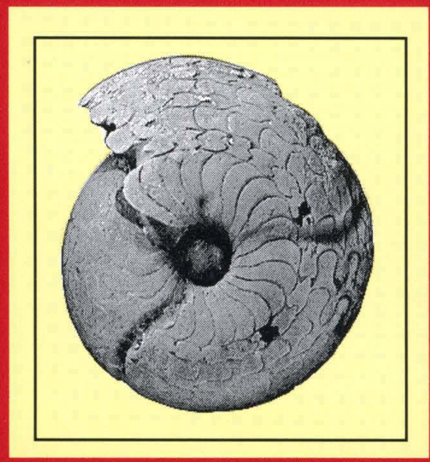
Biostratigraphy of Middle and Late Pennsylvanian (Desmoinesian–Virgilian) ammonoids



by Darwin R. Boardman II,
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Abstract

New stratigraphic ranges for genera of Desmoinesian–Virgilian ammonoids are presented, based on analysis of 40,000 specimens collected from over 70 ammonoid-bearing horizons that represent at least 40 successive stratigraphic levels in the North American midcontinent. These range revisions indicate that current generic-level ammonoid zonations are inadequate, especially for correlation of Pennsylvanian series and stage boundaries. Six high-confidence, largely generic-level first-occurrence zones are proposed for the Desmoinesian through Virgilian stages: *Wellerites* Zone, *Eothalassoceras* Zone, *Pennoceras* Zone, *Preshumardites* Zone, *Pseudaktubites* Zone, and *Shumardites* Zone. Fifteen zones of lesser confidence for correlation are also suggested.

The Shumarditidae Plummer & Scott, 1937, is emended to include *Preshumardites* Plummer & Scott, 1937, *Pseudaktubites* gen. nov. (type species, *Preshumardites stainbrooki* Plummer & Scott, 1937), and *Shumardites* Smith, 1903. Early Permian (Sakmarian) species previously assigned to *Preshumardites* are reassigned to *Andrianovia* gen. nov. (type species ?*Preshumardites sakmarae* Ruzhencev, 1938). *Aktubites* Ruzhencev, 1955, *Eoshumardites* Popov, 1960, and *Parashumardites* Ruzhencev, 1939, previously included in the Shumarditidae, are assigned to the new family Parashumarditidae. *Eovidrioceras inexpectans* gen. nov., sp. nov. is included and is interpreted as the ancestor of the cyclobacean family Vidrioceratidae Plummer & Scott, 1937.

The base of the revised *Wellerites* Zone, defined by the first occurrence of the nominate genus, approximates but does not coincide with the Atokan-Desmoinesian boundary. Recorrelation of the stratigraphic level of the Collinsville, Oklahoma, ammonoid locality from the "Seminole Formation" (basal Missourian) to the Holdenville Formation (upper Desmoinesian), based on lithostratigraphic evidence, effectively places the first occurrence of *Eothalassoceras* in the upper Desmoinesian. Because *Wellerites* apparently became extinct before the end of the Desmoinesian, the revised *Eothalassoceras* Zone is used to represent the upper Desmoinesian.

The Middle-Upper Pennsylvanian boundary (Desmoinesian-Missourian boundary) can be recognized by the appearance of *Pennoceras*, which defines the base of the new *Pennoceras* Zone. The *Pennoceras* Zone is an excellent indicator of lower Missourian strata in the northern midcontinent, north-central Texas, the Marathon Uplift, and the Appalachian Basin. The new *Preshumardites* Zone occupies most of the upper part of the Missourian Stage.

The appearance of the ancestral shumarditid *Pseudaktubites*, which defines the base of the new *Pseudaktubites* Zone, occurs one cycle below the Missourian-Virgilian boundary, which is currently recognized at the top of the South Bend Limestone Member in eastern Kansas. No recognizable biostratigraphic event coincides with the South Bend Member, thereby resulting in an uncorrelatable chronostratigraphic boundary. The largest changeover in ammonoid faunas takes place at the base of strata containing the upper part of the *Pseudaktubites* Zone (*Pseudaktubites stainbrooki* Subzone). The base of the *Pseudaktubites stainbrooki* Subