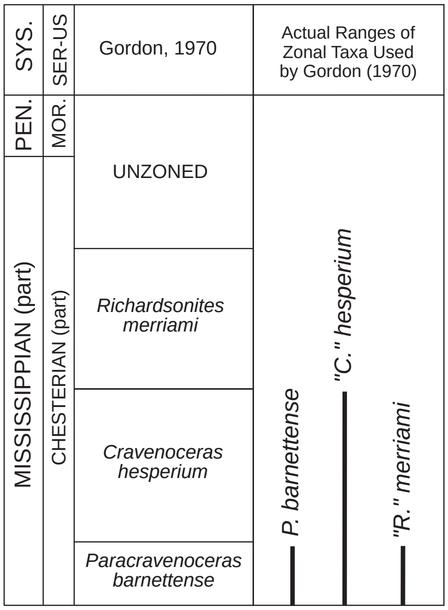


Figure 8. Comparison of the ammonoid zonation proposed in Gordon (1970) with the actual ranges of the zonal indices. Abbreviations are as follows: SYS, System; SER-US, United States Series; PEN, Pennsylvanian; MOR, Morrowan.

Eumorphoceras sp., *Paracravenoceras barnettense* (Plummer and Scott), *Eosyngastrioceras quadratum* n. sp., and *Syngastrioceras scotti* (Miller and Youngquist). *Stenoglaphyrites merriami* does not range into the Arnsbergian and, without exception, forms previously referred to *S. merriami* by Gordon (Gordon, 1964; Drewes, 1967; Gordon and Poole, 1968; Webster and others, 1984; Gordon and Yochelson, 1987) are actually misidentified specimens of *Stenoglaphyrites*, *Euroceras*, and *Richardsonites*. The use of *S. merriami* as a zonal index for the Arnsbergian is thus invalid, although it may be considered an auxiliary taxon for recognition of the *Paracravenoceras barnettense* Biozone because it ranges concurrently with the zonal index.

2. *Cravenoceras* (*Eosyngastrioceras* of this report) *hesperium* Miller and Furnish ranges down into the Pendleian, where it occurs with *Paracravenoceras barnettense*. Its range is not restricted to the Arnsbergian (figure 8).

3. The long stratigraphic ranges of both *Paracravenoceras barnettense* and *Eosyngastrioceras hesperium* preclude their use as high-resolution zone fossils.

A completely new substage-level biozonation is needed that is based on the ranges of characteristic and widespread, yet extremely short-lived species. Plots of the stratigraphic ranges of all known Great Basin Arnsbergian ammonoid species (figures 9 and 10) demonstrate that *Eumorphoceras* consistently provides the highest possible biostratigraphic resolution. *Eumorphoceras*, although typically uncommon, is usually found when large collections are made and is geographically widely distributed. Even more importantly, phylogenetic continuity can be recognized within the genus in the western United States, placing good constraints on the first appearances of most species. For these reasons, first appearances of species of *Eumorphoceras* are used to establish three of the five biozones proposed below.

Eumorphoceras paucinodum Biozone

The oldest Arnsbergian ammonoid biozone here recognized in the western United States is the *Eumorphoceras paucinodum* Biozone (figure 11). It is defined as the interval between the first appearance of the zonal namebearer and the first appearance of its descendent, *E. rotuliforme* Ruan. The reference section for the *E. paucinodum* Biozone is the Rest Spring Shale type section in the Cottonwood Mountains, Inyo County, California (figure 3, locality 3). In the measured section at locality 3, the *E. paucinodum* Biozone is represented by an 18-m interval that starts at the base of the Rest Spring Shale. Other ammonoid taxa associated with *E. paucinodum* include *Delepinoceras eothalassoide* Wagner-Gentis and many other forms of less biostratigraphic value such as *Arcanoceras*, *Eosyngastrioceras*, *Fayettevillea*, and *Syngastrioceras*.

The highest thin limestone beds (bioclastic grainstone turbidites) of the underlying Perdido Formation at the Rest Spring locality contain *Paracravenoceras barnettense* (Plummer and Scott), *Eosyngastrioceras* spp., *Platygoniatites americanus* Titus, and *Fayettevillea* sp. and lie within the upper portion of the Pendleian (E_1) *P. barnettense* Biozone of Gordon (1970). Because the first appearance of *Eosyngastrioceras hesperium* (Miller and Furnish) is actually in the late Pendleian, the *E. paucinodum* Biozone is equivalent to the middle portion of the *Eosyngastrioceras hesperium* Biozone of Gordon and Yochelson (1987).

Eumorphoceras rotuliforme Biozone

The *E. rotuliforme* Biozone is defined as the interval between the first appearance of *E. rotuliforme* Ruan and the first appearance of its descendant species, *E. girtyi* Elias (figure 11). Ammonoids of this zone, including *E. rotuliforme*, are widespread in the AFB, and the type locality of the long-ranging species *Eosyngastrioceras hesperium* (Miller and Furnish) is within it. At locality 3, the reference section for the *E. rotuliforme* Biozone, the zonal namebearer occurs in a six-m interval in the Rest Spring Shale starting at 18 m and ending at 24 m above the base of the measured section. Associated ammonoid taxa include many of the longer-ranging species also found in the underlying *E. paucinodum* Biozone, with *Stenoglaphyrites intermedius* n. sp. and *E. hesperium* being especially characteristic.

Eumorphoceras girtyi Biozone

This biozone is defined as the interval between the first appearance of the zonal namebearer and the first appearance of *Cravenoceratoides nititoides* (Bisat). The zonal index and its accompanying assemblage is the youngest commonly found in the Mississippian of the western United States, where it frequently occurs in the condensed portion of a major middle Arnsbergian transgressive systems tract (Loutit and others, 1988). The first appearances of two very important index genera, *Cravenoceratoides* and *Euroceras*, coincide with the base of this biozone, making it a key one for intercontinental correlation.

The Rest Spring Shale type section (a 70-m interval starting 26 m above the base of the Rest Spring Shale in the measured section) is designated as the reference for *Eumorphoceras girtyi* Biozone as the relationships of the lower and upper limits of the zone with adjacent zones are best displayed there. Supplemental sections to document additional phylogenetic relationships and stratigraphic ranges can be found at the North Syncline Ridge, Apex, Trough Springs Canyon, Foote Ranch partial, and west Antelope Summit localities.

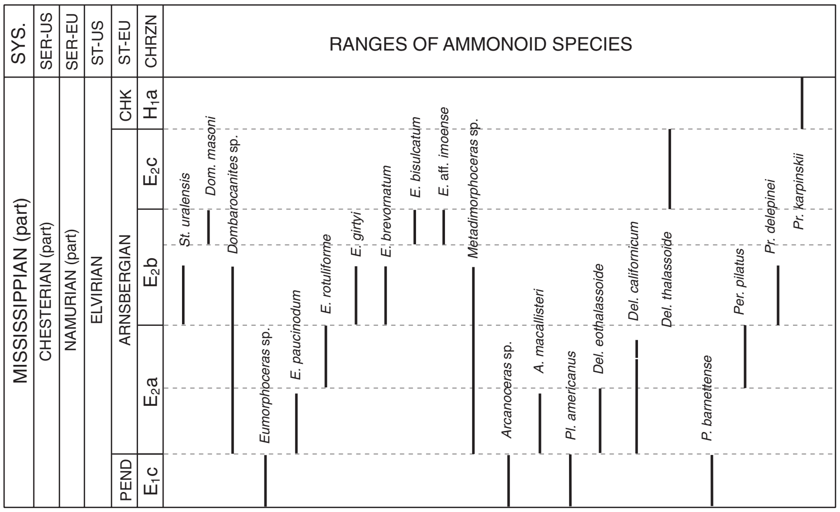


***Figure 9.** Composite species-level ammonoid range chart for late Pendleian through early Chokierian prolecanitacean, medlicottiacean, dimorphoceratacean, and goniatitacean ammonoid taxa in the AFB. Ranges are based on data in appendix A and unpublished sources. Abbreviations are as follows: SYS, System; SER-US, United States Series: SER-EU, European Series; ST-US, United States Stages; ST-EU, European Stages; CHRZN, Chronozone; CHK, Chokierian; PEND, Pendleian. Ammonoid generic abbreviations:* St., Stenopronorites; Dom., Dombarocanites; E., Eumorphoceras; A., Arcanoceras; Pl., Platygoniatites; Del., Delepinoceras; P., Paracravenoceras; Per., Pericleites; Pr., Proshumardites.

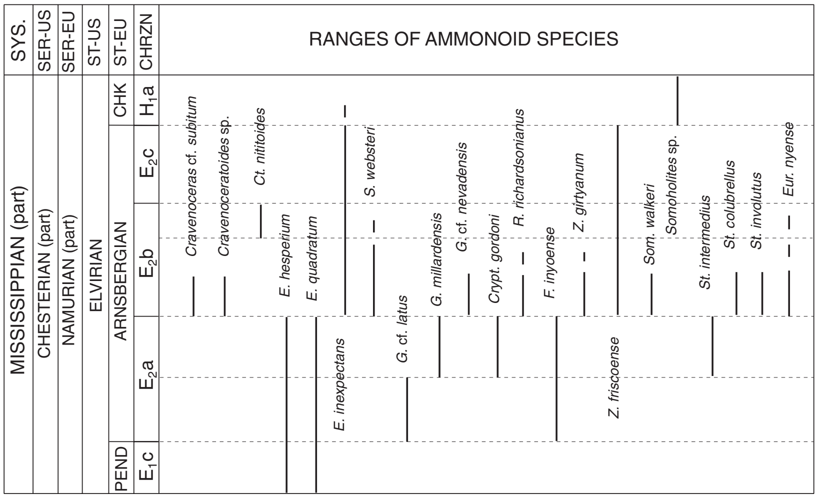


***Figure 10.** Composite species-level ammonoid range chart for late Pendleian through early Chokierian neoglyphioceratacean and gastrioceratacean ammonoid taxa in the AFB. Ranges based on data in appendix A and unpublished sources. Ammonoid generic abbreviations:* Ct., Cravenoceratoides; E., Eosyngastrioceras; S., Syngastrioceras; G., Glaphyrites; R., Richardsonites; F., Fayettevillea; Z., Zephyroceras; Som., Somoholites; St., Stenoglaphyrites; Eur., Euroceras. *Other abbreviations same as for figure 9.*

SYS.	SER-US	SER-EU	ST-US	ST-EU	CHRZN	AMMONOIDS This Paper	M.F.Z.	CONODONTS Poole & Sandberg (1991)	BRACHIOPODS T.W. Henry (unpublished data)	GASTROPODS Gordon & Yochelson (1987)
MISSISSIPPIAN (part)	CHESTERIAN (part)	NAMURIAN (part)	ELVIRIAN	CHK	H_1a	*I. subglobosum*	19	*R. primus* (=u. *R. muricatus*)	*Rugoclostus* sp. B	
				ARNSBERGIAN	E_2c	*D. thalassoide*		l. *R. muricatus*	*Rhipodomella nevadensis*	?
					E_2b	*Ct. nititoides*		*Adetognathus unicornis*		*G. binodosum*
						E. girtyi				?
					E_2a	*E. rotuliforme*				*G. quadrigatum*
						E. paucinodum		*Cavusgnathus naviculus*		
				PEND	E_1c	*Eumorph.* n. sp.				?

***Figure 11.** Correlation of proposed Arnsbergian ammonoid biozonation for the western United States with established biozonations for selected micro and macrofaunal taxa and the standard European reference. Foraminifera zonation (M.F.Z.) from data in Brenckle and others (1977) and Titus and others (1997). Generic abbreviations as follows:* Eumorph., E., Eumorphoceras; Ct., Cravenoceratoides; D., Delepinoceras; I., Isohomoceras; R., Rachistognathus; G., Glabrocingulum. *u., upper; l., lower; SYS, System; SER-US, United States Series; SER-EU, European Series; ST-US, United States Stages; ST-EU, European Stages; CHRZN, Chronozone; CHK, Chokierian; PEND, Pendleian.*

Cravenoceratoides nititoides Biozone

The *Cravenoceratoides nititoides* Biozone, which was originally defined in Europe (Yates, 1962), is based upon the total stratigraphic range of the nominate taxon. The zonal index has been collected from the lower portion of the Rest Spring Shale in the Cerro Gordo and Conglomerate Mesa areas of the southern Inyo Mountains, and the Rest Spring Shale type locality in the Death Valley region. At Rest Spring (figure 3, locality 3), the *C. nititoides* Biozone is in direct superposition over the *E. girtyi* Biozone, with its base 97 m above the base of the Rest Spring Shale in the measured section (appendix A). The upper limit of the *C. nititoides* Biozone cannot be identified at Rest Spring because of a lack of ammonoids higher in the section. Another key zonal index, *Eumorphoceras bisulcatum sensu stricto*, occurs sparingly in the *C. nititoides* assemblage at Cerro Gordo.

Delepinoceras thalassoide Biozone

This biozone is also based on the total stratigraphic range of the zonal index. The reference section is at the south end of Syncline Ridge, Nye County, Nevada (figure 3, locality 4). Unfortunately this locality has not yielded either *Eumorphoceras* or *Nuculoceras*. The most time-sensitive element contained in this assemblage is *Delepinoceras thalassoide* (Delepine) which occurs uncommonly, but through an extended stratigraphic interval. Probably the most significant relationship at the Syncline Ridge section is the occurrence of the important Chokierian index *Isohomoceras subglobosum* approximately one meter above the highest *D. thalassoide* in a conformable shale-mudstone sequence (Titus and others, 1997). Comparison of girtyoceratids found in the *C. nititoides* assemblage with those of the latest Arnsbergian *Delepinoceras thalassoide* Biozone also implies that the latter is younger even though the two cannot be seen in direct superposition. The *C. nititoides* assemblage at Cerro Gordo contains *Eumorphoceras bisulcatum* Girty, while midcontinent *Delepinoceras thalassoide* assemblages contain *E. richardsoni* McCaleb, Quinn and Furnish (plate 3, figures 26-28), the most advanced species of the genus known (McCaleb and others, 1964; Riley, 1987).

Global Correlations

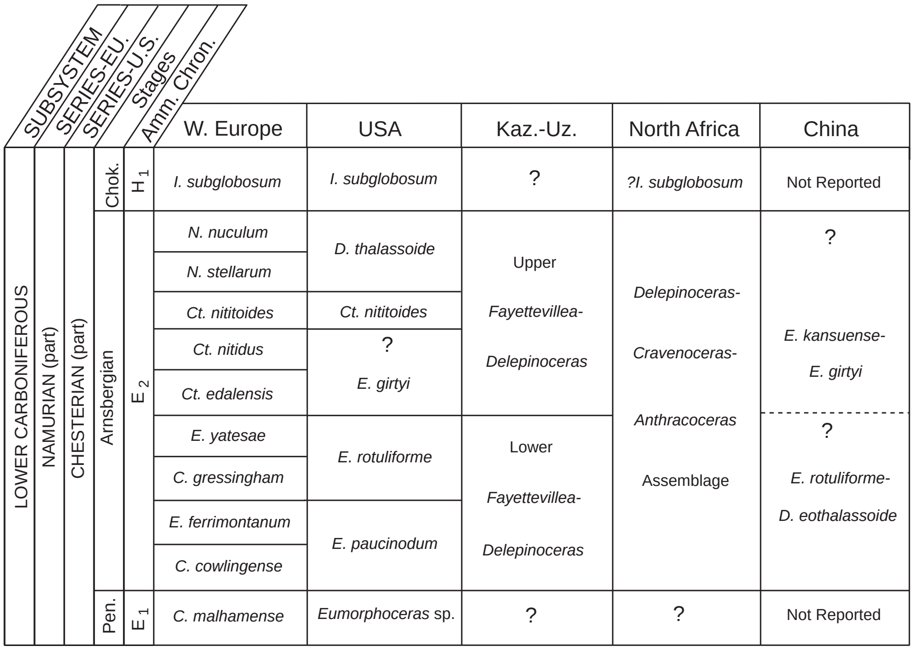
Eumorphoceras paucinodum Biozone

***Europe*:** The appearance of *E. paucinodum* in the basal portion of the Rest Spring Shale is the earliest known occurrence of robust, *E. bisulcatum*-type girtyoceratids with relatively broad, depressed whorl cross sections in juveniles. Ancestral species of *Eumorphoceras* possess compressed conch profiles similar to their ancestor, *Edmooreoceras plummeri* (Miller and Youngquist). Although no conspecific *Eumorphoceras* are found between the two regions, the same innovation is seen in the European section at the base of the Arnsbergian, where *E. grassingtonense* Dunham and Stubblefield appears. More important for correlation is the coincidental first appearance of *E. paucinodum* and *Delepinoceras eothalassoide* Wagner-Gentis. The latter, which is the earliest known *Delepinoceras*, marks the base of the Arnsbergian (Kullmann and others, 1990). Precise correlation of the upper limit of the *E. paucinodum* Biozone with the European standard is not possible. However, it almost certainly lies within the *Eumorphoceras ferrimontanum*-*E. erinense* interval (figure 12).

***North America*:** It is very likely that the *E. paucinodum* Biozone is represented in the lower portion of the Pitkin Formation of northern Arkansas. Poorly preserved specimens of *Eumorphoceras* recovered from the Lick Mountain locality of Manger and Quinn (1972), but higher in the section than the main ammonoid horizon, are tentatively identified here as *E. paucinodum* Gordon. In addition, a specimen illustrated by Girty (1909, plate 11, figure 16) from the Antlers quadrangle along Caney Creek, Oklahoma (one of the paratypes of *E. bisulcatum*), is referable to *E. paucinodum* (see taxonomic discussion of *E. paucinodum*), allowing the recognition of the biozone in the lower portion of the Sand Branch Member of the Caney Shale. Undescribed specimens from the Goddard Shale near its type section at Goddard Ranch, Oklahoma indicate that it can be recognized there also.

***Africa*:** No exact equivalents of this biozone can be recognized in Algerian sections based on available data. If present, it would lie somewhere in the lower portion of the Djenien Formation or the underlying Hid El Kef Formation (Lemosquet and others, 1985).

***Asia*:** Although *Eumorphoceras paucinodum* has been reported from the Arnsbergian of Kazakhstan (Ruzhencev and Bogoslovskaya, 1971a) this report is regarded as incorrect as these specimens are herein excluded from that taxon.



SUBSYSTEM	SERIES-EU.	SERIES-U.S.	Stages	Amm. Chron.	W. Europe	USA	Kaz.-Uz.	North Africa	China
LOWER CARBONIFEROUS	NAMURIAN (part)	CHESTERIAN (part)	Chok.	H_1	*I. subglobosum*	*I. subglobosum*	?	*?I. subglobosum*	Not Reported
			Arnsbergian	E_2	*N. nuculum*	*D. thalassoide*	Upper *Fayettevillea-* *Delepinoceras*	*Delepinoceras-* *Cravenoceras-* *Anthracoceras* Assemblage	? *E. kansuense-* *E. girtyi*
					N. stellarum				
					Ct. nititoides	*Ct. nititoides*			
					Ct. nitidus	? *E. girtyi*			
					Ct. edalensis				
					E. yatesae	*E. rotuliforme*	Lower *Fayettevillea-* *Delepinoceras*		? *E. rotuliforme-* *D. eothalassoide*
					C. gressingham				
					E. ferrimontanum	*E. paucinodum*			
					C. cowlingense				
			Pen.	E_1	*C. malhamense*	*Eumorphoceras* sp.	?	?	Not Reported

Figure 12. *Correlation of proposed Arnsbergian ammonoid biozonation for the Western United States with those established for other parts of the world. Abbreviations as follows: EU, Europe; Chok, Chokierian; Pen, Pendleian; Kaz, Kazakhstan; Uz, Uzbekistan. Ammonoid generic abbreviations:* C., Cravenoceras; E., Eumorphoceras; Ct., Cravenoceratoides; N., Nuculoceras; D., Delepinoceras; I., Isohomoceras. *Other zonations based on: (W. Europe) Riley and others (1994); (Kaz.-Uz.) Nikolaeva (1995); (North Africa) Lemosquet and others (1985); (China) Ruan (1981), Li and others (1987).*

As a result, no equivalents from middle Asia can be currently recognized. The part of the Gansu, China assemblage described by Ruan (1981) that contains *Delepinoceras eothalassoide* probably, in part, correlates with this biozone (figure 12), however there is no stratigraphic control on the specimens and the collections are obviously mixtures as *Neoglyphioceras* is reported as occurring together with *Eumorphoceras*.

Eumorphoceras rotuliforme Biozone

Europe: I correlate the *E. rotuliforme* Biozone with the upper part of the E_2a of western Europe (roughly the *Cravenoceras gressinghamense* and *E. yatesae* biozones) based mostly on its stratigraphic position below the first appearance of *Cravenoceratoides*, but above unquestioned early Arnsbergian strata. Comparison of the exact number of eustatic cycles present in both regions may help refine this further.

North America: A specimen illustrated by Miller and Youngquist (1948, plate 100, figures 15-17) indicates that the *E. rotuliforme* Biozone is present in the Barnett Shale, about 13 km southwest of Mason, Texas. Specimens tentatively identified herein as *Eosyngastrioceras hesperium* and reposited in the collections of Texas A & M University were collected from the type section of the Cieneguita Formation, west Texas, by C. L. Baker in the 1920s (illustrated in Miller, 1945, plate 50, figures 1-8). If the identifications are correct then the biozone may also be recognizable there. It is also present in the upper portion of the Pitkin Limestone near Leslie, Arkansas (= *E. bisulcatum* of McCaleb and others, 1964), where it occurs with *Stenoglaphyrites* sp., cf. *S. intermedius* n. sp. Locally, *E. rotuliforme* may range into the lower portion of the overlying *E. girtyi* Biozone (early middle Arnsbergian-E_2b).

***Africa*:** As with the previous biozone, no exact equivalents can be recognized in the Algerian succession. If present, it would probably lie in the lower Djenien Formation.

***Asia*:** The *E. rotuliforme* Biozone is present in southern Fergana (Pitinova, 1974) and southern China (Ruan, 1981) (figure 12) based on the presence of the zonal namebearer in assemblages from these regions (see discussion portion of taxonomic treatments of *Delepinoceras californicum* Gordon and *E. rotuliforme*), although the possibility exists that the species ranges into the lower part of the middle Arnsbergian. Elsewhere it cannot be recognized with certainty.

Eumorphoceras girtyi Biozone

***Europe*:** The first appearance of *Cravenoceratoides* in the southern AFB is at the base of the *E. girtyi* Biozone, and coincides with a major eustatic flooding event. A similar relationship exists at the type locality for *E. kullmanni* (referred to *E. girtyi* herein) in central Asia (Nikolaeva, 1997). On this basis the base is correlated with the base of the E_2b (*Cravenoceratoides edalensis* Biozone), which is commonly developed in European sections and also coincides with a major flooding event (Ramsbottom, 1981; Yates, 1962; Korejwo, 1969). Its upper limit is marked by the first appearance of *Cravenoceratoides nititoides* which means it extends through the *Cravenoceras holmesi* Biozone (Riley, 1987).

***North America*:** Outside of the Great Basin, the zonal namebearer occurs in the upper portion of the Barnett Shale at the type locality of *E. girtyi*, 24 km southeast of Llano, in central Texas, which has also yielded undescribed *Proshumardites* sp., and *Cravenoceras* sp. In Arkansas the *E. girtyi* Biozone has its equivalents in the lower portion of the Imo Formation (*Stenoglaphyrites involutus* Biozone). This is based on the presence of *Stenoglaphyrites involutus* (Gordon), *Eumorphoceras girtyi* Elias, and undescribed *Euroceras* in that part of the Imo (Gordon, 1965; Saunders, 1973). The lower shale portion of the Imo (upper Pitkin Shale of Gordon, 1965) has previously been assigned a middle Arnsbergian age based on conodonts (Mapes and Rexroad, 1986) and ammonoids (Saunders and others, 1977; Saunders and Ramsbottom, 1986), a position which is supported by this study. The *E. girtyi* Biozone is also probably represented in the Sand Branch Member of the Caney Shale, but Oklahoma specimens of the zonal index have not been illustrated in the literature. Specimens of *Eumorphoceras* from the type Cieneguita Formation of western Texas probably belong in *E. girtyi*, and thus correlate the interval they occur in with this biozone. The *Cravenoceratoides macrocephalum* (Frech) occurrence in Montana is also equivalent.

***Africa*:** Phylogenetic considerations (see taxonomic discussion of *Delepinoceras thalassoide*) constrain the range of the widespread "Tethyan" index taxon *Delepinoceras bressoni* Ruzhencev to the middle Arnsbergian, implying that at least the lower range of this species coincides with the *E. girtyi* Biozone (figure 12). If this is the case, then ammonoid assemblages in the middle Djenien Formation of Algeria are correlative.

***Asia*:** This biozone can be recognized with certainty in the southwest Darvaz region (see comments under *E. girtyi*). In addition, specimens referred to *E. bisulcatum* by Li and others (1987-plate 2, figures 1, 2) are herein referred to *E. girtyi* Elias, indicating that the Gansu assemblage partly illustrated by these authors, which also contains *Stenoglaphyrites involutus* Gordon and *Proshumardites delepinei* Schindewolf, can be referred to this zone. The presence of *Delepinoceras bressoni* in assemblages reported from Kazakhstan and other regions in central Asia (Ruzhencev and Bogoslovskaya, 1971a; Pitinova, 1974; Nikolaeva, 1995) indicates that equivalents are almost certainly widespread there also.

Cravenoceratoides nititoides Biozone

Europe: Occurrence of *C. nititoides* (Bisat) in the Rest Spring Shale assemblages allows direct recognition of the highest middle Arnsbergian (E_2b) ammonoid biozone of northwestern Europe. The zonal index has been documented from assemblages representing this biozone (based on the presence of nominate taxon) from Ireland (Yates, 1962), England (Bisat, 1932; Hudson, 1941) (figure 12), Poland (Korejwo, 1969) and the Czech Republic (Vasícek, 1983).

***North America*:** The occurrences of *E. bisulcatum* in the upper portion of the lower part of the Imo Formation (Gordon, 1965) and in the upper part of the Sand Branch Member of the Caney Shale are correlative with the *C. nititoides* Biozone as the California assemblages contain that same taxon. No other occurrences of either taxa are known from North America.

***Africa*:** No definitive taxa to correlate the *C. nititoides* assemblage with have been reported from Algeria. If present, it is probably confined to the top of the Djenien and possibly the overlying lowermost portion of the Tagnana

Formation (Lemousquet and others, 1985).

Asia**:** Pitinova (1974) reported the presence of the zonal index in assemblages from Fergana. No other assemblages from west or central Asia or China have yielded ammonoids diagnostic of this zone.

Delepinoceras thalassoide Biozone

Europe**:** Riley and others (1994) imply that *Nuculoceras* must be present to diagnose latest Arnsbergian strata. If this procedure is strictly followed it is not possible to conclusively prove the existence of *Nuculoceras* Biozone equivalents in North America. Irrespective, phylogenetic evidence and superpositional relationships given in Titus and others (1997) for the Syncline Ridge and Rest Spring localities show that either *Delepinoceras thalassoide* or *Eumorphoceras richardsoni* diagnose the latest Arnsbergian and thus represent *Nuculoceras* equivalents in North America. With this correlation established, equivalent *Nuculoceras* zone assemblages are widespread in Europe (Riley, 1987; Schmidt, 1934; Aisenverg and others, 1983). "Proto-Tethyan" assemblages in Spain containing *D. thalassoide* (Wagner-Gentis, 1963) also correlate with this interval.

North America**:** The presence of the zonal namebearer in the upper portion of the Imo Formation in Arkansas and the lower portion of the Rhoda Creek Formation of Oklahoma (Saunders, 1973) demonstrates the existence of correlative strata. No other ammonoid assemblages on the continent can be conclusively demonstrated to be this age.

Africa**:** The type region for the zonal namebearer is in the Bechar Basin area of Algeria (Furnish and others, 1964). Bearing in mind the caveats given in the taxonomic discussion of *D. thalassoide*, conodont data (presence of *Rachistognathus muricatus*) indicate that the zone should be confined to the lower Tagnana.

Asia**:** In all of Asia only the Sholak Say region of Kazakhstan has yielded ammonoids that can be positively correlated with this zone. This is based on the presence of *Nuculoceras kazakhstanicum* Ruzhencev and Bogoslovskaya (very close to *N. nuculum*), and not *Delepinoceras*. Claims by Nikoleaeva (1995) that co-occurrences of *Isohomoceras* and *Eumorphoceras* in middle Asia represent the top of this zone are disputed (Riley personal communication, 1997).

INTEGRATION OF AMMONOID BIOZONES WITH OTHER FAUNAL ZONATIONS

Calcareous Foraminifers

Foraminiferal-based zonations and correlations reported in the literature commonly use some variation of the numbered zonal scheme devised by B. Mamet (Sando and others, 1969). Although recent consensus of foraminiferal workers is that this scheme is fraught with problems (P. Brenckle and A. Derewetzky, personal communication, 1995-1996), I use it in the following discussion because it is still widely used by stratigraphers working in the Great Basin region.

Gordon and Yochelson (1987) and Webster and others (1984) regarded the Pendleian (E_1) and Mamet's Foraminiferal Zone (MFZ) 17 as approximate equivalents and correlated MFZ 18 with the lower Arnsbergian (E_2), with the remaining Arnsbergian assigned to MFZ 19. An alternative correlation was given by Brenckle and others (1977) who concluded that the base of MFZ 19 was well within the Pendleian. These conflicting correlations appear to be resolved by new data from the Willow Gap Limestone Member of the Chainman Shale in west-central Utah (figure 3, locality TWG), where, in a rare association, calcareous foraminifera and ammonoids both occur throughout the Willow Gap. The Willow Gap Limestone Member contains foraminifers of MFZ 18 from bottom to top (Gordon and Yochelson, 1987). However, contrary to Sadlick (1995), *Eosyngastrioceras hesperium* does not occur in the Willow Gap Limestone Member at locality TWG. All ammonoids in that unit represent older assemblages. Collections from the middle portion of the Willow Gap Limestone Member (93UTMI-20; 95UTMI-6) contain *Megapronorites* sp., *Epicanites* sp., *Girtyoceras* sp., *Edmooreoceras* sp., *Cousteauceras involutum* (Horn), *Paracravenoceras* sp., *Emstites kingi* (Hall and Whitfield), and *Emstites lineolatum* (Gordon). *Girtyoceras* and *Emstites lineolatum* are characteristic of the early Pendleian (E_1a-early E_1b) in the southern midcontinent (Meeks and others, 1997) and this portion of the Willow Gap Limestone Member is of similar age. Ammonoids collected from three meters below the top of the Willow Gap Limestone Member (95UTMI-7) include *Megapronorites* sp., *Epicanites* sp., *Fayettevillea* sp., and *Paracravenoceras* sp. This assemblage indicates that the top of the Willow Gap Limestone Member is no younger than late Pendleian and, based on preliminary faunal comparisons with the Jensen Wash section, it is probably middle Pendleian (E_1b).

Since the above-mentioned ammonoids collected from the top portion of the Willow Gap Member are unequivocally Pendleian, MFZ 18 must be Pendleian and not early Arnsbergian. These findings strongly corroborate those of Brenckle and others (1977) who demonstrated that the upper portion of the Fayetteville Shale, which contains eosigmoilinid foraminifers characteristic of MFZ 19, also yields *Tumulites varians*, a middle Pendleian index (Saunders and others, 1977; Meeks and others, 1997).

Study of a North American *Homoceras*-bearing mid-Carboniferous boundary section has demonstrated that the oldest possible placement of the *Eosigmoilina-Millerella* biozonal boundary (Mamet's 19-20 zonal boundary) is within the Chokierian (*Homoceras* Biozone) (Titus and others, 1997). The Arnsbergian thus lies entirely within the limits of MFZ 19 (figure 11). Higher resolution with foraminifers is presently not possible.

Conodonts

Several different conodont zonations for AFB Arnsbergian equivalents have been proposed (for a summary, see Webster, 1984; Tynan, 1980, Poole and Sandberg, 1991), but without exception, they are based on studies in shallow-water carbonate successions on the eastern margin of the basin. The zonation proposed by Poole and Sandberg (1991), which is widely accepted, is followed here with slight modifications (figure 11).

Analysis of conodonts recovered from ammonoid-bearing horizons indicates that established conodont biozones cannot be consistently recognized in basinal, ammonoid-bearing facies. *Cavusgnathus naviculus* (Hinde), for example, has not been identified in any of my processed samples. Other zonal indices such as *Rachistognathus muricatus* (Dunn) and *Adetognathus unicornis* (Rexroad and Burton), which are characteristic of shallow-water carbonate lithofacies (Davis and Webster, 1985), are rare. Arnsbergian ammonoid biofacies in the AFB are instead dominated by gnathodids such as *Gnathodus girtyi* Hass and *G. bilineatus* (Roundy), which are longer ranging and of less biostratigraphic value than the ammonoids. Key sections for integration of ammonoid and conodont zonations are found at Willow Gap, Arrow Canyon, and the Nevada Test Site (figure 3, locations 4, 5, 9, TWG).

At Willow Gap, the namebearer of the *Cavusgnathus naviculus* Conodont Biozone first appears in the upper part of the Willow Gap Limestone Member (Sandberg and others, 1980), an interval which Tynan (1980, p. 1291) identified as his Zone B. Ammonoid data demonstrates that the Willow Gap Limestone Member is Pendleian in age (see discussion above under foraminiferal biostratigraphy). Data from the U. S. midcontinent (Manger and Sutherland, 1992) indicate that the upper limit of the *C. naviculus* Conodont Biozone lies somewhere within the lower portion of the Arnsbergian (probably within the *E. rotuliforme* Ammonoid Biozone). The *C. naviculus* Biozone thus straddles the Pendleian-Arnsbergian boundary (figure 11).

At Arrow Canyon, the first occurrence of *Adetognathus unicornis* (Rexroad and Burton), which defines the base of the biozone of the same name (Zone C of Tynan, 1980), is within five meters below the widespread “marker conglomerate” horizon. (Baesemann and Lane, 1985). Since the “marker conglomerate” and equivalent horizons have yielded early middle Arnsbergian (E_2b) ammonoids at several localities including Arrow Canyon (Webster and Lane, 1967; this paper), the lower limit of the *A. unicornis* Biozone (figure 11) slightly predates the lower limit of the middle Arnsbergian (E_2b). Unfortunately, the first appearance of *A. unicornis* in the southern Cordillera is not based upon an evolutionary event but the introduction of a cryptogene, and the actual phylogenetic first appearance of *A. unicornis* could significantly predate current placement of the biozone’s lower limit. In eastern Nevada and western Utah, the *A. unicornis* Biozone extends upwards through most of the Jensen Siltstone Member and the upper portion of the Scotty Wash Formation.

The diagnostic conodont for the next overlying biozone, *Rachistognathus muricatus* Dunn, appears in the uppermost portion of the Indian Springs and Scotty Wash Formations (Dunn, 1970; Baesemann and Lane, 1985), and the upper portion of the Jensen Siltstone Member of the Chainman Shale (Tynan, 1980; Webster and others, 1984; Morrow and Webster, 1992). The first appearances of the zonal index are usually in association with longer-ranging gnathodids like *Gnathodus bilineatus* Roundy, and *Gnathodus girtyi simplex* Dunn, which is characteristic of the Lower *R. muricatus* Biozone (Baesemann and Lane, 1985). The appearance of *Adetognathus lautus* (Gunnel) marks the base of the overlying Upper *R. muricatus* Biozone (Baesemann and Lane, 1985).

Because of widespread development of ammonoid-excluding carbonate facies during the Upper and Lower *R. muricatus* Biozone intervals, the only place to directly relate ammonoid and conodont biozonal frameworks is in southern Nye County and eastern California, where “Antler” related clastic sedimentation persisted until well into the Early Pennsylvanian. Study of sequences in these regions, especially in the Nevada Test Site region of southern Nye County, Nevada, has demonstrated that the Lower *R. muricatus* Biozone is nearly equivalent to the latest Arnsbergian (E_2c) (figure 11), while the Upper *R. muricatus* Biozone (*R. primus* Biozone of Morrow and Webster, 1992) is equivalent to the early Chokierian stage (H_1a) (Titus and others, 1997).

Gastropods

Eight assemblages of Late Mississippian gastropods attributed biostratigraphic significance have been described in detail by Gordon and Yochelson (1987). The assemblages were treated in that report as adjuncts of the ammonoid zonation used by Gordon (1970) that has been abandoned in this report. For the same reasons the ammonoid zonation used in Gordon and Yochelson (1987) is rejected, additional study is required to confidently correlate the gastropod zonation proposed in that paper with the new ammonoid zonation introduced here. Preliminary correlation of the Arnsbergian (?) portion of the gastropod zonation with the new ammonoid zonation is shown in figure 11.

DISCUSSION AND CONCLUSIONS

Biodiversity and Paleobiogeography

The Arnsbergian ammonoid faunas of the AFB are much more diverse than previous documentation has revealed. Previously, 10 genera, representing 17 species, had been described or shown. A total of 20 genera and 35 species are here recognized in AFB Arnsbergian strata. Genera never before recognized from the southwestern United States include *Cryptotyloceras*, *Eosyngastrioceras*, *Fayettevillea*, *Metadimorphoceras*, *Pericleites*, *Proshumardites*, *Stenoglaphyrites*, and *Stenopronorites*. Their presence adds a more cosmopolitan aspect to the fauna and ally it with those of the “Proto-Tethyan” Realm (Titus, 1997b). Although obsolete or inaccurate systematics are partly responsible for the lowered diversity of previously described assemblages, five of the above genera were collected for the first time during this study.

The complete dominance of *Eosyngastrioceras* over the North American assemblages is remarkable, since I cannot recognize this taxon with certainty in assemblages from any other region, including the southern Urals. It is clearly a North American endemic that evolved from the widespread Pendleian genus *Emstites*. Its descendant, *Syngastrioceras*, is globally distributed in middle Arnsbergian through Atokan strata. *Cravenoceras sensu stricto* simultaneously evolved from *Emstites* in Eurasia and spread to North America, along with *Proshumardites* and *Cravenoceratoides*, at the same time (early middle Arnsbergian) *Syngastrioceras* went east. Interestingly, most of the Eurasian cravenoceratids did not survive the mid-Carboniferous extinction event. Causes of observed Arnsbergian ammonoid biogeographic patterns have been hypothesized by Titus (1997b) and were largely driven by global climate change.

Biostratigraphy

Ammonoids provide much higher biostratigraphic resolution for the Arnsbergian of the AFB than previously thought. In fact, they are unrivalled in this regard by any other faunal group including conodonts. A total of five ammonoid biozones are recognized herein for this period, the highest resolution outside of western Europe. In addition, the Chokierian (earliest Pennsylvanian) *Isohomoceras subglobosum* and *Homoceras* sp. biozones can be recognized in the southern portion of the study area (Titus and others, 1997). All of these biozones closely correlate with other ammonoid biozonations in other geographic regions, including the U. S. midcontinent, western and southern Europe, North Africa, eastern Europe, the southern Urals, Uzbekistan, and China. Data presented above also argue contrary to Poole and Sandberg (1991, p. 107), who state that ammonoids are useful only for correlation of deep-water basinal facies. Surprisingly, the majority of the ammonoids were collected from clastic facies interpreted herein as representing relatively shallow-water prodeltaic or muddy shelf settings. Notwithstanding, ammonoids *are* also useful for correlation of deeper-water foreland sequences where they may be one of the only biostratigraphically useful taxa present.

Revised ammonoid-foraminiferal correlations made in this paper conflict with those presented in the widely cited paper by Ross and Ross (1987), which follows Sando and others (1969), but are in general agreement with those of Brenckle and others (1977). The former authors equate the base of MFZ 19, following standard United States Geological Survey practice, with the base of the middle Arnsbergian. Lowering of the MFZ 19 boundary down into the Pendleian as the ammonoids indicate, also necessitates recorrelation of their sequences and reinterpretation of their timing of global eustatic events, which is beyond the scope of this paper.

SYSTEMATIC PALEONTOLOGY

Definition of Terms and Repository Information

Higher taxonomic classification is modified from Kullmann (1981) and Hewitt and others (1993). Morphometric and sutural terminology follows that of Ruzhencev and Bogoslovskaya (1971a). All measurements of umbilical diameter are U_{max} unless otherwise noted. The following abbreviations are used throughout: AFB = Antler foreland basin; D = total conch diameter; H = whorl height; W = whorl width; U = umbilical diameter; H_L = sutural lobe height; W_L = sutural lobe width.

Listings under the “material” headings are given as collection numbers (keyed to appendices A and B), with the number of specimens referable to the identified taxon from each locality given in parentheses. Where appropriate, individual specimens are referred to by their catalogue numbers.

All type, figured, measured, and referred specimens have been reposited in appropriate collections. Previously uncataloged specimens collected by Titus have been reposited in the University of Iowa collections and have the prefix SUI. All Titus specimens from field collections that are not type, measured or depicted, have been assigned to a single number, SUI 93693. Specimens in the invertebrate collections of the National Museum of Natural History (Smithsonian Institution) bear the catalogue prefix USNM. Additional specimens from the collections of the University of Iowa (Iowa City) also have the prefix SUI, while those from the British Museum (Natural History), London, U.K., are depicted by BMNH. Specimens from the British Geological Survey’s collections in Nottingham have the prefix BGSM. Specimens from the Paleontological Institute, Moscow, Russia are denoted as PIN. The type invertebrate collections formerly reposited with Stanford University, Palo Alto, California, have been accessioned to the California Academy of Sciences collections in San Francisco. These Stanford collections are identified with SU or CAS prefixes. Material from the collections of the University of California Los Angeles, which is now reposited in the Los Angeles County Museum, has the prefix UCLA.

Subclass AMMONOIDEA Zittel, 1884
Order PROLECANITIDA Miller and Furnish, 1954
Suborder PROLECANITINA Miller and Furnish, 1954
Superfamily PROLECANITACEA Hyatt, 1884
Family PROLECANITIDAE Hyatt, 1884
Genus *DOMBAROCANITES* Ruzhencev, 1949
Dombarocanites masoni Gordon, 1964
Figure 13

Dombarocanites masoni Gordon, 1964, p. A21, text figure 10a, plate 4, figures 4-6, 14.

Holotype. SU 9168 (paratype: SU 9169); Rest Spring Shale, Cerro Gordo, California.

Diagnosis. Species with swollen, incipiently trifid ventral lobe.

Description. See Gordon (1964).

Comparisons. As indicated previously, *D. masoni* is unique in its possession of a swollen ventral lobe. All other species of the genus can be differentiated from *D. masoni* by their less advanced ventral lobes.

Comments. The species may be the most advanced for the genus.

Distribution. Late middle Arnsbergian portion of the Rest Spring Shale, Cerro Gordo, California (*Cravenoceratoides nititoides* Biozone).

Material. 89CAIN-5 (1).

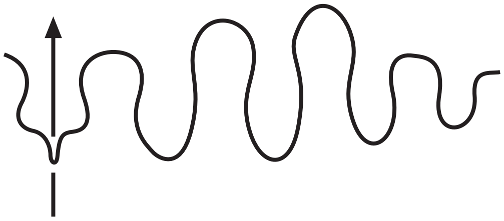


Figure 13. *Suture diagram (x6) for* Dombarocanites masoni *(holotype, SU 9168). After Gordon (1964).*

Dombarocanites sp. indet.

Prolecanites (*Rhipaecanites*)? sp., Gordon, 1964, p. A21, text figure 10d, plate 4, figures 15-17.

Description. For a description of the Rest Spring Shale specimen, see Gordon (1964). The Foote Ranch specimen, which is broken in half, preserves parts of the first five volutions. Conch form ophioconic (D = 7.5 mm, H = 2.0 mm, and W= 2.0 mm, U not known). Determinable proportions of this specimen are: W/D = 0.27 and W/H = 1.10. Ventral part of external suture visible at end of penultimate volution. Ventral lobe somewhat funnel shaped, wider, and roughly parallel-sided adorally, then narrowing rather suddenly and extending adapically to a narrow tip. First lateral saddle well rounded. Lateral lobes are preserved but are not all visible.

Comments. The Rest Spring Shale specimen (USNM 120624) was originally assigned to *Prolecanites* by Gordon (1964) based on the assumption that the first lateral lobe of *Dombarocanites* is longer, and extends farther posteriorly than on the Rest Spring specimen. Sutural comparisons between the specimen in question and a growth series illustrated by Ruzhencev and Bogoslovskaya (1971a) for *Dombarocanites* clearly show that at similar diameters (about 5 mm), the sutures are nearly identical. Since *Prolecanites* is not known from the Arnsbergian, USNM 120624 is here referred to *Dombarocanites*. The Foote Ranch specimen is only slightly larger than the Rest Spring specimen. Its suture is nearly identical to that of the Rest Spring specimen, and it is likewise referred to *Dombarocanites*. Since neither specimen is large enough to exhibit adult characteristics, they cannot be assigned to any species with certainty.

Material. 15783-PC (1-[USNM 120624]); 15370-PC (1-[USNM 414814]).

Superfamily MEDLICOTTIACEAE Karpinsky, 1889
Family PRONORITIDAE Frech, 1901
Genus *STENOPRONORITES* Schindewolf, 1934
Stenopronorites sp., cf. *S. uralensis* (Karpinsky, 1889)
Plate 1, figures 1-5; figure 14

Pronorites sp., Webster and Lane, 1967, p. 517, figures 3b, 3c, p. 518, figures 4a, 4b, 4e, 4h.

Description. Shell subplatyconic (maximum D = 30-35 mm), whorls completely involute, and umbilicus of average to moderately narrow width [U/D around 0.35]. Umbilical and ventrolateral shoulders sub-rounded. Whorls in specimens where D < 8 mm, rounded to oval in cross section. At larger diameters, whorls sub-rectangular. At D > 35 mm, conch becomes platyconic and umbilicus is narrow (U/D = 0.25-0.30 mm). Mature conchs smooth, but some individuals smaller than D = 15 mm may display 10-15 very shallow transverse annulations per whorl, evenly developed across flanks and venter. Annulations fade on flanks of larger shells, transforming to subtle fluting on ventrolateral shoulder region.

Mature suture [formula: $(V_2V_1V_2)$ (U_1U_1) $U^1U^2U^3U^5U^6$: U^4ID] possesses narrow trifid ventral lobe that is constricted at base and joined to sinuous series of four to five umbilical lobes located on flanks. Lobes on flanks attenuate and become asymmetrically lanceolate and pointed through ontogeny.

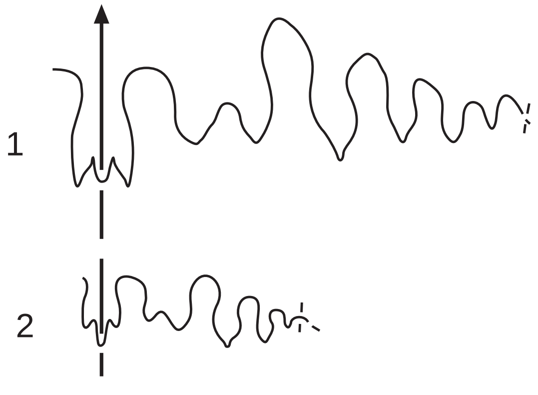


Figure 14. *Suture diagrams for* Stenopronorites *sp., cf.* S. uralensis *(Karpinsky); 1 (SUI 93471) at 25 mm D (x4.3); 2 (SUI 93469) at 12 mm D (x4.3). Distortion in suture caused by tectonic shearing of specimens.*

Comments. This AFB species has more-developed lateral lobes than *Pronorites* and can be excluded from that genus. Sutures illustrated for specimens assigned to *S. uralensis* by both Ruzhencev and Bogoslovskaya (1978) and Popov (1975) show 18 lobes at diameters of around 20-25 mm. However, the holotype of *S. uralensis* (based on Librovitch, 1941, p. 141, text figure 20) shows an external suture with 15 lobes at an estimated D of about 25 mm. Assuming there are nine internal lobes, this would give *S. uralensis* a total of 24 lobes at a relatively small diameter. A suture illustrated for a specimen assigned to *S. uralensis* by Ruan (1981, text figure 11a) also possesses 24 lobes at D = 21.2 mm.

The Apex specimens possess a nearly symmetrically divided first lateral lobe and thus can be unequivocally referred to *Stenopronorites*. Unfortunately, a mature suture (D = 35-45 mm) is not preserved. Although the Apex forms are probably conspecific with Ural specimens referred to *S. uralensis* by Ruzhencev and Bogoslovskaya (1978), and Popov (1975), the sutures of these forms are slightly less advanced (less lateral lobes) than that of the holotype. The Apex and Ural forms may represent a new species, but thorough reevaluation of the original types of *S. uralensis* (Karpinsky), *S. ferganensis* (Rauser-Tschernoussova), and *S. leonensis* (Kullmann), beyond the scope of this paper, would be required to resolve this assignment.

Distribution. Known in North America only from the Apex ammonoid lens, which is middle Arnsbergian (E_2b) age (*Eumorphoceras girtyi* Biozone). Elsewhere *S. uralensis* has been reported from mid-Arnsbergian (late Serpukhovian) through Yeadonian (middle Bashkirian) strata throughout Asia.

Material. 93NVCL-1 (1); 94NVCL-3 (8).

Order GONIATITIDA Hyatt, 1884
Suborder GONIATITINA Hyatt, 1884
Superfamily DIMORPHOCERATACEAE Hyatt, 1884
Family DIMORPHOCERATIDAE Hyatt, 1884
Subfamily GLYPHIOLOBINAE Ruzhencev and Bogoslovskaya, 1969
Genus *METADIMORPHOCERAS* Moore, 1958
Metadimorphoceras sp. indet.
Plate 4, figure 1

Description. 17 specimens, from 6 widespread localities, all immature, ranging from 2.8 to 6 mm diameter. Conch subdiscoconic with completely involute whorls, very narrow to closed umbilici, and gently convex venters and sides. Umbilical areas appear as a dimple, or shallow depression. In all cases conchs appear smooth.

Sutures of more advanced specimens show notching by a shallow saddle on each prong of ventral and first lateral lobes. Notch of first lateral lobe near, but not quite at tip of lobe.

Comments. After examining every available British type, Manger (1988) concluded that all early Namurian non-sulcate glyphiolobins are referable to *Metadimorphoceras* or *Currieoceras*. The sutures of the largest Antler foreland basin (AFB) glyphiolobins show clear asymmetry in the lateral lobe's subdivision. Based on this observation, all glyphiolobin specimens from the Arnsbergian of the AFB are referred to *Metadimorphoceras*. No specimen displays terminal suture patterns, and thus is diagnostic at the species level.

Distribution. *Metadimorphoceras* has been recovered from early and middle Arnsbergian strata at several widespread localities in California, Nevada, and Utah (*Eumorphoceras paucinodum-E. girtyi* biozones). The genus is cosmopolitan and long ranging (Manger, 1988).

Material. 15370-PC (2); 20444-PC (2); 25260-PC (4); 92NVLI-2 (1); 93CAIN-2b (2); 95NVWP-22a (6).

Family GIRTYOCERATIDAE Wedekind, 1918
Genus *EUMORPHOCERAS* Girty, 1909
Eumorphoceras paucinodum Gordon, 1964
Plate 1, figures 6-23; figure 15

Eumorphoceras paucinodum Gordon, 1964, plate 2, figures 7-9, text figure 7.

Eumorphoceras bisulcatum Girty, 1909, plate 11, figures 16, 16a, 16b; Plummer and Scott, 1937, p. 175, text figure 37; Shimer and Shrock, 1944, plate 233, figures 16-18.

Eumorphoceras girtyi Elias, 1956, plate 6, figure 7.

Holotype. SU 9163.

Diagnosis. Species with compressed conchs and prominent ribs (around 20-22 per whorl) up to diameters of approximately 6-8 mm. Larger conchs (9-20 mm diameter) distinguished by their compressed outline and sparse nodes on the umbilical shoulder. Shells larger than 30 mm cannot currently be differentiated from similar species.

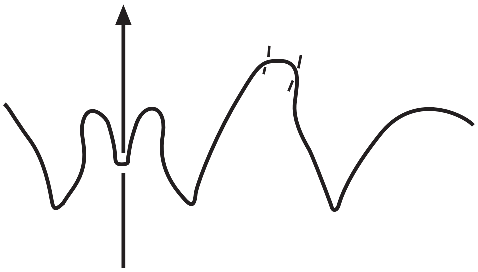


Figure 15. *Suture diagram for* Eumorphoceras paucinodum *Gordon (SUI 93473) at 25 mm D (x3).*

Description. Small conchs (D about 10 mm) subdiscoconic, very to completely involute, with average umbilical widths. At this stage, intrasulcate region is narrow and arched in a shallow U-shape. Umbilical shoulder subangular and lacking raised rim. Large conchs (D > 35 mm) oxyconic with sub-angular venter, completely involute whorls, and a very narrow umbilicus.

Prominent ornament on specimens where D < 15 mm consists of geniculate ribs on flanks (20-22 per whorl) and two ventrolateral grooves. Ribs on specimens whose D is < 8 mm are prominent and canted prosiradiate. At D > 8 mm, ribs generally radial along flanks above umbilical shoulder. Curve in ribs is rounded, not angular. At D > 12 mm, rib relief begins to fade progressively from spiral groove towards umbilicus. At D = 15-17 mm, ribs reduced to nodes on umbilical shoulder. Ventrolateral grooves faintly persist at least to D = 50 mm. Ventral sulcus usually found on internal molds where D < 15 mm. Constrictions absent at all ontogenetic stages.

Suture, which is typical of genus, possesses wide ventral lobe divided into two wide, triangular prongs. First lateral saddle deep and V-shaped with rounded tip. First lateral lobe asymmetric, bluntly pointed, and attenuate.

Comparisons. *Eumorphoceras paucinodum* is closest overall to *E. transuralense* Ruzhencev and Bogoslovskaya (1971a). Both species have about 10-11 ribs per half whorl at a D = 10 mm, relatively compressed whorl sections, and a ventral groove on the internal mold. *Eumorphoceras transuralense* can be differentiated from *E. paucinodum* because the former still shows visible ribs at D = 15 mm. *Eumorphoceras imoense* Saunders, *E. beta* Riley, *E. tumulosum* Ruzhencev and Bogoslovskaya, *E. ferrimontanum* Yates, *E. brevornatum* n. sp., and *E. leitrimense* Yates are also similar to *E. paucinodum*. All of these forms exhibit an early loss of ribs that results in nodes on the umbilical shoulder by D = 10-12 mm. *Eumorphoceras imoense*, *E. brevornatum* n. sp., and *E. beta* are distinguished by their finer, thread-like early ribs (lost after D = 8 mm) and wider whorl cross sections. *Eumorphoceras tumulosum* has a wider whorl section (W/D at 11 mm D = 0.65 versus 0.5) and possesses constrictions. The species *E. leitrimense* (described from crushed material) also possesses constrictions. *Eumorphoceras ferrimontanum* has a much higher rib count than *E. paucinodum* (at least 30 per whorl). The ribs in all other species of *Eumorphoceras* are either more numerous or persist to greater diameters.

Comments. Kazakhstan specimens illustrated as *E. paucinodum* by Ruzhencev and Bogoslovskaya (1971a, plate 8, figures 2-3, text figure 28a) are not typical for the species. The whorl profiles of these forms are wider (W/D= 0.47 at 16.7 mm D versus 0.39 at 17 mm D for topotype) and on this basis they are excluded from *E. paucinodum*. The Ural species is probably a new late-early or early-mid Arnsbergian taxon transitional between *E. paucinodum* and forms such as *E. leitrimense* and *E. tumulosum*. Precise taxonomic placement of the Ural form awaits further study.

Distribution. Early Arnsbergian strata, southern Antler foreland basin, and equivalent strata in the Caney Shale, in the vicinity of Antlers, Oklahoma (*E. paucinodum* Biozone). Undescribed specimens are also present in collections from the Goddard Shale, near its type locality at Goddard Ranch, southern Arbuckle Mountains, Oklahoma.

Material. 93CAIN-2a (3); 93CAIN-2c (3); 93CAIN-2d (2); 89NVLI-17 (2); 89NVLI-18 (1).

Eumorphoceras rotuliforme Ruan, 1981
Plate 2, figures 4-10, 12-16; figure 16

Eumorphoceras bisulcatum Girty, 1909. Miller and Youngquist, 1948, plate 100, figures 15-17; Cloud and Barnes, 1948, plate 44, figures 33-35; Miller, Furnish, and Schindewolf, 1957, p. L59, figures 75A-C (not 75D); McCaleb, Quinn, and Furnish, 1964 [part], plate 1, figures 1,2, plate 2, figures 4, 5, p. 14, text figure 3B, p. 21, text figures 4A-C; Ruzhencev and Bogoslovskaya, 1971a, plate 7, figure 9, p. 183, text figure 27b; Saunders, Manger, and Gordon, 1977, plate 2, figures 4, 5.

Eumorphoceras (*Eumorphoceras*) aff. *bisulcatum* Girty. Pitinova, 1974, plate 3, figure 4.

Eumorphoceras rotuliforme Ruan, 1981, p. 189, text figure 35, plate 5, figures 21-22; Yang and others, 1983, plate 13, figures 6-7.

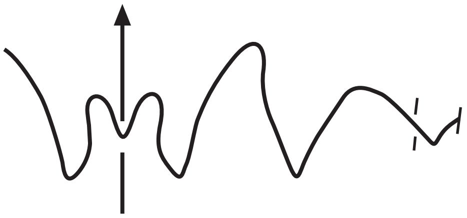


Figure 16. *Suture diagram for* Eumorphoceras rotuliforme *Ruan (hypotype-SUI 11523) at 33 mm D (x1.6). From McCaleb and others (1964) .*

Holotype. Nanjing Institute of Geology specimen 48830.

Diagnosis. Species with a moderate number of regularly shaped, high relief, sickle-shaped ribs (approximately 22-26 per whorl), a broad intrasulcate ventral region in juvenile shells, and an average width umbilical diameter in shells less than 10-15 mm in diameter.

Description. Small individuals (D < 12 mm) pachyconic and very involute, with average umbilical width. Venters broadly rounded. At intermediate diameters conch is subdiscoconic. Large specimens oxyconic by 50-60 mm D. Oxyconic phragmacones whose D exceeds 120 mm known from Arkansas. Largest Antler foreland basin specimen (D at least 80 mm) is ventral fragment of phragmacone.

Ornament in specimens where D < 15 mm consists of 24-26 regular, well-defined ribs. Ribs originate on umbilical shoulder, are initially radial to slightly prosiradiate, and extend slightly over rounded umbilical shoulder. Ribs curve smoothly (non-angular) into lingular groove on ventrolateral region. At D > 15-20 mm, ribs reduced to small nodes on flanks, ultimately disappearing altogether. Subsidiary lingular groove not present. Constrictions absent at all diameters. Ventral groove uncommonly developed on internal molds where D < 10-12 mm.

At D > 15-20 mm, suture possesses wide ventral lobe deeply divided by bilobed medial saddle. Ventral prongs attenuate, sharply pointed, and swollen in appearance. First lateral saddle V-shaped, slightly asymmetric. First lateral lobe also V-shaped and distinctly asymmetric. Second lateral lobe curves broadly to umbilical margin. Internal suture not observed.

Comparisons. *Eumorphoceras rotuliforme* is closest to the early Arnsbergian species *E. grassingtonense* Dunham and Stubblefield (plate 2, figures 17, 18). Both species possess broad intrasulcate ventral regions and rib counts of around 24 per whorl at comparable diameters. It can be differentiated from *E. grassingtonense* by its lack of constrictions.

Eumorphoceras rotuliforme is also close to *E. paucinodum* Gordon when specimens of diameters of less than 12 mm are compared. The latter possess somewhat weaker ribs, a slightly lower rib count (20-22 per whorl), a narrower intersulcate region and, in general, has a more compressed shell and intersulcate ventral region. *Eumorphoceras girtyi* Elias is also very close to *E. rotuliforme*, but has slightly higher average rib counts and rib persistence. They can also be differentiated on the basis of the former species' narrower intrasulcate ventral region at diameters of less than 10 mm. *Eumorphoceras transuralense* Ruzhencev and Bogoslovskaya can be distinguished from *E. rotuliforme* by its narrower (H/W ratios 0.42 compared with 0.53 for *E. rotuliforme*) conch and more weakly developed ribs. *Eumorphoceras imoense* Saunders, has similar conch proportions and possesses a comparably wide intrasulcate region, but in the early stages of that species, the ribs are more sinuous and much less pronounced. In addition, the ribs of *E. imoense* lose prominence at much earlier diameters compared to *E. rotuliforme*. All other species can be distinguished either by their higher rib counts (for instance, *E. erinense* Yates, *E. ferrimontanum* Yates, *E. rostratum* Yates, *E. richardsoni* McCaleb, Quinn and Furnish, *E. varicatum* Schmidt and *E. chungweiense* Liang) or earlier loss of ribs on the flanks (as in *E. leitrimense* Yates). In addition, the European species *E. ferrimontanum* and *E. erinense* have greater U/D ratios than any of their early or middle Arnsbergian counterparts in North America.

Comments. Ruan (1981) erected *Eumorphoceras rotuliforme* for a single specimen found associated with an early Arnsbergian assemblage that includes *Delepinoceras eothalassoide* Wagner-Gentis, and *Pericleites pilatus* Ruan. Very similar assemblages occur in the study area and essentially no differences can be detected between the *Eumorphoceras* of these two widely separated regions.

Eumorphoceras rotuliforme as here interpreted also includes forms that have previously been identified as *E. bisulcatum* Girty (McCaleb and others, 1964; Saunders and others, 1977; Ruzhencev and Bogoslovskaya, 1971a) from a locality near Leslie, Arkansas. The Leslie specimens, which are from the upper portion of the Pitkin Limestone, have been compared directly to the holotype of *E. bisulcatum* for this study. The low rib counts (about 24 per whorl), robust whorl sections, and broad venters displayed by the smaller Leslie specimens (D < 15 mm) are diagnostic of *E. rotuliforme*, not *E. bisulcatum*.

A fauna reported by Pitinova (1974) from 11 m of thin-bedded argillaceous limestones along the Aravan River in southern Fergana is reported to contain the following species: *Dombarocanites chancharensis* Ruzhencev, *Epicantites aktubensis* Ruzhencev, *Paradimorphoceras* sp., *Eumorphoceras* sp. aff. *E. bisulcatum* Girty, *Delepinoceras bressoni* Ruzhencev, and *Pericleites uralicus* Librovitch. The *Eumorphoceras* of this report possesses only 6-7 ribs per quarter whorl, has a broad ventral region, and has an umbilical to diameter ratio of 0.2 at D = 20 mm, all of which exclude it from all named species except *E. rotuliforme*. The specimens of *D. bressoni* were not illustrated and might actually be *D. californicum* Gordon, which would be expected in the *E. rotuliforme* Biozone. Alternatively, the possibility exists that *E. rotuliforme* ranges slightly into the early middle Arnsbergian.

Distribution. *Eumorphoceras rotuliforme* occurs in early Arnsbergian (E_2a) strata of the western and south-central United States (*E. rotuliforme* Biozone), China, and central Asia. Locally it may range up into the lower part of the middle Arnsbergian.

Material. 88NVCL-1 (1); 89NVCL-5 (1); ; 93CAIN-5 (5); 93NVLI-9 (3); 93NVWP-11 (2); 93UTMI-13b (6); 94NVLI-10 (4).

Eumorphoceras girtyi Elias, 1956
Plate 2, figures 1-3, 19-35; figure 17

Eumorphoceras girtyi Elias, 1956, p. 130 [part].

Eumorphoceras bisulcatum Girty. Miller and Youngquist, 1948, text figure 2B, plate 100, figures 9-14; Youngquist, 1949a, plate 58, figures 4, 5; Miller, Furnish, and Schindewolf, 1957, figure 75D; McCaleb

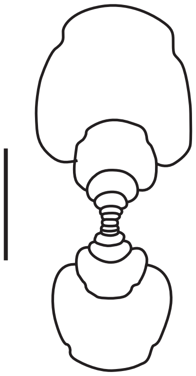


Figure 17. Cross-sectional diagram for Eumorphoceras girtyi *Elias (SUI 93515). Bar scale, 5 mm.*

and others, 1964 [part], ?plate 3, figure 2; Li and others, 1987, plate 2, figures 1-2.

Eumorphoceras kullmanni Nikolaeva, 1997, p. 230, figures, 3A, 5.1.

?*Eumorphoceras* cf. *E. bisulcatum erinense* Yates. Saunders, 1973, plate 6, figure 1.

Eumorphoceras aff. *E. bisulcatum* Girty. Gordon and Poole, 1968, plate 1, figures 18, 22, 23.

Type. USNM 112989; upper part of Barnett Shale, about 24 km southeast of Llano, Texas.

Diagnosis. Species with 24-28 ribs per whorl, a moderately compressed whorl section and, at diameters of 5-10 mm, a moderately narrow intrasulcate ventral region.

Description. At D < 8 mm, conch pachyconic, moderately involute and umbilicus is of average width. Venter distinctly arcuate; umbilical shoulder rounded. At D = 12 mm, the diameter of largest intact specimens, shell is subdiscoconic, completely involute, and has average width umbilicus. Large specimens (D > 40-50 mm) are oxyconic.

At D = 4-10 mm, ornament consists of regularly spaced, high-relief ribs, and lingular grooves. Ribs originate on umbilical shoulder and are initially radial or slightly prosiradiate. Ribs bend smoothly (not angular) into lingular groove and display occasional bifurcation. Constrictions (one or two per whorl) uncommonly developed at D around 7 mm. At D > 12 mm, ribs become more irregular in distribution and merge more frequently, giving staggered appearance to their origin on umbilical shoulder. Ribs generally still prominent at D = 12-15 mm. Lingular groove usually develops second subsidiary groove on ventral side at about D = 10-12 mm. Subsidiary groove persists to at least 15-17 mm D. Suture, which is typical for the genus, only observed on juvenile specimens.

Comparisons. This species is very similar to *Eumorphoceras rotuliforme* Ruan, but is distinguished by the latter's broader whorl cross-section. *Eumorphoceras paucinodum* Gordon and *E. transuralense* Ruzhencev and Bogoslovskaya are also similar in their compressed whorl sections and general ornamental features. The ribs of *E. paucinodum* are lost at earlier diameters and are less numerous, even though both forms have relatively compressed whorls. *Eumorphoceras transuralense* has a slightly more compressed conch (W/D = 0.42 at D = 17 mm). Both *E. transuralense* and *E. paucinodum* also have lower rib counts (20-22 versus 24-28). *Eumorphoceras chungweiense* (Liang) is fairly close to the species under present consideration. The Chinese taxon yields higher rib counts (30+) and has a slightly higher U/D ratio than *E. girtyi*.

Eumorphoceras leitrimense Yates, *E. imoense* Saunders, and *E. beta* Riley, can be differentiated by their early loss of ribs. *Eumorphoceras grassingtonense* Dunham and Stubblefield has a similar rib count, but possesses a wider whorl profile and much stronger constrictions. Other species, including *E. varicatum* Schmidt, an excellent example of which was illustrated by Lemosquet and others (1985, identified as *E.* cf. *bisulcatum* Girty, plate 7, figure 4), *E. erinense* Yates, *E. ferrimontanum* Yates, *E. richardsoni* McCaleb and others, and *E. rostratum* Yates, have higher rib/whorl counts (35-40 versus 26).

Comments. Elias (1956) proposed the name *Eumorphoceras girtyi* for *Eumorphoceras* with rounded venters and lower rib counts than *E. bisulcatum*, selecting a specimen from the Barnett Formation identified by Miller and Youngquist (1948 plate 100, figures 13, 14) as *E. bisulcatum*, as the type. This species is common and widespread in the Great Basin Region. Crushed specimens of *Eumorphoceras* (tentatively referred to this species) occur in the basal portion of the Imo Formation at Peyton Creek (identified as *Eumorphoceras* sp., cf. *E. bisulcatum erinense* Yates in Saunders, 1973, plate 6, figures 1-2). The stratigraphic occurrence and ornament of these specimens, associated with crushed *Stenoglaphyrites involutus* (Gordon), are a close match to *E. girtyi*, however these Imo specimens seem to have slightly higher relief ribs. Identification of the Imo specimens will remain equivocal without solid material. Specimens from the Cieneguita Formation of west Texas, referred to *E. bisulcatum* by McCaleb and others (1964), probably belong in this species, but diagnostic juveniles have never been described or illustrated.

Eumorphoceras kullmanni Nikolaeva, 1997 is very close to *E. girtyi*, a taxon with which it was not compared in the original description. The two forms are so close, in fact, that the present author cannot find any basis for differentiation and has synonymized them. It is also noted here that Nikolaeva's (1997, p. 231) original comparison of *E. kullmanni* with *E. paucinodum* is not valid as it was based on material from Kazakhstan erroneously referred to the latter species by Ruzhencev and Bogoslovskaya (1971a) and not topotype material.

A specimen identified as *E. bisulcatum* Girty by Li and others (1987, plate 2, figures 1, 2) possesses too few ribs to be either that species or *E. chungweiense* (Liang). The narrow intrasulcate region of this specimen suggests *E. girtyi* to which it transferred herein. No basis seems to exist for separating *Eumorphoceras kansuense* Liang from *E. chungweiense* (Liang), especially as the morphometrics, rib counts, and intrasulcate areas are identical at similar diameters. In addition, Liang has never published a comparison of the two forms. Until additional criteria are established for distinguishing them, the former must be regarded as the junior synonym of the latter.

Distribution. Early mid-Arnsbergian strata of the western United States, Tajikistan, and China (*E. girtyi* Biozone). Undescribed specimens from the lower portion of the Manning Canyon Shale in Provo Canyon, Utah (USGS collections 17220-PC; 17222-PC; 17225-PC) are also referable to this species. The species may occur in equivalent age strata in northern Arkansas (lower portion of Imo Formation).

Material. 15149-PC (1); 15370-PC (4); 17024-PC (2); 22882-PC (1); 20558-PC (6); 89NVNY- 4 (12); 93CAIN-6 (3); 93UTMI-4 (13); 94NVLI-11 (5); 95NVWP-22a (1); 95NVWP-22b (2); 95NVWP-23 (6).

Eumorphoceras brevornatum n. sp.
Plate 3, figures 1-10; figure 18

?*Eumorphoceras bisulcatum* aff. *varicatum* Schmidt. Lee and others 1974, plate 1, figure 2.

Etymology. A reference to the loss of ornament in early ontogenetic phases.

Types. SUI 93519 (holotype); SUI 93515-93518, 93520, 93690-93692 (paratypes)

Diagnosis. Species whose early whorls bear thread-like sinuous ribs and transverse constrictions. Ribs fade at diameters of around 8 mm.

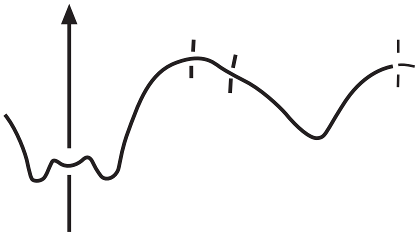


Figure 18. *Suture diagram for* Eumorphoceras brevornatum *n. sp. (SUI 93516) at 9 mm D (x12.8).*

Description. Conch pachyconic, very involute; umbilical diameter average at D = 4-10 mm. At this stage, intrasulcate ventral region broad and slightly convex. Umbilical shoulder rounded. At larger diameters, shell becomes subdiscoconic, completely involute and narrowly umbilicate.

Ornament at D < 7 mm consists of regularly spaced, fine, thread-like ribs, two lingular grooves, and growth constrictions. Ribs retrosiradiate near umbilical margin, curving broadly to become prosiradiate by mid-flank, ultimately merging with lingular groove. Constrictions number about two per whorl. At D = 7-8 mm, ribs become irregular, merging with one another near umbilical margin, with flanks becoming annulate. Constrictions further exaggerate annulate appearance. At D = 10 mm, ribs are lost and annulations start to decrease in relief leaving a slightly scalloped flank, with costae formed by annulations becoming reduced to nodes on umbilical shoulder. This ornament persists to greatest observed diameters (15 mm). Suture, which is typical for genus, only preserved on juvenile specimens.

Comparisons. The new species is closest to *Eumorphoceras tumulosum* Ruzhencev and Bogoslovskaya, and *E. leitrimense* Yates. *Eumorphoceras brevornatum* can be distinguished from the former because its ribs in the earlier stages (D < 8-10 mm) are more numerous (25-27 per whorl) and it has a slightly lower W/D ratio (at 8 mm D: 0.5. versus 0.65 at 11 mm D). From the latter it differs by its more numerous, finer ribs and fewer constrictions. *Eumorphoceras paucinodum* Gordon, *E. imoense* Saunders, and *E. beta* Riley, which are also similar, lack constrictions and are distinguished on that basis. The ribs of all other species persist to greater diameters.

Comments. This species gives the impression that it is transitional between *E. tumulosum* and *E. imoense* or *E. beta*. It has the rib development of the latter and the constrictions and wide conch of the former. A specimen illustrated by Lee and others (1974) as *Eumorphoceras bisulcatum* aff. *varicatum* Schmidt from similar age strata in China bears close resemblance to the new species. It can be distinguished from *E. varicatum* by its narrower umbilicus, lower rib count, and lack of regular constrictions. However, the ribs of the Chinese specimen are also somewhat wider than typical *E. brevornatum* and it is here only tentatively placed in that species.

Distribution. The species is currently known only from the Great Basin region of the United States (*E. girtyi* Biozone), and possibly China. Both occurrences are in middle Arnsbergian strata. Similar species (*E. imoense*, *E. beta*, *E. tumulosum*, *E. leitrimense*) are known from the middle and late Arnsbergian of western Europe, North America, and the southern Urals.

Material. 95NVWP-23 (9).

Eumorphoceras bisulcatum Girty, 1909
Plate 2, figure 11; plate 3, figures 11-19

Eumorphoceras bisulcatum Girty, 1909 [part], plate 11, figures 15, 17-19; Moore, 1946, plate 25, figures 5a-5d; Elias, 1956, plate 6, figure 6; Gordon, 1964, plate 2, figures 13-14; Gordon, 1965, p. 237, text figures. 65c, 66c, plate 25, figures 16-18, 28, 29-30; Ruzhencev and Bogoslovskaya, 1971a, plate 7, figure 8.

Holotype. USNM 119596.

Diagnosis. Species is characterized by numerous (30-40) medium-strength, slightly prosiradiate ribs with a sub-angular bend at 10 mm diameter. Lack of constrictions and relatively narrow umbilicus (U/D = 0.25 at D = 10-15 mm) and intrasulcate ventral area also diagnostic. Conchs with D > 30 mm cannot be differentiated from similar species.

Description. Three specimens from the Inyo Range are available. The largest has D = 7 mm. All are somewhat distorted. Conch somewhat compressed; umbilical diameter average (U/D = 0.3). Venter moderately convex, umbilical shoulders rounded.

Prominent ornament consists of sickle-shaped ribs and two lingular grooves. Ribs number about 15 per half whorl and are regularly spaced. Alignment of rib tips on umbilical margin even, not irregular. Ribs have semi-geniculate appearance at point of maximum curvature on ventrolateral region, merging gradually into lingular groove. Suture not preserved.

Comparisons. This species can be distinguished from nearly every other species by its high rib counts (30+ per whorl) and/or relatively narrow umbilicus. *Eumorphoceras richardsoni* McCaleb and others, 1964 (see plate 3, figures 26-28) and *E. rostratum* Yates, 1962, which have similar rib counts, can be differentiated by ribs that do not merge directly into the lingular groove, but into a smooth lateral region below the groove that gives the venter a platform-like appearance. *Peytonoceras ornatum* Saunders, 1966, a probable direct descendant of *E. bisulcatum,* differs by its smaller, almost closed umbilicus and finer, thread-like, more numerous ribs. *Eumorphoceras grassingtonense* Dunham and Stubblefield, *E. erinense* Yates, and *E. ferrimontanum* Yates, which have previously been referred to *E. bisulcatum*, have wider umbilici at comparable diameters (figure 19).

Comments. *Eumorphoceras bisulcatum sensu lato* has been reported from numerous Arnsbergian ammonoid localities in western and eastern Europe (Moore, 1946; Korejwo, 1969), North Africa (Manger and others, 1985, Lemosquet and others, 1985), the southern Urals (Ruzhencev and Bogoslovskaya, 1971a), the Tian Shan region (Pitinova,

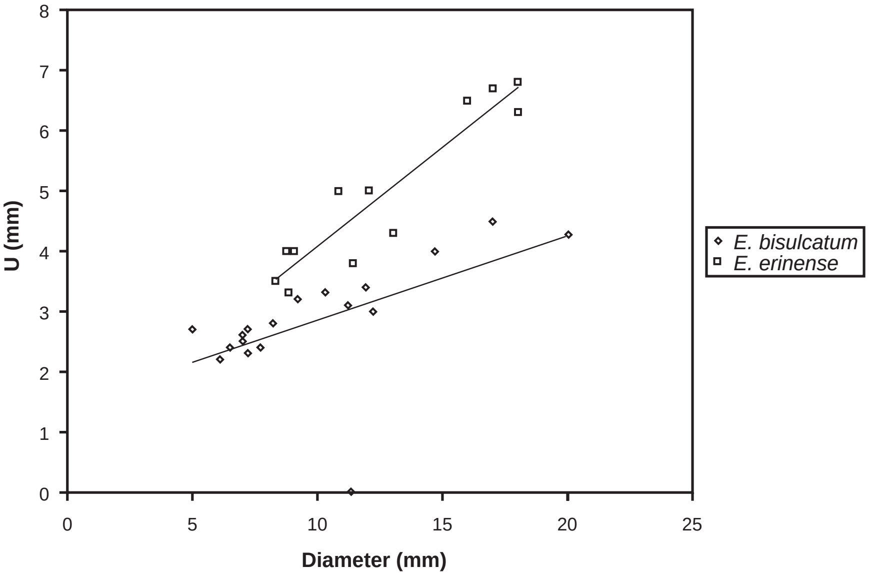


***Figure 19.** U plotted against D for* Eumorphoceras erinense *Yates (squares) and topotypes of* Eumorphoceras bisulcatum *Girty (diamonds). Data taken from appendix C. Regression lines added to show trends.*

1974), and China (Lee and others, 1974). In fact, the supposed presence of *Eumorphoceras bisulcatum* in the Arnsbergian of northwestern Europe has served as the basis for correlation of European and North American Namurian strata for over 70 years. While many of the taxa in these reports have subsequently been referred to other species, (for example, Moore, 1946, plate 27, figure 1), *E. bisulcatum sensu stricto* is still reported in the literature to occur in the middle early Arnsbergian (E_2a_2) of England (House, 1985). In eastern Europe, *E. bisulcatum* is reported from middle Arnsbergian strata in association with *Cravenoceratoides* (Korejwo, 1969; Musial and Tabor, 1980; Korejwo, 1986; Dembowski and Porzycki, 1988). Reports such as these from the Craven Basin region of England and the Polish lowlands were considered by Gordon (1965), Saunders (1973), Saunders and others (1977), and Brenckle and others (1977) as critical for high-resolution international correlation of Arnsbergian equivalents. Because European and midcontinental United States ammonoid assemblages do not contain any other diagnostic taxa in common, the correlations of these authors depend almost entirely on the correct identification of *E. bisulcatum*. Given the global biostratigraphic significance and morphologic variability attributed to this species, a need for critical taxonomic reevaluation is indicated.

Comparison of morphometric data for European middle early Arnsbergian forms referred to *E. bisulcatum* by House (1985), with data obtained from numerous topotypes of *E. bisulcatum*, show that the former consistently possess significantly larger umbilici at comparable diameters (figure 19). The umbilical diameters are consistent within populations, but contrast when European and North American assemblages are compared (plate 3, figure 21 versus figure 22). I consider this contrast of taxonomic significance and exclude the European E_2a forms from *E. bisulcatum*, referring them instead to *E. erinense* Yates and *E. ferrimontanum* Yates (originally described as subspecies of *E. bisulcatum*). Middle Arnsbergian specimens of *E.* "*bisulcatum*" from Poland, which are all crushed, can be variously referred to *E. yatesae*, *E. varicatum*, and *E. leitrimense*. I regard the ornamental similarities between European species and *E. bisulcatum sensu stricto* as convergence within two lineages isolated both spatially and temporally. Previous correlations based on the supposed presence of *E. bisulcatum* in European strata are misleading and must be reevaluated in this light.

Outside of the type region in Oklahoma, the only recognized occurrences of *E. bisulcatum sensu stricto* in North America are in the upper portion of the lower part of the Imo Formation of Arkansas ("upper Pitkin Shale" of Gordon, 1965) and the lower portion of the Rest Spring Shale at the Cerro Gordo locality. The lower Imo is considered E_2b undifferentiated in age (Saunders and Ramsbottom, 1986). Significantly, the Cerro Gordo specimens are associated with *Cravenoceratoides nititoides* (Bisat), which is diagnostic of the latest middle Arnsbergian. All of the North American occurrences are here considered approximately the same age. Ruzhencev and Bogoslovskaya's (1971a) unique Kia River specimen (PIN 455/36865) has the high rib counts, narrow umbilicus, lack of constrictions, and persistence of ribs to the lingular groove that is typical of *E. bisulcatum sensu stricto*. This is the only known occurrence of the species outside of North America, and therefore unequivocal occurrences of *E. bisulcatum* are restricted to Asia and North America.

Distribution. Upper-middle Arnsbergian strata, south-central and western United States. The species is also known from time equivalent strata in central Asia.

Material. 89CAIN-5 (3).

Eumorphoceras aff. *E. imoense* Saunders, 1973

Description. Material poorly preserved. Larger specimen has D = 9 mm. Whorls rounded, with rounded umbilical shoulders and moderately convex venters. Umbilicus high, moderately narrow to low, average diameter (U/D about 0.3). Whorls involute.

Ornament at D = 4 mm consists of stubby ribs numbering about 10 per half whorl. Ribs attenuate and become thread-like at D = 8-9 mm. At D = 9 mm, ribs essentially radial at umbilical shoulder. Immediately before reaching lingular groove, ribs make pronounced apicad bend and then turn sharply orad and merge into groove, giving them a "fishhook" shape. Suture not preserved.

Comments. The "fishhook" shape of the ribs on the larger specimen closely resembles that of a specimen illustrated by Saunders (1973, plate 6, figure 5) as *E. imoense* (?). Because of the poorly preserved nature of the Cerro Gordo material, further comparison is not possible.

Distribution. The types of *E. imoense* are from the upper Arnsbergian portion of the Imo Formation of north-central Arkansas. The species has been tentatively identified in collections from the age-equivalent Rhoda Creek Formation of south-central Oklahoma and possibly slightly older beds (*Cravenoceratoides nititoides* Biozone) within the Rest Spring Shale, eastern California.

Material. 89CAIN-5 (2).

Family EOGONIOLOBOCERATIDAE Ruzhencev and Bogoslovskaya, 1978
Genus *ARCANOCERAS* Ruzhencev, 1965
Arcanoceras macallisteri (Gordon, 1964)

Plate 4, figures 2-7, 10, 11; figure 20

Anthracoceras macallisteri Gordon, 1964, plate 4, figures 1-3, 7-9, text figure 8.

Holotype. SU 9165 (paratype: SU 9166).

Diagnosis. Species with subangular venters at a diameter of 5-9 mm and lacking longitudinal lirae in all ontogenetic phases.

Description. First five whorls serpenticonic, with rounded whorl profile. By sixth or seventh volution, whorls are moderately involute with sub-angular venters. At D > 10 mm, whorls hyperinvolute, with venter flattening and umbilicus essentially closed. Mature conchs (D > 15-20 mm) are subdiscoconic, and extremely involute. Umbilicus nearly closed. No visible ornament other than faint growth lines. No constrictions present.

Suture at D = 12 mm has wide ventral lobe with two wide, strongly asymmetric ventral prongs with parallel dorsad sides. Medial saddle, which is about one-fourth the height of ventral lobe, has strongly divergent sides, creating triangular appearance in ventral prongs. First lateral saddle V-shaped, with rounded tip. First lateral lobe asymmetric; bluntly pointed. Lobe asymmetry created by angular bend in dorsad side. Subsequent sutures similar, but with more attenuate elements.

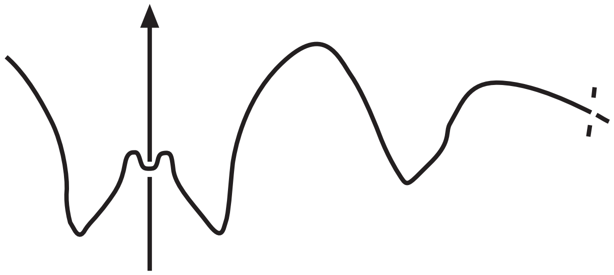


Figure 20. *Suture diagram for* Arcanoceras macallisteri *Gordon (SUI 93544) at 11 mm D (x6.4).*

Comparisons. This species differs from the genotype, *Arcanoceras burmai* (Miller and Downs, 1950) because it lacks longitudinal lirae at all diameters. In addition, the early whorls (D = 5-9 mm) of *A. macallisteri* have subangular venters, while those of *A. burmai* are more elliptical. Cross sections illustrated for *A. consuetum* Kusina and Yatskov, 1988 and *A. furnishi* (Saunders, 1964) also show rounded ventral profiles in the fifth through eighth whorls. *Arcanoceras preacox* Ruzhencev, 1966 possesses constrictions, which *A. macallisteri* does not.

Comments. This species, which was originally described as an *Anthracoceras*, was transferred to *Arcanoceras* by Ruzhencev and Bogoslovskaya (1971a). It is the youngest known representative of the genus in North America.

Distribution. Known with certainty only from early Arnsbergian strata (*Eumorphoceras paucinodum* Biozone) at its type locality.

Material. 93CAIN-2a (2); 93CAIN-2c (2).

Superfamily GONIATITACEA De Haan, 1825
Family DELEPINOCERATIDAE Ruzhencev, 1957
Genus *DELEPINOCERAS* Miller and Furnish, 1954

Type species. *Dimorphoceras thalassoide* Delepine, 1937.

Diagnosis. Pachyconic (juvenile) to platyconic (adult), narrowly umbilicate goniatitids with a very wide sutural ventral lobe bearing two swollen, bifid or trifid prongs. Numerous fine longitudinal lirae usually present in juveniles (D < 20 mm).

Comments. *Delepinoceras* is differentiated from its ancestor, *Platygoniatites* [sutural formula: (V_1V_1) LU: I], by its subdivided ventral lobe. Analysis of conch parameters provides little basis for subdivision of *Delepinoceras,* because in the same way as the dimorphoceratids (Manger, 1988), the conch parameters change little in phylogenetic series. The suture and details of ornament are essentially the only practical basis on which species-level taxonomic differentiation can be made. Diagnosis of any given species using sutures must be made by comparing adult (D > 45 mm) sutures at similar diameters.

Distribution. Arnsbergian strata, cosmopolitan.

Delepinoceras eothalassoide Wagner-Gentis, 1963

Plate 4, figures 8-9; figure 21.3

Delepinoceras eothalassoide Wagner-Gentis, 1963 [part], plate 4, figures 1-2, plate 5, figure2; Ruan, 1981, p. 180, text figure 23, plate 4, figures 1-2, 18-19, 22-26; Yang and others, 1983, plate 13, figures 21-22.

Delepinoceras californicum Gordon, 1964, plate 2, figures 16-17.

Platygoniatites altilis Ruan, 1981, p. 179, text figure 22, plate 4, figures 13-17.

Holotype. Specimen illustrated in plate 4, figures 1-2 and plate 5, figure 2 of Wagner-Gentis (1963), by original designation.

Diagnosis. *Delepinoceras* that develops a single, pronounced ventrad digit on the ventral lobe where D = 35-45 mm. Once developed, bifid ventral lobe retained through all later ontogenetic stages. Lateral lobe remains undivided throughout ontogeny. Mature sutural formula: $(V_{1.1}V_{1.2}\ V_{1.2}V_{1.1})$ LU:ID.

Description. Youthful conch (D < 15-20 mm) pachyconic; subdiscoconic at D = 35-40 mm. Whorls completely involute, very narrowly umbilicate; with high, arched cross sections. Ornament of fine spiral lirae covers entire external whorl surface through D = 20-25 mm, after which they are lost. Weak constrictions (2 to 4 per whorl) present in shells where D < 30 mm.

Suture has very wide ventral lobe that develops single subsidiary digit on ventrad side of each ventral prong at D = 30-35 mm. First lateral lobe V-shaped, deep, with narrowly rounded to sub-angular tip by D = 35 mm. First lateral lobe, which has a swollen base and a deltoid, sharply pointed tip, remains undivided throughout ontogeny. Second lateral saddle sweeps in a broad arc to umbilical margin. Internal suture not observed.

Comparisons. This species is very close to three others, two of which are advanced species of *Platygoniatites*. *Platygoniatites americanus* Titus and *Platygoniatites superior* Ruzhencev and Bogoslovskaya can be differentiated from *Delepinoceras eothalassoide* by lack of secondary digitation on the ventral lobe at all ontogenetic stages. In

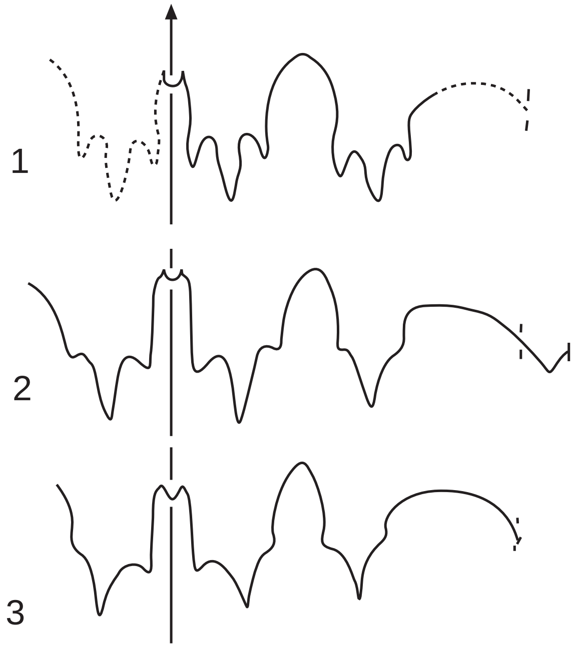


Figure 21. *Suture diagrams for* Delepinoceras. *1* - Delepinoceras thalassoide *(Delepine) (USNM 486310) at D, 65 mm (xl.8); 2* - Delepinoceras californicum *Gordon (USNM 120622) at a diameter of 60 mm (xl.9); 3* - Delepinoceras eothalassoide *Wagner-Gentis (adapted from photos of the holotype in Wagner-Gentis, 1963) at D, 35 mm (x3).*

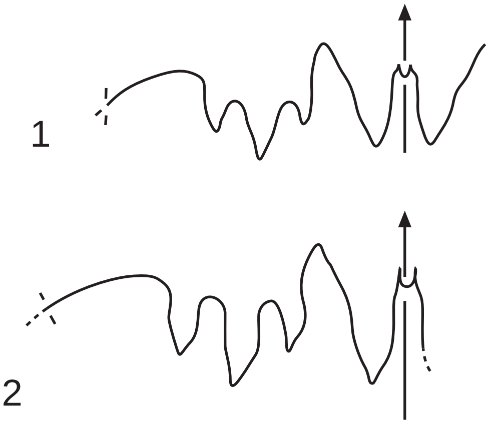


Figure 22. *Suture diagrams for* Pericleites *and* Proshumardites. *1* - Pericleites pilatus *Ruan (USNM 414882) at D, 35 mm (x2.3); 2* - Proshumardites delepinei *Schindewolf (SUI 93546) at D, 30 mm (x2.3).*

addition, *P. superior* retains lirae into maturity (D > 45 mm). *Delepinoceras californicum* Gordon can be differentiated from *D. eothalassoide* because the latter never develops a dorsad digit on the ventral lobe (Titus, 1993). *Delepinoceras acceptum* Nikolaeva, 1994, a species reported from central Asia, belongs in *Platygoniatites* since the holotype (D = 35-40 mm) has not developed digitation of the ventral lobe. Based on the degree of swelling on the ventral prongs, *P. acceptum* may be synonymous with either *P. americanus* or *P. superior*. Further study is needed. Other species of *Delepinoceras* possess digitation on the first lateral lobe by D = 45-50 mm.

Comments. This species is the earliest representative of the genus. Its phylogenetic relationships were discussed in Titus (1993).

Distribution. *Delepinoceras eothalassoide* has been reported from China (Ruan, 1981) and northern Spain (Wagner-Gentis, 1963). The recognition of this species in the Rest Spring Shale (*Eumorphoceras paucinodum* Biozone) extends its range to western North America. All occurrences are here considered early Arnsbergian (E_2a) in age. The stratigraphic range of the species is at least partially concurrent with *D. californicum*, which ranges slightly higher.

Material. Only a single specimen (SU 9167), one of the paratypes of *D. californicum* Gordon, from the base of the Rest Spring Shale at Rest Spring, Cottonwood Mountains, Inyo County, California (FL 27) can be referred with certainty to this species.

Delepinoceras californicum Gordon, 1964

Plate 4, figure 14; figure 21.2

Delepinoceras californicum Gordon, 1964, p. A19, A20, plate 2, figures 10, 15-22, text figures 9A-C.

Delepinoceras bressoni Ruzhencev, 1958b. Pitinova, 1974, plate 3, figures 5-7, p. 32, text figure 4a.

Holotype. USNM 120622; from the lower portion of the Rest Spring Shale, Rest Spring, California.

Diagnosis. *Delepinoceras* with a trifid ventral lobe where D = 50 mm, with the further condition that the lateral lobes remain undivided throughout all later ontogenetic stages. Mature sutural formula: $(V_{1.3}V_{1.1}V_{1.2}V_{1.2}V_{1.1}V_{1.3})$ LU:ID

Description. Small individuals (D = 15-20 mm) pachyconic with rounded ventral region, completely involute whorls and very narrow umbilici. At larger diameters, shell subdiscoconic with rounded venter, completely involute whorls, and narrow umbilicus. Conchs where D < 30 mm ornamented with about 70 longitudinal lirae across external whorl surface. At D > 30 mm, lirae progressively lost off flanks and venter. Conchs where D > 45 mm smooth. Constrictions not observed on large shells, but present on specimens where D < 25 mm. For a description of the mature suture, see Gordon (1964).

Comparisons. This species is close to both *D. eothalassoide* Wagner-Gentis and *D. bressoni* Ruzhencev, 1958b as it is transitional between the two. The holotype of *D. californicum* is distinct from *D. eothalassoide*, however, because the latter lacks a dorsad digit on the ventral prong in adult stages (D> 45-50 mm). It can be distinguished from *D. bressoni* by lack of a ventrad digit on the lateral lobe at large diameters (D > 65 mm).

Comments. A partial *Delepinoceras* phragmacone found associated with a *Eumorphoceras girtyi* Biozone assemblage in the Burbank Hills is the only example of this species from North America outside of California. The fragment has a whorl height of 18.6 mm and a width approximating 15 mm (the specimen is slightly crushed laterally). The venter is well rounded and the flanks nearly flat. The surface is ornamented by fine sinuous runzelschicht.

The suture of the Utah specimen at approximately 18 mm compares favorably with that of the type of *D. californicum* at diameters of 9 mm and 30 mm, showing a stage of development about midway between those two. A large paratype of *D. californicum* (from FL 27) collected from the same general vicinity as the holotype lacks a dorsal digit on its ventral prong and is referred herein to *D. eothalassoide* Wagner-Gentis.

Suture diagrams and photos of *Delepinoceras* (referred by Pitinova (1974) to *D. bressoni*) recovered from southern Fergana, middle Asia, along the Aravan River, show that the adult lateral lobe of these forms possesses no subsidiary prongs. Since the ventral lobe is fully trifid, these forms belong in *D. californicum* Gordon.

Distribution. *Delepinoceras californicum* is known from the early Arnsbergian (E_2a) of the Rest Spring area (*Eumorphoceras paucinodum* Biozone), Cottonwood Mountains, Inyo County, California. A single immature specimen of the genus from the *E. girtyi* Biozone of the Burbank Hills (figure 3, locality 18) is referred to this species based upon its gross sutural characteristics (swelling of the dorsad side of the ventral lobe in early maturity). It also occurs in early Arnsbergian strata of southern Fergana, Uzbekistan (middle Asia), along the Aravan River.

Material. 17219-PC (1); 93CAIN-2b (1).

Delepinoceras thalassoide (Delepine, 1937)
Plate 4, figure 15; figure 21.1

Dimorphoceras thalassoide Delepine, 1937 (in Delepine and Menchikoff, 1937), plate 5, figures 6-7; p. 84, text figure 11-13; Delepine, 1952, figure 40.

Delepinoceras thalassoide (Delepine). Miller and Furnish, 1954, p. 690; Wagner-Gentis, 1963, plate 6, figures 1-3; Wagner-Gentis, 1971, p. 654, plate 2, figure 9.

Delepinoceras bressoni Ruzhencev, 1958b. Furnish and others, 1964, p. 178, text figure 2, plate (table) 30, figures 1-5; Saunders, 1973, p. 56, text figure 22, plate 7, figures, 1-2, 4-6; Saunders, 1975, plate 1, figure 4; Saunders and others, 1977, plate 3, figure 4.

Delepinoceras bressoni cantabricus Kullmann, 1962 [part], p. 339, text figure 13b, plate 6, figure 7a, 7b.

Lectotype. Specimen illustrated in plate 5, figure 7 of Delepine and Menchikoff, 1937 (Furnish and others, 1964).

Diagnosis. *Delepinoceras* developing both trifid ventral prongs and trifid lateral lobes by 45-50 mm diameter. Mature sutural formula: $(V_{1.3}V_{1.1}V_{1.2}V_{1.2}V_{1.1}V_{1.3})(L_2L_1L_2)$ U:ID

Description. Only three adult or subadult specimens of this species, all of which are from the South Syncline Ridge locality of Titus and others (1997), are known from the Antler foreland basin. One consists of a fragment of the ventral region of a phragmacone. The other two are phragmacones preserving most of the penultimate whorl. Adults are subdiscoconic, very narrowly umbilicate, and completely involute. Shell is smooth. Juvenile conch (D < 20 mm) completely involute, pachyconic, and covered with fine longitudinal lirae. Longitudinal ornament lost at approximately 20 mm D. Suture has distinctive tripartite ventral prongs and lateral lobes joined by a deep U-shaped first lateral saddle. Medial saddle narrow and slightly wider in mid-portion than at either end.

Comparisons. This species is differentiated from all others on the basis of its trifid lateral lobe.

Comments. It is clear from Delepine's (1937) text and figures that "*Dimorphoceras*" *thalassoide* was erected for forms that possess fully trifid ventral and lateral lobes. Ruzhencev (1958b) also implied that *Delepinoceras thalassoide* possessed a trifid lateral lobe by stating that its suture was more advanced than that of *D. bressoni*. Unfortunately, no holotype was designated for "*Dimorphoceras*" *thalassoide* in the original work. The only specimen illustrated by Delepine (1937) that displayed an adult suture was from the Pyrenees Mountains, Spain. This syntype cannot be demonstrated to be conspecific with the immature and non-diagnostic Haci Diab (Algerian) specimen later designated as the lectotype by Furnish and others (1964).

An adult specimen of *Delepinoceras* from the Bechar Basin region (Chebket Djihani) referred to *D. thalassoide* by Pareyn (1961, plate 22, figure 12) displays sutures transitional between Delepine's concept of *D. thalassoide* and *D. bressoni*. The lateral lobe on this specimen is incipiently trifid, however, it has an estimated D of about 80 mm. The greatest diameter for which a Ural *D. bressoni* suture was figured is 70 mm. A similarly large adult (also from Chebket Djihani) illustrated by Lemosquet and others (1985, plate 7, figure 12) and Manger and others (1985, plate 2, figure 4) shows a suture more typical of *D. bressoni*. Accordingly, Chebket Djihani occurrences of *Delepinoceras* from the Djenien Formation can be referred to *D. bressoni*, with the specimen illustrated by Pareyn being an extreme gerontic variation. Since the Chebket Djihani specimens belong to *D. bressoni*, I strongly suspect that *D. bressoni* is a junior synonym of *D. thalassoide* as a result of Furnish and others (1964) selection of the lectotype and not Delepine's original work. This question cannot be resolved until additional material is recovered from the Haci Diab type locality which is approximately 120 km northwest of Chebket Djihani. Until then, Delepine's species, which is based conceptually on the more advanced Pyrenees syntype, should be considered a distinct form.

Distribution. *Delepinoceras thalassoide* (Delepine) is known in the western United States only from the upper portion of the Scotty Wash Formation at the South Syncline Ridge locality, Nye County Nevada (*D. thalassoide* Biozone). The species also occurs in the Rhoda Creek Formation of south-central Oklahoma and the upper portion of the Imo Formation of north-central Arkansas (Furnish and others, 1964; Saunders, 1973). In Eurasia the species is known only from Cantabrian region of northern Spain, the Pyrenees Mountains, and possibly the Algerian-Moroccan border area. All occurrences are late Arnsbergian (Titus and others, 1997).

Material. 89NVNY-5 (1); 89NVNY-6 (3); 94NVNY-19 (1).

Family AGATHICERATIDAE Arthaber, 1911
Genus *PERICLEITES* Renz, 1910
Pericleites pilatus Ruan, 1981
Plate 4, figures 12, 13; figure 22.1

Pericleites pilatus Ruan, 1981, p. 186, text figures 30-32, plate 5, figures 1-2, 10-11, 16-17, 19-20.

Holotype. Specimen illustrated on plate 5, figures 10, 11 (48826) of Ruan (1981), by original designation.

Diagnosis. Species with ventral lobe of suture showing slanting sides and a pair of tapering symmetrical prongs; first lateral lobe three-pronged, central prong largest, extending about twice as far adapically as later ones.

Description. Shell pachyconic and completely involute, having broadly rounded venter and gently convex flanks that curve into moderately narrow umbilicus. Fragments of shell material adhering to internal mold are smooth.

Ventral lobe of external suture has slanting sides and deep median saddle that is three-fourths height of ventral lobe. Sides of ventral lobe gently sigmoidal; prongs long, tapering; first lateral saddle very narrowly rounded, asymmetrical; first lateral lobe tripartite, central prong wider and longer than others, slightly asymmetrical, curving parallel to curvature of shell, and pointed; lateral prongs narrow, pointed, curving inward toward central prong and separated from it by shallow, rounded, adventitious saddles; second lateral saddle fairly shallow, asymmetrical and bowed; umbilical lobe short and pointed. Configuration of external suture does not change much at whorl heights between 15 and 30 mm. Internal suture having three long, tapering pointed lobes, separated by rounded saddles; dorsal lobe about half width of first lateral internal lobe.

Comparisons. The trifid lateral lobe in *P. pilatus* is less advanced than *P. atticus* (Renz), and more advanced than *P. uralicus* (Librovitch) and *P. qixuensis* Ruan. According to Nikolaeva (1995), *Pericleites insolitus* Nikolaeva has a wider conch.

Comments. This is the first report of the genus from North America. However, J. Kullmann (written communication, 1998) has suggested that all lower Carboniferous species of *Pericleites* should be transferred to *Proshumardites*. I concur that this is probably true, but since no formal transferral has occurred in previous literature, and I have not examined the genotype of *Pericleites*, I am leaving Ruan's generic assignment unmodified.

Distribution. Early Arnsbergian strata (*Eumorphoceras rotuliforme* Biozone) of the AFB. The species is also known from similar age strata in China.

Material. 17188-PC (1-USNM 414882), 17310-PC (5-USNM 414883 [lot of 5 crushed specimens]).

Genus *PROSHUMARDITES* Rauser-Tschernoussova, 1928

Proshumardites delepinei Schindewolf, 1939

Plate 4, figures 16-18; figure 22.2

Proshumardites karpinskii Rauser-Tschernoussova. Delepine and Menchikoff, 1937, p. 78, text figure 4, plate 5, figures 1-5; Delepine, 1941, p. 82, text figure 17.

Proshumardites delepinei Schindewolf, 1939, p. 429, text figure 2; Pareyn, 1961, p. 161, text figure 20a-20h, plate 18, figures 18-31, plate 19, figures 1-13; Kullmann, 1962, plate 5, figures 1-5, p. 330, text figure 11b; Wagner-Gentis, 1963, plate 2, figure 3, plate 3, figures 1-2, 4; Wagner-Gentis, 1971, p. 654, plate 1, figure 5, plate 2, figure 10; Ruzhencev and Bogoslovskaya, 1971a, p. 241, text figure 53b, 53c, plate 21, figures 1-2; Ruzhencev and Bogoslovskaya, 1978, p. 141, text figure 11, plate 3, figure 1; Nikolaeva, 1994, p. 78, text figure 32a, plate 5, figures 1-3; Nikolaeva, 1995, plate 4, figures 4-7, p. 58, text figure 43.

Proshumardites fraudulentus Nikolaeva, 1994, p. 79, text figure 32b, plate 5, figures 4-5; Nikolaeva, 1995, p. 58, text figure 44, plate 4, figures 8-10.

Holotype. Specimen illustrated on plate 5, figures 2-3 of Delepine and Menchikoff (1937).

Diagnosis. Species with numerous fine longitudinal lirae (about 70-80 per whorl), and first lateral lobe of suture divided into three prominent prongs by D = 20 mm. In larger conchs (D > 25 mm), the central projection in the tripartite lateral lobe equals 1/2 to 2/3 the total height of the lobe.

Description. The Apex specimen is a partial phragmacone that preserves about half a whorl, with an estimated D of 30 mm. Conch form discoconic or pachyconic, completely involute, and very narrowly umbilicate. Whorl sections moderately convex and evenly rounded, almost hemispherical.

Most of the soft, limonitic shell material has exfoliated and the external mold is lost. Distinctive typical lirae are fine and numerous, and preserved on one patch near venter.

Ventral lobe of suture, which is about 5 mm wide at D = 30 mm, is divided into two wide, tapering, sharply pointed prongs. Medial saddle about one-half to two-thirds total height of ventral lobe. First lateral saddle relatively narrow, V-shaped and sigmoidal, with a dorsad trending curve in its midsection. First lateral lobe wide (6.5 mm at D = 30 mm), sharply pointed, and deeply tripartite. Sides of secondary digits strongly convex along outside edges and parallel along inside. Second lateral saddle broad; gently curved. Internal suture not preserved.

Comparisons. *Proshumardites delepinei* is close to *Pericleites atticus* (Renz), *Proshumardites principalis* Ruzhencev and Bogoslovskaya, and possibly *P. keideli* (Leuchs). *Pericleites atticus* has lost its longitudinal lirae by D = 30 mm and can be differentiated from *P. delepinei* on that basis. In addition, the ventral prongs of *P. atticus* are more triangular than those of *P. delepinei*, and smaller specimens of the former species possess three constrictions per whorl (versus four on *P. delepinei*) (Ruzhencev and Bogoslovskaya, 1971a). *Proshumardites keideli* is too poorly understood for conclusive comparisons. All other species of *Proshumardites* possess less numerous longitudinal lirae (30-50 per whorl).

Comments. *Proshumardites fraudulentus* Nikolaeva, 1994, possesses the same number of longitudinal lirae as *P. delepinei* (about 70). The sutures of the two species are identical (compare Nikolaeva's text figures 32a and 32b). The only significant difference is a slightly lower W/D ratio for *P. fraudulentus* (where D = 36-38 mm: W/D = 0.46 vs. 0.49). In a manner similar to *Delepinoceras* (Ruzhencev and Bogoslovskaya, 1971a), the conch width of *Proshumardites delepinei* probably varies within these limits. Differentiation of *P. fraudulentus* from *P. delepinei* on this one feature alone should be based on a more rigorous statistical analysis. Until such is made, I consider the former a variant of the latter.

It has been speculated that *Proshumardites keideli* (Leuchs, 1919), a species described from the Tian Shan region, is a senior synonym of *P. karpinskii* Rauser-Tschernoussova (McCaleb, 1968). However, Leuchs' original sutural drawings of *P. keideli* are closer to *P. delepinei*, as they depict a very deeply divided lateral lobe. *Proshumardites keideli* also appears to have numerous, fine lirae, a feature found on *P. delepinei* but not *P. karpinskii*. Both *P. delepinei* and *P. karpinskii* occur in the type region of *P. keideli*. If the illustrations of *P. keideli* are accurate, there is a high probability that Leuchs' species is actually a senior synonym of *P. delepinei*. This cannot presently be resolved without reexamination of Leuch's type.

A specimen illustrated by Pareyn (1961: plate 19, figures 16-17) has a much lower lirae count than typical *P. delepinei* (2/mm vs. 5/mm) and is referred here provisionally to *P. karpinskii* Rauser-Tschernoussova.

Distribution. The occurrences of this species at the Apex and Rest Spring localities are the only known for North America. Both are middle Arnsbergian (*Eumorphoceras girtyi* Biozone). *Proshumardites delepinei* is widespread in southern Europe, North Africa, and Asia, where it occurs in middle Arnsbergian through Chokierian age strata.

Material. 93NVCL-1; (1); 93CAIN-6 (?1).

Superfamily NEOGLYPHIOCERATACEAE Plummer and Scott, 1937
Family CRAVENOCERATIDAE Ruzhencev, 1957
Subfamily CRAVENOCERATINAE Ruzhencev, 1957
Genus *CRAVENOCERAS* Bisat, 1928
Cravenoceras sp., cf. *C. subitum* Astachova, 1983
Plate 5, figures 1-8; figure 23

Description. At 13 mm D, conch subcadiconic, completely involute, with average umbilical width. Whorl section has moderately convex venter and rounded umbilical shoulders. By 30-40 mm D, conch ranges from weakly to strongly subcadiconic, with very involute whorls and moderately wide to average width umbilici. At these diameters, umbilical shoulder becomes narrowly rounded. Ornament consists of low- to medium-relief growth lamellae only, which are essentially radial until 15-20 mm D. Subsequent lamellae develop slight, broad, hyponomic sinus which stays shallow until at least 65 mm D.

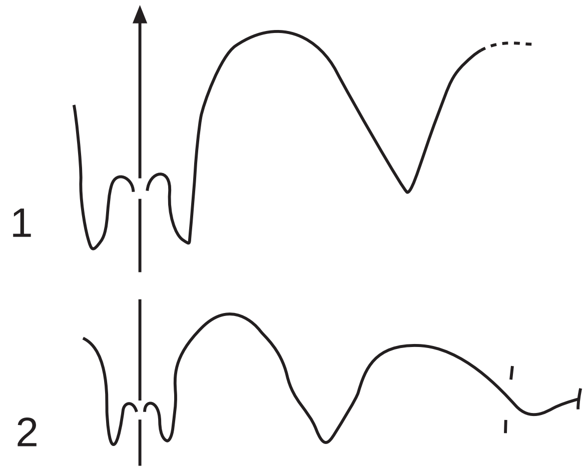


Figure 23. Suture diagrams for Cravenoceras *sp., cf.* C. subitum *Astachova. 1 (SUI 93585) at 26 mm D; 2 (SUI 93586) at 14 mm D. Both x4.*

At 15 mm D, ventral lobe very narrow (ratio of ventral lobe to first lateral saddle equals 0.68). Medial saddle, which is one-third to one-fourth height of ventral lobe, separates two slender parallel prongs. First lateral saddle U-shaped and asymmetric, with ventrad side parallel to direction of coiling and dorsad side skewed dorsad. First lateral lobe triangular, mammilate, and slightly shorter than ventral lobe. By 25 mm D (largest at which a suture was observed), width of ventral lobe is two-thirds to three-fourths width of first lateral saddle. Medial saddle one-third height of ventral lobe. Ventral prongs asymmetric, with dorsad sides essentially parallel to direction of coiling, and ventrad sides gently convex. First lateral saddle U-shaped, and retaining same asymmetry as earlier sutures. First lateral lobe narrow, triangular, and sharply pointed. Internal suture not observed.

Comments. The general conch form and suture of this form are especially close to *C. subitum*. However, the types of *C. subitum* are all small. Without a description of the later growth stages of *C. subitum*, a firm identification is impossible. The California specimens are also morphologically similar to *C. subplicatum* Bisat. Based on comparison with topotypes, *C. subplicatum* is a smaller species with longer, more attenuate ventral and lateral lobes. Middle Arnsbergian specimens from China identified by Li and others (1987, plate 2, figures 3-6) as *Cravenoceras arcticum* Librovitch and *C. leionoides* Ruzhencev and Bogoslovskaya, both Pendleian species, are also very close to *C. subitum* and *C. subplicatum* and should rather be referred to one of the latter. As a result, they also may be conspecific with the Rest Spring taxon, although further study is needed.

Distribution. This and similar forms are found in lower middle Arnsbergian strata of the southernmost AFB (*Eumorphoceras girtyi* Biozone), China, western Europe, and the Donets Basin.

Material. 93CAIN-6 (17+).

Subfamily NUCULOCERATINAE Ruzhencev, 1957

Cravenoceratidae Ruzhencev, 1957. Vašícek, 1983 [part], p. 42.

Nuculoceratidae Ruzhencev, 1957 [part], p. 56.

Homoceratinae Spath, 1934. Hudson, 1946 [part], p. 377; Yates, 1962 [part], p. 388.

Nuculoceratinae Ruzhencev, 1957. Ruzhencev and Bogoslovskaya, 1971a [part], p. 308; Riley, 1987, p. 25.

Ramositidae Ruzhencev and Bogoslovskaya, 1969. Ruzhencev and Bogoslovskaya, 1971a [part], p. 344.

Diagnosis (emended). Cravenoceratids with pronounced bifurcating transverse ornament and suture with a narrow ventral lobe, slender, parallel to sub-parallel prongs, and a simple generally elongate-spatulate first lateral lobe. May or may not have longitudinal striae.

Discussion. Ruzhencev and Bogoslovskaya (1971a) separated the genera *Cravenoceratoides* and *Nuculoceras*, both based upon British types, into different families. This was apparently based upon their assumption that the genotype of *Cravenoceratoides* possessed a wide ventral lobe with swollen prongs. *Cravenoceratoides* was referred to the newly erected Ramositidae, while *Nuculoceras* was retained in the Cravenoceratidae under the monogeneric subfamily Nuculoceratinae. Even though no mature suture diagram has ever been published for European *Cravenoceratoides*, my examination of *Ct. nitidus* (Phillips) type material in the British Museum and in the collections of the British Geological Survey confirms the original contention of British workers: *Cravenoceratoides* and *Nuculoceras* are part of a morphologic and phylogenetic continuum. The species succession *Ct. nitidus* (Phillips) to *Ct. nititoides* (Bisat) to *Nuculoceras stellarum* Holdsworth to *Nuculoceras nuculum* Bisat clearly shows the generic transition. All of these forms share bifurcating ornament and suture with a narrow, *Cravenoceras*-like ventral lobe. Based upon this phylogenetic continuity and the characteristic narrow ventral lobe, *Cravenoceratoides sensu stricto* is excluded from the wide-lobed Ramositidae. The ornamental similarities between these two different groups are convergent and purely coincidental. In order to avoid erecting a new monogeneric subfamily to accommodate *Cravenoceratoides*, the definition of the Nuculoceratinae is here amended to include all cravenoceratids with bifurcating ornament, with or without longitudinal striae. This includes only two genera; *Cravenoceratoides* Hudson, 1941 and *Nuculoceras* Bisat, 1924. Consequently, "*Cravenoceratoides*" *hudsoni* Ruzhencev and Bogoslovskaya 1971a and "*Ct.*" *zapaltjubensis* Astachova, 1983 from the middle or late Arnsbergian of the southern Urals and the Donets Basin, respectively, should be referred to *Ramosites* because both have wide ventral lobes and swollen ventral prongs.

The origin of *Ramosites* can be deduced from certain variants (D < 15 mm) of *Richardsonites richardsonianus* (Girty) from both Utah and Oklahoma which possess coarse lamellae suggesting *Ramosites* (and also *Homoceras*, another indirect descendant). Based upon this, and the fact that the suture lines of *Richardsonites* and *Ramosites* are identical, *Ramosites*, and ultimately, the Ramositidae, originated directly from *Richardsonites*, not *Cravenoceratoides*.

Distribution. Middle and late Arnsbergian strata, worldwide.

Genus *CRAVENOCERATOIDES* Hudson, 1941
Cravenoceratoides nititoides (Bisat, 1932)
Plate 5, figures 9-18; plate 6, figures 1, 2

Cravenoceras nititoides Bisat, 1932, p. 35, plate 2, figure 2.

Cravenoceratoides nititoides (Bisat). Hudson, 1941, p. 282; Hudson, 1946, plate 21, figure 8; Yates, 1962, p. 391, plate 57, figures 4, 5; Korejwo, 1969, plate 26, figures 5, 6; Vašícek, 1983, p. 46, text figure 7, figures k, l, o, plate 5, figure 1, plate 6, figure 1, plate 7, figure 2, plate 8, figure 1.

Cravenoceratoides cf. *C. nititoides* (Bisat). Gordon, 1964, p. A16, plate 4, figures 18-23.

Holotype. GSM 49964

Diagnosis. Species with narrow umbilicus and closely spaced, forward-canted radial lirae.

Description. Small juveniles (about D = 5 mm) pachyconic, very involute, with average to moderately wide umbilici. At D = 10.4 mm (largest measurable diameter), the conch is pachyconic, very to hyperinvolute, and narrowly umbilicate. Umbilical shoulder rounded and whorl cross section moderately to strongly convex and rounded. Larger conchs probably platyconic or subdiscoconic and very narrowly umbilicate. Mature conchs exceed D = 35-40 mm.

Ornament consists of coarse, high-relief, transverse growth lirae which form distinct ventral salient in individuals where D < 8 mm, and attain bifurcate aspect at around 4-5 mm D. At around 10 mm D, lirae are less sinuous and oriented more or less prosiradiate (canted forwards). Hyponomic sinus develops at approximately D = 15 mm, progressively deepening in subsequent ontogenetic stages. Lirae density at D = 10 mm ranges from 13/5 mm to 16/5 mm. Secondary dichotomy uncommonly developed in lirae at D > 17 mm. Constrictions and sutures not observed.

Comparisons. This species is closest in conch form to *Nuculoceras stellarum* (Bisat) and *Cravenoceratoides simplex* (Knopp). The former differs because it bears faint longitudinal lirae. The latter is very close, but apparently has finer ornament in the early stages (Vašícek, 1983). Two other species of *Cravenoceratoides* are somewhat similar, *Ct. nitidus* (Phillips), and *Ct. macrocephalum* (Frech). Both of these forms have wider umbilici at comparable diameters. Contemporary species of *Ramosites* have much coarser ornament.

Comments. Based on direct comparison with the holotype, the California specimens are in every morphological and ornamental aspect identical to *Ct. nititoides*. This is apparently the only Arnsbergian species that the AFB and northwestern Europe share in common. Other reported occurrences in eastern Europe and Uzbekistan indicate that the species was widespread in the late middle Arnsbergian. Specimens identified as *Ct. nititoides* by Schmidt (1934, p. 450, figure 47, p. 451, figure 49) possess longitudinal striae. These forms are here referred to *Nuculoceras*.

Distribution. Late middle Arnsbergian strata (Rest Spring Shale), eastern California (*Ct. nititoides* Biozone). Outside of North America the species is known from similar age strata of western and eastern Europe, and Uzbekistan (Pitinova, 1974).

Material. 89CAIN-5 (50+); 89CAIN-7 (3); 93CAIN-8 (32); 93CAIN-9 (1).

Cravenoceratoides sp.
Plate 6, figures 7, 8

Description. The conch form could not be ascertained by direct measurement due to the poor preservation of available specimens. Probably pachyconic. Whorls completely involute and umbilicus is of average width. Whorl section is moderately convex and umbilical shoulders are rounded to narrowly rounded.

At 25 mm D, ornament consists of high-relief, irregularly dichotomizing, transverse lirae (about 2 per mm) that are radial to canted slightly prosiradiate. By 30 mm D, lirae crowded (4 per mm); attaining appearance of very high-relief growth lamellae with slight hyponomic sinus. This ornament persists to at least 42 mm D.

Sutures only poorly preserved on one specimen, allowing description of ventral lobe and first lateral saddles only. Ventral lobe is narrow with medial saddle about one-third its total height. Prongs narrow and parallel. First lateral saddle U-shaped and symmetric.

Comments. The wide umbilicus and irregular dichotomy of the stout lirae of this form are similar to those of *Ct. bisati* Hudson, 1946 and *Ct. edalensis* (Bisat). However, the smallest specimen recovered from the AFB is slightly larger than the largest type specimens of either species in the collections of British Geological Survey. Lack of better preserved specimens, especially those showing the diagnostic earlier growth stages, prevents any further comparison.

Distribution. Early middle Arnsbergian strata (*Eumorphoceras girtyi* Biozone-lower portion of the Rest Spring Shale), Rest Spring-Quartz Spring area, Death Valley, California.

Material. 93CAIN-6 (12).

Superfamily GASTRIOCERATACEAE Hyatt, 1884
Family GLAPHYRITIDAE Ruzhencev and Bogoslovskaya, 1971a
Subfamily GLAPHYRITINAE, Ruzhencev and Bogoslovskaya, 1971a
Genus *GLAPHYRITES* Ruzhencev, 1936

Type Species. *Gastrioceras modestum* Böse, 1919

Diagnosis (emended). Glaphyritins without an extended ophioconic stage, simple, non- to moderately inflated ventral and lateral lobes, and either fine multiple spiral threads or simple transverse lamellae on the umbilical shoulder.

Comparisons. The similar genus *Eoasianites* possesses prominent nodes in its early ontogeny while *Glaphyrites* does not. *Syngastrioceras* has only a single spiral umbilical cord during early and mid-ontogenetic stages. *Richardsonites* possesses a much more inflated ventral lobe and prongs, while *Fayettevillea*, *Zephyroceras*, and *Neoicoceras* all have more extended ophioconic stages, either as adults or juveniles.

Comments. *Glaphyrites* is long ranging and historically has been difficult to differentiate from other similar genera such as *Syngastrioceras*, *Fayettevillea*, *Richardsonites*, and *Eoasianites*. Some authors have even synonymized *Syngastrioceras* with *Glaphyrites* (for example, Gordon, 1965). It is my opinion that this confusion has arisen primarily because too great an emphasis on sutural criteria has been made in generic definitions. Examination of Böse's (1919) types of *G. modestus* reveals that the sutural lobes are non-pouched and relatively "conservative." Furthermore, the ornament consists only of multiple fine spiral threads on the umbilical shoulder and simple strap-like transverse lamellae. Specimens that fit this exact description can be found in Mississippian through Permian strata, and the Desmoinesian *Glaphyrites welleri* Miller and Owen, 1939 is remarkably similar to the Mississippian *G. limicolus* n. sp., possessing only a more widely umbilicate conch in maturity. I conclude from this that *Glaphyrites* was actually a long-ranging, evolutionarily conservative genus that, while not changing appreciably itself, did give rise, directly or indirectly, to several important late Paleozoic ammonoid groups. An analogy can be found in the Mesozoic ammonoid genera *Lytoceras* and *Phylloceras*.

The differentiation of *Glaphyrites* from the shorter-lived *Syngastrioceras* is one of the greatest taxonomic problems in the subfamily. Most previous authors have preferred to emphasize sutural characteristics rather than ornament when attempting to solve this problem (for example, Gordon, 1965; Ruzhencev and Bogoslovskaya, 1971a, 1978). However, examination of these works proves that reliance on the suture alone creates additional taxonomic problems. A good example of this is the species *Syngastrioceras glaphyritoides* Ruzhencev and Bogoslovskaya, 1978. Morphologically and ornamentally this species is close to others of *Syngastrioceras* found in the southern Urals. Unfortunately, its suture is too primitive for its original author's own definition of the genus. Rather than put it into *Glaphyrites* as their generic definition would dictate, this form was referred to *Syngastrioceras*, probably because of its stratigraphic position and associated taxa. The trivial name reflects those authors' inability to satisfactorily deal with this taxon. Problems like this would, in part, be eliminated if ornamental criteria were given at least the same emphasis as the suture, with the fine multiple spiral threads of the *Glaphyrites* genotype used in the generic definition. Noting that *S. glaphyritoides* lacks these multiple threads, but instead has a single strong umbilical cord, it must be referred to something other than *Glaphyrites*. Eurasian forms lacking the single spiral shoulder cord, but bearing pouched or "advanced" swollen, basally constricted lobes and deep medial saddles should probably be referred to *Somoholites* or *Glaphyrites*, not *Syngastrioceras*.

The type of *Syngastrioceras*, *Gastrioceras orientale* Yin, 1935, bears a single, strong spiral cord on the umbilical shoulder. Subsequently illustrated Chinese specimens from the same age strata (see Ruan, 1981) have identical ornament. My examination of many hundreds of specimens of *Syngastrioceras globosum* from northwestern and north-central Arkansas, which are only slightly older than the genotype, has revealed that they all possess the single prominent spiral cord. No gradation into a form with multiple spiral threads occurs. In fact, the latter ornament is unknown in these populations. A similar pattern occurs in large populations of *Glaphyrites* such as occur in the Desmoinesian and Missourian of Oklahoma (Miller and Owen, 1937). From my examination of dozens of individuals of *Glaphyrites clinei* in the collections of the University of Arkansas Museum, I have concluded there is no gradation into a form bearing only one prominent spiral cord on the umbilical shoulder. Thus I also conclude that spiral ornament is consistent in large populations over time in both genera and has taxonomic significance. Consequently, I propose that the umbilical ornament is one of the most important features for differentiation of *Glaphyrites* and *Syngastrioceras*. I further maintain, along with Ruzhencev and Bogoslovskaya (1971a), that "phylogenetic taxonomy," or taxonomic evaluation in both time and space is crucial to solving complex taxonomic problems such as this. When the origins of these two genera are sought, the importance of ornamental criteria for taxonomic distinction is made even clearer.

Both *Glaphyrites* and *Syngastrioceras* occur in the late Pendleian of North America (as in *Syngastrioceras scotti*, plus many undescribed forms). These are without doubt the earliest records of both genera. Continuity with older transitional forms and even older species of *Emstites* can be demonstrated both in the western United States (Chainman Shale) and Arkansas (Fayetteville Shale and Pitkin Limestone). In the subsequent Arnsbergian, the two genera become cosmopolitan, with most early occurrences outside North America being middle Arnsbergian in age. Examination of these early populations shows that *Syngastrioceras* derives from *Emstites* bearing a strong spiral cord such as *E. leion* (Bisat) via the intermediate genus *Eosyngastrioceras* (figure 24), while *Glaphyrites* derives from *Emstites* with finer, multiple spirals across the umbilical shoulder (see *E. novalis* Korn). The similar sutures and conch forms of *Glaphyrites* and *Syngastrioceras* thus reflect not an ancestor-descendant relationship as proposed by Ruzhencev and Bogoslovskaya (1971a), but a shared ancestry in *Emstites*.

Glaphyrites millardensis n. sp.

Plate 6, figures 9-18; figure 25

Etymology. The trivial name is a reference to Millard County, Utah, which has yielded all of the known specimens in the study area.

Types. SUI 93602 (holotype); SUI 93600-93601, 93603-93605 (paratypes)

Diagnosis. Species with broad whorls and straight growth lines at all diameters.

Description. First three to four post-nuclear volutions ophioconic but gradually increasing in width. Subsequent whorl expansion rapid, with shell attaining cadiconic to subcadiconic, completely involute, widely umbilicate form

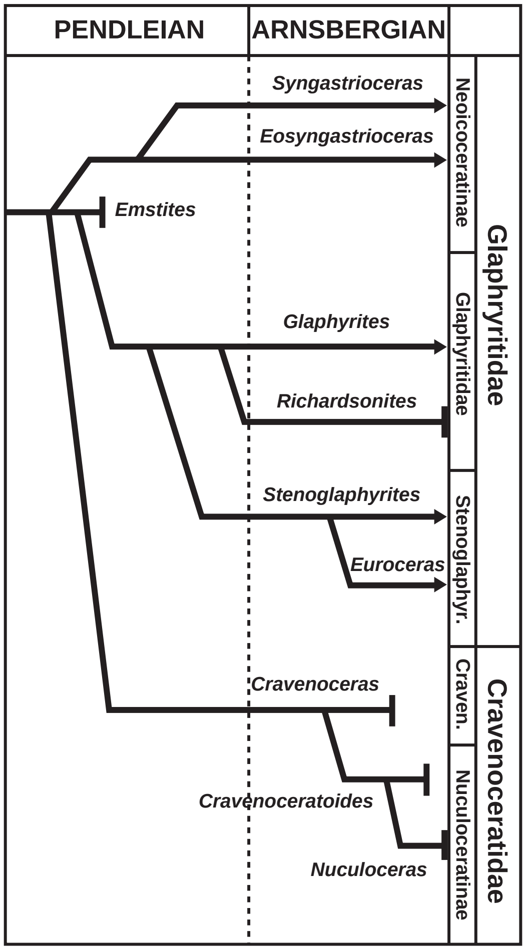


Figure 24. Diagram showing the phylogenetic relationships of selected glaphyritids and cravenoceratids. The ancestral genus for both families, Emstites, *is better classified with the Cravenoceratidae, but is shown in the Glaphyritidae to emphasize its ancestral status with that group.*

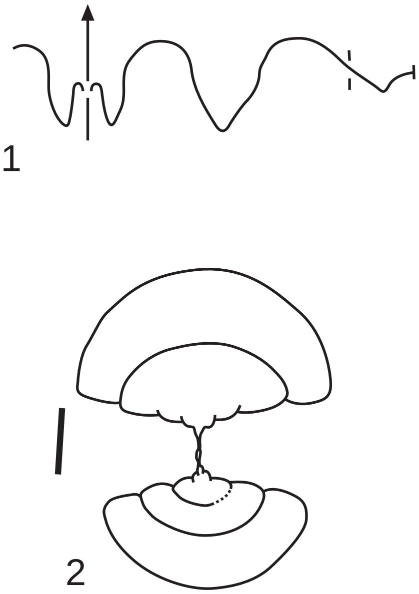


Figure 25. Suture and cross-sectional diagrams for Glaphyrites millardensis *n. sp. 1 (USNM 422319) at 20 mm D (x 3); 2 (SUI 93605 - inner whorls are crushed). Bar scale for 2 is 4 mm.*

by 10 mm D. Umbilical margin wavy due to irregularities created by constrictions. Succeeding whorls adding height slowly, but steadily. By 25 mm D, conch pachyconic and completely involute, with moderately narrow to average diameter umbilicus. Mature whorl strongly convex and fairly evenly rounded, but greatest curvature barely perceptible at venter and over ventrolateral zones; umbilical shoulder subangular; umbilical wall very gently rounded.

Large conchs have near smooth surface. Smaller conchs (D < 25 mm) marked by very fine, irregularly but generally closely spaced transverse lirae, almost straight across whorl, but forming small shallow sinus on each flank, not far from umbilical shoulder; on some specimens transverse lirae become stronger on crossing umbilical shoulder, which is slightly swollen and marked by two to four closely spaced longitudinal lirae in mature shells. Narrow transverse irregularly spaced growth constrictions, up to four per volution, are present, following the same course as transverse growth lirae.

External suture consists of fairly short, moderately broad ventral lobe, with gently curved sides, but not pinched in adorally, ending in two pointed prongs; first lateral saddle nearly evenly rounded and narrower than ventral lobe; first lateral lobe approximately same width as first lateral saddle, rather symmetrical, with rounded sides, and pointed; second lateral saddle curving asymmetrically across umbilical shoulder to short, pointed lobe near middle of umbilical wall.

Comparisons. *Glaphyrites millardensis* n. sp. is closest to *G. nevadensis* (Miller and Furnish, 1940). It differs from that species in its consistently lower and broader whorl section at equivalent diameters, its fewer and coarser longitudinal lirae bordering the umbilical shoulder, its wavy umbilical margin, and its less prosiradiate transverse lirae crossing the venter. The sides of the ventral lobe are more slanted in the only suture available in the type lot of *G. nevadensis*, but as this is a rather immature shell, this character may not be as marked in the mature suture. *Zephyroceras* (?) *uralensis* Ruzhencev and Bogoslovskaya, 1971a is somewhat similar to the new species in its submature form (Ruzhencev and Bogoslovskaya, 1971a, plate 31, figure 6). Based on a cross section in the original description of *Z.* (?) *uralensis*, that species is distinct because it has a longer ophioconic stage which suggests inclusion in *Zephyroceras*. Further study of the types is needed. Most other species can be differentiated on the basis of their wider mature conchs and/or their more pronounced ventral orad salients.

Comments. The species is probably the direct ancestor of *Glaphyrites nevadensis* (Miller and Furnish).

Distribution. Currently known only from early Arnsbergian strata (*Eumorphoceras rotuliforme* Biozone) of Millard County, Utah, where it is widespread.

Material. 17056-PC (9); 17188-PC (40+); 17209-PC (2); 17219-PC (18+); 17310-PC (53+); 22859-PC (3); 25547-PC (24+); 25550-PC (29); 17022-PC (57); 20445-PC (1); 20444-PC (22); 25260-PC (138); 93UTMI-36 (3); W84-19 (18 [type lot]).

Glaphyrites sp., cf. *G. latus* Ruzhencev and
Bogoslovskaya, 1971a
Plate 7, figures 1-9, figure 26

Description. Ophioconic to 3rd or 4th post nuclear whorl. Subsequent whorl expansion rapid. By 10 mm D, conchs are subcadiconic, completely involute, and moderately

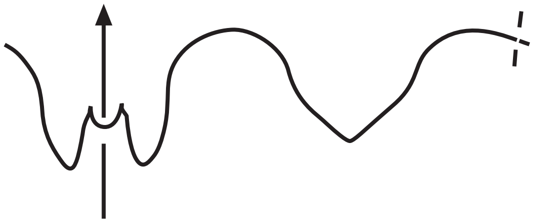


Figure 26. *Suture diagram for* Glaphyrites *sp., cf.* G. latus *Ruzhencev and Bogoslovskaya (SUI 93612) at 10 mm D (x 11).*

widely umbilicate. Umbilical shoulder moderately rounded to subangular. At larger diameters (D > 30 mm), conch form subcadiconic to barely pachyconic (W/D around 0.70), completely involute, with average width umbilici. Whorl section convex, broad and somewhat depressed. Convexity in ventral profile steadily increases through successive ontogenetic stages.

Ornament consists of medium-relief growth lamellae, nodes and spiral threads. At D around 10 mm, lamellae mildly sinuous, with distinct ventral salient, almost forming raised thread at mutual boundaries. Lamellae fade at 15-20 mm D, forming indistinct growth lines, and are mildly sinuous to rectilinear; ventral salient is lost. Faint, fine, multiple spiral threads commonly present on umbilical shoulder, less commonly over entire ventrolateral region. At 25-30 mm D, growth lines form faint hyponomic sinus and spiral threads fade. At D > 40 mm, hyponomic sinus moderately deep.

Suture at 7-10 mm D has shallow lobes and saddles with about equal widths. Ventral lobe sides parallel; prongs short and stubby. Medial saddle about one-fifth total height of ventral lobe. First lateral saddle U-shaped and symmetric. First lateral lobe deltoid and incipiently pointed. At 15 mm diameter, suture has moderately wide ventral lobe with pointed, moderately attenuate, medium width prongs, and gently convex sides. Medial saddle about one-half total lobe height. Width of first lateral saddle, which is slightly asymmetric, is 80 percent of ventral lobe. First lateral lobe same width and height as ventral lobe, sub-deltoid, and mammilate. Second lateral saddle curves broadly into umbilical region. Internal suture not observed.

Comments. The Nevada and California specimens are very close in conch form and ornament to the Ural species with which they are compared. The suture of the Ural species appears to be slightly less advanced (shorter ventral lobe with shorter, narrower prongs) than that of the North American form. These differences cause the assignment to be queried until direct comparisons can be made with Russian type material.

Distribution. *Glaphyrites latus* was originally described from the Arnsbergian of the southern Urals. The North American form tentatively assigned to this species occurs in early Arnsbergian strata (*Eumorphoceras paucinodum* Biozone) of the southern AFB.

Material. 89NVLI-17 (11); 89NVLI-18 (9); 93CAIN-2a (2); 93CAIN-2c (2).

Glaphyrites sp., cf. *G. nevadensis*
(Miller and Furnish, 1940)
Plate 7, figures, 10-12; figure 27

Description. Conch ophioconic to third or fourth volution. By fifth whorl, expansion is rapid. By largest observed D (6.5 mm), shell subcadiconic, very involute, and widely umbilicate. Whorls depressed with nearly flat venter; umbilical shoulder narrowly rounded to rounded; umbilical margin straight, not wavy.

Ornament consists of transverse growth lamellae that form broad, prominent orad bow or salient bisected by very shallow, narrow hyponomic sinus.

External suture at 6.5 mm D has equal width lobes and saddles. Medial saddle very shallow. Ventral prongs narrow, stubby, and slightly divergent. First lateral saddle symmetric and U-shaped; first lateral lobe triangular and bluntly pointed.

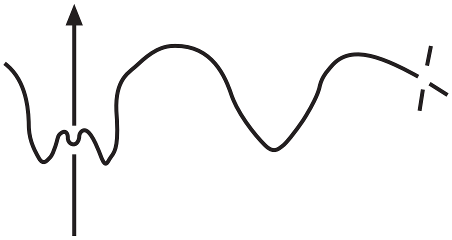


Figure 27. *Suture diagram for* Glaphyrites *sp., cf* G. nevadensis *Miller and Furnish (SUI 93613) at 6 mm D (x19).*

Comments. Because no holotype has previously been designated for *G. nevadensis*, the specimen of "*C.*" *nevadensis* illustrated by Miller and Furnish (1940) on their plate 49, figures 9, 10 is here designated the lectotype. *Cravenoceras nevadensis* was transferred to *Glaphyrites* by Ruzhencev and Bogoslovskaya (1971a, p. 286). The White Pine Range specimens, which occur with *Stenoglaphyrites colubrellus* (Miller and Furnish), are very similar to the smaller types of *G. nevadensis*. Both forms possess distinctly prosiradiate lamellae in the juvenile stage and the immature sutures are identical. The small White Pine specimens do not preserve the fine spiral threads characteristic of *G. nevadensis*, but this may be because they are too immature. Until larger specimens are found the identification must be queried.

A single specimen from the lower portion of the Imo Formation identified as *Cravenoceras* sp. A in Gordon (1965, p. 215) may be conspecific with *G. nevadensis*, judging from its prosiradiate lamellae, general conch form, and suture. As Gordon originally stated, this specimen cannot be unequivocally assigned to a species until better-preserved material becomes available.

Distribution. *Glaphyrites nevadensis* is known currently only from middle Arnsbergian strata of North America (*Eumorphoceras girtyi* Biozone). Nikolaeva (1995) reported *Glaphyrites* aff. *G. nevadensis* from the *Fayettevillea-Delepinoceras* Biozone of Uzbekistan.

Material. 95NVWP-22b (3); 95NVWP-23 (1).

Genus *CRYPTOTYLOCERAS* n. gen.

Etymology. From Greek *cryptos* (hidden) and *tylos* (nodose). A reference to the early noded juvenile stage.

Type Species. *Cryptotyloceras gordoni* n. gen., n. sp.

Diagnosis. Glaphyritids with very distinct umbilical nodes that appear near the beginning of the cadicone stage and disappear in maturity.

Comparisons. The new genus resembles *Eoasianites* Ruzhencev, 1933 because both forms possess a temporary nodose stage. However, the nodes on *Eoasianites* are less pronounced and persist to larger diameters than those of *Cryptotyloceras*. The nodes in *Fayettevillea*, the only other close form, are also less pronounced and are less regularly developed. The ancestral genus, *Glaphyrites*, lacks the prominent nodes of *Cryptotyloceras*, but is in most other aspects similar.

Distribution. Early Arnsbergian strata (*Eumorphoceras rotuliforme* Biozone), of the AFB.

Cryptotyloceras gordoni n. gen., n. sp.

Plate 7, figures 13-16; figure 28

Etymology. The trivial name honors Mackenzie Gordon, Jr., who, among his many contributions to Carboniferous ammonoid paleontology, first recognized this species as a distinct form in an unpublished manuscript.

Types. USNM 414930 (holotype); USNM 414931-414942 (paratypes).

Diagnosis. As the genus is monospecific, the species is recognized by the same features that distinguish the genus.

Description. First three to four whorls ophioconic. Subsequent whorl expansion rapid. At 10 mm D, conch cadiconic, very involute, widely umbilicate and has narrowly rounded umbilical shoulders. At this diameter, whorl section depressed, only moderately convex. By 20 mm D, shell attains pachyconic shape, is very involute, and has an average width to moderately wide umbilicus. Whorl outline well rounded over venter; flanks less convex, sloping outward slightly to subangular umbilical shoulder. Umbilical wall convex, attached to previous volution at or near its periphery.

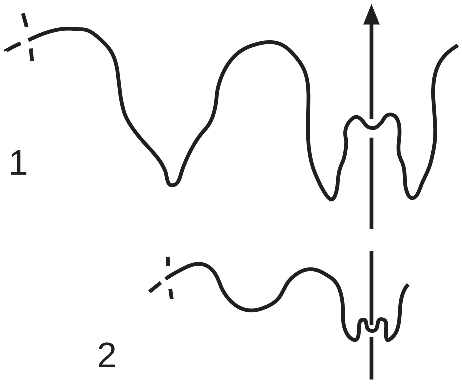


Figure 28. *Suture diagrams for* Cryptotyloceras gordoni *n. gen., n. sp. 1 (SUI 93615) at 12 mm D (x10); 2 (SUI 93614) at 6 mm D (x10).*

Nodes appear near end of fourth volution, continuing on to fifth and sixth volutions (in cadicone stage), somewhat regularly spaced, approximately 13 to 15 per volution. Peripheral thread present on sixth and seventh volutions, as umbilical shoulder becomes more angular and nodes more subdued. At D = 15-20 mm, whorls become proportionately higher, umbilical shoulder subangular, and nodes and peripheral thread die out. Shell surface smooth, but bearing tiny growth lirae, appearing almost straight transversely, but bowing adorally very slightly and almost imperceptibly indented by sinus near each umbilical shoulder and flattened or extremely shallowly indented over venter. Shallow internal constrictions follow growth lirae and are present on final volutions; approximately four per volution.

External suture has moderately narrow ventral lobe, divided adapically into two extremely narrow, parallel-sided symmetrical prongs. First lateral saddle slightly asymmetrical, subspatulate; first lateral lobe about same width as first lateral saddle, fairly symmetrical, acuminate; second lateral saddle broadly asymmetrical, curving across umbilical shoulder; umbilical lobe curving shallowly across umbilical wall but with sharp tip protruding adapically at middle.

Comments. The type lot of *Cryptotyloceras gordoni* came from a fault block in the Bishop Springs anticline, near the east edge of the Foote Range. Although faulting precludes accurate placement in a measured section, the bed also yields *Eosyngastrioceras hesperium* and *Eumorphoceras rotuliforme*, putting it within the *Eumorphoceras rotuliforme* Biozone. A single well-preserved specimen was also found at the *Eosyngastrioceras hesperium* type locality in the Egan Range which further constrains the taxon biostratigraphically.

Distribution. Known only from the *Eumorphoceras rotuliforme* Biozone of east-central Nevada and west-central Utah.

Material. 17022-PC (57); 20444-PC (22); 20445-PC (1); 25260-PC (138); 93NVLI-9 (1); W84- 19 (1).

Genus *RICHARDSONITES* Elias, 1956

Gastrioceras Hyatt, 1884. Girty, 1909 [part], p. 54.
Cravenoceras (*Richardsonites*) Elias, 1956, p. 128; Elias, 1970, p. 703.
Cravenoceras Bisat, 1928. Youngquist, 1949a [part], p. 290; Gordon, 1965 [part], p. 204; Saunders, 1973 [part], p. 29.
Eoasianites (*Glaphyrites*), Kullmann, 1962 (part), p. 303.
Glaphyrites? Wagner-Gentis, 1971, p. 653.
Homoceras Hyatt, 1884. Bisat, 1924 [part], p. 103; Bisat, 1930 [part], p. 31.
Kardailites Ruzhencev and Bogoslovskaya, 1971a. Wagner-Gentis, 1971, plate 2, figure 11.
Richardsonites Elias, 1956. Ruzhencev and Bogoslovskaya, 1971a [part], p. 298; Aisenverg and others, 1983, p. 119.
Syngastrioceras Librovitch, 1938. Ruan, 1981 [part], p. 199.

Type Species. *Gastrioceras richardsonianum* Girty, 1909.

Diagnosis. Glaphyritids with short ophioconic (3rd or 4th whorl) and cadiconic phases (D < 15 mm) and adults (D > 30 mm) with U/D ratios of 0.4 or less and a wide ventral lobe (one-third to twice as wide as first lateral lobe or saddle) with swollen, bluntly pointed prongs.

Discussion. Elias (1956, p. 128) erected the subgenus *Richardsonites* with *Gastrioceras richardsonianus* Girty, from the Caney Shale of Oklahoma as its type. Its prime identifying character, according to Elias (1956; 1970), was the internal “varix” (longitudinal ridge) in adult shells, for which Gordon (1965, p. 87) later introduced the term “intraventral ridge.” The structure appears near the end of the phragmacone at the back of the living chamber in adult shells. As this structure is found in a number of unrelated genera, including *Eumorphoceras*, Gordon (1965) correctly rejected it as a valid generic-level character. Regardless of

Elias' erroneous diagnosis for *Richardsonites*, the genus was subsequently firmly established by Ruzhencev and Bogoslovskaya (1971a), who considered the wide ventral lobe of the suture, along with the dimensions of the conch and ornament, as diagnostic. In addition to validating *Richardsonites*, these authors also erected a new species, *R. girtyanus*, which is herein referred to *Zephyroceras* based on its conch parameters and medium width ventral lobe.

The transferal of the type species of *Richardsonites* (*R. richardsonianus* (Girty)) to *Syngastrioceras* by Ruan (1981) is unjustifiable given that *Richardsonites* lacks the single spiral cord and suture that typifies *Syngastrioceras*. Although the genera are closely linked together by their similar origins in *Emstites*, they are readily differentiated and *Richardsonites* is here retained as valid. As mentioned in the discussion under *Zephyroceras*, *Richardsonites* intergrades somewhat with that genus. Criteria for distinction of the two genera include:

1. General lack of an extended ophioconic phase in the post-nuclear whorls of *Richardsonites*,
2. an umbilical to diameter ratio of around 40 percent or less in mature (diameters of greater than 25-30 mm) *Richardsonites*, and
3. the wider ventral lobe and fatter prongs of *Richardsonites*.

Also similar to *Richardsonites* is the ancestral genus *Glaphyrites* Ruzhencev, 1936, which is distinguished by its narrower ventral lobe and ventral prongs in juvenile shells. *Glaphyrites* also typically possesses multiple fine umbilical spiral threads on the umbilical shoulder which further differentiates it from *Richardsonites*, which only infrequently shows crenistriate umbilical ornament.

Another taxonomic problem concerning *Richardsonites* that has been little addressed is the distinction of that genus from *Isohomoceras* and *Homoceras*, which are its immediate descendants. Ruzhencev and Bogoslovskaya (1971b) erected the genus *Isohomoceras* for homoceratids with rounded umbilical shoulders and relatively unornamented conchs. The similarities between homoceratids and *Richardsonites* has been pointed out previously by Bisat (1924; 1930), Moore (1945), and Elias (1970). Saunders (1973, p. 30) correctly stated that juvenile and subadult shells of *Richardsonites* are easily confused with homoceratids. As far as can be told, the only significant distinction between *Richardsonites* and descendant homoceratids is the more-compressed, oxyconic conch form of the latter's adults, and perhaps the more exaggerated "calyx" stage of *Homoceras*. In regards to the preceding, the following species are included in *Richardsonites*:

R. asiaticus (Pitinova, 1988)
R. baccans Popov, 1979
R. mapesi (Saunders, 1973)
R. promodestus (Kullmann, 1962)
R. richardsonianus (Girty, 1909)

Distribution. *Richardsonites* is probably restricted to Arnsbergian strata, and with the exception of northwest Europe, has a cosmopolitan distribution.

Richardsonites richardsonianus (Girty, 1909)

Plate 8, figures 1-25; figure 29

Gastrioceras richardsonianum Girty, 1909, p. 54, plate 11, figures 1-4, 6-9, 11.

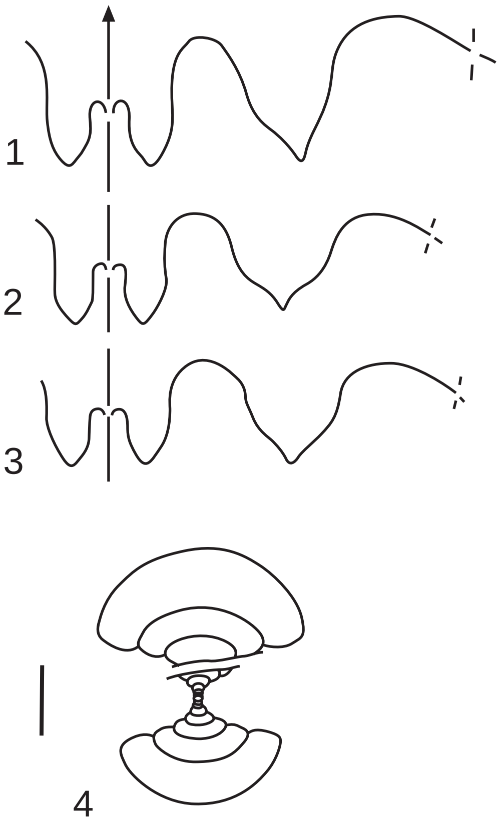


Figure 29. *Suture and cross-sectional diagrams for* Richardsonites richardsonianus *Girty. 1 (SUI 93618) at 19 mm D; 2 (SUI 93626 [topotypes]) at 12 mm D; 3 (SUI 93616) at 13 mm D; 4 (SUI 93622). 1-3 x 4. Bar scale for 4 is 5 mm.*

Cravenoceras richardsonianum (Girty). Youngquist, 1949a, plate 64, figure 17-18, text figure 2B; Gordon, 1965, plate 22, figures 28-30, text figures 53A-53D, 55A, 55B; ?Gordon, 1965, plate 22, figures 31-34, text figure 55K.

Cravenoceras (*Richardsonites*) richardsonianum (Girty). Elias, 1956, p. 129; 1970, plate 2, figures 1-5.

Richardsonites richardsonianus (Girty). ?Ruzhencev and Bogoslovskaya, 1971a, plate 33, figure 3, text figures 76a, 76b.

Holotype. USNM 119585

Diagnosis. Species with medium to strongly ornamented, cadiconic to subcadiconic juveniles (D < 10 mm) and/or only moderately attenuate sutural elements.

Description. Conch ophioconic to third or fourth post-nuclear whorl. Subsequent whorl expansion rapid. By 10 mm D, conch is subcadiconic, completely involute, and moderately widely umbilicate. Whorl cross section broad and depressed and umbilical shoulders are narrowly rounded. By 20-25 mm D, conchs exhibit a dimorphic trend initiated at about 10 mm D, with some individuals having broader conchs (subcadicone) and average umbilical widths; others have pachyconic shells with moderately narrow umbilici. At these advanced diameters, whorl cross sections are moderately to strongly convex, and umbilical shoulders are rounded. Some intergradation between two morphotypes is evident. By 30-35 mm D, venter becomes narrowly rounded, creating V-shaped, elliptical outline to whorl. Gerontic forms (> 60 mm D) probably oxycones.

At D = 10 mm, ornament consists of moderate to high-relief growth lamellae that turn to lirae on umbilical shoulder. Lamellae make a broad, shallow to moderately deep ventral salient. By 15 mm D, lamellae are reduced to low or moderate relief and attain a nearly perpendicular aspect relative to umbilical edge. At about 30 mm D, hyponomic sinus appears that continues to deepen through subsequent ontogeny. Uncommon individuals display three to five bands of crenulations in their growth lines near umbilical margin starting at 15-20 mm D.

At 10 mm D, suture has wide ventral lobe (1.5 times width of first lateral saddle), with wide, stubby, asymmetric prongs. Medial saddle about one-half height of ventral lobe. First lateral saddle symmetric and U-shaped. First lateral lobe broad at base, initially tapering to triangular shape about one-third the way from base, and is mammilate. At 22 mm D, ventral lobe is 1.8 times width of first lateral saddle. Ventral prongs are wide, strongly convex on ventrad side, and gently convex on dorsad side. Medial saddle is about one-third height of ventral lobe. First saddle U-shaped, but with ventral side nearly parallel to direction of coiling, and dorsad edge skewed towards umbilical margin. First lateral lobe essentially same configuration as at D = 10 mm except more attenuate. Umbilical lobe ends in short sharp point just inside center of umbilical wall. Internal suture not observed.

Comparisons. On specimens where D < 10 mm, *Richardsonites richardsonianus* generally has coarser lamellae than *R. baccans* and *R. mapesi*. The Donets species, *R. baccans*, also appears to develop an angular umbilical rim, which further differentiates it from *R. richardsonianus*. *Richardsonites promodestus* and *R. asiaticus* (formerly referred to *Paracravenoceras*) have more attenuate sutural elements (deeper lobes and saddles) at comparable diameters.

Comments. This is the first description of the species from outside of the midcontinental United States. Suites of material from the type locality demonstrate that *R. richardsonianus* (Girty) is highly variable in conch form and suture, although the juveniles are consistently widely umbilicate. Specimens recovered from the AFB are equally variable. Although the species is widespread in the south-central U. S., the report of *R. richardsonianus* from the Barnett Shale by Plummer and Scott (1937) is regarded here as incorrect. Examination of the illustrated specimens shows that their ventral lobes are much too narrow to diagnose as *Richardsonites*. The sutures and conch form of these specimens closely resemble those of *Cravenoceras* or *Glaphyrites*, but without direct examination they cannot be referred to a genus with certainty. Identification of specimens from the upper part of the Pitkin Limestone as *R. richardsonianus* by Saunders and others (1977) is also incorrect. These specimens are completely involute and very narrowly umbilicate at D < 10 mm and belong in *Stenoglaphyrites*. The report of *R. richardsonianus* from the Rancheria Limestone of west Texas by McCaleb and others (1964) is correct, based on my comparisons with topotype material.

Distribution. Middle Arnsbergian strata (*Eumorphoceras girtyi* Biozone) of the AFB. Elsewhere, it has been reported from similar age strata of west Texas, south-central Oklahoma, and northern Arkansas.

Material. 15161-PC (6); 15370-PC (129); 16959-PC (36); 16960-PC (2); 17024-PC (62); 22880-PC (8); 25258-PC (2); 29066-PC (20); 89NVNY-4 (2); 93CAIN-6 (98+); 93NVWP-12 (13+); 93UTMI-4 (93+); 93UTMI-38 (3); 95NVWP-23 (1).

Subfamily FAYETTEVILLEINAE Ruzhencev and Bogoslovskaya, 1971a

Diagnosis. See Ruzhencev and Bogoslovskaya (1971a).

Comments. Ruzhencev and Bogoslovskaya (1971a; 1978) concluded that the Fayettevilleinae originated from the evolute, highly decorated Pendleian genus *Rhymmoceras*, and thus placed it in the Rhymmoceratidae. However, the following evidence indicates that *Parafayettevillea* and *Fayettevillea*, and thus the Fayettevilleinae did not originate from *Rhymmoceras* as proposed by Ruzhencev and Bogoslovskaya (1971a).

1. *Fayettevillea* appears in its fully characteristic form in the middle Pendleian of North America (Saunders and others, 1977), it apparently does not appear in the Urals until the late Pendleian or early Arnsbergian (Nm_1c). *Parafayettevillea* appears even earlier, in the lower Pendleian (E_1a).
2. Contemporaneous rhymmoceratids, which posses strong longitudinal lirae, are very dissimilar ornamentally to *Fayettevillea*.
3. *Parafayettevillea*, *Zephyroceras*, and *Fayettevillea*, which bear only simple transverse lamellae and very faint spirals on the umbilical shoulder, intergrade morphologically, ornamentally, and suturally with the contemporaneous genera *Emstites* and *Glaphyrites*, not *Rhymmoceras*.

For these reasons the Fayettevilleinae, which are characterized by juveniles with planorbid conchs to at least the 5th to 7th post-nuclear whorl, pachyconic to cadiconic adults, simple strap-like lamellae, and rounded umbilical shoulders that are smooth or ornamented with multiple fine lirae, are here removed from the Rhymmoceratidae and placed in the Glaphyritidae, which is expanded to accommodate forms with planorbid early whorls. The Fayettevilleinae consists of the following three genera: *Fayettevillea* Gordon, 1960, *Parafayettevillea* Yang, 1986, and *Zephyroceras* Kullmann, 1962. The latter genus probably arose independently from *Glaphyrites* and not from *Parafayettevillea* as *Fayettevillea* did, but cannot be conveniently placed elsewhere in the Glaphyritidae. *Parafayettevillea*, the earliest known representative of the subfamily, has a relatively narrow, *Emstites* or *Cravenoceras*-like ventral lobe. All later members have a medium-width ventral lobe with a moderately shallow to moderately deep medial saddle.

Distribution. Namurian strata, worldwide.

Genus *FAYETTEVILLEA* Gordon, 1960

Cravenoceras Bisat, 1928. Gordon, 1964 [part], p. A11.

Tympanoceras Ruzhencev, 1958a. ?Wagner-Gentis, 1963, p. 18.

Eoasianites (*Eoasianites*) Ruzhencev, 1933. ?Kullmann, 1963 [part], p. 295.

Eoasianites (*Glaphyrites*) Ruzhencev, 1936. ?Kullmann, 1963 [part], p. 303.

Type Species. *Fayettevillea planorbis* Gordon, 1960

Diagnosis (emended from Horn and others, 1989). Glaphyritids with at least the first 5-6 post-nuclear whorls ophioconic, moderately evolute, very widely umbilicate, and typically, but not always, ornamented by irregular nodes. Suture critical to diagnosis, and by 10 mm D ventral lobe is relatively wide and has a slightly constricted base. Single, sharply defined, high-relief spiral chord absent from umbilical shoulder, which instead bears multiple fine lirae or is smooth.

Comparisons. *Fayettevillea* is close to *Parafayettevillea*, *Glaphyrites*, *Zephyroceras*, and *Richardsonites*. *Parafayettevillea* has a narrow ventral lobe with an unconstricted base, shallow medial saddle, and narrow prongs. The ophioconic (planorbid) stage of *Richardsonites* and *Glaphyrites* does not persist past the 4-5 post-nuclear whorl. *Zephyroceras* is very close, but fundamental differences in the juvenile suture distinguish the two. *Fayettevillea* has a more "advanced" suture displaying a high ventral lobe with a distinctly constricted base and a higher degree of pouching in the lateral lobes.

Comments. *Fayettevillea* was erected for immature phragmacones collected from a middle Pendleian (E_1b) horizon in the Fayetteville Shale, Washington County, Arkansas. Because an adult was not included in the type lot, the later ontogenetic stages of the genus were not known. However, the juvenile holotype displays a distinctly pouched ventral lobe that is unusual for glaphyritids, cravenoceratids, and even other fayettevilleans of similar diameter (compare Gordon, 1965, figure 62c with Ruzhencev and Bogoslovskaya, 1971a, figure 88b). Two possible explanations are:

1. the holotype is actually a very small specimen of *Pronorites*; or
2. *Fayettevillea sensu stricto* possesses an advanced suture that is diagnostic of the genus.

Other features found on the holotype, including constrictions and node-like swellings on the umbilical rim, exclude the first possibility, forcing the diagnosis of *Fayettevillea* to include a goblet-like ventral lobe with a distinctly constricted base. This fact has been ignored by most subsequent workers. The shape of the holotype's ventral lobe is significant because it indicates that the adult shell would develop a constricted, *Syngastrioceras*-like suture. It also demonstrates close affinity of the genotype with *F. inyoense* (Gordon) and an undescribed form from the Lick Mountain locality of Manger and Quinn (1972).

Yang (1986) erected the subgenus *Parafayettevillea* to accommodate forms previously referred to *Fayettevillea* that had shallow medial saddles. Horn and others (1989) raised *Parafayettevillea* to full generic rank and modified the diagnosis to include only "small" forms with acute first lateral lobes. I have concluded that the criteria given by Horn and others (1989) for distinction of *Fayettevillea* from *Parafayettevillea* (rounded lateral lobes and smaller shell of the former) can be consistently applied.

Study of Pendleian and early Arnsbergian fayettevilleins from the AFB has led me to conclude that all species ultimately develop acute first lateral lobes, and the exact diameter at which this happens is somewhat variable even within a population. In addition, the size of individuals at any given locality is determined mostly by taphonomic or ecological factors rather than genetics. On the other hand, the relative width and distinctly constricted base of *Fayettevillea* forms a ready basis for separating the two genera. Examination of the juvenile suture pattern of the genotype of *Parafayettevillea*, *P. serpentina* Yang, 1986, shows that the ventral lobe of that species has an unconstricted base and is very narrow, with narrow, short ventral prongs. The narrow, unconstricted lobe of *Parafayettevillea serpentina* is characteristic only of early Pendleian species described from China (Yang, 1986) and Portugal (Horn and others, 1989). *Fayettevillea* can be differentiated from *Zephyroceras* (= in part, *Parafayettevillea* of Horn and others, 1989) because the latter, although their sutures are similar, also possesses an unconstricted ventral lobe in juvenile stages. Based on the preceding, the following species are assigned to *Fayettevillea*:

?*F. getinoi* (Wagner-Gentis, 1963)
F. inyoense (Gordon, 1964)
F. planorbis Gordon, 1960
?*F. prior* (Kullmann, 1962)
?*F. subangulatum* (Kullmann, 1962)

Distribution. Pendleian and Arnsbergian strata, North America and possibly northern Spain.

Fayettevillea inyoense (Gordon, 1964)
Plate 9, figures 1-5; figure 30

Cravenoceras inyoense Gordon, 1964 [part], plate 3, figures 1, 2, 6-9, 18-20, p. A14, text figure 4F, 4G.

Holotype. SU 9157.

Diagnosis. Individuals possess extended juvenile ophioconic stage (past sixth post-nuclear volution) and pachyconic, widely umbilicate adults (D > 15 mm). Suture highly developed, with an attenuate ventral lobe that is constricted at the base and possesses asymmetric prongs. Ornament simple rectilinear to retrosiradiate growth lamellae.

Description. First 6-7 post-nuclear whorls ophioconic, with wide, rounded umbilical shoulders. Subsequent whorl expansion rapid. By D = 10 mm, conch has attained subcadiconic shape, is completely involute, and widely to very widely umbilicate. Umbilical shoulders at this stage narrowly rounded. Whorl cross section broad, low, and gently convex. At D = 20-30 mm, whorl section becomes progressively more convex, and conch becomes pachyconic, completely involute, and widely umbilicate.

Ornament primarily simple, moderately sinuous, medium- to low-relief growth lamellae, and in juvenile shells, irregularly spaced nodes. Growth lines slightly retrosiradi-

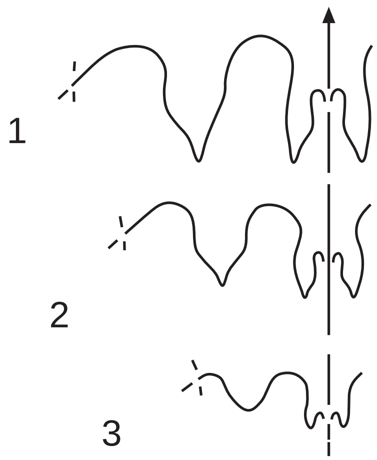


Figure 30. Suture diagrams for Fayettevillea inyoense *(Gordon). 1 (SUI 93631) at 35 mm D (x2); 2 (SUI 93630) at 14.5 mm D (x3.5); 3 (SUI 93629) at 7 mm D (x6.5).*

ate near umbilical margin, forming shallow salient midflank, and very faint sinus at mid-venter. Starting at D = 15-20 mm, lamellae become nearly rectilinear to entirely retrosiradiate. Hyponomic sinus progressively deepens through successive ontogeny. At approximately D = 40-50 mm, lamellae fade to give conch smooth appearance. Multiple (3-6), faint, thin spiral traces in the form of crenulations on lamellae uncommonly present on umbilical shoulder. Five to 10 irregularly spaced nodes per whorl occur on shells less than 15-20 mm D. At larger diameters, umbilical margin typically irregular, but lacks distinct nodes. Constrictions number 3 to 4 per whorl and visible only on internal mold. An ontogenetic suture series is depicted in figure 30.

Comparisons. Meaningful comparisons with the genotype, *F. planorbis* (Gordon, 1960), are impossible because an unequivocal adult has never been described. Larger, undescribed specimens that are probably conspecific with *F. planorbis* are in the Quinn collection at the University of Arkansas. These have a slightly less-developed ventral lobe (weaker basal constriction and less attenuate prongs) than *F. inyoense* at comparable diameters. All other species (which are only doubtfully referred to this genus) differ because they have distinct ventral salients in their lamellae and constrictions visible on the exterior of the conch. Because the early sutures of the Spanish species like *F. prior* are not known, it is possible these forms belong in *Zephyroceras*.

Comments. Youngest occurrence of the genus in western North America. Other occurrences are known from the middle and late Pendleian. Younger forms previously referred to *Fayettevillea* are transferred herein to *Zephyroceras*.

Distribution. Early Arnsbergian (*Eumorphoceras paucinodum* and *E. rotuliforme* biozones) strata of the AFB.

Material. 89NVLI-17 (9); 89NVLI-18 (22); 93CAIN-2a (8); 93CAIN-2b (4); 93CAIN-2c (7); 93CAIN-2d (2).

Genus *ZEPHYROCERAS* Kullmann, 1962

Eoasianites (*Zephyroceras*) [part], Kullmann, 1962, p. 56.

Zephyroceras Kullmann, 1962. Ruzhencev and Bogoslovskaya, 1971a [part], p. 305.

Pseudoparalegoceras Miller, 1934. Miller and Owen, 1944 [part], p. 427.

Cravenoceras Bisat, 1928. Gordon, 1965 [part], p. 204; Saunders, 1973 [part], p. 29; Nassichuk, 1975 [part], p. 81.

Eoasianites (*Eoasianites*) Ruzhencev, 1933. Kullmann, 1962 [part], p. 295.

Eoasianites (*Glaphyrites*) Ruzhencev, 1936. Kullmann, 1962 [part], p. 303.

Fayettevillea Gordon, 1960. Saunders and others, 1977 [part], p. 120; Ruzhencev and Bogoslovskaya, 1971a [part], p. 341; Horn and others 1989 [part], p. 478.

Cravenoceras (*Richardsonites*) Elias, 1956 [part], p. 128.

Zidadarites Nikolaeva, 1997, p. 232.

Type species. *Eoasianites* (*Zephyroceras*) *asturicum* Kullmann, 1962.

Diagnosis (emended from Ruzhencev and Bogoslovskaya, 1971a). Fayettevilleins with the ventral lobe not exceeding the first lateral saddle in width and unconstricted at the base in specimens where D < 10-12 mm. In addition, the medial saddle is greater than 30-40% of the height of the ventral lobe.

Comments. *Zephyroceras* was originally erected by Kullmann (1962) as a subgenus of *Eoasianites* to accommodate moderately widely umbilicate forms (holotype has an adult U/D ratio of about 0.3) with medium-width ventral lobes and an extended ophioconic juvenile stage (see Kullmann, 1962, plate 4, figure 3). Ruzhencev and Bogoslovskaya (1971a, p. 305) subsequently raised *Zephyroceras* to generic rank, demonstrated it had no affiliation with *Eoasianites*, and inexplicably referred it to the Stenoglaphyritidae. Continuing the misconception of the genus, in the same paper these authors erected a species, *Zephyroceras kianense*, in apparent disregard of the fact that the conch form (very narrow umbilicus) of "*Z.*" *kianense* is completely different from that of *Z. asturicus*. Based upon the relatively narrow ventral prongs and umbilicus of "*Zephyroceras*" *kianense*, that species is here referred to *Rhadinites* Saunders, 1973. Based on the sutural and morphologic traits of the genotype discussed herein, *Zephyroceras* is transferred from the Stenoglaphyritidae to the Fayettevilleinae.

This study has also led to the conclusion that *Zephyroceras* forms a near-morphologic continuum with species that do not posses extended ophioconic stages, and as such would normally be referred to *Richardsonites* or *Glaphyrites*. A very close phylogenetic tie between *Richardsonites*, *Glaphyrites*, and *Zephyroceras* is demonstrated by their degree of intergradation, which almost certainly reflects a mutual ancestry in *Emstites*. In addition, the suture line of *Zephyroceras* appears to be relatively plastic, varying unpredictably not only through time, but also between apparently contemporaneous, isolated populations. Sutures of some species seem closer to *Glaphyrites* (see Nassichuk, 1975, text figure 31), while others appear closer to *Richardsonites* (see Riley, 1987, figure 4B). *Richardsonites* can be distinguished from *Zephyroceras* because the former has a wider ventral lobe and no extended ophioconic phase. The line between *Zephyroceras* and *Glaphyrites* is less clear, but the latter generally lacks an extended juvenile ophioconic phase and typically has a more compressed conch form. The differentiation of *Zephyroceras* from *Fayettevillea* is based on the unconstricted base of the juvenile ventral lobe of the former, which is discussed above under *Fayettevillea*. *Parafayettevillea* has a much narrower mature ventral lobe with narrow prongs and presumably never develops a particularly deep medial saddle.

Nikolaeva (1997) erected the genus *Zidadarites* (type species: *Z. leveni* Nikolaeva, 1997) to accommodate fayettevilleins with relatively compressed whorl sections, more rapid loss of the serpenticonic (ophioconic) phase, and narrower umbilici than typical for *Fayettevillea*. *Zidadarites* is readily distinguished from *Fayettevillea* because its ventral lobe is not constricted at the base. However, *Zidadarites* was not compared with *Zephyroceras*, probably because of the "Russian" misconception of the genus. Because I find no practical way to separate the two genera, they are here placed in synonymy.

Some contemporaneous species of *Cravenoceras* (see *C. holmesi* Bisat, 1932) display the evolute, widely umbilicate conchs characteristic of *Zephyroceras*. These can be distinguished by sutures, the latter having a wider ventral lobe with less symmetrically shaped prongs. Using the

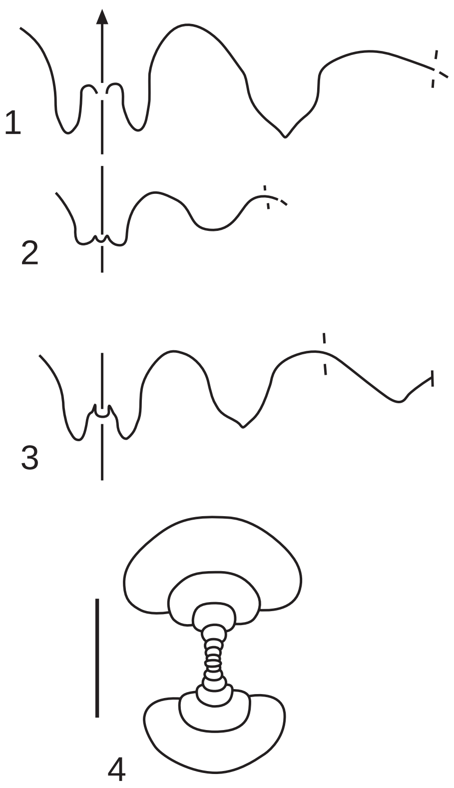


Figure 31. *Suture and cross-sectional diagrams for* Zephyroceras. *1, 2, 4 -* Zephyroceras girtyanum *Ruzhencev and Bogoslovskaya, 1 (SUI 93638) at D, 14 mm (x 6.8), 2 (SUI 93639) at D, 5 mm (x13), 4 (SUI 93637) bar scale, 4 mm; 3 -* Zephyroceras friscoense *(Miller and Furnish) (SUI 93642) at D, 9 mm (x8.3).*

emended diagnosis, the following species can be assigned to *Zephyroceras*:

- *Z. asturicum* Kullmann, 1962
- *Z. bransoni* (Saunders, 1973)
- *Z. darwenense* (Moore, 1945)
- ?*Z. embolicum* (Ruzhencev and Bogoslovskaya, 1971a)
- *Z. friscoense* (Miller and Owen, 1944)
- *Z. girtyanum* (Ruzhencev and Bogoslovskaya, 1971a)
- ?*Z. ibericum* (Kullmann, 1962)
- *Z. leveni* (Nikolaeva, 1997)
- *Z. occidentalis* (Ruzhencev and Bogoslovskaya, 1971a)
- *Z. orientalis* (Ruzhencev and Bogoslovskaya, 1971a)
- *Z. pseudomalhamense* (Kullmann, 1962)
- *Z. tozeri* (Nassichuk, 1975)
- ?*Z. uralense* (Ruzhencev and Bogoslovskaya, 1971a)

Distribution. Pendleian and Arnsbergian strata, cosmopolitan.

Zephyroceras girtyanum (Ruzhencev and Bogoslovskaya, 1971a)

Plate 9, figures 6-12, 15, 16; text figures 31.1, 31.2, 31.4

Richardsonites girtyanus Ruzhencev and Bogoslovskaya, 1971a, p. 299, plate 33, figures 1-2, text figure 76c.

?*Cravenoceras* sp. B Gordon, 1965, plate 21, figures 8-11, text figure 55I.

Holotype. PIN 455/36437.

Diagnosis. Species with low pachyconic conch and moderately wide umbilicus (U/D ratio of around 0.3).

Description. Ophioconic stage persists to about fourth or fifth post-nuclear whorl. Subsequent rapid whorl expansion gives conch subcadiconic, very involute, moderately wide umbilicate shape by D = 15 mm. Up to D = 10 mm, umbilical wall steep and shoulders subrounded to subangular. After D = 10 mm, umbilicus funnel-shaped. By D = 17-18 mm, umbilical wall nearly parallel to axis of coiling. Whorl cross section initially broad and gently, progressively becoming higher and more convex through growth. By D = 30 mm conch pachyconic and very involute, with average width umbilicus (U/D = 0.30-0.35).

Ornament is medium- to low-relief growth lamellae only. These are rectilinear to mildly sinuous to D = 15 mm. Subsequent lamellae develop distinct hyponomic sinus that continues to deepen through later ontogeny. At D > 25 mm hyponomic sinus is deep. Nodes absent. Constrictions present on internal mold only, numbering about three to four per whorl, and following growth lines in configuration.

Suture at D = 12 mm has equal width external lobes and saddles. Ventral lobe has nearly parallel sides and shallow medial saddle about one-fourth to one-fifth the height of ventral lobe. Ventral prongs short, nearly symmetric and bluntly pointed. First lateral saddle U-shaped, broadly rounded. First lateral lobe deltoid and bluntly pointed. Internal suture not observed.

Comparisons. This species is especially close to *Z. bransoni* (Saunders, 1973) (compare Ruzhencev and Bogoslovskaya, 1971a, plate 33, figure 2 with Saunders, 1973, plate 4, figures 7, 8). *Zephyroceras bransoni* appears to have a slightly more compressed conch, as does *Z. leveni* (Nikolaeva). The Spanish species *Z. asturicum* also has a similar adult conch form, but has a less involute juvenile stage. All other species have wider conchs, lower umbilical to diameter ratios, or more extended ophioconic stages at comparable diameters.

Comments. Although originally described as a species of *Richardsonites*, the widely umbilicate form of the adult conch refers this species to *Zephyroceras*. *Zephyroceras bransoni*, a form very similar to, and a possible descendant of, *Z. girtyanum*, was originally described as a species of *Cravenoceras* by Saunders (1973). Later it was referred to *Fayettevillea* by Saunders and others (1977). However, the ophioconic stage of the species is limited to the first three or four post-nuclear volutions. This single feature excludes "*C.*" *bransoni* from *Fayettevillea*. In addition, while the U/D ratio of adult "*C.*" *bransoni* (D > than 30 mm) was reported to range as high as 50 percent by Saunders (1973), none of the actual illustrated specimens even approach this figure. Based on the holotype and undescribed material in the University of Arkansas collections, the typical "*C.*" *bransoni* has a U/D ratio of around 0.3 to 0.4. Together, these characteristics refer "*C.*" *bransoni* to *Zephyroceras*.

Distribution. Middle Arnsbergian strata (*Eumorphoceras girtyi* Biozone) of the AFB. Elsewhere the species occurs in ?Arkansas (middle Arnsbergian) and the southern Urals (late Arnsbergian).

Material. 92NVLI-4 (2); 92NVLI-2 (11); 93NVCL-1 (10); 94NVCL-3 (19).

Zephyroceras friscoense (Miller and Owen, 1944)

Plate 9, figures 13, 14, 17, 18; text figure 31.3

Pseudoparalegoceras friscoense Miller and Owen, 1944, p.

421, figure 2a, Plate 66, figures 1-2.

Cravenoceras friscoense (Miller and Owen). Saunders, 1973, p. 33, text figures 9-10, plate 2, figures 1-19, plate 3, figures 1-16; Saunders, 1975, plate 1, figures 5, 18-19.

Fayettevillea friscoense (Miller and Owen). Saunders, and others, 1977, plate 3, figures 5, 18-19.

not *Cravenoceras* (*Richardsonites*) *friscoensis* (Miller and Owen). Elias, 1956, p. 129.

Diagnosis. Widely umbilicate species with no ventral salient and a relatively shallow medial saddle (about 30-40% total height of ventral lobe).

Description. Conch ophioconic to fifth or sixth post-nuclear whorl. Subsequent whorl expansion rapid. By D = 10 mm, conch cadiconic to subcadiconic, very involute, and widely umbilicate, with broad, depressed whorl cross section. Umbilical shoulders initially rounded, changing to narrowly rounded by D = 10 mm. Umbilical margin attains an irregular outline (wavy) by D = 7 mm. After D = 20 mm, whorl section becomes progressively more convex, and conch width to diameter ratio drops. Large individuals (D = 63 mm) are broadly subdiscoidal and widely umbilicate, with a broadly parabolic whorl cross section. Umbilical wall flat and inclined inward at an angle of roughly 60° to axis of coiling.

Ornament solely medium- to low-relief transverse growth lamellae. Lamellae rectilinear and perfectly radial where D < 7-10 mm. Subsequently they attain mildly sinuous aspect, with some conchs showing slight ventral salients. Subsequent expression of lamellae somewhat variable, although by D = 30 mm, distinct hyponomic sinus typically develops.

At D < 15 mm, ventral lobe of suture moderate in width and has somewhat bluntly tipped prongs. Ventral sides of prongs parallel to direction of coiling, dorsad side slightly convex. First lateral saddle U-shaped, symmetric, and same width as ventral lobe. First lateral lobe slightly asymmetric, developing mammilate aspect at about D = 15 mm. At D = 50 mm, sutural elements very attenuate. First lateral lobe V-shaped and sharply pointed. Ventral lobe bears two asymmetric, slightly divergent, attenuate, sharply pointed prongs. Internal suture not observed.

Comparisons. *Zephyroceras friscoense* is especially close to *Z. darwenense*, *Z. tozeri*, and *Z. occidentalis*. The British species, *Z. darwenense*, which is likewise highly variable morphologically, differs by the nature of its suture, which has a deeper medial saddle and somewhat wider ventral prongs. Differentiation of *Z. friscoense* and *Z. occidentalis* is more difficult, and the two species may ultimately prove to be synonyms. Based on an illustrated suture for *Z. occidentalis* the species has a somewhat deeper medial saddle than typical *Z. friscoense*. Based on figure 3 of plate 7 in Nassichuk (1975), *Z. tozeri* has a strong ventral salient at D > 20 mm. This feature serves to distinguish that species from *Z. friscoense* and allies it with forms in the middle Arnsbergian of Spain.

Comments. The Nevada and Utah specimens fit within the wide range of variation given to *Zephyroceras friscoense* by Saunders (1973). A specimen in table 2 of Saunders (1973) has a D equal to 42.5 mm, a U/D of 0.44, and a W/H of 1.52; these values are very close to those of a Utah specimen from locality 17008-PC.

From the illustrated cross section and discussion in Elias (1956), it is clear that the form referred to in that paper as *Cravenoceras* (*Richardsonites*) *friscoensis* is compressed and narrowly umbilicate. Since these features exclude this specimen from *Zephyroceras*, it must be referred to the only comparable Rhoda Creek taxon, *Rhadinites miseri* (Gordon).

Distribution. Middle and upper Arnsbergian strata (*Eumorphoceras girtyi-Delepinoceras thalassoide* Biozones) of the AFB, and similar age strata in the southern midcontinental United States (Saunders, 1973).

Material. 17008-PC (1), 89NVNY-4 (3); 89NVNY-5 (2); 89NVNY-6 (1); 92 NVLI-2 (1); 93NVCL-1 (5); 94NVCL-4 (1); 94NVNY-16 (1); 95NVWP-22a (1).

Subfamily NEOICOCERATINAE Hyatt, 1900

Genus *EOSYNGASTRIOCERAS* n. gen.

Cravenoceras Bisat, 1928. Miller and Furnish, 1940 [part]; Youngquist, 1949a [part]; 1949b [part]; Gordon, 1964 [part]; Gordon, 1970 [part]; Saunders and others, 1977 [part]; Webster and others, 1984 [part].

Syngastrioceras Librovitch, 1938. Saunders, 1973; Saunders and others, 1977 [part].

Type species. *Eosyngastrioceras quadratum* n. sp.

Etymology. The name is a reference to the ancestral relationship the new genus has with its descendant, *Syngastrioceras*.

Diagnosis. Forms with pachyconic to cadiconic conchs and simple mildly sinuous growth lines, bearing only a single, prominent spiral cord on the umbilical shoulder. Ventral lobe of suture with moderate width ($H_L/W_L = 1.3$), a moderately deep medial saddle (approximately 75% the height of the ventral lobe in mature individuals), and moderately wide, sharply pointed, relatively narrow sub-parallel ventral prongs. Lobes only mildly constricted to non-constricted at the base.

Comparisons. The new genus is close to *Glaphyrites*, a sister genus, but can be differentiated from it by the latter's possession of multiple fine lirae around the umbilical shoulder in earlier growth stages. Certain forms of *Emstites* with a single spiral umbilical cord are very close, but posses a much shallower median saddle (50% or less total height of ventral lobe). *Syngastrioceras*, the immediate descendant of the new genus is distinguished by its wider ventral lobe and more inflated ventral prongs, which frequently diverge in middle and late growth stages. The base of sutural lobes in *Syngastrioceras* are also generally more constricted. *Neoicoceras* is much more evolute and widely umbilicate. *Cravenoceras*, which many species here assigned to the new genus were formerly referred to, can be readily differentiated by its possession of a narrower ventral lobe with slender prongs.

Comments. Many North American forms referred by previous workers to *Cravenoceras* can now be placed in other genera such as *Fayettevillea*, *Richardsonites*, *Glaphyrites*, *Emstites*, *Euroceras*, and *Zephyroceras*. It is ironic that *Cravenoceras sensu stricto* is very rare in North America. The dominant generic taxon in the Great Basin, which is characterized by a single strong cord on the umbilicus, a moderately wide ventral lobe with a deep median saddle, moderate-width subparallel ventral prongs, and simple mildly sinuous strap-like lamellae, does not fit into any pre-existing taxa as defined herein. Direct comparison of these

North American specimens with topotypic specimens of the genotype of *Cravenoceras* (*C. malhamense* Bisat) reveal that the forms are easily differentiated. *Cravenoceras sensu stricto* is characterized by a relatively smooth conch bearing no longitudinal ornament and a suture whose ventral lobe is very narrow, parallel-sided, and has a very shallow median saddle. Nothing matching this description occurs in pre-mid-Arnsbergian strata in North America. The prolific North American form, with its single shoulder cord and well-developed ventral lobe is actually closest to *Syngastrioceras*, and is here considered its immediate ancestor. It apparently does not occur outside of North America and is restricted to Pendleian, Arnsbergian, and possibly early Chokierian strata.

Certain forms of *Emstites* in both Europe and North America (for example, *Emstites leion* (Bisat)) bear a single spiral cord on the umbilical shoulder, while others, like *Emstites novalis* Korn, bear multiple spiral lirae (see comments under *Glaphyrites*). I hypothesize that climatic-driven isolation of western and eastern Laurussia from each other during the Pendleian (Titus, 1997b) lead to the evolution of *Eosyngastrioceras* and *Glaphyrites* respectively, from these two forms of *Emstites* in North America (figure 24), while in Eurasia, *Cravenoceras* and several other endemic cravenoceratids (such as *Verancoceras*) appeared from the latter. The following species are included in the new genus:

E. quadratum n. sp.
E. hesperium (Miller and Furnish, 1940)
E. imprimum (Saunders, 1973)
E. inexpectans n. sp.

Distribution. Pendleian through Arnsbergian strata, North America. The genus is also probably present in lower Chokierian strata of Nevada, but this cannot be confirmed without further collecting.

Eosyngastrioceras quadratum n. gen., n. sp.
Plate 10, figures 1-17; figure 32

Cravenoceras nevadense Miller and Furnish. Youngquist, 1949a, plate 58, figures 7-11; plate 59, figures 1, 14-18; plate 60, figures 3, 4, plate 62, figures 11-15; plate 64, figures 13-16.

Cravenoceras hesperium Miller and Furnish. Youngquist, 1949a [part], plate 59, figures 14-16, plate 60, figures 8-10, plate 62, figures 1-6, 16-18; ?1949b, p. 613, 614, plate 100, figures 4-7; Gordon, 1964 [part], p. A12, text figure 4E, plate 3, figures 3-5, 24-26.

Cravenoceras sp. Saunders and others, 1977 [part].

Etymology. Named for the fourfold division frequently created on internal molds by growth constrictions.

Types. Holotype, USNM 120617, illustrated in Gordon, 1964, plate 3, figures 3-5; paratypes, SUI 93550-93559.

Diagnosis. Moderately evolute species with a sub-rounded to sub-rectangular venter and umbilical ratios of approximately two-fifths (42 to 35 percent) of D. Growth lamellae distinct until at least 30 mm diameter.

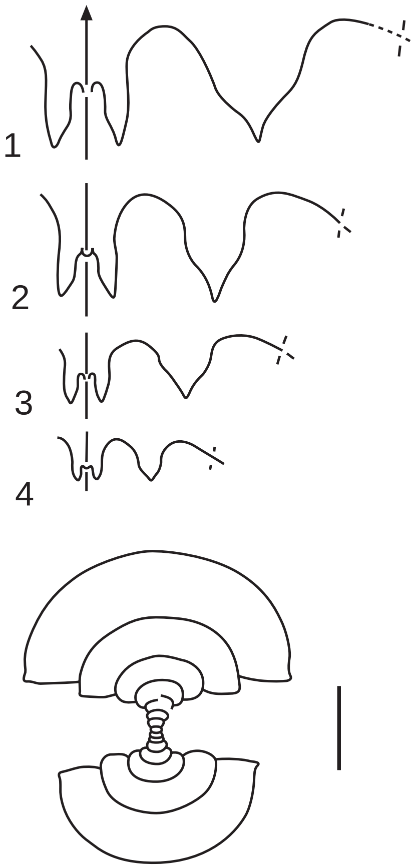


Figure 32. *Suture and cross-sectional diagrams for* Eosyngastrioceras quadratum *n. sp. 1 (SUI 93560) at 32 mm D; 2 (SUI 93557) at 20 mm D; 3 (SUI 93558) at 16 mm D; 4 (SUI 93559) at 10 mm D; 5 (SUI 93556). 1-4 x 2.4. Bar scale for 5 is 4 mm.*

Description. Protoconch globose and followed by ophioconic stage for no more than two volutions. At D = 7 mm, whorl depressed, venter very gently rounded and flanks narrowly rounded. By D = 10 mm, conch pachyconic to subcadiconic, very involute, and moderately widely umbilicate, with less-depressed whorl section. Umbilical shoulder subangular, nearly forming right angle. Umbilical walls nearly parallel to axis of coiling. Proportionate heightening of whorl and narrowing of umbilicus continues through subsequent growth stages. Body chamber exceeds one volution in length. Septal crowding initiated in one individual at around 33 mm diameter.

Conch ornamentation consists of simple, moderately widely spaced lamellae, slightly raised at adoral edge, forming shallow sinus on each flank near umbilical shoulder, either straight or forming slight orad salient over venter. Very slight hyponomic sinus develops at D > 25-30 mm. Umbilical shoulder marked by prominent single spiral cord. Three to four internal constrictions per volution, these having similar configurations to surface growth lamellae. Intraventral sulcus commonly present (30-40 percent of specimens) on internal mold of specimens greater than 15-20 mm diameter.

External suture possesses moderately wide ventral lobe with straight, to slightly swollen, commonly asymmetric, narrow prongs. Outer edges of ventral lobe fairly straight in adult, but commonly slightly constricted at base in immature conchs. First lateral saddle asymmetrical, slightly wider than ventral lobe, subspatulate in adult conchs, but more circular in immature ones; first lateral lobe has convex sides, is fairly symmetrical, and ends in sharp point; second lateral saddle curves asymmetrically across umbilical shoulder to short, sharp umbilical lobe in middle of umbilical wall. Internal lobes of moderate width and attenuate throughout ontogeny.

Comparisons. *Eosyngastrioceras quadratum* is most easily confused with *E. inexpectans* n. sp. The latter does not possess strap-like lamellae at diameters of greater than 15 mm, but has a smooth appearance and is separated on that basis. The same is true for *E. imprimum* (Saunders), which is also more cadicone in early growth stages. *Eosyngastrioceras hesperium* has a more involute conch and narrower umbilicus. In addition, the ventral lobe of *E. quadratum* is generally wider than that of *E. hesperium*.

Comments. This long-ranging species was regarded by Gordon (1964) as dimorphic with *E. hesperium*. New field evidence showing variation of populations in time and space suggests that the two forms are separate species. Of the dozens of specimens of *Eosyngastrioceras* collected at the type locality of *E. hesperium*, only five can be referred to *E. quadratum*. This pattern is consistent in the *Eumorphoceras rotuliforme* Biozone throughout the AFB. Conversely, in the late Pendleian, *E. quadratum* is always abundant and *E. hesperium* is rare. This temporally controlled mutual exclusion strongly suggests that the two forms are separate species.

The specimen illustrated by Gordon (1964) in plate 3, figures 3-5, is designated the lectotype for the new species. Measurements and plots of the morphometrics for the type lot can be found in table 3 and figures 5 and 6 in that same paper.

Distribution. The species is abundant and ranges from the upper Pendleian to the top of the early Arnsbergian *Eumorphoceras rotuliforme* Biozone throughout the AFB, although its acme seems to occur in the late Pendleian. Undescribed specimens of probable late Pendleian age are abundant in the lower portion of the Pitkin Limestone at the Lick Mountain locality of Manger and Quinn (1972) (reported as *Cravenoceras* sp. in Saunders and others, 1977). It also occurs uncommonly in the upper portion of the Barnett Formation of central Texas and possibly in the Helms Formation of west Texas.

Material. 15163-PC (1+), 17205-PC (12), 19604-PC (100+), 20448-PC (1), 22859-PC (3), 25551-PC (1); 88NVCL-2 (1); 89NVLI-17 (22); 89NVLI-18 (46); 93CAIN-2a (38); 93CAIN-2b (26); 93CAIN-2c (17); 93CAIN-2d (32); 93NVLI-9 (3); 93UTMI-13a (3).

Eosyngastrioceras hesperium (Miller and Furnish, 1940)

Plate 11, figures 1-13; plate 12, figures 1-4; figure 33

Cravenoceras hesperium Miller and Furnish, 1940, p. 374, 375, plate 49, figures 1-3, 5-8, text-figures 15B, 16B; Youngquist, 1949a [part], p. 292, text figure 1B, plate 59, figures ?4-7, 8-11, plate 60, figures 1, 2, 13-15; Gordon, 1964 [part], plate 3, figures 14-17, 21-23, 27-33, p. A12 text-figures 4A, D; Gordon, 1965, p. 205, figures 52C, D, 54B;

Stenoglaphyrites hesperius (Miller and Furnish). Ruzhencev and Bogoslovskaya, 1971a, p. 301.

?*Eoasianites kansasensis* (Miller and Gurley)?. Miller, 1945, p. 342, figure 1, plate 50, figures 1-8.

Holotype. USNM 120617.

Diagnosis. Species with sphaeroconic to pachyconic conchs, very narrow umbilici, and a single prominent spiral cord on the umbilical shoulder.

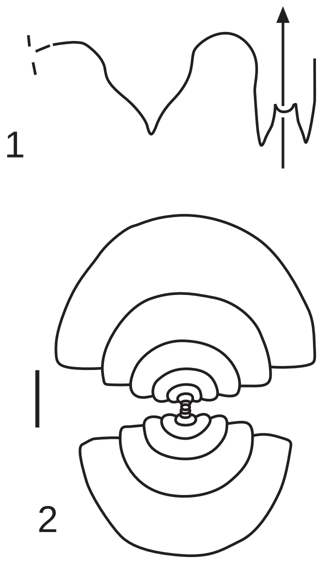


Figure 33. *Sutural and cross-sectional diagrams for* Eosyngastrioceras hesperium *(Miller and Furnish). 1 (SUI 93567) at 25 mm D (x3.6); 2 (SUI 93568) bar scale, 5 mm.*

Description. At D < 10 mm, conchs sphaeroconic, completely involute, with moderately narrow umbilici. At D = 12-15 mm, conch becomes subsphaeroconic. At greater diameters, conch is pachyconic, completely involute and narrowly umbilicate. Whorl cross sections have steep umbo-lateral regions with sharp, right angle bend into umbilical region. Ventrolateral area strongly convex, typically with somewhat flattened venter. Standard measurements for this species are given in Gordon, 1964 (table 1).

Simple, moderate-relief transverse lamellae that are slightly prosiradiate at umbilical margin, retrosiradiate on lower flanks, and prosiradiate on ventrolateral area (with forward salient) are present through all observed ontogenetic phases. Single prominent spiral cord occupies umbilical rim. Lamellae develop mild hyponomic sinus at D > 20-25 mm. Constrictions usually number 3-4 per whorl. Their configuration parallels growth lines.

Suture typically possesses a narrow ventral lobe (height versus width) with relatively narrow, parallel to sub-parallel prongs whose height is about half that of the ventral lobe. Ventral lobe joined to nearly symmetrical U-shaped first lateral saddle and mammilate first lateral lobe. Internal suture not observed.

Comparisons. All other species of *Eosyngastrioceras* are more widely umbilicate.

Comments. Gordon (1964), following Youngquist (1949a), modified the original concept of *E. hesperium* to include a wider, more loosely coiled form that was interpreted as a probable sexual dimorph. Subsequent observations have caused me to abandon that interpretation (see discussion above). The wider form is now referred to *E. quadratum* n. sp. based on telling spatial and stratigraphic relationships (see comments under *E. quadratum*). Dimorphism probably exists in both species but is subtle and difficult to document. Reference of this species to *Stenoglaphyrites* by Ruzhencev and Bogoslovskaya (1971a) is incorrect as it possesses a strong umbilical spiral cord and relatively narrow ventral prongs.

Specimens from the type section of the Cieneguita Formation of west Texas illustrated in Miller (1945) are almost certainly this species based on their umbilical diameters, sutures, and ornament.

Distribution. In the southern Great Basin, *Eosyngastrioceras hesperium* is found in upper Pendleian through upper lower Arnsbergian strata, a range that spans three ammonoid biozones (*Eumorphoceras* sp., *E. paucinodum, E. rotuliforme*). As indicated above, the taxon also occurs in the type Cieneguita Formation, although a lack of diagnostic taxa in the illustrated assemblage preclude precise zonal assignment. Other reports of this species from the midcontinental United States are based on misidentified specimens of *Paracravenoceras* and *Eosyngastrioceras quadratum* n. sp.

Material. 17022-PC (122), 17188-PC (7+), 17209-PC (1+), 17219-PC (13+), 17310-PC (4+), 19604-PC (10), 19605-PC (17), 19606-PC (20), 20441-PC (13), 20442-PC (33), 20445 (27), 20450-PC (15), 25260-PC (49), 25550-PC (2+); 88NVCL-1 (4); 88NVCLI-2 (9); 89NVLI-17 (35); 89NVLI-18 (18); 93CAIN-2a (64); 93CAIN-2b (57); 93CAIN-2c (71); 93CAIN-2d (55); 93CAIN-3 (2); 93CAIN-4 (11); 93NVLI-9 (137+); 93NVWP-11 (18+); 93UTMI-13a (76+); 93UTMI-13b (78+); 93UTMI-36 (2); 93UTMI-37 (9); 94NVLI-10 (93+) W84-19 (3).

Eosyngastrioceras inexpectans n. gen, n. sp.
Plate 12, figures 5-19; figure 34

Etymology. The name is an allusion to the high stratigraphic occurrence of the genus in the middle and late Arnsbergian.

Types. SUI 93576 (holotype); SUI 93570-93575, 93577-93580a (paratypes, + 55 additional paratypes in a single lot-SUI 93580b)

Diagnosis. Species that loses distinct lamellar ornament, attaining a smooth appearance by 20 mm D.

Description. Conch ophioconic to about third post-nuclear whorl. Subsequent whorl expansion very rapid, becoming very involute by the seventh whorl. At D > 10 mm, conch generally subcadiconic, very involute, and moderately widely to moderately narrowly umbilicate. Umbilical shoulder subangular and whorl section broad and moderately convex, with steep sides. Umbilical wall very steep but not quite parallel to coiling axis.

Ornament consists of simple medium- to low-relief growth lamellae. These are mildly sinuous at D < 5 mm. At 5-10 mm D, lamellae display distinct, broad ventral salient. Ventral salient persists to largest observed D, although at about 25-30 mm D, it becomes subdued. Growth lamellae fade into indistinct growth lines at 15-20 mm D, giving conch a nearly smooth surface. All ontogenetic stages display single, prominent spiral cord on each umbilical shoulder. Constrictions, which are visible on internal mold only, moderately deep, number about 3-4 per whorl, and follow growth lamellae. Suture identical to *E. quadratum* n. sp.

Comparisons. This species is especially close to *E. quadratum* n. sp. The latter retains its strap-like lamellae into maturity (D > 20 mm), while *E. inexpectans* n. sp. loses its transverse ornament around D = 15-20 mm. *Eosyngastrioceras imprimum* (Saunders) is more cadicone in early growth stages (D = 10 mm), while *E. hesperium* has a narrower umbilicus. Similarly ornamented species of *Syngastrioceras* have wider ventral lobes and thicker ventral prongs in the suture.

Comments. This appears to be the youngest species of *Eosyngastrioceras* in the AFB. Specimens from the Syncline Ridge localities of Nye County Nevada were referred to *Syngastrioceras* by Titus and others (1997). However, the ventral lobes of these specimens are narrow with medium-width prongs, which refers them to *Eosyngastrioceras*, not *Syngastrioceras*.

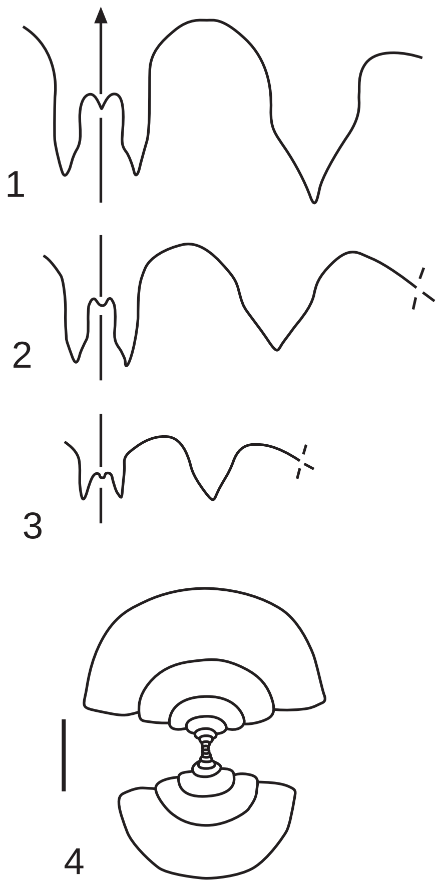


Figure 34. *Suture and cross-sectional diagrams for* Eosyngastrioceras inexpectans *n. sp. 1 (SUI 93579) at 26 mm D; 2 (SUI 93578) at 18 mm D; 3 (SUI 93580a) at 11 mm D; 4 (SUI 93577). 1-3 x3. Bar scale for 4 is 5 mm.*

Distribution. Middle and upper Arnsbergian strata (*E. girtyi* through *D. thalassoide* Biozones) of the AFB. The species is also probably associated with *Homoceras* and *Isohomoceras* in the Chokierian of Nevada, however, specimens large enough to display diagnostic adult suture characteristics have not been recovered.

Material. 69UTMI-1 (1); 90NVNY-4 (45+); 91NVCL-10 (1); 91NVNY-4 (5); 92NVLI-4 (11); 93CAIN-6 (2); 94NVCL-3 (3); 94NVLI-11 (5); 94NVLI-21 (1); 95NVWP-23 (65+ [type lot]); 95NVWP-24 (9).

Genus *SYNGASTRIOCERAS* Librovitch, 1938

Type species. *Gastrioceras orientale* Yin, 1935

Diagnosis. Glaphyritids (neoicoceratins) with no ophioconic phase, moderately wide to narrow umbilici, a wide ventral lobe with swollen ventral prongs and a frequently constricted base, and a prominent single spiral cord on each umbilical shoulder. Ornament usually broadly prosiradiate over the ventral region,

Comments. This genus has a long history of controversy, with some authors even questioning its validity (see Gordon, 1965). Most of the controversy has arisen from the apparent morphologic intergradation of many similar, weakly ornamented, globose, eight-lobed genera such as *Neoicoceras*, *Somoholites*, *Glaphyrites*, *Fayettevillea*, *Cravenoceras*, and *Syngastrioceras*. Recent studies have all validated the genus (Nassichuk, 1975; Ruzhencev and Bogoslovskaya, 1978; Ruan, 1981; Nikolaeva, 1995), and I concur with this opinion. However, most previous authors' distinction of *Syngastrioceras* from Mississippian *Glaphyrites* is based primarily on details of the suture line, essentially the degree of "pouching" developed in the first lateral lobe. I have found that this practice creates as many taxonomic problems as it solves (see comments under *Glaphyrites*). In addition to "pouching" of the first lateral lobe, which is here considered of minor to no importance, the following additional features of the genotype are paramount for recognition of this taxon:

1. Prosiradiate ventral salient in both the growth lamellae and the internal constrictions,
2. wide, deeply divided (medial saddle at least 50 % total height of ventral lobe), ventral lobe with either divergent, or swollen sub-parallel ventral prongs,
3. umbilical diameter does not exceed 50-60 % of the total diameter, and
4. presence of a distinct, single, spiral chord on the umbilical shoulder.

Contrary to Ruzhencev and Bogoslovskaya (1971a) and Nassichuk (1975), I do not consider *Paracravenoceras* Gordon, 1960 a junior synonym of *Syngastrioceras*. Ruzhencev and Bogoslovskaya's synonymizing of the two genera apparently was based in their belief that *Paracravenoceras* is actually an Arnsbergian taxon. However, the Fayetteville and Barnett Shales, that yielded the types of the two currently described species of the genus, have long been known to be Pendleian in age (Gordon, 1960; 1965; Saunders and others, 1977; Meeks and others, 1997). *Paracravenoceras*, an endemic North American goniatitid closely related to *Neogoniatites*, is confined to Pendleian strata (Gordon, 1970; Titus, 1993). *Paracravenoceras* can be distinguished from *Syngastrioceras* by the highly sinuous growth lines found on its juvenile shells (D < 15 mm) and the slightly different configuration of its suture line (ventral prongs are much larger at earlier diameters) during early ontogenetic stages. Similarities between the two genera are solely the result of convergence. Based on the similarities of *Paracravenoceras* to *Hibernicoceras* (compare Gordon, 1965, plate 22, figures 17-19 with Korn, 1988, plate 28, figures 7-8), I propose that the former evolved from the latter in the latest Viséan.

Ruzhencev and Bogoslovskaya (1971a; 1978) concluded that *Syngastrioceras* arose from Late Mississippian species of *Glaphyrites* during their Nm_1c_2 division (= Arnsbergian) of the Namurian. For reasons also spelled out in the comments section of *Glaphyrites*, I propose the alternative that *Syngastrioceras* arose from similarly ornamented species of *Emstites* (single spiral cord) via the transitional genus *Eosyngastrioceras* (figure 24) while *Glaphyrites*, lacking the single prominent spiral cord, arose from *Emstites* with multiple fine lirae on the umbilical shoulder (as in *Emstites novalis* Korn). Homeomorphic Eurasian forms lacking the definitive single umbilical spiral cord should be referred to *Somoholites* or some other genus. Following the expanded generic definition, the following species are considered to be unequivocal *Syngastrioceras*:

S. aktubense Ruzhencev and Bogoslovskaya, 1971a
S. constrictum Nassichuk, 1975
S. cucurbitoides Ruan, 1981
S. discoidale Ruan, 1981
S. dolioforme Ruan, 1981
S. dronovi Ruzhencev and Bogoslovskaya, 1978
S. firmum Ruan, 1981
S. fornicatum (Ruzhencev and Bogoslovskaya, 1978)
S. glaphyritoides Ruzhencev and Bogoslovskaya, 1978)
S. globosum (Easton, 1943 = *S. elegantulum* Wang, 1981)
S. guangxiense Ruan, 1981
S. lanei Gordon, 1969
S. oblatum (Miller and Moore, 1938)
S. orientale (Yin, 1935)
S. parasupinum Ruzhencev and Bogoslovskaya, 1978
S. qixuense Ruan, 1981
?*S. sangruntauense* Pitinova, 1974
S. scotti (Miller and Youngquist, 1948)
S. smithwickense (Plummer and Scott, 1937)
S. stenumbilicatum Ruan, 1981
S. suborientale (Yin, 1935)
S. supinum Ruzhencev and Bogoslovskaya, 1978
S. websteri n. sp.

Distribution. Widespread globally in lower Namurian (Pendleian) through Westphalian (Atokan) strata.

Syngastrioceras websteri n. sp.

Plate 13, figures 2-13; figure 35

Cravenoceras hesperium Miller and Furnish, 1940. Gordon and Poole, 1968, plate 1, figures 19-21.

Cravenoceras sp., Webster and Lane, 1967, figures 3a, 4c, 4d.

Syngastrioceras sp., Gordon and Poole, 1968, plate 1, figure 17.

Etymology. Named for Gary D. Webster, co-author of the paper that first illustrated this form.

Types. SUI 93648 (holotype); SUI 93649-93650a (paratypes, + 15 additional paratypes in a single lot-SUI 93650b)

Diagnosis. Narrowly umbilicate species with medium-strength, ontogenetically persistent (to diameters of 15 mm) growth lamellae that form a prominent ventral salient.

Description. No ophioconic stage. Shell essentially sphaeroconic to subsphaeroconic, completely involute, and narrowly to moderately narrowly umbilicate through all ontogenetic stages. Whorl expansion rapid immediately following protoconch. Whorl sections moderately convex and evenly rounded (semi-circular). Umbilical shoulders subangular. Umbilical wall funnel-shaped, with individual convexities on each whorl.

Ornament on shells where D < 15 mm is sinuous, medium-relief growth lamellae and single distinct spiral cords on umbilical shoulders. Lamellae retrosiradiate near umbilical margin. Halfway across flank lamellae direction reverses to form strong ventral salient. Growth lines fade at around D = 15 mm, giving shell smooth appearance. Constrictions, which are not visible on exterior, number three to four per whorl and follow lamellae. Very faint spiral lirae rarely present across entire ventrolateral region.

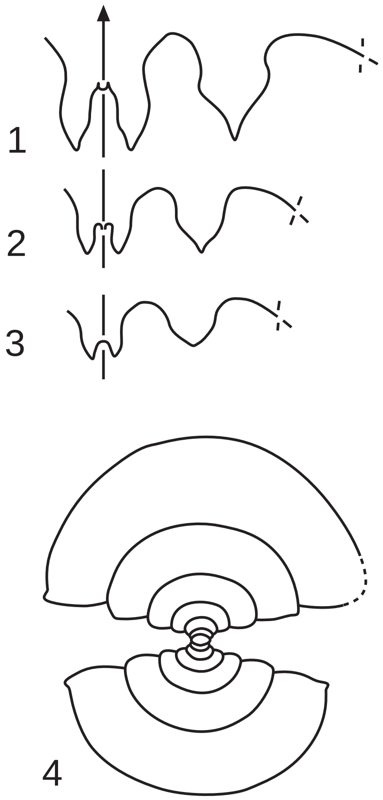


Figure 35. *Suture and cross-sectional diagrams for* Syngastrioceras websteri *n. sp. 1 (SUI 93649) at D, 20 mm; 2 (SUI 93651) at D, 13 mm; 3 (SUI 93650) at D, 6 mm; 4 (SUI 93647) bar scale, 4 mm. 1-3 x3.*

Suture at D = 8 mm looks like mature *Eosyngastrioceras*, with lateral lobe and ventral lobe about same width. Ventral lobe slightly constricted at base; ventral prongs are attenuate and asymmetric. By D = 10-15 mm, external suture has fairly short, broad ventral lobe, divided into two rather stout, pointed prongs having gently convex sides. First lateral saddle subspatulate, slightly asymmetrical and narrower than ventral lobe; first lateral lobe is goblet-shaped, pointed and narrower than first lateral saddle; second lateral saddle relatively short, curving across well-rounded umbilical shoulder; umbilical lobe broad, with short point just inside center of umbilical wall. At D = 20 mm, suture has wide ventral lobe that is 25 percent wider than lateral lobe and saddle. Ventral prongs swollen and highly asymmetric, with long, moderately sharp tips. Medial saddle half of ventral lobe height. First saddle medially constricted; slightly asymmetric. First lateral lobe wide, slightly swollen in mid-portion, and has long, sharply pointed tip. Second lateral saddle curves broadly to umbilical margin. Umbilical lobe and internal suture not observed.

Comparisons. *Syngastrioceras websteri* n. sp. is closest to the narrowly umbilicate morphotypes of the Morrowan species *S. oblatum* (Miller and Moore, 1938), and the two Atokan species *S. constrictum* Nassichuk, 1975, and *S. smithwickense* (Plummer and Scott, 1937). It can be differentiated from *S. smithwickense* with sutural criteria, as the latter has a less attenuate, less “pouched” first lateral lobe and less inflated ventral prongs at comparable diameters. *Syngastrioceras oblatum* and *S. constrictum* can be differentiated on the basis of their less-prominent growth lines lost in early ontogeny. In addition *S. constrictum* generally has higher numbers of constrictions per whorl. All other species of *Syngastrioceras* have wider umbilici at comparable diameters.

The goniatitid *Paracravenoceras* bears some similarity to the new species, but it can be differentiated on the basis of its wider ventral lobe, larger ventral prongs, and, at D < 12 mm, more sinuous, closely spaced growth lines.

Comments. *Syngastrioceras websteri* is one of the most widespread and abundant species in middle Arnsbergian ammonoid assemblages of the AFB, and is found at nearly every locality of that age. It is also the oldest known narrowly umbilicate species of *Syngastrioceras*. The sutural configuration of *S. websteri* at D < 10 mm reveals it is closely related to *Eosyngastrioceras* (figures 32-34), and probably originated from narrowly umbilicate forms like *E. hesperium* (Miller and Furnish).

Distribution. Middle Arnsbergian strata (*Eumorphoceras girtyi* Biozone) throughout the AFB.

Material. 17059-PC (1); 90NVLI-4 (24); 90NVNY-4 (18 [type lot]); 92NVLI-2 (50+); 93NVCL-1 (7); 93NVLI-3 (10); 94NVCL-3 (12); 94NVCL-4 (1); 94NVLI-1 (10); 94NVLI-11 (8); 94NVLI-21 (1); 95NVWP-23 (41); 95NVWP-24 (1).

Family SOMOHOLITIDAE Ruzhencev, 1938
Genus *SOMOHOLITES* Ruzhencev, 1938

Type Species. *Gastrioceras beluense* Haniel, 1915.

Diagnosis. Cadiconic to subcadiconic forms with highly “pouched” external and internal lobes (deep constrictions at the bases). May or may not have multiple spiral lirae, but lacks a single strong spiral cord on the umbilical shoulder.

Distribution. Upper Mississippian through Permian strata, worldwide.

Somoholites walkeri (Webster and Lane, 1967)
Plate 13, figures 14-21; plate 14, figures 1-6; figure 36

Syngastrioceras walkeri Webster and Lane, 1967, p. 579, figures 3d, 4g, 4i.

Holotype. UCLA 39482, from the Indian Springs Formation (*Eumorphoceras girtyi* Biozone), eastern Clark County, Nevada.

Diagnosis. Species with radial growth lines at diameters greater than 30 mm, very wide umbilici, and moderately pouched lobes.

Description. Essentially no ophioconic stage. Whorl expansion rapid starting at third post-nuclear whorl. By D = 5 mm, conch cadiconic to subcadiconic, very involute, and moderately widely umbilicate. Whorl sections broad and depressed with narrowly rounded umbilical shoulders. Conch form and whorl profiles change little through subsequent ontogenetic phases, except that umbilical shoulders become subangular in some specimens.

Ornament is medium- to low-relief transverse growth lamellae, which are sinuous at D < 15-20 mm, forming broad ventral orad salient. Lamellae still visible and essentially radial at D = 30 mm. At D > 35 mm, lamellae form broad, shallow apicad bow. Spiral ornament not present; constrictions not observed.

Suture at D = 7 mm has equal width ventral lobe and first lateral saddle. First lateral lobe slightly narrower.

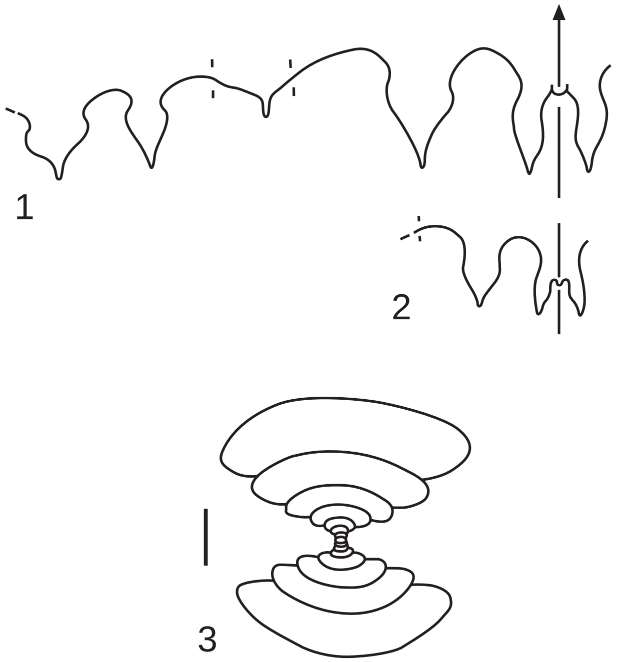


Figure 36. Suture and cross-sectional diagrams for Somoholites walkeri *(Webster and Lane). 1 (SUI 93659) at estimated 35 mm D (x1.8); 2 (SUI 93654) at 14 mm D (x2.3); 3 (SUI 93660) bar scale, 5 mm. Distortion in both the suture and the cross section are created by tectonic shearing of the specimens.*

Ventral lobe fairly attenuate (Hl/Wl = 2), with slightly constricted base. Ventral prongs distinctly divergent. Medial saddle about one-fourth to one-fifth height of ventral lobe. First lateral saddle U-shaped and symmetrical. First lateral lobe deltoid and mammilate. By D = 15 mm, sides of ventral and first lateral lobes strongly convex, giving first lateral saddle distinctive "keyhole" shape. All lobes at this stage are attenuate and sharply pointed. Medial saddle one-half ventral lobe height. At D = 45 mm, width of ventral lobe exceeds that of first lateral saddle (8 mm versus 5 mm). Prongs highly swollen, asymmetric, attenuate, and sharply pointed. First lateral lobe medially inflated, sharply pointed and nearly same width as ventral lobe (7 mm versus 8 mm). Internal suture at estimated D = 30-35 mm has three distinctly pouched lobes. Dorsal lobe symmetrical, sharply pointed, with greatest degree of inflation. Other internal lobes asymmetric; slightly less pouched. Saddles "keyhole"-shaped with obtuse, subangular apex.

Comparisons. *Somoholites walkeri* (Webster and Lane, 1967) can be differentiated from *S. laxumbilicale* (Ruzhencev and Bogoslovskaya) by its wider umbilicus (U/D greater than 0.5 versus 0.38) at comparable diameters. A younger Chokierian form from the Scotty Wash Formation of the Nevada Test Site referred to *Somoholites* cf. *S. merriami* (Miller and Furnish) by Titus and Manger (in press) possesses a very similar conch, but has a smaller umbilicus at comparable diameters and a higher degree of "pouching", or basal constriction in its lobes, which is also true for *S. merriami* proper. The less-constricted bases of the lobes in *N. walkeri* also serve to distinguish it from all other species of the genus. Comparison of *N. walkeri* with the imperfectly known holotype of *S.* (?) *cadiconiformis* (Wagner-Gentis) is impossible without direct examination of Spanish material. If the North American forms referred to that species by Saunders (1971, 1973) are conspecific with the Spanish species, which is not certain, then *N. walkeri* can be distinguished by its less sinuous growth lamellae and slightly less developed pouching at D > 15 mm.

Comments. This is one of the most primitive forms still referable to the genus. The internal suture does display the degree of pouching that Saunders (1971) made a criteria for generic assignment (figure 36). However, I feel, in agreement with Nassichuk (1975), that the genus is probably polyphyletic, and there is little possibility that the Permian and Mississippian forms are directly related. Lack of a strong umbilical shoulder cord indicates that the genus has a higher degree of affinity with *Glaphyrites* or *Fayettevillea* than with *Syngastrioceras*, with which it is frequently compared.

Distribution. Middle Arnsbergian strata (*E. girtyi* Biozone) of the AFB.

Material. 91NVCL-10 (1); 93NVCL-1 (15+); 94NVCL-3 (19+).

Family STENOGLAPHYRITIDAE Ruzhencev and Bogoslovskaya, 1971a

Genus *STENOGLAPHYRITES* Ruzhencev and Bogoslovskaya, 1971a

Stenoglaphyrites colubrellus (Miller and Furnish, 1940)

Plate 14, figures 7-12; figure 37

Anthracoceras? *colubrellus* Miller and Furnish, 1940, plate 49, figures 14-20, p. 375, text figure 17 B.

Anthracoceras? *columbrellus* (sic) Miller and Furnish, 1940. Youngquist, 1949a, plate 62, figures 8-10.

Types. The specimen illustrated by Miller and Furnish (1940) in plate 49, figures 19 and 20, is hereby designated the lectoholotype. The rest of the original syntypes are lectoparatypes. They were collected from Scotty Wash Formation (*Eumorphoceras girtyi* Biozone), east-central Nevada.

Diagnosis. Species with small, pachyconic, involute, very narrowly umbilicate compressed conchs with one or no constrictions per whorl.

Description. Conchs subdiscoconic to pachyconic (W/D around 0.5), with narrow to very narrow umbilici and completely involute to hyper-involute whorls. Venters well rounded, flanks steeply sloped and gently convex. Umbilical margin non-angular and slopes moderately steeply into umbilicus.

Ornament varies from crowded to widely spaced, fine growth lines. Growth lines nearly rectilinear at D < 12 mm, with only mild sinuosity. At D > 12 mm, growth lines

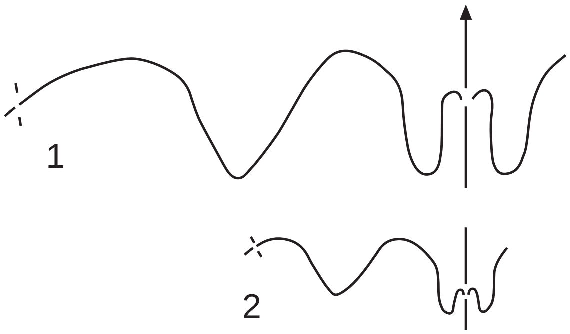


Figure 37. Suture diagrams for Stenoglaphyrites colubrellus *(Miller and Furnish). 1 (SUI 93662) at 10 mm D (x8.2); 2 (SUI 93661) at 5 mm D (x7.1).*

become distinctly sinuous with ventral sinus and lateral salients. Constrictions rarely present. When present, limited to one per whorl and developed only at D > 15 mm. Sutural crowding at D = 15 mm indicates mature conchs probably do not exceed D = 20-25 mm.

Suture possesses parallel, narrow ventral prongs on medium-wide ventral lobe. Ventral prongs 0.5 to 0.3 the height of ventral lobe, and they remain relatively unswollen throughout all ontogenetic phases. Ventral lobe joined to U-shaped, rounded first lateral saddle and bluntly pointed, deltoid lateral lobe.

Comparisons. Species is narrowest known for the genus and can be distinguished from all other species, except for narrow variants of the genotype, on that basis. Narrow variants of the genotype (*St. involutus*) are distinguished from *St. colubrellus* by the presence of three to five constrictions in all but the earlier ontogenetic phases, and a generally more flattened ventral region.

Comments. This taxon has been the subject of considerable speculation because the original type lot was collected by a private collector from a locality in the southern Snake Range, White Pine County, Nevada, that has never been relocated. In addition, it does not resemble any previously described ammonoid from late Chesterian strata, leading to speculation that it was actually a *Wiedyoceras* of Middle Pennsylvanian (Atokan or Desmoinesian) age (W. B. Saunders written communication to M. Gordon Jr., 1970). Even the original authors compared the species to a Morrowan taxon from Oklahoma. After examining the primary types I realized that the suture drawings in figure 17 of Miller and Furnish (1940) are mislabeled. This is readily confirmed by the reader by comparing the two illustrated sutures with the photo of the specimen (Plate 49, figures 19-20). The figure caption for 17B actually is for figure 17A and vice-versa. Now that "*A.* (?)" *colubrellus* has been found in the Scotty Wash Formation of the White Pine Range, there is little doubt that the original types are Mississippian. The suture, and near morphologic intergradation of *A.* (?) *colubrellus* with *Stenoglaphyrites involutus* refer it to *Stenoglaphyrites*.

Distribution. This species is known only from lower mid-Arnsbergian (E_2b) strata, White Pine County, Nevada (West Antelope Summit and Johns Valley localities). Although *St. involutus* and *St. colubrellus* occur together in the White Pine Range, *St. colubrellus* is unknown from the type locality of *St. involutus* (Gordon, 1965), which has yielded numerous specimens.

Material. 15154-PC (12); 95NVWP-22a (25).

Stenoglaphyrites intermedius n. sp.

Plate 15, figures 5-16, plate 16 figures 1-3,
text figures 38.1, 38.2, 38.4

Cravenoceras hesperium Miller and Furnish, 1940, plate 49, figure 4.

Cravenoceras merriami Youngquist. Gordon, 1964, plate 2, figures 11-12, p. A12, text figures 4b?, 4c.

?*Cravenoceras richardsonianum* (Girty, 1909). Saunders and others, 1977, plate 2, figures 6,7.

Stenoglaphyrites involutus (Gordon). Ruzhencev and Bogoslovskaya, 1971a, plate 33, figs 5-7, p. 302, text figures 77b, 77d.

Etymology. Named for possession of intermediate morphologic characteristics between *S. incisus* (Hyatt) and *S. involutus* (Gordon).

Types. SUI 93666 (holotype); SUI 93663-93665, 93667, 93669-93671a (paratypes, + 212 additional paratypes in a single lot SUI 93671b)

Diagnosis. Species with sphaeroconic juvenile shells (D < 10 mm) with wide, hyper to completely involute whorls and nearly closed umbilici.

Description. Juvenile conchs (D < 10 mm) sphaeroconic and hyper to completely involute. Whorls in early stages broad and low, coiling with periodic angularity. In later ontogenetic phases, conch passes through subsphaeroconic stage; ultimately becoming pachyconic. Specimens with D > 35 mm not uncommon. Umbilicus very narrow in early stages, but opens up progressively starting at about D = 10 mm. At D = 30 mm, umbilicus is narrow. Umbilical margin sub-angular to sub-rounded and umbilical wall slightly convex.

External ornament is simple, closely spaced, slightly sinuous growth lamellae. At D = 15-20 mm, growth lines nearly rectilinear. At larger diameters, ventral sinus and lateral salients develop. Internal molds possess approximately 3-5 constrictions per whorl.

For description of suture, see Gordon (1964; Rest Spring specimens identified as *Cravenoceras merriami* Youngquist).

Comparisons. *Stenoglaphyrites intermedius* n. sp. is closest in form and suture to *St. incisus* (Hyatt) (which probably ranges into the Arnsbergian) and *St. merriami* (Youngquist)

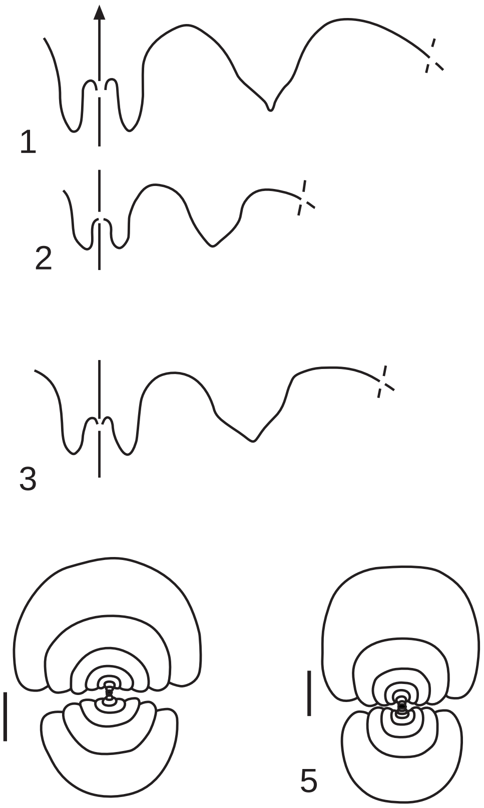


Figure 38. *Suture and cross-sectional diagrams for* Stenoglaphyrites. *1, 2, 4 -* Stenoglaphyrites intermedius *n. sp., 1 (SUI 93669-paratype) at 18.5 mm D (x3.2); 2 (SUI 93670-paratype) at 7 mm D (x7.2); 4 (SUI 93671-paratype) bar scale, 5 mm; 3, 5 -* Stenoglaphyrites involutus *(Gordon), 3 (SUI 93676) at 7.5 mm D (x6.8); 5 (SUI 93677) bar scale, 4 mm.*

(restricted to the Pendleian of Nevada). It can be distinguished from those and all other species, except for the genotype and *St. colubrellus*, on the basis of its completely involute, very narrowly umbilicate early whorls. It can be differentiated from *St. colubrellus* and *St. involutus* on the basis of its much broader, sphaeroconic juvenile shell.

Comments. Specimens from the Kardaelovka region identified by Ruzhencev and Bogoslovskaya (1971a) as *Stenoglaphyrites involutus* (Gordon) do not display the ventral sinus and lateral salients that characterize that species. However, every morphological and sutural feature discussed or illustrated for these specimens matches the new species exactly. In addition they occur with an apparent early Arnsbergian fauna that includes (?) *Eumorphoceras paucinodum* Gordon, *Pericleites uralicus* (Librovitch) and *Proshumardites principalis* Ruzhencev and Bogoslovskaya. Accordingly these specimens are here considered E_2a in age and are referred to *St. intermedius* n. sp. The Kia River specimens illustrated by the same authors should probably also be referred to the new species, though they are associated with a slightly younger (mid-Arnsbergian) fauna.

Distribution. Late early Arnsbergian (*Eumorphoceras rotuliforme* Biozone) strata of the AFB. Similar undescribed forms occur with *Eumorphoceras rotuliforme* Ruan in the upper portion of the Pitkin Limestone of Arkansas at the Leslie locality of McCaleb and others (1964). It also occurs in the upper lower and ?lower middle Arnsbergian strata of the southern Urals.

Material. 88NVCL-1 (220+ [type lot]); 88NVCL-2 (140); 89NVCL-3 (12); 89NVCL-4 (3); 89NVCL-5 (25+); 89NVLI-19 (55+); 89NVLI-20 (2); 92NVLI-1a (3); 92NVLI-1b (2); 92NVLI-3 (1); 92NVLI-11 (1); 93CAIN-5 (68+); 93NVLI-1 (1); 93NVLI-2 (2); 93NVWP-8 (?2); 94NVLI-10 (1).

Stenoglaphyrites involutus (Gordon, 1965)

Plate 14, figures 13-24, plate 15, figures 1-4,
text figures 38.3, 38.5

Cravenoceras involutum Gordon, 1965, plate 21, figures 17-20, text figures 53F, 53G, 55E.

Glaphyrites sp. B, Liang, 1957, p. 564, plate 1, figures 8, 9.

Holotype. USNM 119523, from the lower portion of the Imo Formation, north-central Arkansas.

Diagnosis. Small pachyconic shells with flattened to gently curved ventral region, completely involute whorls with a closed umbilicus almost throughout ontogeny and three to five internal constrictions in all but the early ontogenetic phases.

Description. Conch form pachyconic, with flattened to gently rounded ventral region. Umbilicus very narrow. Umbilical margin rounded and umbilicus funnel shaped. Whorls very involute. Sutural crowding commonly developed at D = 20-25 mm, indicating that diameters greater than 30 mm unlikely. Prominent ventral trough infrequently developed on internal molds.

Fine, crowded growth lines only observed ornament. Growth lines nearly rectilinear at D < 10 mm, with only mild sinuosity. At D > 10 mm, growth lines form distinct ventral sinuses and lateral salients and are less closely spaced. Three to five internal constrictions, visible on internal mold only, on nearly all specimens where D > 5 mm.

Suture has wide ventral lobe subdivided into two narrow to medium-width prongs that range from parallel with symmetrical outlines to parallel with non-symmetrical outlines. Non-symmetric prongs straight on dorsad side and curved on ventrad side. Prongs one-third to one-half total height of ventral lobe. First lateral saddle U-shaped and rounded. First lateral lobe triangular and bluntly pointed. Internal suture not observed.

Comparisons. Only one other species, *St. colubrellus* (Miller and Furnish), is especially close to the genotype. The former is more compressed and does not typically posses more than one constriction per whorl. All other species are wider or less involute at comparable diameters.

Comments. This is the first report of the species from outside its type region in north-central Arkansas. Based on all illustrated characteristics, a specimen identified by Liang (1957, plate 1, figures 8, 9) as *Glaphyrites* sp. B actually belongs in *Stenoglaphyrites* and is very close to the genotype. Ruzhencev and Bogoslovskaya (1971a) already referred the assemblage from which this specimen was recovered to the lower Namurian based on the presence of *Cravenoceras* (= *Glaphyrites acutus* Liang, 1957). Liang's *Glaphyrites* sp. B is here regarded as *St. involutus*, and the containing beds are referred to the middle Arnsbergian since Li and others, (1987) reported that the Gansu (=Kansu) assemblage contains both *Stenoglaphyrites involutus* and *Eumorphoceras kansuense* Liang (= *E. chungweiense* (Liang)).

Distribution. Occurs at the West Antelope Summit locality of Nevada and the type region of north-central Arkansas (Gordon, 1965), where it is restricted to the middle Arnsbergian (E_2b). Most Ural specimens referred to this species by Ruzhencev and Bogoslovskaya (1971a) probably belong in *St. intermedius* n. sp. Reported occurrences at Sholak Say cannot be confirmed without direct comparisons. Also present in the middle Arnsbergian of China.

Material. 15154-PC (7); 95NVWP-22a (5); 95NVWP-22b (50+).

Genus *EUROCERAS* Ruzhencev and Bogoslovskaya, 1971a

Gonioloboceras Hyatt, 1900. Miller and Owen, 1944 [part], p. 428.

Cravenoceras Bisat, 1928. Gordon, 1965 [part], p. 204; Gordon and Poole, 1968 [part].

Bisatoceras Miller and Owen, 1937. Ruan 1981 [part], p. 200.

Neoglaphyrites Ruzhencev, 1938. Nassichuk, 1975 [part] p. 105.

Zephyroceras Kullmann, 1962. ?Pitinova, 1988, p. 42.

Eoasianites (Schartymites) Librovitch, 1939. Kullmann, 1962 [part], p. 319.

?Cravenoceras (Richardsonites) Elias, 1956 [part], p. 128.

Type Species. *Euroceras ellipsoidale* Ruzhencev and Bogoslovskaya, 1971a, upper Arnsbergian strata of the Sholak Say region, Kazakhstan.

Diagnosis. Narrowly umbilicate, compressed forms with wide ventral lobes, swollen, bluntly pointed ventral prongs, and relatively wide first lateral saddles.

Comments. *Euroceras* was erected by Ruzhencev and Bogoslovskaya (1971a) to accommodate stenoglaphyritids with very wide ventral lobes and swollen ventral prongs. Nassichuk placed the genus in synonymy with *Neoglaphyrites* Ruzhencev, 1938, but Titus and Manger (in press) and Popov (1979) have retained *Euroceras* on the basis of its different sutural configuration. That practice is followed here. The wide ventral lobe and swollen ventral prongs are very important features of this genus. Species erroneously referred to *Zephyroceras* by Ruzhencev and Bogoslovskaya (1971a) and Nikolaeva (1995) belong in *Stenoglaphyrites* or *Rhadinites* Saunders, 1973.

A specimen identified by Pitinova (1988) as *Zephyroceras truncum* Pitinova, probably doesn't belong in *Stenoglaphyrites* or *Euroceras*. However, a suture illustrated for the same species (which was not based on the specimen shown) is completely typical of *Euroceras*, and on this basis "*Z.*" *truncum* is hesitantly referred herein to *Euroceras*. One of the paratypes (Nr. Ce 1206/255) of "*Eoasianites* (*Schartymites*)" *rauserae rauserae* Kullmann, 1962 is clearly *Euroceras*. However, the holotype (Nr. Ce 1206/170), that is herein referred to *Stenoglaphyrites* based on its narrow umbilicus and medium width ventral lobe, is not conspecific with this paratype. The following species are attributed to *Euroceras*:

E. ellipsoidale Ruzhencev and Bogoslovskaya, 1971a
E. kalmiussense Popov, 1979
E. latior (Kullmann, 1962)
E. nyense n. sp.
E. praecursor (Ruan, 1981)
?*E. truncum* (Pitinova, 1988)

Distribution. Middle Arnsbergian through latest Namurian strata, cosmopolitan.

Euroceras nyense n. sp.

Plate 16, figures, 4-17, text figures 39, 40

Cravenoceras merriami Youngquist, 1949. Drewes, 1967, p. 40, table 6; Gordon and Poole, 1968, plate 1, figure 24-26.

Etymology. The name refers to Nye County, Nevada where the primary types were collected.

Types. SUI 93684 (holotype), SUI 93680-93683, 93685-93688a (paratypes, + 57 additional paratypes in a single lot SUI 93688b)

Diagnosis. Species with large subdiscoconic shells in early maturity, relatively widely spaced, more irregular lamellae, and ventral prongs that become parallel sided (non-pouched) at intermediate diameters.

Description. Ophioconic to about the third post-nuclear whorl. Subsequently whorl expansion rapid. At D = 5-10 mm, conch sub-sphaeroconic, completely involute, and narrowly umbilicate. At larger diameters, conch progressively becomes pachyconic (D = 15-20 mm), subdiscoconic (D = 20-40 mm) and ultimately oxyconic (D > 50-60 mm).

Whorls completely to hyper involute and umbilicus narrow to very narrow at all but earliest ontogenetic phases. Umbilical shoulder ranges from rounded to sub-angular.

External ornament is simple, moderate- to low-relief growth lamellae only. At D < 15 mm, lamellae only very mildly sinuous, nearly rectilinear. At D = 15-20 mm, sinuosity increases and distinct hyponomic sinus appears. In later ontogenetic phases, hyponomic sinus deepens and accompanying orad salient on flanks becomes exaggerated. Constrictions visible on internal mold only and irregularly developed, typically numbering two to four per whorl.

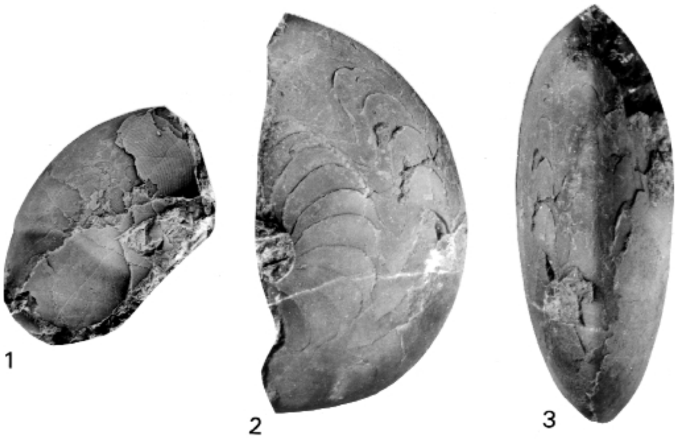


Figure 39. Euroceras nyense *n. sp. 1, (SUI 93685) lateral view (x1) of submature specimen (coll. 89NVNY- 4); 2-3, (unnumbered USGS specimen) lateral and ventral views (x0.5) of large, gerontic phragmacone (collection 18801-PC).*

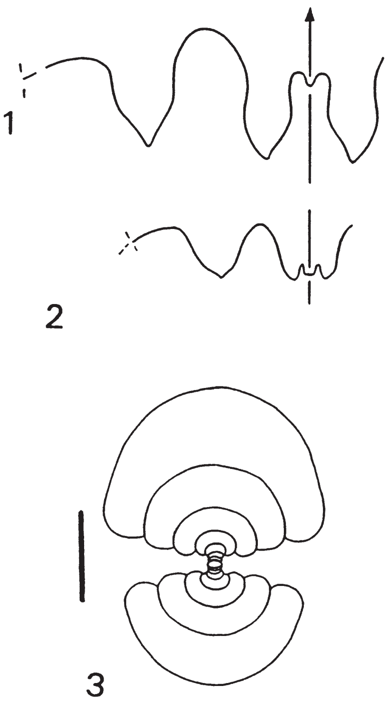


Figure 40. *Suture and cross-sectional diagrams for* Euroceras nyense *n. sp. 1 (SUI 93685) at 35 mm D (x1.5); 2 (SUI 93687) at 8 mm D (x 6.4); 3 (SUI 93688) bar scale, 4 mm.*

Suture somewhat variable. Typically at D = 10 mm it has a ventral lobe-first lateral saddle-first lateral lobe width ratio of 3:1.8:1.8. Medial saddle nearly half total height of ventral lobe. Ventral prongs initially swollen and asymmetric, with blunt tips, later appearing sub-parallel sided. First lateral saddle deep, U-shaped, and slightly asymmetric. First lateral lobe long, symmetric, and mammilate. As ontogeny progresses, sutural elements change little except for attenuation of elements. Ventral prongs uncommonly develop slight divergent aspect. Internal suture not observed.

Comparisons. The new species is closest to *E. ellipsoidale* Ruzhencev and Bogoslovskaya and *E. kalmiussense* Popov. *Euroceras ellipsoidale* possesses a wider ventral lobe that doesn't attenuate as rapidly, as well as more regularly spaced, finer growth lamellae. *Euroceras kalmiussense* has a wider conch, as well as a slightly wider sutural ventral lobe. *Rhadinites miseri* has very similar conch form and ornament at diameters less than 35 mm, but possesses a much narrower ventral lobe and prongs in the suture and apparently doesn't achieve an oxyconic form in later stages. All other species have wider conchs.

Comments. This form has repeatedly and mistakenly been referred to *Richardsonites merriami* (Drewes, 1967; Gordon and Poole, 1968; Gordon, 1970; Webster and others, 1984). This practice is hard to explain since the latter, which is a Pendleian species transferred herein to *Stenoglaphyrites*, bears little resemblance to the new species. *Stenoglaphyrites merriami* (Youngquist) has a narrower ventral lobe, more slender ventral prongs, a wider conch, and never develops an oxyconic form.

Populations of this taxon seem to vary slightly from locality to locality but little basis for additional taxonomic subdivision exists at the present time.

Distribution. Widespread in Middle Arnsbergian (*E. girtyi* Biozone) strata of the AFB. No other occurrences can be confirmed.

Material. 18801-PC (4); 63NVCL-1 (1); 89NVNY-4 (66+ [type lot]); 92NVLI-2 (1); 92NVLI- 4 (4); 93CAIN-6 (4); 93UTMI-4 (1); 94NVLI-11 (64+); 94NVLI-21 (1); 95NVWP-22a (2); 95NVWP-23 (24); 95NVWP-24 (2).

ACKNOWLEDGMENTS

The genus name for *Cryptotyloceras gordoni* n. gen., n. sp. was coined by M. Gordon Jr. in an unpublished manuscript. Very small parts of descriptions of the same taxon from the same manuscript, as well as of a large specimen of *Fayettevillea* from the Ely Limestone in Utah and of some of the USGS localities have been modified and included herein. In addition, much of the material bearing USNM prefixes was initially studied by Gordon, but was left unpublished. I am using Gordon's genus name to give tribute to his pioneering work on Carboniferous ammonoid research in the western United States and am greatly indebted to both Gordon, and Thomas W. Henry (formerly USGS) for allowing me access to Gordon's work.

Thanks are due to Gary D. Webster who supervised this project while I was a graduate student. Field expenses and travel to various repositories in both the United States and Europe were made possible in part by Geological Society of America grant #5266-93. The cooperation of the staff of Death Valley National Monument facilitated the collecting of critical material at Rest Spring. I would also like to thank Svetlana Nikolaeva (Paleontological Institute, Moscow, Russia), Jürgen Kullmann and Dieter Korn (University of Tübingen, Germany), Nicholas J. Riley (British Geological Survey, Nottingham), William M. Furnish, Brian F. Glenister, David M. Work, and Lisa K. Meeks (University of Iowa), W. Bruce Saunders (Bryn Mawr College), and Walter L. Manger (University of Arkansas), for hospitality, literature, access to critical comparative material, or insightful discussions that helped shape the views presented in this paper. Reviews of this paper by David M. Work and Jürgen Kullmann provided helpful comments and led to significant improvements.

Examination of comparative material in the National Museum of Natural History (USNM) was made possible by Jann Thompson and Mark Florence. Tom Dutro (USGS) assisted by showing me Mackenzie Gordon Jr.'s undescribed material in the stratigraphic collections reposited at the Smithsonian Institute. Julia Golden and David M. Work, State University of Iowa, Iowa City, greatly assisted me with the collections there. Steve Tunnicliffe, Curator, British Geological Survey, Nottingham, also greatly contributed to this study with his knowledge of the BGS collections, preparation of loans, and delightful tea times. I was able to examine types at the British Museum of Natural History thanks to Steve Baker, Department of Palaeontology.

Some of the material in this study was collected in support of the field mapping program of the United States Geological Survey (USGS) in the Confusion Range and in other areas of west-central Utah and east-central Nevada, directed by Richard K. Hose. John E. Welch, formerly of the Kennecott Copper Corporation, contributed an extensive fossil collection from the Burbank Hills (to the USGS). Dwight Schmidt, USGS, also contributed three small lots of ammonoid fossils from northern Clark County. Gary D. Webster and Kenneth W. Snell, both of Washington State University, assisted the author in collecting at various localities and provided additional material. Norman J. Silberling (USGS-retired), Kathy M. Nichols (USGS), Ryan Crosby, Calvin H. Stevens (San Jose State University), and James H. Trexler (University of Nevada Reno) provided field data and discussions on stratigraphic problems that helped shape the ideas presented in this study, although I claim sole responsibility for its contents.

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APPENDIX A

MEASURED SECTIONS AND STRATIGRAPHIC CONTEXT OF AMMONOID HORIZONS

California

Inyo County

Cerro Gordo Pipeline Trail (figure 3, locality 1). The Rest Spring Shale outcrops extensively in the vicinity of the old mining town of Cerro Gordo at the very southern end of the Inyo Mountains. The strata have undergone metamorphic alteration and the clastic portions are low-grade slates and quartzites. A narrow northwest-trending trail, known as the pipeline trail, contours the west flank of the crest of the Inyo Mountains northwest from Cerro Gordo. Approximately 2.2 km northwest of Cerro Gordo along the trail, immature ammonoids occur fairly commonly on the east side of the trail (see Gordon, 1964 for more locality information), at a stratigraphic position within 60 m of the base of the Rest Spring Shale. Associated non-ammonoid fauna consists almost exclusively of pelagic bivalves such as *Posidoniella*. The ammonoids occur as altered limonite pseudomorphs after pyrite in what was once a black shale. Although most specimens are small and poorly preserved, the assemblage is very significant as it contains the important index taxon *Cravenoceratoides nititoides* (Bisat). Crushed impressions of both large and small ammonoids are also in the slates. A collection made from this horizon (89CAIN-5) includes the following taxa:

Dombarocanites masoni Gordon
Eumorphoceras bisulcatum Girty
Eumorphoceras sp., cf. *E. imoense* Saunders
Cravenoceratoides nititoides (Bisat)
Eosyngastrioceras? sp.

A few poorly preserved larger ammonoids (89CAIN-6) were also recovered from within 10 m west of the trail at the previous locality (89CAIN-5) in a completely different stratigraphic horizon that is probably higher. Due to their extremely poor preservation these specimens cannot be referred to any genus with certainty, although general conch form (compressed, involute, narrowly umbilicate) and stratigraphic level suggests they might be either mature *Cravenoceratoides* or *Euroceras*.

Conglomerate Mesa (figure 3, locality 2). The Rest Spring Shale outcrops in the Conglomerate Mesa area east of Cerro Gordo, which was mapped by Stone and others (1989). At one locality, approximately 1.6 km due north of Conglomerate Mesa, ammonoids occur as crushed impressions in the lower 10 m of the Rest Spring Shale**.** Rare ammonoids also occur higher in the section though none were collected. The following species was collected about 2- 3 m above the Rest Spring Shale-Perdido Formation contact (89CAIN-7):

Cravenoceratoides nititoides (Bisat)

Rest Spring (figure 3, locality 3). Mid-Carboniferous strata in the Rest Spring region of the northern Cottonwood Mountains, Inyo County, California include the Perdido Formation, Rest Spring Shale, and possibly the lower Tihvipah Limestone (Stevens and others, 1991). A composite section was measured through the uppermost portion of the Perdido Formation (= Mexican Spring Formation of Perdido Group of Stevens and others, 1991) and all of the exposed Rest Spring Shale in the vicinity of Rest Spring (figure 41). At least eight separate ammonoid-yielding horizons, ranging in age from late Pendleian to late Arnsbergian, have been identified in the measured section. Although it has never been unequivocally documented, the Mississippian-Pennsylvanian boundary is almost certainly within the Rest Spring Shale in this vicinity. The following Arnsbergian ammonoids were recovered.

From a thin, coquinoid, dark grey packstone filled with mollusks, brachiopods, other invertebrates, and phosphate clasts, approximately 9 m above the base of the Rest Spring Shale at several localities (FL 27; 93CAIN-2a; 93CAIN-2b; 93CAIN-2c; 93CAIN-2d):

Eumorphoceras paucinodum Gordon
Arcanoceras macallisteri (Gordon)
Delepinoceras californicum Gordon
Delepinoceras eothalassoide Wagner-Gentis
Metadimorphoceras sp.
Eosyngastrioceras hesperium (Miller and Furnish)
Eosyngastrioceras quadratum n. sp.
Glaphyrites sp., cf. *G. latus* Ruzhencev and Bogoslovskaya
Fayettevillea inyoense (Gordon)

From subspherical gray micrite concretions 13 m above the base of the Rest Spring Shale (93CAIN-3):

Eosyngastrioceras hesperium (Miller and Furnish)

Weathering from a purplish shaley interval (material is all crushed) approximately 19-20 m above the base of the measured section (93CAIN-4):

Eosyngastrioceras hesperium (Miller and Furnish)

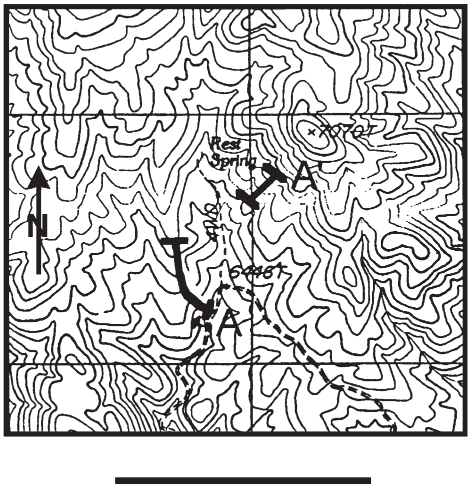
From small (7-15 cm diameter) orange-weathering siderite concretions in a gray to black shale interval ranging from 21 to 24 m above the base of the measured section (93CAIN-5):

Stenoglaphyrites intermedius n. sp.
Eumorphoceras rotuliforme Ruan

From 5-20 cm diameter oval to subspherical siderite concretions weathering from a 15-m-thick claystone interval immediately overlying a sandy, fossiliferous, orange grainstone whose top is 26 m above the base of the measured section (93CAIN-6):

Eumorphoceras girtyi Elias
?Proshumardites delepinei Schindewolf
Eosyngastrioceras inexpectans n. sp.
Cravenoceras sp., cf. *C. subitum* Astachova
Cravenoceratoides sp.
Richardsonites richardsonianus (Girty)
*Zephyroceras girtyanum (*Ruzhencev and Bogoslovskaya)
Euroceras nyense n. sp.

From a 3-m-thick pinkish-purple to tan-gray, platy, calcareous siltstone interval whose base is approximately 98 m



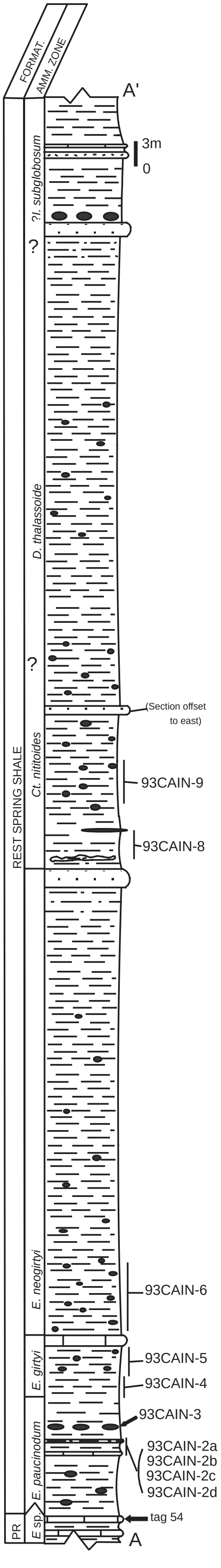


Figure 41. *Topographic map and stratigraphic section for the Rest Spring, California locality. Location of the measured section shown with the thick line. Ammonoid horizons indicated by collection numbers on the measured section. Bar scale under map, 1 km. Abbreviations are as follows: FORMAT, Formation; AMM. ZONE, Ammonoid Biozone; PR, Perdido Formation (Mexican Spring of this report). Ammonoid generic abbreviations are the same as those in figure 12. Lithologic symbols are the same as those in figure 43.*

above the base of the measured formation. This horizon occurs 2.5 m above the first prominent gray to brown platy-weathering quartz arenite in the section. The ammonoids are all crushed and are preserved as bedding plane impressions (93CAIN-8):

Cravenoceratoides nititoides (Bisat)

From small (2-5 cm diameter) subspherical dense siderite concretions in a 9-m-thick claystone interval whose base is 106 m above the base of the measured section and 9 m above the previously mentioned platy brown arenite below 93CAIN-8 (93CAIN-9):

Cravenoceratoides nititoides (Bisat)

Nevada

Clark County

Picture Canyon (figure 3, locality 6). Exposures of the lower portion of the Indian Springs Formation at the eastern end of Picture Canyon, on the western side of the Sheep Range, about 1.6 km south and 0.4 km east of Cow Camp Spring (USGS Black Hills 7.5 min. quad.), have yielded an abundant molluscan fauna dominated by ammonoids. The area is structurally very complex however, and a measured section was not attempted. All of the ammonoids are apparently middle early Arnsbergian (*Eumorphoceras rotuliforme* Biozone) in age. The following taxa were recovered (88NVCL-1; 88NVCL-2):

Eumorphoceras rotuliforme Ruan
Eosyngastrioceras hesperium (Miller and Furnish)
Eosyngastrioceras quadratum n. sp.
Stenoglaphyrites intermedius n. sp.

Apex (figure 3, locality 7). The mid-Carboniferous section at the Apex locality of Webster (1969) (figure 42) consists of the Battleship Wash, Indian Springs, and the lower portion of the Bird Spring Formations. A lens in the middle of the Indian Springs Formation, immediately overlying a phosphatic conglomerate, has yielded a prolific and unique middle Arnsbergian ammonoid fauna. Measured sections for this locality have been published previously (Webster and Lane, 1967; Webster, 1969; Webster and others, 1984), however the section was remeasured and the goniatite-bearing lens was resampled (figure 43). In the course of recollecting, it was found that the lens grades laterally into a persistent micritic concretionary horizon that contains an impoverished version of the lens assemblage**.** This is the only known ammonoid horizon in the immediate vicinity. The lens is probably a channel deposit as it contains broken shells of a variety of benthic and nektonic (primarily molluscan) faunal elements and sand-sized phosphate grains reworked from the underlying conglomerate and concentrated into an narrow lens. Laterally equivalent concretions consist of blue gray micrite, and contain a sparse nektonic molluscan (primarily ammonoid) fauna**.** The following ammonoid taxa are known from the lens (93NVCL-1; 94NVCL-3):

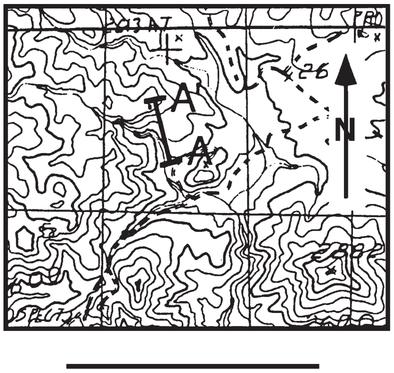


Figure 42. Topographic map of the Apex locality showing location of the measured section. Bar scale under map, 1 km.

Stenopronorites sp., cf. *S. uralensis* (Karpinsky)
Proshumardites delepinei Schindewolf
Eosyngastrioceras inexpectans n. sp.
Syngastrioceras websteri n. sp.
Somoholites walkeri (Webster and Lane)
Zephyroceras girtyanum (Ruzhencev and Bogoslovskaya)
Zephyroceras friscoense (Miller and Owen)

From concretions at approximately the same stratigraphic level as the channel lens (94NVCL- 4):

Zephyroceras friscoense (Miller and Owen)
Syngastrioceras websteri n. sp.

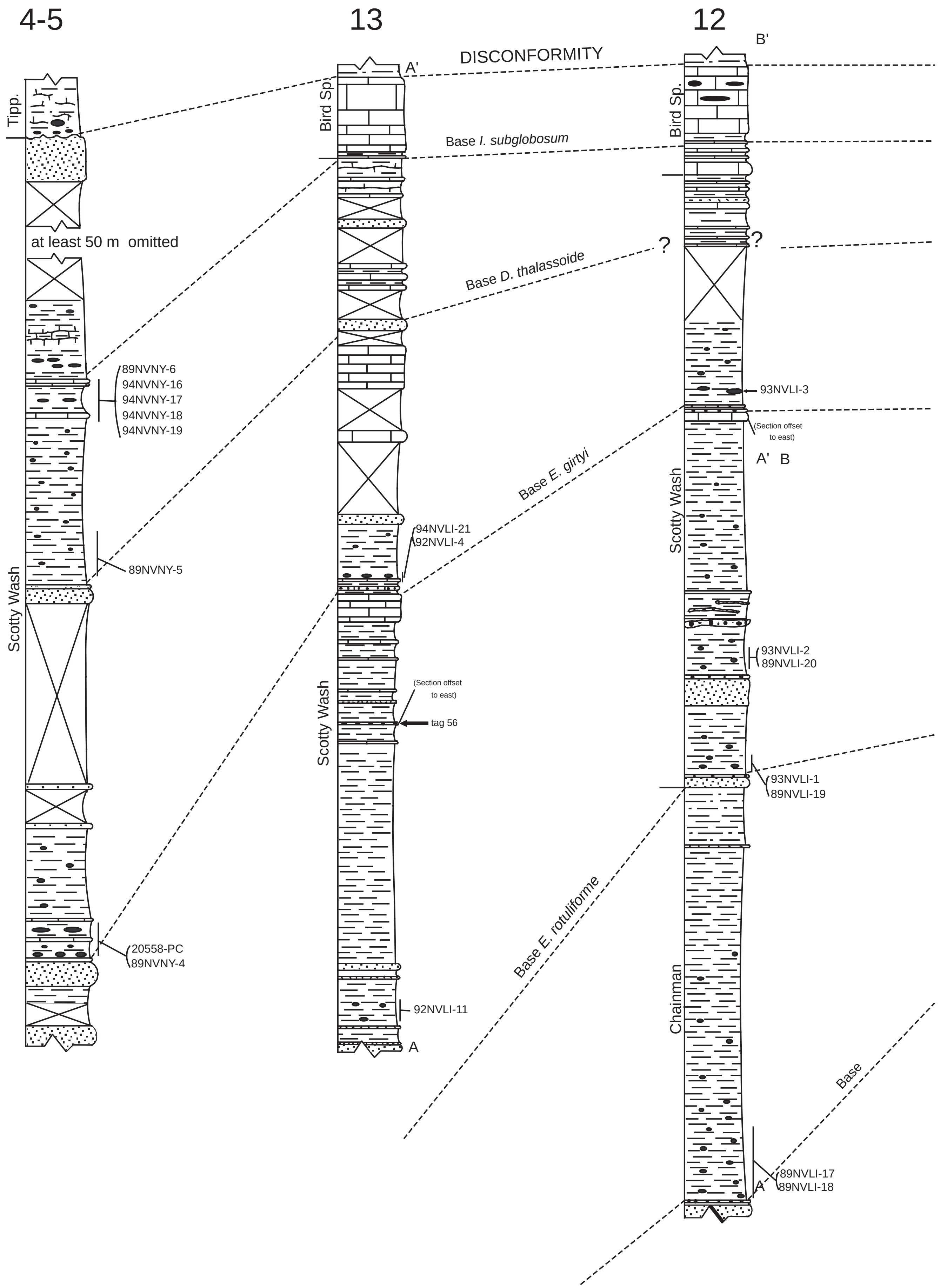
Northern Las Vegas Range (figure 3, locality 8). A single ammonoid was recovered by G. D. Webster (63NVCL-1) from the "marker" conglomerate unit of the Indian Springs Formation at the Las Vegas Range locality (USGS Arrow Canyon NW 7.5-minute quadrangle) of Webster (1969). Although a poorly preserved phosphatic internal mold, this specimen is one of the largest specimens of *Euroceras nyense* n. sp. recovered from the study area. It is the only known occurrence of the species in the Indian Springs Formation.

Arrow Canyon (figure 3, locality 9). Very few ammonoids have been collected from the mid-Carboniferous section exposed in Arrow Canyon which consists of the Battleship Wash, Indian Springs, and lower portion of the Bird Springs Formations (figure 43). However, because the section has been selected as an international boundary stratotype, any occurrences are significant. Webster and Lane (1969) reported a single specimen of "*Cravenoceras*" from the shale of the lower portion of the Indian Springs Formation (below the marker conglomerate). The generic affinities of this specimen are unknown as it was not examined. However, it is almost certainly not *Cravenoceras* in the sense of this report. *Stenoglaphyrites intermedius* n. sp. occurs abundantly in the same stratigraphic position at nearby localities (Three Prongs).

The author found rare phosphatized internal molds of goniatites associated with other phosphatic molluscan internal molds in the upper portion of the "marker" conglomerate bed of Webster (1969) (for more detailed stratigraphic data, see Baesemann and Lane, 1985). Similarly preserved ammonoids were also reported from this locality by Webster and Lane (1967). The assemblage contains two of the same taxa found at the Apex locality. The marker conglomerate at Arrow Canyon contains the following taxa (93NVCL-10):

Syngastrioceras websteri n. sp.
Somoholites walkeri (Webster and Lane)

Three Prongs (figure 3, locality 10). Small, isolated outcrops of the lower portion of the Indian Springs Formation on the east side of Coyote Springs Valley, west of the


4-5
13
12
B'
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DISCONFORMITY
Tipp.
Bird Sp.
Bird Sp.
Base I. subglobosum
at least 50 m omitted
?
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Base D. thalassoide
89NVNY-6
94NVNY-16
94NVNY-17
94NVNY-18
94NVNY-19
93NVLI-3
(Section offset
to east)
A' B
Base E. girtyi
Scotty Wash
94NVLI-21
92NVLI-4
89NVNY-5
Scotty Wash
93NVLI-2
89NVLI-20
(Section offset
to east)
tag 56
Scotty Wash
93NVLI-1
89NVLI-19
Base E. rotuliforme
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Chainman
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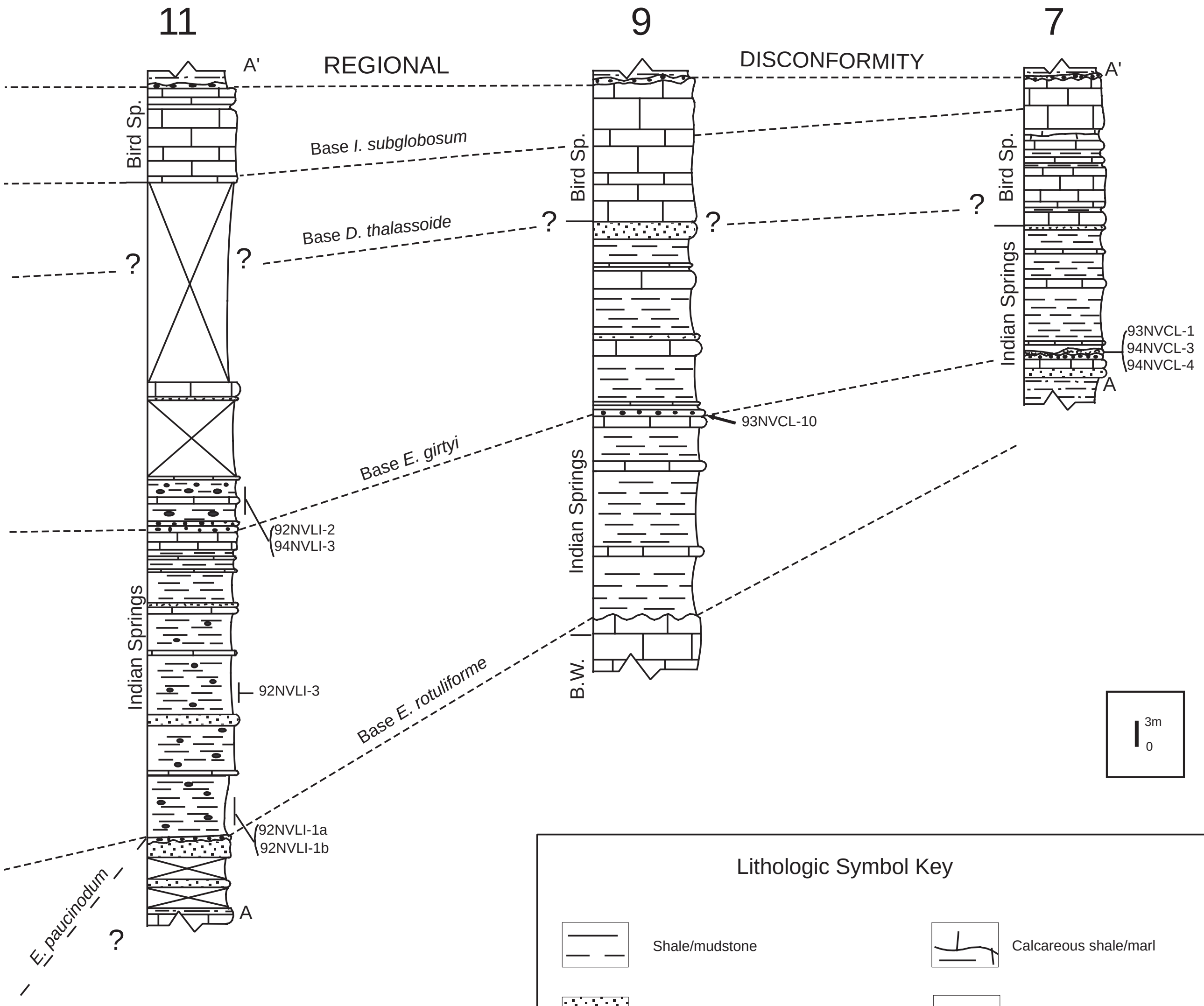


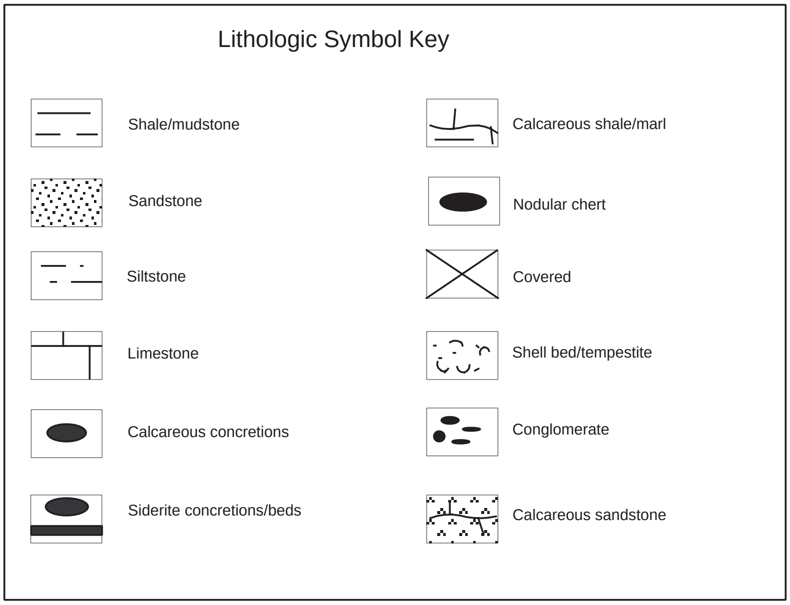


Figure 43. *Measured sections for the Syncline Ridge (4-5), Hancock Summit (13), Kane Springs Wash (12), Bunker Hills (11), Arrow Canyon (9), and Apex (7) ammonoid localities in southern Nevada. Ammonoid horizons indicated by collection numbers. Abbreviations are as follows: Tipp, Tippipah Formation; Bird Sp, Bird Spring Formation. Ammonoid generic abbreviations are the same as those in figure 12.*

Meadow Valley Range (USGS-Wildcat Wash SW 7.5-minute quadrangle), yield a prolific early Arnsbergian ammonoid fauna. Ammonoids were first discovered here by Dwight Schmidt of the U. S. Geological Survey during a mapping project in the late 1980s. The ammonoids occur loose or in maroon-colored siderite concretions weathering from the basal few meters of the Indian Springs Formation, which is preserved as erosional remnants on downthrown fault blocks of Battleship Wash Formation. Other invertebrates (mostly mollusks) are also associated with the ammonoids. The following taxa have been recovered from three closely spaced localities in this general region (89NVCL-3; 89NVCL-4; 89-NVCL5):

Stenoglaphyrites intermedius n. sp.
Eumorphoceras rotuliforme Ruan

Lincoln County

Bunker Hills (figure 3, locality 11). During the author's field work, new ammonoid localities were discovered in the Bunker Hills, north of the Arrow Canyon area (figure 44). Mid-Carboniferous strata here are represented by a deeper water equivalent of the Battleship Wash Formation, the Indian Springs Formation, and the lower portion of the Bird Spring Formation. A composite section was measured through the Indian Springs Formation into the lower portion of the Bird Spring Formation (figure 43). The lithologies of the Indian Springs Formation in this area are fairly typical, although the section is thicker than the one in Arrow Canyon. Early and middle Arnsbergian ammonoids occur at three separate horizons in the Indian Springs Formation. The stratigraphic lowest occurrence is in small (7-15 cm), oval, fossiliferous maroon-orange siderite concretions weathering from a 4-5 m claystone interval immediately above an orange-weathering phosphate clast conglomerate. Ammonoid biostratigraphic data indicate that this conglomerate, which rests on a prominent *Stigmaria*-bearing calcareous quartz arenite, is older than the "marker" conglomerate at Arrow Canyon or Apex. The following species was recovered (92NVLI-1a; 92NVLI-1b):

Stenoglaphyrites intermedius n. sp.

From small (5-10 cm) subrounded siderite concretions and weathering directly from a 3-4 m shale interval whose top is approximately 6-7 m stratigraphically below 92NVLI-2 (92NVLI-3):

Stenoglaphyrites intermedius n. sp.

The "marker" conglomerate equivalent at the Meadow Valley locality is a much thicker phosphatic grain and pebble interval that contains an abundant molluscan fauna preserved as phosphatic internal molds. Poorly preserved goniatites occur uncommonly in this phosphate interval, however none were collected. A five-meter-thick shale interval immediately above the phosphate beds has yielded a number of well-preserved mid-Arnsbergian goniatites from medium-sized (0.2-0.4 m diameter), brown-weathering, elliptical micrite concretions. Preservation is generally exceptional in the concretions and a fossil shrimp was collected. Exceptionally large ammonoids also occur rarely in this unit, and an umbilical plug (external mold) of a *Zephyroceras* from these beds measured 16.5 cm in diameter. The following species have been recovered from this horizon (92NVLI-2; 94NVLI-3):

Metadimorphoceras sp.
Syngastrioceras websteri n. sp.
Zephyroceras girtyanum (Ruzhencev and Bogoslovskaya)
Zephyroceras friscoense (Miller and Owen)

Kane Springs Wash East (figure 3, locality 12). The presence of ammonoids at the Kane Springs Wash East locality (figure 45) of Webster (1969) was reported by Tschanz and Pampeyan (1970). In spite of their abundance, ammonoids have never previously been illustrated or described from this locality. The mid-Carboniferous section is represented by the Chainman Shale, the Scotty Wash Formation, and the lower portion of the Bird Spring Formation. Based on its ammonoid content, the upper portion of the Chainman Shale at Kane Springs Wash is age equivalent to the lower portion of the Scotty Wash Formation at its name location in north-central Lincoln County.

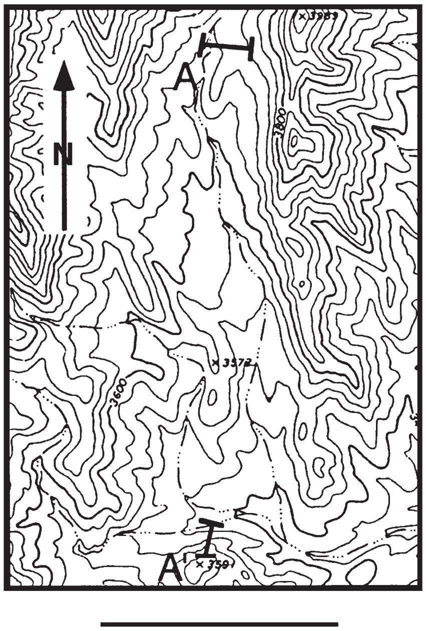


Figure 44. Topographic map of the Bunker Hills locality showing location of the measured section. Bar scale under map, 1 km.

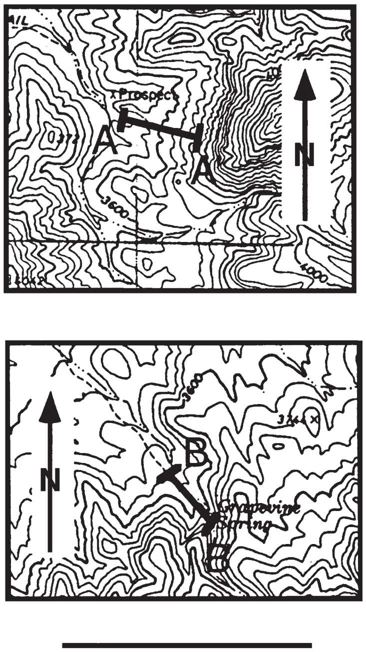


Figure 45. Topographic maps of the Kane Springs Wash locality showing location of the measured sections. Bar scale under map, 1 km.

Four Arnsbergian ammonoid horizons are now known from the Kane Springs Wash locality. The horizons have been keyed to a composite measured section for this locality which was measured at two separate places (figure 43). Pendleian and older ammonoid faunas are also present in the section. The following ammonoid taxa were recovered weathered free, or in small to large (10-30 cm), disc-shaped, maroon to orange-yellow-weathering siderite concretions from a 10 m interval above a flaggy weathering, thin bedded, orange, phosphatic, conglomeratic sandstone that marks the Pendleian-Arnsbergian boundary (89NVLI-17; 89NVLI-18):

Eumorphoceras paucinodum Gordon
Eosyngastrioceras hesperium (Miller and Furnish)
Eosyngastrioceras quadratum n. sp.
Glaphyrites sp., cf. *G. latus* Ruzhencev and Bogoslovskaya
Fayettevillea inyoense (Gordon)

From small (5-10 cm diameter) siderite concretions weathering from a two-m-thick olive-gray shale interval immediately above the lowest prominent quartz arenite of the Scotty Wash Formation (89NVLI-19; 93NVLI-1):

Stenoglaphyrites intermedius n. sp.

From small (5-10 cm diameter) siderite concretions in a five-m-thick shale interval immediately overlying the second lowest prominent quartz arenite in the Scotty Wash Formation (89NVLI-20; 93NVLI-2):

Stenoglaphyrites intermedius n. sp.

From small (10-20 cm diameter) gray, oval, calcareous concretions in a one-m-thick black phosphatic shale immediately above a bryozoan-crinozoan-rich grainstone capped by the phosphate pebble "marker" conglomerate (93NVLI-3):

Syngastrioceras websteri n. sp.

Hancock Summit (figure 3, locality 13). The mid-Carboniferous of the northern Pahranaghat Range is represented by the Chainman, Scotty Wash, and lower part of the Ely Formations. Two horizons yielding Arnsbergian ammonoids were discovered while measuring a section through the Scotty Wash Formation on the east side of Hancock Summit (figure 46). The stratigraphic positions of the ammonoid occurrences in the measured section are given in figure 43. The collections indicate that middle early Arnsbergian and early mid-Arnsbergian (*Eumorphoceras rotuliforme* and *E. girtyi* Biozones) faunas are represented. In the lower horizon, the following taxon was found weathered free from a olive-green to gray shale (92NVLI-11):

Stenoglaphyrites intermedius n. sp.

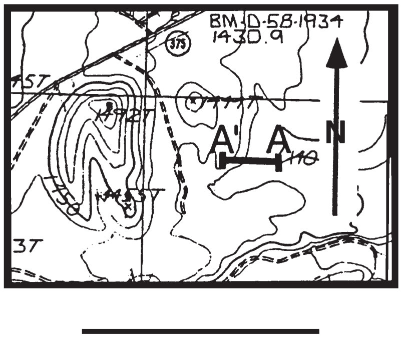


Figure 46. *Topographic map of the Hancock Summit locality showing location of the measured section. Bar scale under map, I km.*

The higher ammonoid horizon is a thin (0.75 m) calcareous concretionary shale that occurs immediately above a phosphatic interval correlated with the "marker" conglomerate. The following ammonoids were recovered from this unit, and from the phosphatic interval immediately below it (92NVLI-4; 94NVLI-21):

Eosyngastrioceras inexpectans n. sp.
Syngastrioceras websteri n. sp.
Zephyroceras girtyanum (Ruzhencev and Bogoslovskaya)
Euroceras nyense n. sp.

Trough Springs (figure 3, locality 14). The mid-Carboniferous of the southern Egan Range is represented by the Chainman Shale, Scotty Wash Formation, and the lower portion of the Ely Limestone. A section was measured in Trough Springs Canyon from a prominent Asbian (latest Meramec) age concretionary horizon in the lower Chainman Shale into the upper portion of the Scotty Wash Formation (figure 47). Ammonoids are extremely abundant at several horizons in the measured section and recovered faunas range in age from late Meramec (late Asbian) to late Chester (middle Arnsbergian). The measured Arnsbergian portion of the section is shown in figure 48. Structural complications in the upper portion of the Scotty Wash Formation prevented taking the section into the Ely Limestone.

Figure 47. *Topographic map of the Trough Springs locality showing location of the measured section. Bar scale under map, 1 km.*

Two separate Arnsbergian ammonoid horizons were identified. The lower horizon is a two-m black shale interval with large (0.3-0.4 m diameter), oval, calcareous concretions, located approximately 12 m above the top of the lowermost thick quartz arenite unit in the Scotty Wash Formation. This horizon is abundantly fossiliferous with well preserved ammonoids and other nektonic-pelagic fauna, including the bivalve Aviculopectin. Uncommon benthic elements are also present in the fauna including high-spired gastropods and the bivalve Edmondia. Comparison of material from this concretionary horizon with material in the U.S. National Museum now make it certain that it is the same one that yielded the original type lot of "Cravenoceras" hesperium (Miller and Furnish, 1940). The following taxa have been identified from this horizon at two localities in Trough Springs Canyon (93NVLI-9; 94NVLI-10):

Eumorphoceras rotuliforme Ruan
Eosyngastrioceras hesperium (Miller and Furnish)
Eosyngastrioceras quadratum n. sp.
Cryptotyloceras gordoni n. gen., n. sp.
Stenoglaphyrites intermedius n. sp.

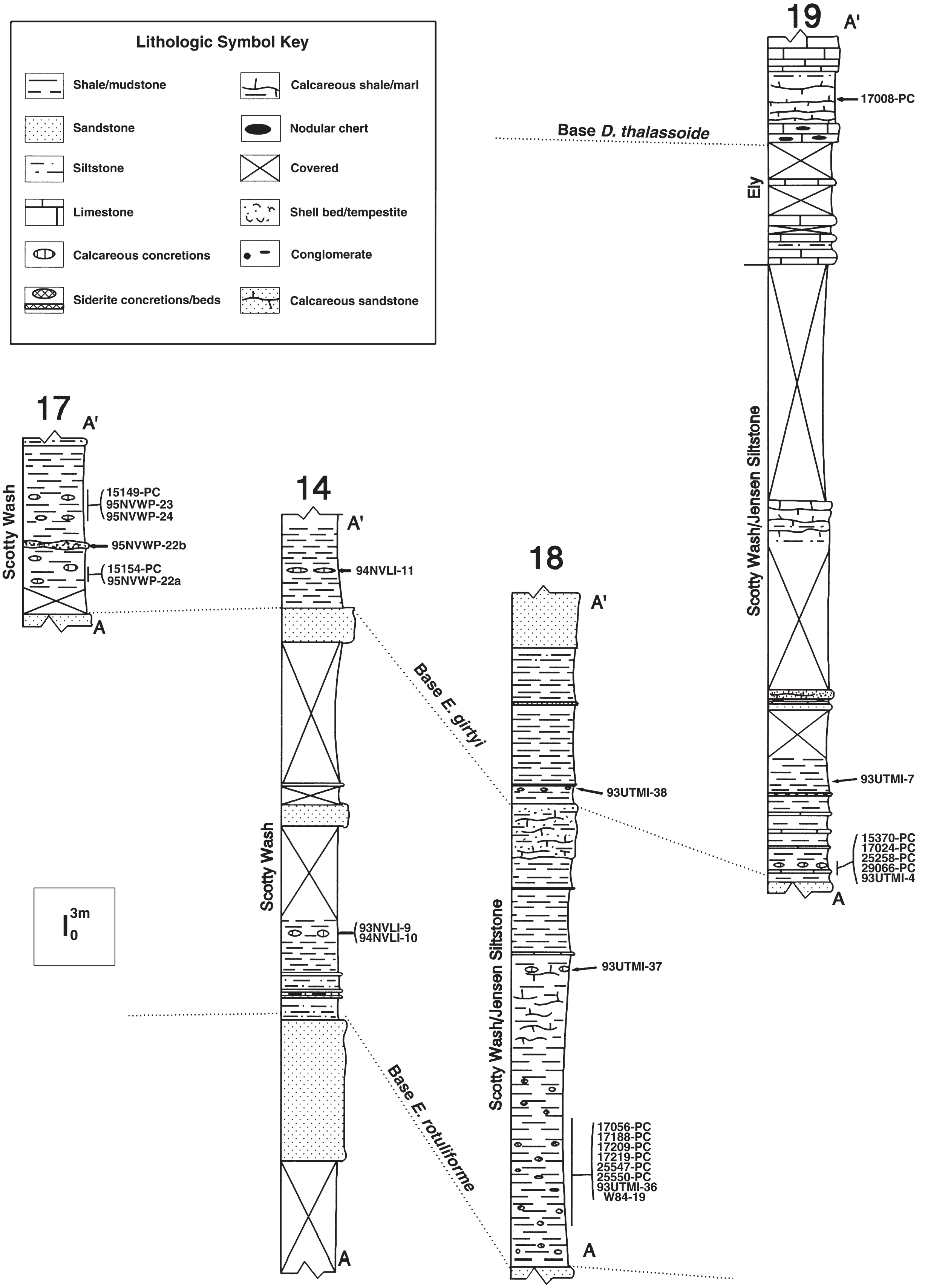


Figure 48. Measured sections for the Little Antelope Summit (17), Trough Springs (14), Jensen Wash (18), and Foote Ranch (19) ammonoid localities in eastern Nevada and western Utah. Ammonoid horizons indicated by collection numbers. Ammonoid generic abbreviations are the same as those in figure 12.

The higher horizon is also a concretionary black shale horizon. It is stratigraphically located about six m above the next higher prominent quartz arenite in the Scotty Wash Formation. The concretions are up to one m long, are flat in appearance, and are filled with vertical septarian fractures. Ammonoids are uncommon in the concretions, and are typically filled with coarsely crystalline calcite which makes them difficult to extract from the extremely hard, dense matrix. The following taxa were recovered (94NVLI-11):

Eumorphoceras girtyi Elias
Eosyngastrioceras inexpectans n. sp.
Syngastrioceras websteri n. sp.
Euroceras nyense n. sp.

Nye County

South Syncline Ridge (figure 3, locality 4). Nearly continuous exposures of the highest portion of the Scotty Wash Formation and the lower portion of the Tippipah Limestone occur at the south end of Syncline Ridge, Nevada Test Site (figure 49). This is the same locality described in Titus (1992) and Titus and others (1997) that has yielded both latest Arnsbergian ammonoids and earliest Pennsylvanian (Chokierian) homoceratids. The geology of this area was published by Orkild (1963). The stratigraphic column for this section is given in figure 43. The following ammonoids were recovered from small (5-10 cm diameter) siderite concretions and thin packstone beds in shales overlying a prominent quartz arenite unit (89NVNY-5; 89NVNY-6; 94NVNY-16; 94NVNY-17; 94NVNY-18; 94NVNY-19):

Eosyngastrioceras inexpectans n. sp.
Delepinoceras thalassoide (Delepine)
Zephyroceras friscoense (Miller and Owen)

North Syncline Ridge (figure 3, locality 5). This locality is the same as the Red Canyon Mississippian ammonoid locality of Gordon and Poole (1968), which is located on the northwestern tip of Syncline Ridge (figure 50). A geologic map for the area was published by Orkild (1963). The ammonoids occur in gray-weathering, black, phosphate-rich, micrite concretions and nodular beds immediately above a prominent quartz arenite unit in the lower portion of the Scotty Wash Formation (figure 43). The following taxa were recovered (20558-PC; 89NVNY-4):

Eumorphoceras girtyi Elias
Eosyngastrioceras inexpectans n. sp.
Syngastrioceras websteri n. sp.
Richardsonites richardsonianus (Girty)
Zephyroceras friscoense (Miller and Owen)
Euroceras nyense n. sp.

White Pine County

Conners Pass (figure 3, locality 15). Good exposures of the lower portion of the Chainman Formation occur in the central Schell Creek Range, approximately 2.4 km west and slightly south of Conners Pass. The northwest-trending drainage originating at Rosebud Spring exposes an especially good Viséan and early Namurian (Pendleian) section of Chainman Formation in which ammonoids are abundant. A measured section was made through the Chainman along this drainage. Unfortunately, the Scotty Wash Formation is highly faulted throughout the Conners Pass area. A single isolated locality (93NVWP-8) in a shale horizon immediately above a thin sandstone unit in the middle portion of the Scotty Wash Formation yielded two crushed specimens of *Stenoglaphyrites*. Based on the general stratigraphic position of this locality the specimens are probably *St. intermedius* n. sp. but this cannot be ascertained for certain. Regardless of their specific affinity, the stratigraphic position of the specimens suggests that they are early Arnsbergian in age.

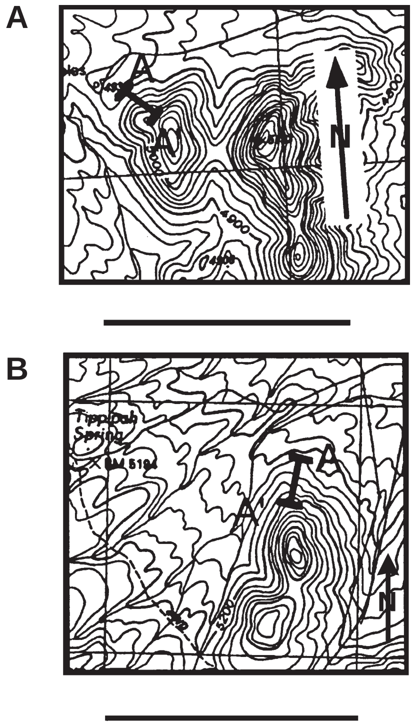


Figure 49. Topographic maps of the north (A) and south (B) Syncline Ridge localities showing location of the measured sections. Bar scale under map, 1 km.

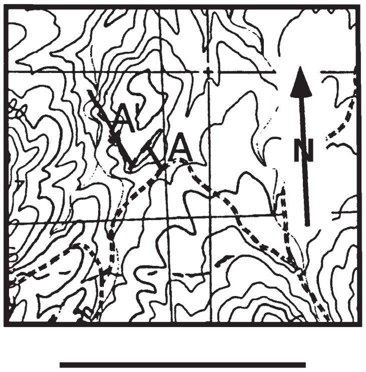


Figure 50. Topographic map of the Jensen Wash locality showing location of the measured section. Bar scale under map, 1 km.

Cave Lake (figure 3, locality 16).—A thick section of Scotty Wash Formation is exposed north of the Cave Lake Park road, starting on the top of a small hogback of quartz arenite. No section was measured because exposures are discontinuous and the section is probably faulted repeatedly. The following taxa were recovered from small (20 cm) concretions in a two-m interval above the quartz arenite horizon mentioned above (93NVWP-11):

Eumorphoceras rotuliforme Ruan
Eosyngastrioceras hesperium (Miller and Furnish)

Cooper Canyon (figure 3, locality 16). A highly faulted section of Scotty Wash Formation is exposed in the upper reaches of Cooper Canyon, in the Schell Creek Range, north of Conners Pass. No measured section could be completed due to the high number of faults. The following taxon was collected from 5-10 cm diameter black micrite concretions weathering from black shale in a small fault sliver of Scotty Wash Formation, probably representing the middle portion of the formation, on the north side of a hillside capped with Oligocene volcanics (93NVWP-12):

Richardsonites richardsonianus (Girty)

Little Antelope Summit (figure 3, locality 17). Three separate stratigraphic horizons within the Scotty Wash-Diamond Peak interval of the Antelope Summit area of the western White Pine Range have yielded Arnsbergian ammonoids. Collections from all of these horizons were made in the same general area, in the core of an anticlinal structure developed in the westernmost outcrops of Scotty Wash Formation and Ely Limestone in the northern White Pine Range along U.S. Highway 50. The lowest of the three horizons consists of about four m of concretionary black shale (figure 48). The following taxa were recovered from the 0.3-0.5 m diameter, gray-weathering micrite concretions (15154-PC; 95NVWP-22a):

Eumorphoceras girtyi Elias
Metadimorphoceras sp.
Stenoglaphyrites involutus (Gordon)
Stenoglaphyrites colubrellus (Miller and Furnish)
Euroceras nyense n. sp.

From a 0.5-m-thick, thin-bedded, brown to orange weathering, highly fossiliferous, somewhat lenticular, sandstone unit (95NVWP-22b):

Eumorphoceras girtyi Elias
Glaphyrites sp., cf. *G. nevadensis* (Miller and Furnish)
Stenoglaphyrites involutus (Gordon)

The third horizon is a 2-3 m mudstone-shale interval containing highly fossiliferous, dark gray to black (on fresh surface), 20-30 cm diameter micrite concretions. This horizon is thought to be slightly higher (within a few meters) than the previous horizons. The concretions contain the following taxa (15149-PC; 95NVWP-23; 95NVWP-24):

Eumorphoceras girtyi Elias
Eumorphoceras brevornatum n. sp.
Eosyngastrioceras inexpectans n. sp.
Syngastrioceras websteri n. sp.
Richardsonites richardsonianus (Girty)
Zephyroceras friscoense (Miller and Owen)
Euroceras nyense n. sp.

Utah

Millard County

Jensen Wash (figure 3, locality 18). The Camp Canyon, Willow Gap Limestone, and Jensen Members of the Chainman Shale have nearly 100 percent exposure in Jensen Wash (figure 51), northern Burbank Hills. Ammonoids are abundant in certain late Asbian, middle Brigantian, Pendleian, and early Arnsbergian horizons. The Asbian through latest Pendleian portion of this section is especially well exposed and fossiliferous, and it has yielded the single best late Viséan-early Namurian ammonoid succession in the western United States. Most of the pre-Arnsbergian ammonoid fauna is undescribed. A section was measured through the unequivocal Arnsbergian portion of the Jensen Member starting at the base of a 9 m, pinkish-yellow-weathering shale (Unit 72 of Sadlick's 1965 northern Burbank Hills measured section) in the NE$^{1}/_{4}$ NE$^{1}/_{4}$ section 35 (figure 48). Although the above-mentioned pinkish-yellow-weathering nodular shale is the lowest horizon from which unequivocal Arnsbergian ammonoids were recovered, there are two non-diagnostic ammonoid-bearing beds below this shale and above highest unequivocal late Pendleian faunas. The uppermost of the two beds could possibly represent the *E. paucinodum* Biozone of earliest Arnsbergian age; however, as stated above, neither horizon has yielded diagnostic girtyoceratids.

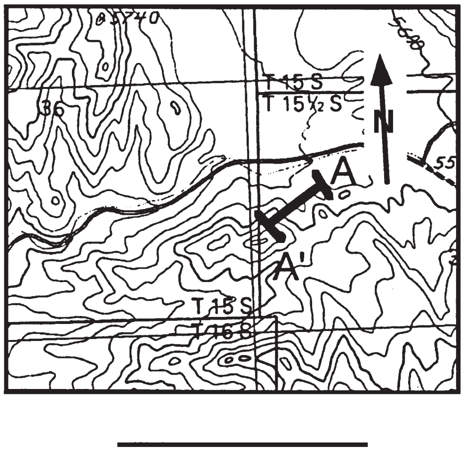


Figure 51. *Topographic map of the Foote Ranch locality showing location of the measured section. Bar scale under map, 1 km.*

The characteristic yellowish tinge of the shale unit is easily recognizable in outcrop, and a number of collections were made in patches where fossils had weathered from this unit along strike for about 0.8 km. The collections from this unit (17056-PC; 17188-PC; 17209-PC; 17219-PC; 25547-PC; 25550-PC; 93UTMI-36; W84-19) include the following ammonoids:

Eumorphoceras rotuliforme Ruan
Delepinoceras californicum Gordon
Pericleites pilatus Ruan
Eosyngastrioceras hesperium (Miller and Furnish)
Glaphyrites millardensis n. sp.
Cryptotyloceras gordoni n. gen., n. sp.

The *Glabrocingulum quadrigatum* assemblage listed by Gordon and Yochelson (1987, p. 20) occurs with this fauna.

The next ammonoid-bearing interval is a 1-2 m dark gray, platy-weathering calcareous shale, with hard micritic concretions that contain a sparse molluscan and leiorhyncid brachiopod fauna. The base of this interval is approximately 40 m above the top of the 9-m-thick pinkish-yellow-weathering shale. The only ammonoid species recorded here, which is uncommon, is (93UTMI-37):

Eosyngastrioceras hesperium (Miller and Furnish)

At the base of the next highest shale unit (32.2 m above the horizon yielding 93UTMI-37), above a calcareous quartz arenite, uncommon, small, crushed ammonoids weather out. The following species was recovered (93UTMI-38):

Richardsonites richardsonianus (Girty)

The highest ammonoid recorded in the Jensen Wash section was found loose in the middle of a 17.1-m-thick, abundantly fossiliferous shale unit containing many brachiopods, including *Carlinia phillipsi* (Norwood and Pratten), whose top is 24.4 m below the Ely Limestone-Chainman Shale contact. The pea-sized ammonoid (USGS colln. 17059-PC) is identified as:

Syngastrioceras websteri n. sp.

Whether this ammonoid came from the same bed that yielded the gastropods listed by Gordon and Yochelson (1987, p. 20) from this locality cannot be determined, but it seems likely because most of the fossils of this interval are brachiopods and ammonoids are much more commonly found associated with gastropods than brachiopods.

Southern Burbank Hills (figure 3, locality 18). Ammonoids were found on the south side of the Burbank Hills in the same pinkish-weathering beds that produced most of the characteristic species of the *E. rotuliforme* Biozone in the Jensen Wash section. A single collection from this locality, which was presented to the U.S. Geological Survey by John E. Welsh, contains the following ammonoids (USGS colln. 17310-PC):

Percleites pilatus Ruan
Eosyngastrioceras hesperium (Miller and Furnish)
Glaphyrites millardensis n. sp.

Foote Range Partial Section (figure 3, locality 19). The geology of this area was mapped by Hose and Ziony (1963). The uppermost 90 m or so of the Chainman Shale and more of the lowermost Ely Limestone are well exposed on both the north and south sides of a northeast-trending drainage approximately 6.4 km northeast of Foote Ranch. A section was measured in the upper portion of the Jensen Member and into the lower portion of the Ely Limestone starting in the middle of the SE $^1/_4$, section 31, T. 15 $^1/_2$ S., R. 17 W. (figure 52). Ammonoids are common at several horizons in the Chainman Shale in this area and the Pendleian is especially prolific.

In the lower portion of the measured section, the base of which is bounded by a normal fault, are a series of four gray-black, nodular limestones and a calcareous concretionary horizon (figure 48). The lowest nodular limestone contains abundant individuals of the brachiopod *Leiorhyncoidea carbonifera* (Girty) and *Richardsonites richardsonianus* (Girty). Collections taken at different times from this outcrop (15370-PC; 17024-PC; 25258-PC; 29066-PC; 93UTMI-4) include the following ammonoids:

Dombarocanites sp.
Eumorphoceras girtyi Miller and Youngquist
Metadimorphoceras sp.
Eosyngastrioceras inexpectans n. sp.
Richardsonites richardsonianus (Girty)

Nearly all of the *Richardsonites* specimens are juvenile to immature; moderate-sized specimens up to 3 cm in diameter are uncommon. Gastropods in this bed included *Lunulazona* sp., cf. *L. sablei* (Yochelson and Dutro), which has been found in the Confusion Range only in association with *Richardsonites richardsonianus* (Girty).

Approximately 13.5 m above the *Leiorhyncoidea-Richardsonites* bed, in tan-weathering shale and associated with an abundant and well-preserved gastropod fauna, the following taxon was recovered (93UTMI-7):

Richardsonites sp.

In a 0.5-m-thick, coarse-grained, light-gray, bioclastic limestone, whose base is 7.25 m above the base of the Ely Limestone, the following ammonoid species was found (17008-PC):

Zephyroceras friscoense (Miller and Owen)

This specimen was found associated with well-preserved specimens of *Rhipidomella nevadensis* and it is the only ammonoid collected from the Ely Limestone in this region.

Southern Bishop Springs Anticline (figure 3, locality 20). The geology of this area was mapped by Hose and Ziony (1963). Complex structure and extensive cover prevents measurement of an accurate Namurian section. Several collections of Arnsbergian ammonoids were made from a section exposed in a fault block in the SE$^1/_4$ SE$^1/_4$ NE$^1/_4$ section 20 composed of almost 9.1 m of dark-gray limestone, in beds 0.15 to 0.3 m thick, alternating with brownish-gray shale. Although faulting has made it impossible to place this interval in a precise stratigraphic context, it probably lies 150-160 m below the base of the Ely Limestone. Gastropods from this locality representing the *Glabrocingulum quadrigatum* assemblage were listed by Gordon and Yochelson (1987, p. 15). The ammonoids, which are mostly small, are distributed as follows:

Lowermost limestone bed (0.3 m thick) (USGS collns. 17022-PC; 20450-PC; 25260- PC):

Metadimorphoceras sp.
Eosyngastrioceras hesperium (Miller and Furnish)
Cryptotyloceras gordoni n. gen., n. sp.

In a 15-cm-thick limestone bed, the base of which is 8.2 m above the top of the *Cryptotyloceras* bed (USGS colln. 19605-PC; 20445-PC):

Eosyngastrioceras hesperium (Miller and Furnish)

From a limestone bed a few meters stratigraphically higher (19606-PC):

Eosyngastrioceras hesperium (Miller and Furnish)

Approximately the same stratigraphic interval is exposed on two small hummocks about 23 m apart, near the junction of two desert roads in the SE$^1/_4$ SE$^1/_4$ SW$^1/_4$ section 20. The following species were collected from gray-weathering calcareous concretions that occur slightly above the bed yielding 19606-PC (20441-PC; 20442-PC; 93UTMI-13a; 93UTMI-13b):

Eosyngastrioceras hesperium (Miller and Furnish)
Eumorphoceras rotuliforme Ruan

APPENDIX B

REGISTER OF COLLECTIONS

United States Geological Survey Collections

15149-PC. White Pine County, NV, Antelope Mountain 7.5-minute quadrangle about 244 m north of U.S. Highway 50, in the SW$^{1}/_{4}$, SE$^{1}/_{4}$, SE$^{1}/_{4}$, section 25, T. 18 N., R. 57 E. *Eumorphoceras girtyi* Biozone. Collected by M. Gordon Jr., 1953.

15154-PC. White Pine County, NV, East of Pancake Summit 7.5-minute quadrangle about 76-84 m north of U.S. Highway 50, in the NW$^{1}/_{4}$, NE$^{1}/_{4}$, NE$^{1}/_{4}$, section 36, T. 18 N., R. 57 E. *Eumorphoceras girtyi* Biozone. Collected by M. Gordon Jr., 1953.

15370-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Foote Range, nearly 1.6 km southeast of well-known Foote Ranch collecting locality, in fractional section 31, T. 15$^{1}/_{2}$ S., R. 17 W., Measured section 6.4 km east of Foote Ranch, from zone constituting units 9-13, which is about 110-140 m below top of the Chainman Shale. Includes bed containing *Richardsonites richardsonianus* (Girty). *Eumorphoceras girtyi* Biozone. Collected by R.K. Hose, September 24, 1954.

17008-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Foote Range partial section, 6.4 km east of Foote Ranch, about 91 to 107 m north of road, on east side of range through wash. Ely Limestone, lower part, a 15 cm bed whose base is 7.25 m stratigraphically above base of formation. (unit 5 of Hose's measured section). Collected by M. Gordon, Jr. and R.K. Hose, May 14, 1957.

17022-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle, 45.7 m west of road, near southern end of Bishop Springs anticline, on east side of Foote Range, in SE$^{1}/_{4}$, NW$^{1}/_{4}$, NW$^{1}/_{4}$, section 20 (unsurveyed), T. 16 S., R. 17 W. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr., C.L. Repenning, and R.K. Hose, May 19, 1957.

17024-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Foote Range, about 1.4 km southeast of Foot Ranch collecting locality, near center of partial section 31, T. 15. S., R. 17 W. Same as 15370-PC. *Eumorphoceras girtyi* Biozone. Collected by M. Gordon, Jr., R.K. Hose, and C.L. Repenning, May 19, 1957.

17056-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Jensen Wash measured section. Fossils from the Chainman Shale in the SE$^{1}/_{4}$, NE$^{1}/_{4}$, section 35, T. 22 S., R. 18 W.; same as Sadlick and Nielsen (1963) locality 2-11 (see Sadlick, 1965, p. 112, unit 72 of northern Burbank Hills measured section; upper part of Jensen Member). *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr., R.K. Hose, and R.J. Ross, June 6, 1957.

17059-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Jensen Wash measured section. Fossils from upper slope of valley cut in small hill in the NW$^{1}/_{4}$, NE$^{1}/_{4}$, NE$^{1}/_{4}$ section 35, T. 22 S., R. 18 W., 27-34 m below top of Chainman Shale (Jensen Member). Collected by M. Gordon, Jr., R.J. Ross, and R.K. Hose, June 6, 1957.

17188-PC Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Jensen Wash measured section. Small tributary of main gully, about 183 m west of road. Roughly 244 m northwest of 17186-PC. Same fauna and interval as 17156-PC. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Christner, September 17, 1957.

17209-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Jensen Wash measured section; offset section of upper part of Chainman Shale where road descends southward to main wash. Same locality and interval as 17056-PC, base of which is 494.7 m above base of Chainman Shale (391.1 m above top of Skunk Spring Limestone Member). *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Christner, September 23, 1957.

17219-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Jensen Wash measured section, NW$^{1}/_{4}$ SW$^{1}/_{4}$ SE$^{1}/_{4}$ section 35, T. 22 S., R. 18 W. Same stratigraphic unit as 17188-PC and same general vicinity. *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Christner, Sept. 26, 1957.

17310-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. Fossils weathered out from shale at stake 158+20 in oil-company section measured in south Burbank Hills, eastern side. Upper part of Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by J.E. Welsh in the late 1950s.

19605-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Southern end of Bishop Springs anticline area, in NE$^{1}/_{4}$ section 20, T. 16 S., R. 17 W. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by R.K. Hose, in Sept. 1960.

19606-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Same location as 19605-PC, but two m higher in section. Chainman Sale, *Eumorphoceras rotuliforme* Biozone. Collected by R.K. Hose in September 1960.

20441-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle, SE1/4 SE$^{1}/_{4}$ section 20, T. 16 S., R. 17 W., at desert road junction, goniatites in fractured limestone concretions on two little hummocks, one alongside road and the other in a drainage 23 m ENE. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Reike, July 26, l961.

20442-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Hummock with goniatites 113 m north 58° E. of 20441-PC, in a slightly different horizon. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Reike, July 26, 1961.

20445-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. Same locality as 20444-PC, but from 15.2 cm bed 8.2 m above top of *Cryptotyloceras* bed and 4.57 m above top of bed of 20444-PC. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and R. Rieke, July 26, 1961.

20450-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle, SE1/4 NW1/$^{1}/_{4}$ NW$^{1}/_{4}$ section 20 (unsurveyed), T. 16 S., R. 17 W. Same locality as 17022-PC. Fossils from lowest ammonoid bed (*Cryptotyloceras*), 46.3 m southwest of 20449-PC. Chainman Shale, *Eumorphoceras rotuliforme*

Biozone. Collected by M. Gordon, Jr., R. K. Hose, and R. Rieke, July 27, 1961.

20558-PC. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. From small, gray-weathering micrite concretions weathering from 2-3 m interval of shale (*Eumorphoceras girtyi* Biozone) exposed immediately east of a prominent double row of resistant quartz arenites in Scotty Wash Formation, at UTM coordinates 4105200, 574330. Collected by F. G. Poole and P. P. Orkild, 1961.

25260-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle, SW$^1/_4$, SE$^1/_4$ section 31, T. 151/2 S., R. 17 W., on southeast side of Foote Range. Same locality and bed as 17022-PC. Chainman Shale, *Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr., E.L. Yochelson, and K.R. Moore, August 18, 1973.

25550-PC. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. At a patch of light-brown shale just above thin limestone bed in first drainage 244 m west of Jensen Wash. About in middle of western side of NW$^1/_4$, SW$^1/_4$, SE$^1/_4$ section 35, T. 11 S., R. 18 W. Drainage runs north and then curves into Jensen Wash. Chainman Shale, ?*Eumorphoceras rotuliforme* Biozone. Collected by M. Gordon, Jr. and W.E. McCaslin, September 15, 1974.

25551-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle. On west limb of Bishop Springs anticline, on slope along east side of north-trending drainage, 518 m north of south line and 3.8 km east of west line of partial section 31, T. 15$^1/_2$ S., R. 17 W., 3.6 km southeast of northwest tip of Foote Range. Fossils from *Anthracospirifer* bed and overlying 9.1 m of shale at northwest strike and dip 73° E., on geologic map (Hose and Ziony, 1963). Chainman Shale, *Rhipidomella nevadensis* Brachiopod Zone. Collected by M. Gordon, Jr. and W.E. McCaslin, September 17, 1974.

29066-PC. Millard County, UT, Gandy NE 7.5-minute quadrangle, NW section 31, T. 15 S., R. 17 W. Same locality as 15370-PC and 17024-PC. Chainman Shale, *Eumorphoceras girtyi* Biozone. Collected by M. Gordon, Jr. and T.W. Henry, April 10, 1983.

A. L. Titus Collections

63NVCL-1. Clark County, NV, Arrow Canyon NW 7.5-minute quadrangle. From top of "marker" conglomerate unit of Indian Springs Formation (*Eumorphoceras girtyi* Biozone) exposed in saddle at UTM coordinates 4059000, 682000 (northern Las Vegas Range). Collected by G. D. Webster, April, 1963.

88NVCL-1. Clark County, NV, Black Hills 7.5-minute quadrangle. From basal portion of the Indian Springs Formation (*Eumorphoceras rotuliforme* Biozone) exposed on the north bank of the northernmost small drainage flowing into Picture Canyon about 1.6 km south, and 400 m east of Cow Camp Spring. Collected by A. L. Titus, June 15, 1988.

88NVCL-2. Clark County, NV, Black Hills 7.5-minute quadrangle. Same unit and horizon as 88NVCL-1, exposed on east and west sides of small drainage flowing directly into Picture Canyon, about 375 m due west of 88NVCL-1. Collected by A. L. Titus, June 15, 1988.

89CAIN-5. Inyo County, CA, Cerro Gordo Peak 7.5-minute quadrangle. Ammonoids from interval of slates (Rest Spring Shale-*Cravenoceratoides nititoides* Biozone) outcropping on east side of pipeline trail, about 2.2 km north of Cerro Gordo. Collected by A. L. Titus, October 14, 1989.

89CAIN-6. Inyo County, CA, Cerro Gordo Peak 7.5-minute quadrangle. Same locality as 89CAIN-5, but immediately west of trail. Collected by A. L. Titus, October 14, 1989.

89CAIN-7. Inyo County, CA, Nelson Range 7.5-minute quadrangle. From 3 m interval of slate, about 2-3 m above Rest Spring-Perdido contact exposed in saddle on narrow ridgeline (*Cravenoceratoides nititoides* Biozone), at 36°33′20″ latitude; 117°44′52″. Collected by A. L. Titus, October 15, 1989.

89NVCL-3. Clark County, NV, Wildcat Wash SW 7.5-minute quadrangle. From siderite concretions weathering from the basal portion of the Indian Springs Formation (*Eumorphoceras rotuliforme* Biozone), in the NW$^1/_4$, NW$^1/_4$, SE$^1/_4$, SE$^1/_4$, section 10, T. 13 S., R. 63 E. Collected by A. L. Titus and D. Schmidt, October 29, 1989.

89NVCL-4. Clark County, NV, Wildcat Wash SW 7.5-minute quadrangle. Same unit and horizon as 89NVCL-3, exposed in the SW$^1/_4$, SE$^1/_4$, SW$^1/_4$, SE$^1/_4$, section 10, T. 13 S., R. 63 E. Collected by A. L. Titus and D. Schmidt, October 29, 1989.

89NVCL-5. Clark County, NV, Wildcat Wash SW 7.5-minute quadrangle. Same unit and horizon as 89NVCL-3, exposed in the NW$^1/_4$, NE$^1/_4$, NE$^1/_4$, section 15, T. 13 N., R. 63 E. Collected by A. L. Titus and D. Schmidt, October 29, 1989.

89NVLI-17. Lincoln County, NV, Sunflower Mtn. 7.5-minute quadrangle. From small to medium-sized siderite concretions weathering from dark-gray to olive shale (*Eumorphoceras paucinodum* Biozone), exposed on east-facing slope at UTM coordinates 4109450, 701960. Collected by A. L. Titus, May 21, 1989.

89NVLI-18. Lincoln County, NV, Sunflower Mtn. 7.5-minute quadrangle. Same unit and horizon as 89NVLI-17, exposed in small east-west-trending gulley at UTM coordinates 4108700, 702040. Collected by A. L. Titus, May 21, 1989.

89NVLI-19. Lincoln County, NV, Sunflower Mtn. 7.5-minute quadrangle. From shale and small siderite nodules in 1-2 m interval immediately above lowermost prominent quartz arenite unit of Scotty Wash Formation (*Eumorphoceras rotuliforme* Biozone) exposed at UTM coordinates 4109570, 702130. Collected by A. L. Titus, May 21, 1989.

89NVLI-20. Lincoln County, NV, Sunflower Mtn. 7.5-minute quadrangle. From 1 m interval of sideritic concretionary shale immediately above next stratigraphically higher quartz arenite unit above that in 89NVLI-19. *Eumorphoceras rotuliforme* Biozone. UTM coordinates 4109570, 702190. Collected by A. L. Titus, May 21, 1989.

89NVNY-4. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. From small, gray-weathering micrite concretions weathering from 2-3 m interval of shale (*Eumorphoceras girtyi* Biozone) exposed immediately east of a prominent double row of resistant quartz arenites in Scotty Wash Formation, at UTM coordinates 4105200, 574330. Collected by A. L. Titus and S. H. Leedom, March 3, 1989.

89NVNY-5. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. From lowermost 10 m of shale (*Delepinoceras thalassoide* Biozone) above the highest prominent quartz arenite outcropping on lower north slope of a small hill at UTM coordinates 4099780, 571740. Collected by A. L. Titus and S. H. Leedom, March 3, 1989.

89NVNY-6. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. Same locality as 89NVNY-5, except 15 m stratigraphically higher, from shales interbedded with 0.3-m-thick fossiliferous packstones (*Delepinoceras thalassoide* Biozone). Collected by A. L. Titus and S. H. Leedom, March 3, 1989.

91ARST-2. Stone County, AR, Batesville 15-minute quadrangle. Ammonoids weathering from base of Imo Formation exposed in the SW$^1/_4$, section 36, T. 14 N., R. 9 W. *Stenoglaphyrites involutus* Biozone. Collected by A. L. Titus and K. P. Titus, March 21, 1991.

91OKJO-1. Johnson County, OK, Wapanucka South 7.5-minute quadrangle. Ammonoids from large (0.75-1 m diameter), elliptical, calcareous concretions weathering from Sand Branch Member of the Caney Shale exposed along Sandy Creek, in the N$^1/_4$, SE$^1/_4$, SW$^1/_4$, section 36, T. 2 S., R. 8 E. Collected by Alan L. Titus, May 15, 1991.

92NVLI-1a. Lincoln County, NV, Wildcat Wash NE 7.5-minute quadrangle. Maroon-weathering sideritic shale interval in lower portion of Indian Springs Formation exposed at UTM coordinates 40912300, 697610, on side of small, rounded hill (*Eumorphoceras rotuliforme* Biozone). Collected by A. L. Titus, June 9, 1992.

92NVLI-1b. Lincoln County, NV, Wildcat Wash NE 7.5-minute quadrangle. Same stratigraphic interval as 92NVLI Bunker Hills *Eumorphoceras rotuliforme* Biozone. Collected by A. L. Titus, June 9, 1992.

92NVLI-2. Lincoln County, NV, Wildcat Wash NE 7.5-minute quadrangle. Bunker Hills *Eumorphoceras girtyi* Biozone. Collected by A. L. Titus and G. D. Webster, June 10, 1992.

92NVLI-3. Lincoln County, NV, Wildcat Wash NE 7.5-minute quadrangle. Bunker Hills *Eumorphoceras rotuliforme* Biozone. Collected by A. L. Titus, June 10, 1992.

92NVLI-4. Lincoln County, NV, Hancock Summit 7.5-minute quadrangle. From phosphatic shale and concretions (*Eumorphoceras girtyi* Biozone) exposed in small northwest-trending gulley perched on top of prominent gray grainstone unit. UTM coordinates 4,150,200, 647,800. Collected by A. L. Titus, June 14, 1992.

92NVLI-11. Lincoln County, NV, Hancock Summit 7.5-minute quadrangle. From olive-weathering shale of Scotty Wash Formation (*Eumorphoceras rotuliforme* Biozone) exposed on northeast side of southeast-east-trending wash at UTM coordinates 4,150,200, 647,600. Horizon is approximately 130 m below the base of the Ely Limestone. Collected by A. L. Titus, June 14, 1992.

93CAIN-2a. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From nodular, phosphatic micrite packstone (*Eumorphoceras paucinodum* Biozone) exposed east of Rest Spring road, about 20-30 m south of white pile of plaster or lime and 100 m east of 93CAIN-2b. Collected by A. L. Titus, December 29, 1993.

93CAIN-2b. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. Same unit and horizon as 93CAIN-2a, exposed west of Rest Spring road and over small rise, at UTM coordinates 4069180, 459775, near bottom of east-facing slope. Collected by A. L. Titus, December 28, 1993.

93CAIN-2c. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. Same unit and horizon as 93CAIN-2a, exposed southwest of 93CAIN-2b, on a flat bench of upper Perdido, about 250 m west and slightly south of 93CAIN-2b. Collected by A. L. Titus, December 29, 1993.

93CAIN-2d. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. Same unit and horizon as 93CAIN-2a, exposed about 300 m west and 100 m north of 93CAIN-2b. Collected by A. L. Titus, December 29, 1993.

93CAIN-3. Inyo County, CA, White Top Mtn. 7.5-minute quarangle. From small, gray micrite concretions and shale (?*Eumorphoceras paucinodum* Biozone) upsection, but in the same vicinity as 93CAIN-2b (along measured section). Collected by A. L. Titus, December 29, 1993.

93CAIN-4. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From purplish-weathering shale (?*Eumorphoceras rotuliforme* Biozone) exposed upsection, but in the same vicinity as 93CAIN-3 (along measured section). Collected by A. L. Titus, December 29, 1993.

93CAIN-5. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From small, orange-brown siderite concretions weathering from olive shale (*Eumorphoceras rotuliforme* Biozone), about 30-50 m due west of 93CAIN-2b. Collected by A. L. Titus, December 29, 1993.

93CAIN-6. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From small siderite concretions weathering from olive shale (*Eumorphoceras girtyi* Biozone), exposed upsection, higher on the same slopes from which 93CAIN-4 and 93CAIN-5 were collected (in measured section and north along strike about 30 m). Collected by A. L. Titus, December 30, 1993.

93CAIN-8. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From gray to tan-weathering, platy, calcareous siltstones (concretions?) (*Cravenoceratoides nititoides* Biozone) exposed at UTM coordinates 4069500, 459500. Collected by A. L. Titus, December 30, 1993.

93CAIN-9. Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. From small siderite concretions weathering from dark olive shale (*Cravenoceratoides nititoides* Biozone), in same vicinity as and slightly upsection from 93CAIN-8. Collected by A. L. Titus, December 30, 1993.

93NVCL-1. Clark County, NV, Apex 7.5-minute quadrangle. From phosphatic dark gray to brown packstone lens containing ferruginous molluscan fossils (*Eumorphoceras girtyi* Biozone) exposed at UTM coordinates 4022150, 683190, on the north side of short east-west-striking gulley formed in Indian Springs Formation. Collected by A. L. Titus, September 4, 1993.

93NVCL-10. Clark County, NV, Arrow Canyon 7.5-minute quadrangle. From top portion of “marker” conglomerate unit (*Eumorphoceras girtyi* Biozone) of Indian Springs Formation exposed on east side of north-south-trending strike valley, approximately 300 m southwest of the Arrow Canyon drainage. Collected by A. L. Titus, September 5, 1993.

93NVLI-1. Lincoln County, NV, Vigo NW 7.5-minute quadrangle. From small siderite concretions weathering from shale (*Eumorphoceras rotuliforme* Biozone) exposed at UTM coordinates 4111800, 703250. Same stratigraphic interval as 89NVLI-19. Collected by A. L. Titus, March 22, 1993.

93NVLI-2. Lincoln County, NV, Vigo NW 7.5-minute quadrangle. From small siderite concretions weathering from shale (*Eumorphoceras rotuliforme* Biozone) exposed at UTM coordinates 4111800, 703275. Slightly higher in section than 93NVLI-1. Approximate same interval as 89NVLI-20. Collected by A. L. Titus, March 22, 1993.

93NVLI-3. Lincoln County, NV, Vigo NW 7.5-minute quadrangle. From small calcareous concretions weathering from shale (*Eumorphoceras girtyi* Biozone) exposed in small gulley bounded on the east by a prominent gray grainstone unit at UTM coordinates 4111750, 703500. Collected by A. L. Titus, March 22, 1993.

93NVLI-9. Lincoln County, NV, Cave Valley Well 7.5-minute quadrangle. From large calcareous concretions weathering from shale (*Eumorphoceras rotuliforme* Biozone) in lower portion of Scotty Wash Formation exposed at UTM coordinates 4250390, 679450, on west-facing slope of narrow north-south-trending valley. Collected by A. L. Titus, August 9, 1993.

93NVNY-9. Nye County, NV. Duckwater Hills 7.5-minute quadrangle. From horizon of medium-gray calcareous petroliferous concretions packed with ammonoid and pectin fossils exposed along very low ridge at UTM coordinates 4315500, 614300 (*Eumorphoceras* sp. Biozone-upper Pendleian). Collected by A. L. Titus, Summer of 1993.

93NVWP-8. White Pine County, NV, Rosebud Spring 7.5-minute quadrangle. From shale immediately above a thin quartz arenite unit (*Eumorphoceras girtyi* Biozone) exposed north of Highway 50, at UTM coordinates 4321850, 701410. Collected by A. L. Titus, August 4, 1993.

93NVWP-11. White Pine County, NV, Cave Creek 7.5-minute quadrangle. From small calcareous concretions in shale immediately above 2-3-m-thick, northeast-dipping quartz arenite unit (*Eumorphoceras girtyi* Biozone) exposed approximately 100 m north of paved Cave Lake Road, in the NE$^1/_4$, NW$^1/_4$, NE$^1/_4$, section 5., T. 15 N., R. 65 E. Jeep track runs up the south side of outcrop. Collected by A. L. Titus, August 5, 1993.

93NVWP-12. White Pine County, NV, Major’s Place 7.5-minute quadrangle. From small sideritic concretions weathering from gray to black shale unit (*Eumorphoceras girtyi* Biozone) exposed on the south side of Cooper Canyon, on a north-facing slope, below massive Tertiary volcanic unit, near the boundary of the NE$^1/_4$ and SE$^1/_4$ of the SE$^1/_4$, SW$^1/_4$, section 36, T. 15 N., R. 65 E. Collected by A. L. Titus, August 6, 1993.

93UTMI-4. Millard County, UT, Gandy NE 7.5-minute quadrangle. From black to gray-weathering concretionary micrite packstones in black shale (*Eumorphoceras girtyi* Biozone) of the Jensen Member exposed in the NW$^1/_4$, SW$^1/_4$, NE$^1/_4$, SW$^1/_4$, section 31, T. 151/2, S., R. 17 W. Collected by A. L. Titus, June 30, 1993.

93UTMI-7. Millard County, UT, Gandy NE 7.5-minute quadrangle. From light olive to tan-weathering shale (*Eumorphoceras girtyi* Biozone) of Jensen Member exposed in the SW1/4, SE1/4, NW1/4, section 31, T. 151/2, S., R. 17 W. Slightly higher in section than 93UTMI-4. Collected by A. L. Titus, June 30, 1993.

93UTMI-13a. Millard County, UT, Gandy NE 7.5-minute quadrangle. From medium to small, tan to gray-weathering micrite concretions in shale exposed in the SE$^1/_4$, SE$^1/_4$, SW$^1/_4$, section 20, T. 16 S., R. 17 W., at desert road junction, on little hummock alongside and north of road. Chainman Shale, ?Jensen Member. *Eumorphoceras rotuliforme* Biozone. Collected by A. L. Titus, July 1, 1993.

93UTMI-13b. Millard County, UT, Gandy NE 7.5-minute quadrangle. Same unit and horizon as 93UTMI-13a, exposed on small hummock 20-30 m ENE of hummock in 93UTMI-13a. Collected by A. L. Titus, July 1, 1993.

93UTMI-36. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. From small, greenish to black, pink to tan-weathering concretions weathering from highly fossiliferous shale (*Eumorphoceras rotuliforme* Biozone) of Jensen Member exposed at UTM coordinates 4305200, 254950. Horizon and locality is same as 17056-PC. Collected by A. L. Titus, July 6, 1993.

93UTMI-37. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. From medium-sized calcareous concretions weathering from calcareous shale and siltstone (*Eumorphoceras rotuliforme* Biozone). Locality is essentially the same as 93UTMI-36, except higher up on the slope of steep east side of small hill west of jeep track. Approximately 30 m higher in the section. Collected by A. L. Titus, July 6, 1993.

93UTMI-38. Millard County, UT, Big Jensen Pass 7.5-minute quadrangle. From very small micrite concretions and shale (*Eumorphoceras girtyi* Biozone) of Jensen Member exposed at UTM coordinates 4305320, 254950, at head of a small southwest-trending drainage. Collected by A. L. Titus, July 6, 1993.

94NVCL-3. Clark County, NV, Apex 7.5-minute quadrangle. Same horizon and locality as 93NVCL-1. Collected by A. L. Titus and K. W. Snell, June 15, 1994.

94NVCL-4. Clark County, NV, Apex 7.5-minute quadrangle. From light-gray micrite concretions found in slopes and drainages immediately east and west of 93NVCL-1. Concretions occur at approximately the same stratigraphic interval (*Eumorphoceras girtyi* Biozone) as 93NVCL-1. Collected by A. L. Titus and K. W. Snell, June 15, 1994.

94NVLI-3. Lincoln County, NV, Wildcat Wash NE 7.5-minute quadrangle. Same horizon and locality as 92NVLI-2, Bunker Hills. Collected by A. L. Titus and K. W. Snell, June 17, 1994.

94NVLI-10. Lincoln County, NV. Cave Valley Well 7.5-minute quadrangle. From same unit and horizon as 93NVLI-9 exposed at UTM coordinates 4251000, 678920, on SW-facing slope. Collected by A. L. Titus and K. W. Snell, June 20, 1994.

94NVLI-11. Lincoln County, NV. Cave Valley Well 7.5-minute quadrangle. From medium to large calcareous, gray-weathering black concretions weathering from black shale (*Eumorphoceras girtyi* Biozone) of middle portion of Scotty Wash Formation exposed at UTM coordinates 4251200, 678000, on SW-facing slope. Collected by A. L. Titus and K. W. Snell, June 20, 1994.

94NVLI-21. Lincoln County, Nevada, Hancock Summit 7.5-minute quadrangle. Same phosphatic and concretionary horizon as 92NVLI-4, exposed in flat area to the east of the end of south-trending jeep track, and west of small drainage. UTM coordinates 4150550, 648200. Collected by A. L. Titus, November 17, 1994.

94NVNY-16. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. Same locality as 89NVNY-6. Collected in place from gray shale exposed in wall of trench dug across the Mississippian-Pennsylvanian subsystemic boundary. Unit SSR 9 of measured section made by Titus and others (1997). Scotty Wash Formation, *Delepinoceras thalassoide* Biozone. Collected by A. L. Titus, G. D. Webster, W. L. Manger, L. K. Meeks, and A. K. Braden, May 21, 1993.

94NVNY-17. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. Same locality and trench as 94NVNY-16 but 2 m higher in the section (SSR unit 12). Scotty Wash Formation, *Delepinoceras thalassoide* Biozone. Collected by A. L. Titus, G. D. Webster, W. L. Manger, L. K. Meeks, and A. K. Braden, May 21, 1993.

94NVNY-18. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. Same locality and trench as 94NVNY-16 but 2.5 m higher in the section in SSR unit 16. Scotty Wash Formation, *Delepinoceras thalassoide* Biozone. Collected by A. L. Titus, G. D. Webster, W. L. Manger, L. K. Meeks, and A. K. Braden, May 22, 1993.

94NVNY-19. Nye County, NV, Tippipah Spring 7.5-minute quadrangle. Same locality and trench as in 94NVNY-16 but 3.5 m higher in the section. Scotty Wash Formation, *Delepinoceras thalassoide* Biozone. Collected by A. L. Titus, G. D. Webster, W. L. Manger, L. K. Meeks, and A. K. Braden, May 22, 1993.

95NVWP-22a. White Pine County, NV, East of Pancake Summit 7.5-minute quadrangle. Same locality as USGS 15154-PC. Ammonoids from small to medium sized, gray-weathering micrite concretions weathering from shale (*Eumorphoceras girtyi* Biozone) exposed on east slope of small rise at UTM coordinates 4361250, 629100. Collected by A. L. Titus and K. W. Snell, June 26, 1995.

95NVWP-22b. White Pine County, NV, East of Pancake Summit 7.5-minute quadrangle. Same locality as 95NVMP-22a except from thin-bedded sandstone unit (*Eumorphoceras girtyi* Biozone) 3-4 m higher in section, exposed immediately west (about 5-7 m) of 95NVWP-22a. Collected by A. L. Titus and K. W. Snell, June 26, 1995.

95NVWP-23. White Pine County, NV, Antelope Mountain 7.5-minute quadrangle. From medium-sized, gray-weathering micrite concretions weathering from black shale (*Eumorphoceras girtyi* Biozone) exposed on south-facing slope at UTM coordinates 4361260, 629230. Same as USGS 15149-PC. Collected by A. L. Titus and K. W. Snell, June 26, 1995.

95NVWP-24. White Pine County, NV, East of Pancake Summit 7.5-minute quadrangle. Same unit and horizon as 95NVWP-23, exposed west and slightly south of that locality, near eastern edge of westernmost outcrop of Ely Limestone. Collected by A. L. Titus and K. W. Snell, June 26, 1995.

Miscellaneous Collections

FL 27 (Stanford University). Inyo County, CA, White Top Mtn. 7.5-minute quadrangle. Fossiliferous packstone about 5-7 m above the base of the Rest Spring Shale, exposed in gully on east side of low ridge, 700 m S., 53° W of Rest Spring. Collected by J. F. McAllister, November 23, 1938.

W84-19. Millard County UT, NV, Big Jensen Pass 7.5-minute quadrangle. Same horizon and locality as 93UTMI-36 (Eumorphoceras rotuliforme Biozone). Collected by G. D. Webster, June, 1984.

AMMONOID MORPHOMETRIC DATA

All measurements are in millimeters. Abbreviations for morphometric parameters are the same as those in the systematic paleontology portion. All umbilical diameter measurements are taken as U_{max}. The symbol * indicates no measurement was taken or no ratio was calculated.

Table 1. Morphometric data for *Eumorphoceras bisulcatum* Girty.

Specimen	D	H	W	U	Ribs	H/D	W/D	U/D	Rb/D
SUI 93521	17	7.3	*	4.5	*	0.43	*	0.26	*
SUI 93522	9.2	3.2	4	3.2	33	0.35	0.43	0.35	3.59
SUI 93523	11.3	4.3	*	*	38	0.38	*	*	3.36
SUI 93524	14.7	6.5	*	4	30	0.44	*	0.27	2.04
SUI 93525	11.9	5.2	6.5	3.4	30	0.44	0.55	0.29	2.52
SUI 93526	10.3	5	5	3.3	32	0.49	0.49	0.32	3.11
SUI 93527	11.2	5.6	5.1	3.1	32	0.5	0.46	0.28	2.86
SUI 93528	8.2	3.2	4	2.8	32	0.39	0.49	0.34	3.90
SUI 93529	6.5	2.3	*	2.4	30	0.35	*	0.37	4.62
SUI 93530	7.7	3.2	4	2.4	32	0.42	0.52	0.31	4.16
SUI 93531	7.2	2.9	3.9	2.3	32	0.40	0.54	0.32	4.44
SUI 93532	7.2	2.8	3.5	2.7	32	0.39	0.49	0.375	4.44
SUI 93533	7	2.5	3.2	2.5	26	0.36	0.46	0.36	3.71
SUI 93534	7	2.5	3.3	2.6	34	0.36	0.47	0.37	4.86
SUI 93535	7.2	2.9	3.7	2.3	30	0.40	0.51	0.32	4.17
SUI 93536	5	2	2.8	2.7	28	0.4	0.56	0.54	5.6

Table 2. Morphometric data for *Eumorphoceras erinense* Yates.

Specimen	D	H	W	U	Ribs	H/D	W/D	U/D	Rb/D
BGS72965	11.4	4.1	5.7	3.8	32	0.36	0.5	0.33	2.81
BGS72965	8.8	3.5	4.9	3.3	32	0.4	0.56	0.375	3.64
BGS72966	8.3	3	4.6	3.5	30	0.36	0.55	0.42	3.61
BGS72964	16	8.3	7	6.5	34	0.52	0.44	0.41	2.13
BGS72964	9	3.4	4.5	4	30	0.38	0.5	0.44	3.33
BGS72962	8.7	3	4.3	4	30	0.34	0.49	0.46	3.45
BGS72967	18	*	*	6.8	*	*	*	0.38	*
Ro7145	10.8	4	5.4	5	27	0.37	0.5	0.46	2.5
Ro7154	13	4.1	*	4.3	33	0.32	*	0.33	2.54
Ro7152	17	7	7	6.7	32	0.41	0.41	0.39	1.88
Ro7186	18	8	8	6.3	*	0.44	0.44	0.35	*
Ro7146	12	5	5.2	5	*	0.42	0.43	0.42	*

Table 3. Morphometric data for *Eumorphoceras girtyi* Elias.

Specimen	D	H	W	U	Ribs	H/D	W/D	U/D	Rb/D
SUI 93496	12.1	5	5.3	4.1	22	0.41	0.44	0.34	1.82
SUI 93497	8	3	3.3	3	23	0.375	0.412	0.375	2.875
SUI 93498	12	5.1	5.2	3.9	23	0.425	0.43	0.325	1.92
SUI 93499	5.2	1.4	2.3	1.9	23	0.27	0.44	0.37	4.42
SUI 93500	6.2	2	3	2.8	24	0.32	0.48	0.45	3.87
SUI 93501	3.5	0.8	*	1.8	21	0.23	*	0.51	6
SUI 93502	6.5	2.4	3.6	2.2	19	0.37	0.554	0.34	2.92
SUI 93503	6.5	2.2	3.2	2.5	23	0.34	0.49	0.38	3.54
SUI 93504	7	2.1	3.7	2.7	24	0.3	0.53	0.39	3.43
SUI 93505	7	2.4	3.4	2.7	26	0.34	0.49	0.39	3.71
SUI 93506	9.1	3.8	4.2	3.2	24	0.42	0.46	0.35	2.64
SUI 93507	5.2	1.8	3	2	24	0.35	0.58	0.38	4.62
SUI 93508	5.9	2	3	2.3	25	0.34	0.51	0.39	4.24
holotype	10.3	5	5.6	3.8	24	0.49	0.54	0.37	2.33

Table 4. Morphometric data for *Eumorphoceras brevornatum* n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93519	9	4.1	5.2	2.8	0.46	0.58	0.31

Table 5. Morphometric data for *Eumorphoceras paucinodum* Gordon.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93473	22.7	12	9	5.1	0.53	0.40	0.22
SUI 93473	17	9.8	6.7	4.9	0.58	0.39	0.29
SUI 93475	11	4.7	5.5	4.1	0.43	0.5	0.37
SUI 93476	13.1	6	6.1	4	0.46	0.47	0.31

Table 6. Morphometric data for *Eumorphoceras rotuliforme* Ruan.

Specimen	D	H	W	U	Ribs	H/D	W/D	U/D	Rb/D
SUI 93481	10.5	4.5	5.3	3.9	23	0.43	0.51	0.37	2.19
SUI 93482	12.1	5.4	5	3.8	24	0.45	0.41	0.31	1.98
SUI 93483	17.7	8	*	5	20	0.45	*	0.28	1.13
SUI 93484	24	12	9	5	*	0.5	0.38	0.21	*
SUI 93484	32	17	11	5.3	*	0.53	0.34	0.17	*
SUI 93485	9	3.3	4.8	3.8	22	0.37	0.53	0.42	2.44
SUI 93486	10	5.7	5	3.8	24	0.57	0.5	0.38	2.4
SUI 93487	7.4	2.7	4	3.2	20	0.36	0.54	0.43	2.70
SUI 93488	16.3	7.5	8.5	4.8	24	0.46	0.52	0.29	1.47
SUI 93489	12.7	4.3	*	4.2	26	0.34	*	0.33	2.05
SUI 93490	11	4.1	*	4.6	26	0.37	*	0.42	2.37
SUI 93491	18	8.8	7.2	4.9	*	0.49	0.4	0.27	*
SUI 93492	17	6.3	7	5	24	0.37	0.41	0.29	1.41

Table 7. Morphometric data for *Cravenoceras* sp., cf. *C. subitum* Astachova.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93581	13	4.5	11	5.1	0.35	0.85	0.39
SUI 93581	18	7.5	14	5.9	0.42	0.78	0.33
SUI 93583	30	9	23	11.5	0.3	0.77	0.38
SUI 93584	39	13	26	16	0.33	0.67	0.41
SUI 93585	35.3	13	25	17	0.37	0.71	0.48

Table 8. Morphometric data for *Cravenoceratoides nititoides* (Bisat).

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93587	4.9	1.3	3	2	0.27	0.61	0.41
SUI 93588	10.4	5.3	7.2	1.4	0.51	0.69	0.13

Table 9. Morphometric data for *Cravenoceratoides* sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93597	25	9	*	9	0.36	*	0.36
SUI 93598	26	12	*	8	0.46	*	0.31

Table 10. Morphometric data for *Glaphyrites millardensis* n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93600	11	3.2	9	5.8	0.29	0.82	0.53
SUI 93601	16	6	12.3	5	0.375	0.77	0.313
SUI 93602	13	5	11.2	5	0.38	0.86	0.38
SUI 93603	23	10.3	15.2	5	0.45	0.66	0.22
SUI 93604	23	10.7	17.1	5.8	0.47	0.74	0.25

Table 11. Morphometric data for *Glaphyrites* sp., cf. *G. latus* Ruzhencev and Bogoslovskaya.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93606	11	3	9.5	5.5	0.28	0.86	0.5
SUI 93610	19	7	17	7.7	0.37	0.89	0.41
SUI 93607	27	10	20	9	0.37	0.74	0.33
SUI 93611	41.2	15	29	15	0.36	0.70	0.36

Table 12. Morphometric data for *Cryptotyloceras gordoni* n. gen., n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
USNM 414930	10.6	5.5	10.7	0.5	0.52	1.01	0.05

Table 13. Morphometric data for *Eosyngastrioceras inexpectans* n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93574	16.7	5.6	14.2	5.2	0.34	0.85	0.31
SUI 93576	27.9	11.8	23.7	7.3	0.42	0.85	0.26

Table 14. Morphometric data for *Somoholites walkeri* (Webster and Lane).

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93652	5.5	2.1	5	2.3	0.38	0.91	0.42
SUI 93652	13.4	4	13.9	6.5	0.30	1.04	0.49
SUI 93653	21.5	6.3	16.1	10.2	0.29	0.75	0.47
SUI 93657	53 1	13.3	37.8	34	0.25	0.71	0.64

Table 15. Morphometric data for *Zephyroceras girtyanum* (Ruzhencev and Bogoslovskaya).

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93632	14	6.9	11	6.3	0.49	0.79	0.45
SUI 93633	30	12.6	16.7	9.8	0.42	0.56	0.33

Table 16. Morphometric data for *Stenoglaphyrites intermedius* n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93663	10.6	5.5	10.7	0.5	0.52	1.01	0.05
SUI 93665	23.2	11.2	16	1	0.48	0.69	0.04
SUI 93666	30.7	15.8	20	2.9	0.51	0.65	0.09

Table 17. Morphometric data for *Euroceras nyense* n. sp.

Specimen	D	H	W	U	H/D	W/D	U/D
SUI 93680	6	2.9	5	1	0.48	0.83	0.17
SUI 93681	10.2	5	8.3	1.7	0.49	0.81	0.17
SUI 93684	23.1	11.5	13.2	2	0.51	0.58	0.08

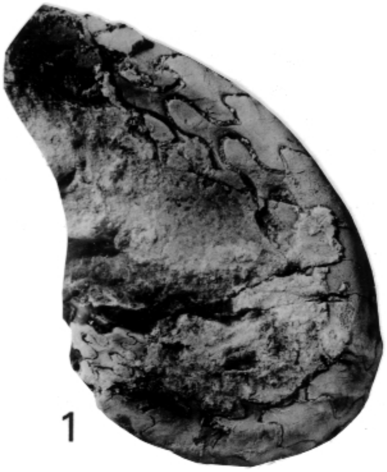
PLATES

PLATE 1

All figures x2 unless otherwise noted.

1-5. *Stenopronorites* sp., cf. *S. uralensis* (Karpinsky) (p. 17). 1-2, (SUI 93471) lateral and ventral views (coll. 94NVCL-3); 3-4, (SUI 93469) lateral and ventral views (coll. 93NVCL1); 5, (SUI 93470) lateral view (coll. 94NVCL-3).

6-23. *Eumorphoceras paucinodum* Gordon (p. 18). 6-8, (USNM 118707) lateral, apertural and reverse lateral views of one of the paratypes of *E. bisulcatum* Girty (Caney Shale, Antlers, Oklahoma); 9-12, (SUI 93474) lateral, apertural, ventral and reverse lateral views (coll. 93CAIN-2a); 13-14, (SUI 93475) lateral and apertural views (coll. 93CAIN-2b); 15-17, (SUI 93473) lateral, apertural, and reverse lateral views (coll. 93CAIN-2a); 18, (SUI 93476) lateral view (coll. 93CAIN-2c); 19-20, (SUI 93477) lateral and apertural views (coll. 93CAIN-2d); 21, (SUI 93478) lateral view, x1 (coll. 93CAIN-2b); 22, (SUI 93479) lateral view (coll. 89NVLI-17); 23, (SUI 93480) lateral view (coll. 89NVLI-17).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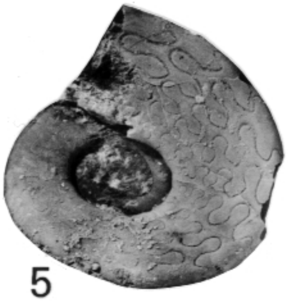
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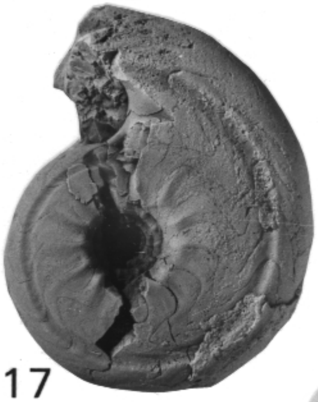
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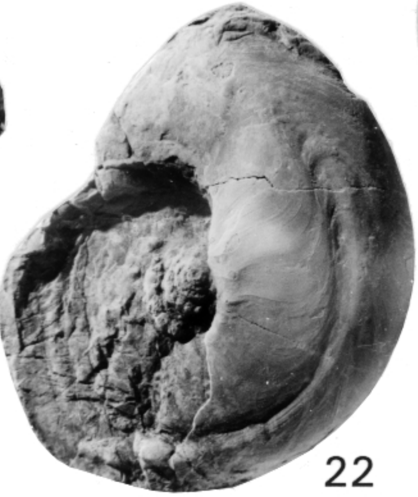
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PLATE 2

All figures x2 unless otherwise noted.

1-3, 19-35. *Eumorphoceras girtyi* Elias (p. 19). 1-3, (USNM 112989) lateral, apertural, and ventral views of the holotype (Barnett Formation, Texas); 19, (SUI 93510) lateral view (coll. 95NVWP-23); 20, (SUI 93509) lateral view (coll. 95NVWP-23); 21, (SUI 93497) lateral view (coll. 93UTMI-4); 22, (SUI 93506) ventral view (coll. 93UTMI-4); 23-24, (SUI 9351 1) lateral and ventral views (coll. 15370-PC); 25, 30-31, (SUI 93498) lateral, apertural, and ventral views (coll. 93UTMI-4); 26-28, (SUI 93496) lateral, apertural and ventral views (coll. 93UTMI-4)- note ventral sulcus; 29, (SUI 93512) lateral view (coll. 15149-PC); 32-34, (USNM 240889) lateral, apertural and reverse lateral views (coll. 15370-PC); 35, (SUI 93513) lateral view, x1 (coll. 93CAIN-6).

4-10, 12-16. *Eumorphoceras rotuliforme* Ruan (p. 18). 4, (SUI 93485) lateral view (Quinn collection from Pitkin Formation near Leslie, Arkansas); 5-7, (SUI 93481) lateral, apertural, and ventral views (same locality as 2.4); 8, (SUI 93482) lateral view (same locality as 2.4); 9, (SUI 93493) lateral view (coll. 93UTMI-13b); 10, (SUI 93494) lateral view (coll. 93UTMI13b); 12-13, (SUI 93495) lateral and apertural views (coll. 93UTMI-13b); 14, (SUI 93483) lateral view (same locality as 2.4); 15-16, (SUI 93484) lateral and apertural views (same locality as 2.4).

11. *Eumorphoceras bisulcatum* Girty (p. 21). Lateral view of holotype (USNM 119596) for comparison (Sand Branch Member of Caney Shale, Big Sandy Creek, Oklahoma).

17-18. *Eumorphoceras grassingtonense* Dunham and Stubblefield. Lateral and reverse lateral views of the holotype (BGSM KD423).


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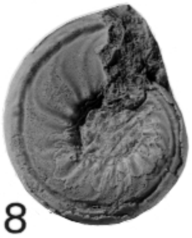
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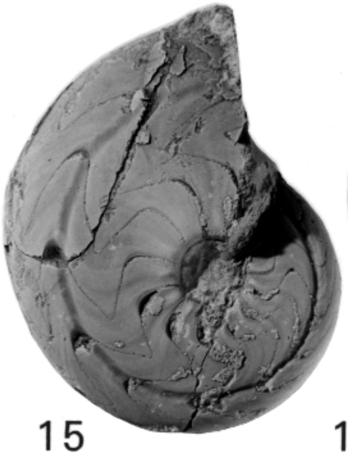
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PLATE 3

All figures x2 unless otherwise noted.

1-10. *Eumorphoceras brevornatum* n. sp. (p. 21). 1, 9, (SUI 93515-paratype) lateral, and reverse lateral views (coll. 95NVWP-23); 2, (SUI 93516-paratype) lateral view (coll. 95NVWP-23); 3, (SUI 93517-paratype) lateral view (coll. 95NVWP-23); 4, (SUI 93518 paratype) lateral view (coll. 95NVWP-23); 5-8, (SUI 93519-holotype) lateral, apertural, ventral, and reverse lateral views (coll. 95NVWP-23); 10, (SUI 93520a-paratype) lateral view (coll. 95NVWP-23).

11-19, 22. *Eumorphoceras bisulcatum* Girty (p. 21). 11, (SUI 93538 [larger] SUI 93539 [smaller]) lateral views of two larger topotypes preserved together (coll. 910KJO-1); 12, 18, 19, (USNM 119596) lateral, ventral, and reverse lateral views of holotype (Sand Branch Member of Caney Shale, Johnson County, Oklahoma); 13-14, (SUI 93522) lateral and ventral views of a topotype (coll. 910KJO-1); 15, (SUI 93525) lateral view of topotype (coll. 910KJO-1); 16, (SUI 93540) lateral view (coll. 89CAIN-5); 17, (SUI 93541) lateral view (coll. 89CAIN-5); 22, (SUI 93539) lateral view for comparison with 3.21.

20-21, 23-25. *Eumorphoceras erinense* Yates. 20, (BGSM 72965) lateral view; 21, (BGSM Ro7l46) lateral view; 23, (BGSM 72964) lateral view; 24, (BGSM Ro7l47) lateral view; 25, (BGSM 72967) lateral view.

26-28. *Eumorphoceras richardsoni* McCaleb, Quinn, and Furnish. Lateral, ventral and apertural views of the holotype (SUI 11260), Imo Formation, Peyton Creek, Arkansas.


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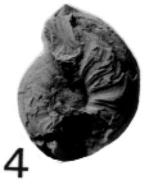
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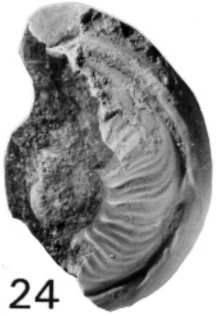
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PLATE 4

All figures x2 unless otherwise noted.

1. *Metadimorphoceras* sp. (p. 17). Lateral view of specimen (SUI 93472) from locality 93CAIN-2b.

2-7, 10-11. *Arcanoceras macallisteri* (Gordon) (p. 23). 2-3, (SUI 93542) lateral and apertural views (coll. 93CAIN-2b); 4-5, (SUI 93453) lateral and ventral views (coll. 93CAIN-2c); 6-7, 10-11, (SUI 93545) lateral, apertural, reverse lateral, and ventral views (coll. 93CAIN-2a).

8-9. *Delepinoceras eothalassoide* Wagner-Gentis (p. 23). Apertural and lateral views of large specimen (SU 9167) from Rest Spring Shale (coll. FL-27).

14. *Delepinoceras californicum* Gordon (p. 24). Lateral view of holotype (USNM 120622) from Rest Spring Shale (coll. 15782-PC).

15. *Delepinoceras thalassoide* (Delepine) (p. 23). Lateral view of specimen (USNM 486310) from locality 89NVNY-6.

12-13. *Pericleites pilatus* Ruan (p. 25). Lateral and ventral views of specimen (USNM 414882) from locality 17188-PC (x 1.4).

16-18. *Proshumardites delepinei* Schindewolf (p. 26). Lateral, oblique lateral, and ventral views of specimen (SUI 93546) from locality 93NVCL-1.


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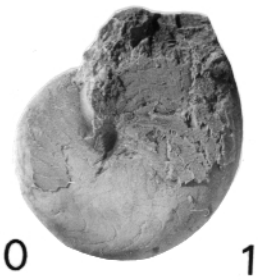
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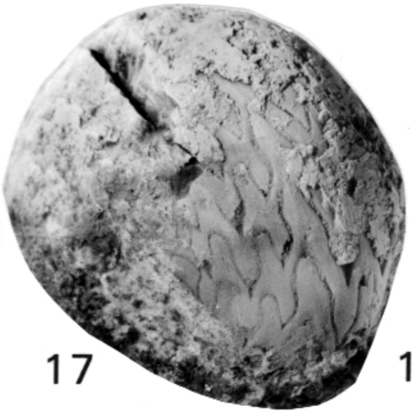
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PLATE 5

All figures x2 unless otherwise noted.

1-8. *Cravenoceras* sp., cf. *C. subitum* Astachova (p. 27). 1-2, (SUI 93581) lateral and ventral views (coll. 93CAIN-6); 3-4, (SUI 93582) lateral and apertural views (coll. 93CAIN6); 5-6, (SUI 93584) lateral and ventral views (coll. 93CAIN-6); 7-8, (SUI 93583) lateral and apertural views (coll. 93CAIN-6).

9-18. *Cravenoceratoides nititoides* (Bisat) (p. 28). 9, (BGSM 49964) lateral view of crushed holotype; 10, (SUI 93594) ventral view (coll. 89CAIN-5); 11, 13, (SUI 93589) lateral and ventral views (coll. 89CAIN-5); 12, (SUI 93591) lateral view (coll. 89CAIN-5); 14, (SUI 93592) lateral view (coll. 89CAIN-5); 15, (SUI 93595) lateral view (coll. 93CAIN-8); 16, (SUI 93593) lateral view showing ornament (coll. 89CAIN-5); 17, (SUI 93588) lateral view of crushed specimen (coll. 89CAIN-5); 18, (SUI 93596) lateral view of uncrushed living chamber (coll. 93CAIN-9).


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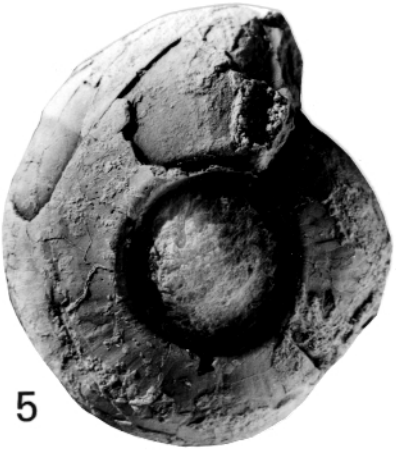
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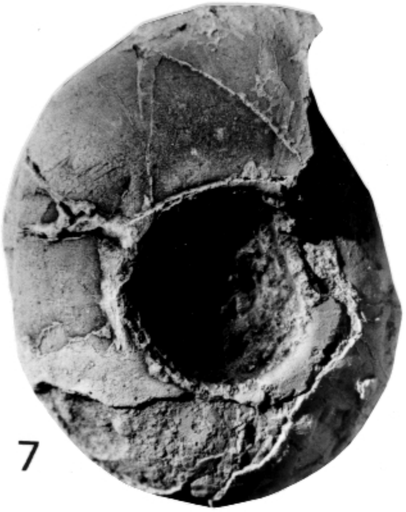
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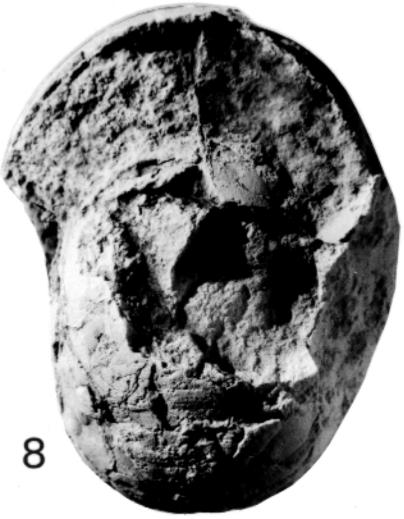
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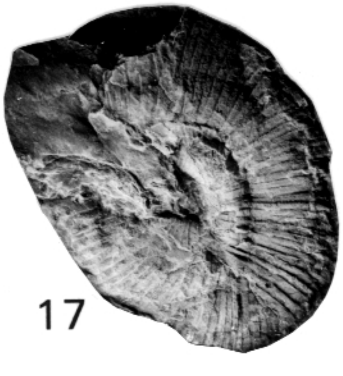
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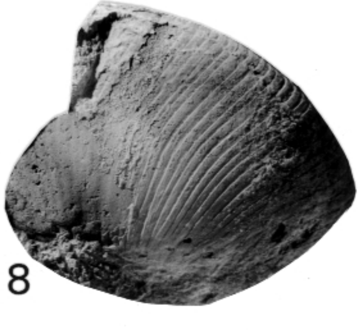
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PLATE 6

All figures x2 unless otherwise noted.

1-2. *Cravenoceratoides nititoides* (Bisat) (p. 28). 1, (SUI 93587) lateral view of larger crushed specimen (coll. 89CAIN-5); 2, (SUI 93590) lateral view of large crushed specimen (coll. 89CAIN-5).

3-4. *Cravenoceratoides bisati* Hudson. Lateral and oblique ventral views of the holotype (BGSM 49968) for comparison.

5-6. *Cravenoceratoides edalensis* (Bisat). Lateral and oblique ventral views of BGSM 72014 (holotype of *Cravenoceratoides lirifer* Hudson [= *Ct. edalensis* (Bisat)]) for comparison.

7-8. *Cravenoceratoides* sp. (p. 28). 7, (SUI 93597) lateral view (coll. 93CAIN-6); 8, (SUI 93599) oblique lateral view showing ornament (coll. 93CAIN-6).

9-18. *Glaphyrites millardensis* n. sp. (p. 29). 9-11, (SUI 93600-paratype) lateral, apertural, and ventral views (coll. W84-19); 12-14, (SUI 93602-paratype) lateral, apertural and ventral views (coll. W84-19); 15-18, (SUI 93604-holotype) lateral, apertural, ventral, and reverse lateral views (coll. (W84-19).


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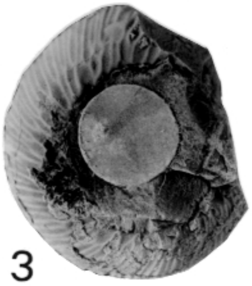
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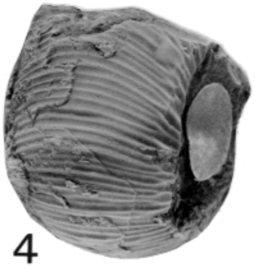
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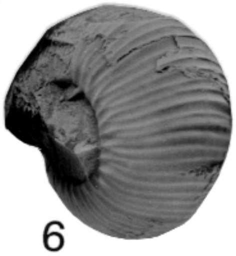
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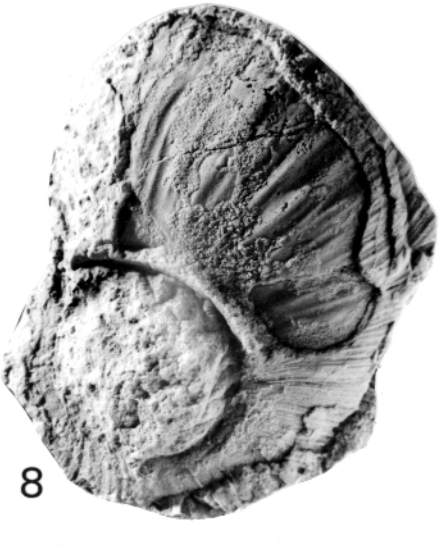
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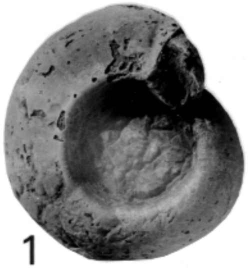
PLATE 7

All figures x2 unless otherwise noted.

1-9. *Glaphyrites* sp., cf. *G. latus* Ruzhencev and Bogoslovskaya (p. 30). 1-2, (SUI 93610) lateral and ventral views (coll. 89NVLI-18); 3-4, 7, (SUI 93607) lateral, apertural, and ventral views (coll. 89NVLI-18); 5-6, (SUI 93608) lateral and apertural views (coll. 89NVLI-18); 8-9, (SUI 93609) lateral and ventral views showing extensive breakage and repair (coll. 89NVLI-17).

10-12. *Glaphyrites* sp., cf. *G. nevadensis* (Miller and Furnish) (p. 31). Lateral, apertural, and ventral views of TAGN-1 (coll. 95NVWP-22b).

13-16. *Cryptotyloceras gordoni* n. gen., n. sp. (p. 32). 13, Lateral view of small specimen (SUI 93614- paratype) showing nodes (coll. W84-19); 14-16, (USNM 414930-holotype) ventral, lateral, and apertural views (coll. 17022-PC).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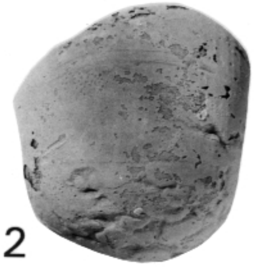
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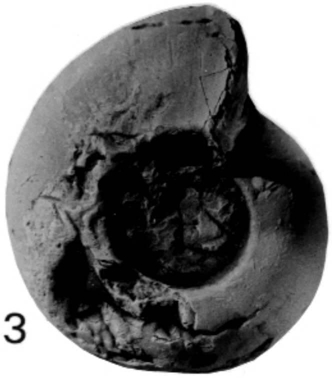
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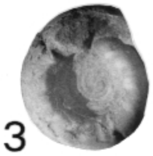
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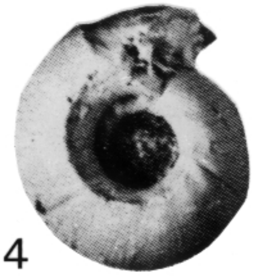
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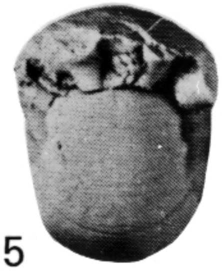
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PLATE 8

All figures x2 unless otherwise noted.

1-25. *Richardsonites richardsonianus* (Girty) (p. 33). 1-3, (SUI 93616) lateral, apertural, and ventral views of small specimen (coll. 93UTMI-4); 4-5, (SUI 93617) lateral and apertural views (coll. 93UTMI-4); 6, (SUI 93625) lateral view of small topotype (coll. 910KJO-1); 7-8, (SUI 93626) lateral and ventral views of topotype (coll. 910KJO-1); 9, 15, 16, (SUI 93620) lateral, apertural, and ventral views (coll. 93UTMI-4); 10-12, (SUI 93618) lateral, apertural, and ventral views (coll. 93UTMI-4); 13-14, (SUI 93619) lateral and apertural views of widely umbilicate variant (coll. 93UTMI-4); 17, (SUI 93627) lateral view of topotype (coll. 910KJO-1); 18, 21-22, (SUI 93621) lateral, apertural, and ventral views (coll. 93UTMI-4); 19-20, (SUI 93623) lateral and apertural views (x1) of larger specimen (coll. 93CAIN-6); 23-25, (USNM 119585) lateral, apertural, and reverse lateral views of the holotype (Sand Branch Member of Caney Shale, Johnson County, Oklahoma).


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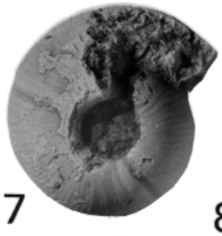
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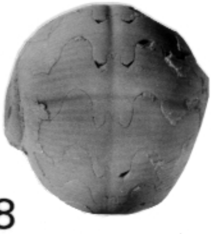
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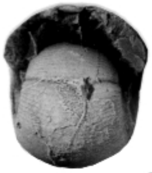
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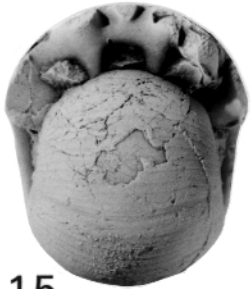
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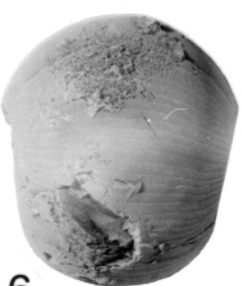
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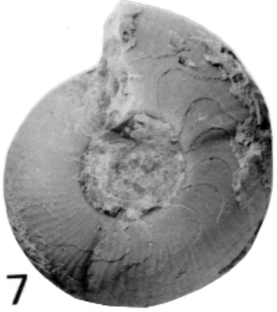
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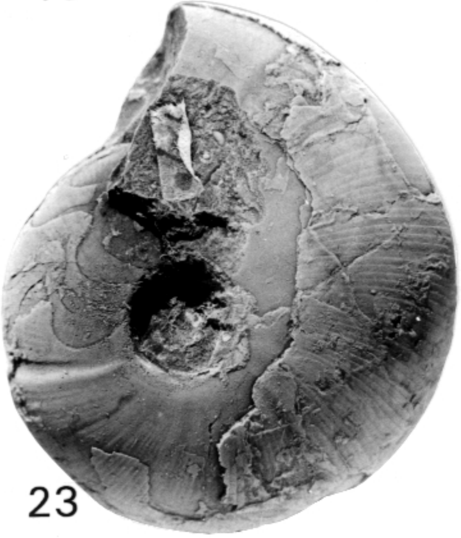
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PLATE 9

All figures x2 unless otherwise noted.

1-5. *Fayettevillea inyoense* (Gordon) (p. 35). 1-2, (SUI 93629) lateral and apertural views of small specimen showing ophioconic stage (coll. 93CAIN-2a); 3-4, (SUI 93630) lateral and apertural views (coll. 93CAIN-2c); 5, (SUI 93631) lateral view (x1) of large specimen (coll. 93CAIN-2c).

6-12, 15-16. *Zephyroceras girtyanum* (Ruzhencev and Bogoslovskaya) (p. 37). 6, 11, 15-16, (SUI 93634) ventral, lateral, reverse lateral, and apertural views (coll. 92NVLI-2); 7-8, (SUI 93636) lateral and ventral views (coll. 92NVLI-2); 9-10, (SUI 93633) lateral and apertural views (coll. 92NVLI-2); 12, (SUI 93635) lateral view (x1) of large specimen (coll. 94NVLI3).

13-14, 17-18. *Zephyroceras friscoense* (Miller and Owen) (p. 37). 13-14, (USNM 486312) lateral and apertural views (coll. 89NVNY-4); 17-18, (SUI 93640) lateral and apertural views (coll. 92NVLI-2).

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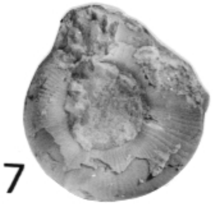

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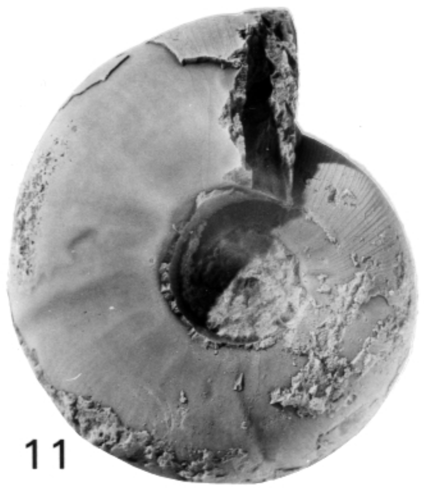

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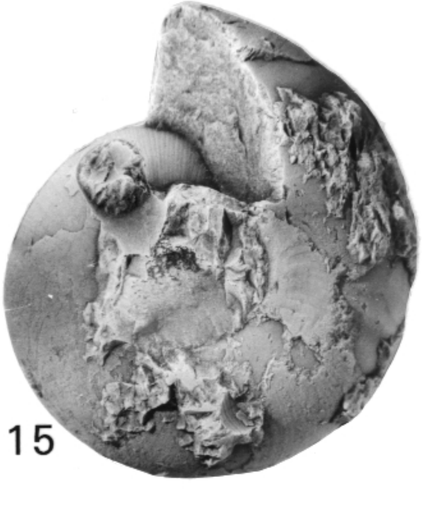

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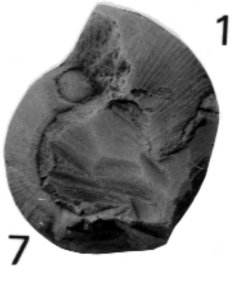

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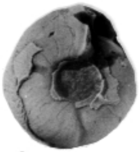
PLATE 10

All figures x2 unless otherwise noted.

1-17. *Eosyngastrioceras quadratum* n. sp. (p. 38). 1-3, (SUI 93550) lateral, ventral, and reverse lateral views (coll. 93NVNY-9); 4-5, (SUI 93551) lateral and apertural views (coll. 93NVNY-9); 6-10, (SUI 93553) lateral and apertural views (coll. 93NVLI-9); 7-9, (SUI 93554) lateral, ventral, and apertural views (coll. 93NVLI-9); 11-14, (SUI 93555) lateral, apertural, ventral, and reverse lateral views (coll. 93NVNY-9); 15, (SUI 93547) lateral view showing ornament (coll. 89NVLI-18); 16-17, (SUI 93552) lateral and apertural views (coll. 93NVNY-9).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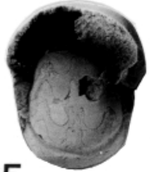
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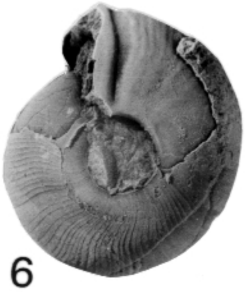
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PLATE 11

All figures x2 unless otherwise noted.

1-13. *Eosyngastrioceras hesperium* (Miller and Furnish) (p. 40). 1-2, (SUI 93561) lateral and apertural views of topotype (coll. 94NVLI-10); 3-5, (SUI 93562) lateral, apertural, and reverse lateral views of topotype (coll. 94NVLI-10); 6-8, (SUI 93563) lateral, apertural, and reverse lateral views of topotype (coll. 94NVLI-10); 9, (SUI 93564) lateral view of topotype (coll. 94NVLI-10); 10, 12-13, (SUI 93566) ventral, lateral, and reverse lateral views of topotype (coll. 94NVLI-10); 11, (USNM 120616-holotype) lateral view x1.


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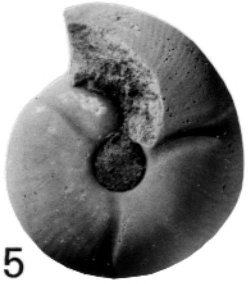
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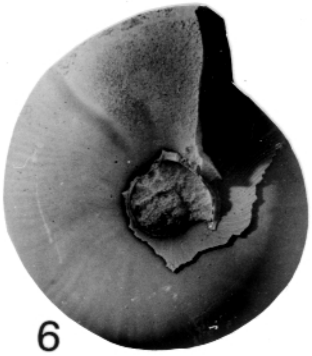
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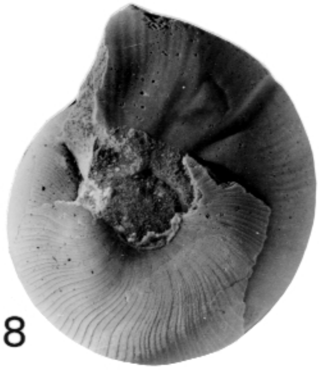
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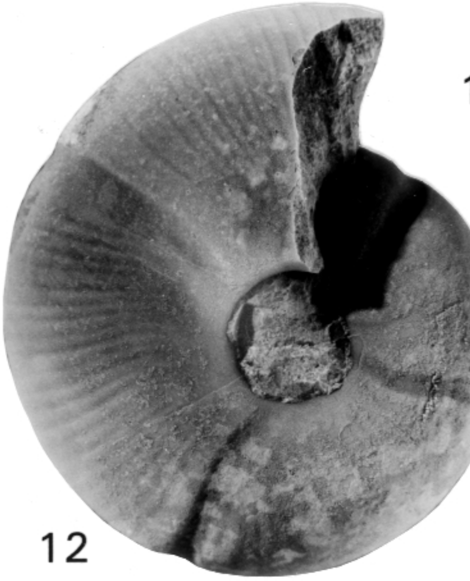
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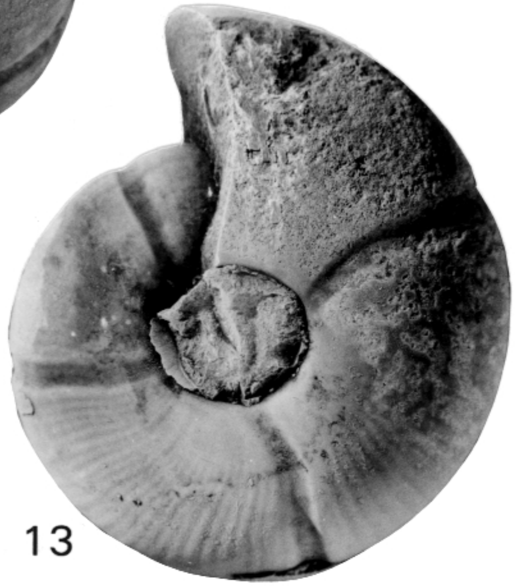
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PLATE 12

All figures x2 unless otherwise noted.

1-4. *Eosyngastrioceras hesperium* (Miller and Furnish) (p. 40). 1, 3-4, (USNM 120617) lateral, reverse lateral (x1), and apertural (x1) views of holotype; 2, (SUI 93569) lateral view of specimen from locality 89NVLI-19 showing ornament.

5-19. *Eosyngastrioceras inexpectans* n. sp. (p. 41). 5-7, (SUI 93570-paratype) lateral, apertural, and ventral views (coll. 95NVWP-23); 8-9, (SUI 93571-paratype) lateral and apertural views (coll. 95NVWP-23); 10-11, (SUI 93572-paratype) lateral and ventral views (coll. 95NVWP-23); 12, (SUI 93575-paratype) lateral view (coll. 95NVWP-23); 13-14, (SUI 93574-paratype) lateral and ventral views (coll. 95NVWP-23); 15-16, (SUI 93575-paratype) apertural and lateral views (coll. 95NVWP-23); 17-19, (SUI 93576-holotype) lateral, apertural, and ventral views (coll. 95NVWP-23)


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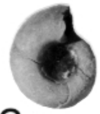
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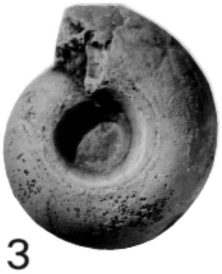
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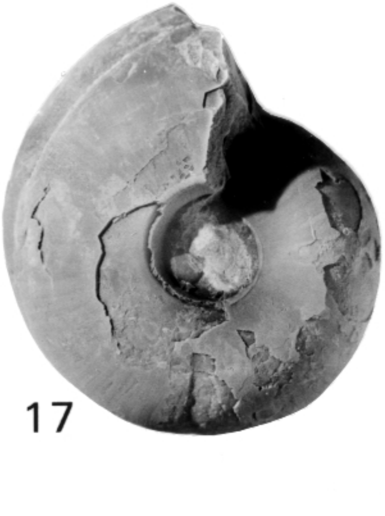
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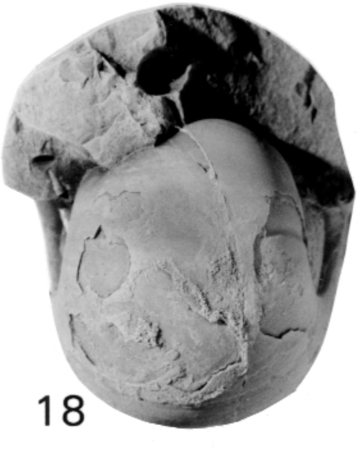
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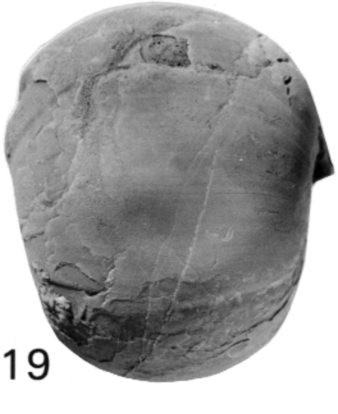
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PLATE 13

All figures x2 unless otherwise noted.

1. *Zephyroceras* sp. Lateral view (x0.5) of umbilical external mold of very large specimen (SUI 93643- coll. 92NVLI-2).

2-13. *Syngastrioceras websteri* n. sp. (p. 42). 2-4, (SUI 93644-paratype) lateral, apertural, and reverse lateral views (coll. 92NVLI-2); 5-8, (SUI 93645-paratype) lateral, apertural, ventral, and reverse lateral views (coll. 92NVLI-2); 9-10, (SUI 93648-holotype) lateral and ventral views (coll. 89NVNY-4); 11-13, (SUI 93646-paratype) lateral, apertural, and ventral views (coll. 92NVLI-2).

14-21. *Somoholites walkeri* (Webster and Lane) (p. 43). 14-15, (SUI 93652) lateral and ventral views (coll. 93NVCL-1); 16-19, (SUI 93653) lateral, apertural, reverse lateral, and ventral views (coll. 94NVCL-3); 20-21, (SUI 93655) lateral and apertural views (coll. 94NVCL-3).


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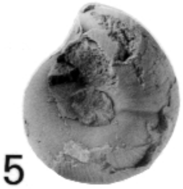
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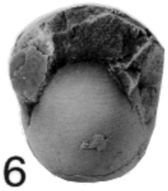
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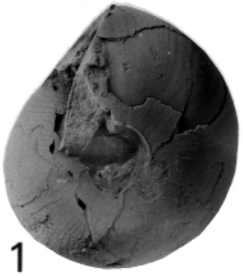
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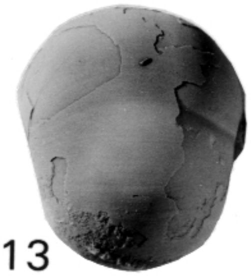
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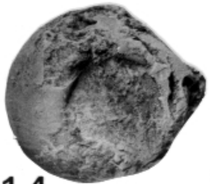
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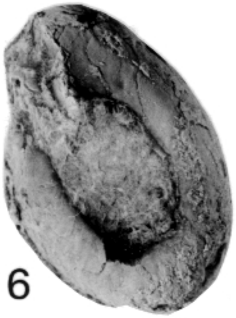
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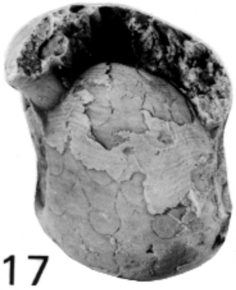
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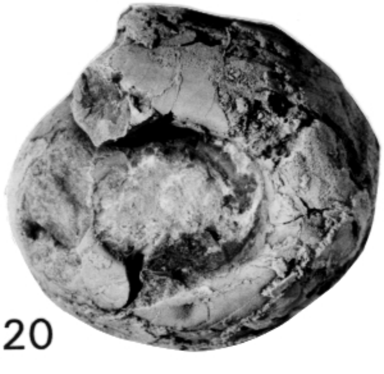
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PLATE 14

All figures x2 unless otherwise noted.

1-6. *Somoholites walkeri* (Webster and Lane) (p. 43). 1-2, (SUI 93656) ventral and apertural views (coll. 94NVCL); 3-6, (SUI 93657) lateral and apertural views (x1) of larger specimen (coll. 94NVCL-3); 4-5, (SUI 93658) lateral and ventral views (x1) of larger specimen (coll. 93NVCL-1).

7-12. *Stenoglaphyrites colubrellus* (Miller and Furnish) (p. 44). 7-9, (SUI 93661) lateral, apertural, and ventral views (coll. 95NVWP); 10-11, (SUI 93662) lateral, apertural, and ventral views (coll. 95NVWP-22a).

13-24. *Stenoglaphyrites involutus* (Gordon) (p. 46). 13-15, (USNM 119523) lateral, apertural, and ventral views of the holotype (Imo Formation, Stone County, Arkansas); 16-17, (SUI 93678) lateral and ventral views of a topotype (coll. 91ARST-2); 18-20, (SUI 93673) lateral, apertural, and ventral views (coll. 95NVWP-22b); 21-22, (SUI 93679) lateral and apertural views of a small topotype (coll. 91ARST-2); 23-24, (SUI 93672) lateral and apertural views (coll. 95NVWP-22b).


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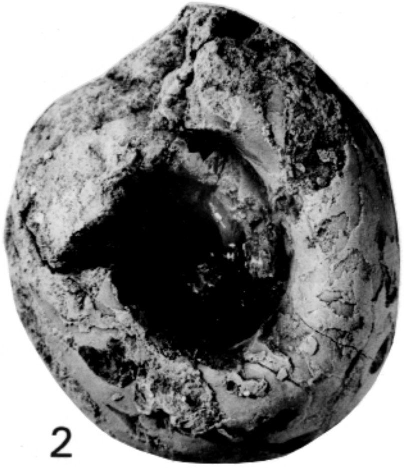
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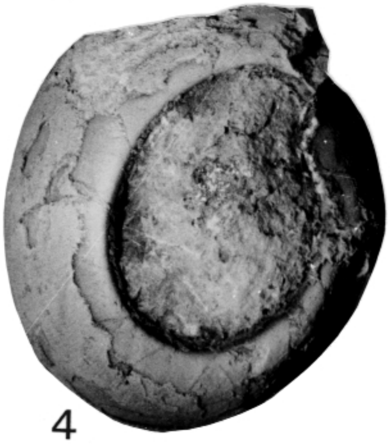
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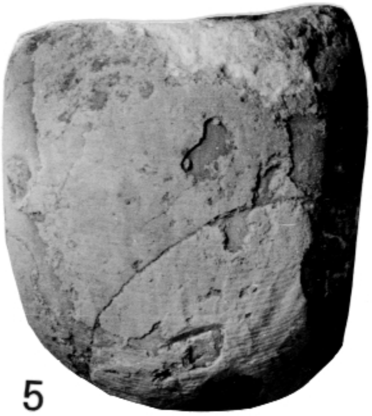
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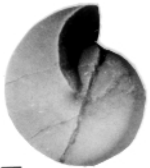
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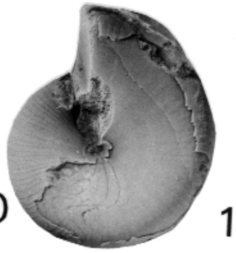
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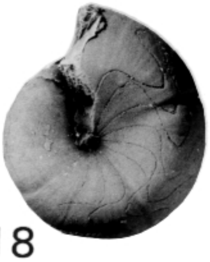
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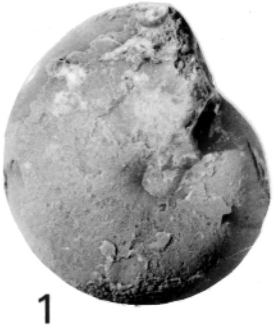
PLATE 15

All figures x2 unless otherwise noted.

1-4. *Stenoglaphyrites involutus* (Gordon) (p. 46). 1-2, (SUI 93674) lateral and apertural views (coll. 95NVWP-22b); 3-4, (SUI 93675) lateral and apertural views of the largest specimen recovered (coll. 95NVWP-22b).

5-16. *Stenoglaphyrites intermedius* n. sp. (p. 45). 5-7, (SUI 93663-paratype) lateral, apertural, and ventral views of small specimen (coll. 88NVCL-1); 8-9, 13, (SUI 93664-paratype) lateral, apertural, and ventral views (coll. 88NVCL-1); 10-12, (SUI 93665-paratype) lateral, ventral, and apertural views (coll. 88NVCL-1); 14-15, (SUI 93666-holotype) lateral and apertural views (coll. 88NVCL-1); 16, (SUI 93668) lateral view of larger specimen (coll. 89NVLI-19).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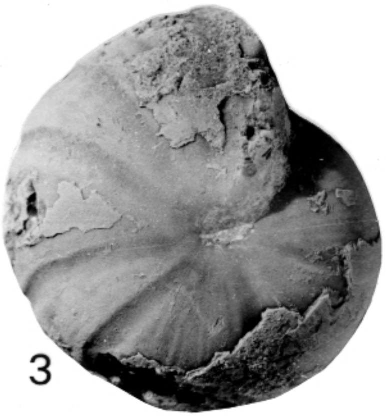
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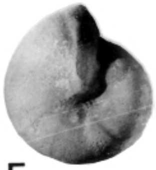
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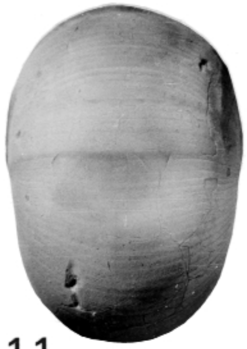
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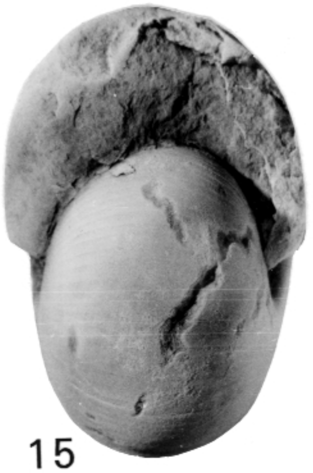
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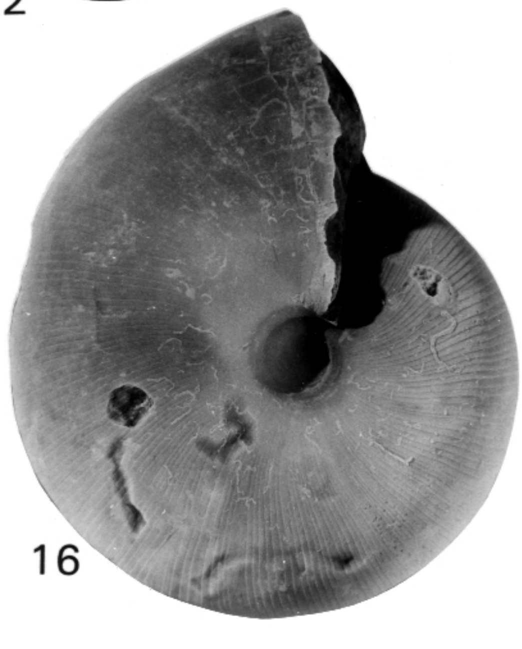
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PLATE 16

All figures x2 unless otherwise noted.

1-3. *Stenoglaphyrites intermedius* n. sp. (p. 45). Lateral, apertural, and ventral views of large paratype (SUI 93667) from locality 88NVCL-2.

4-17. *Euroceras nyense* n. sp. (p. 47). 4-6, (SUI 93680-paratype) lateral, apertural, and ventral views (coll. 89NVNY-4); 7-8, (SUI 93681-paratype) lateral and ventral views (coll. 89NVNY-4); 9-11, (SUI 93682-paratype) lateral, apertural, and ventral views (coll. 89NVNY-4); 12-14, (SUI 93683) lateral, apertural, and ventral views (coll. 94NVLI-11); 15-16, (SUI 93684-holotype) lateral and apertural views (coll. 89NVNY-4); 17, (SUI 93640) lateral view of large specimen (coll. 93CAIN-6).

18. Calcareous concretion (SUI-93628) from locality 94NVLI-10 with numerous topotype specimens of *Eosyngastrioceras hesperium* (Miller and Furnish) (x0.5).


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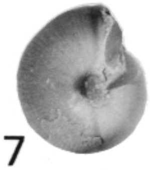
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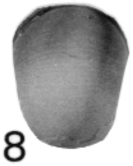
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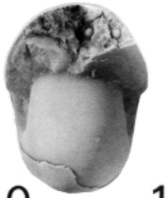
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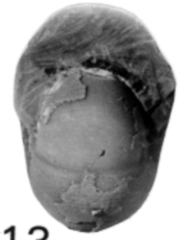
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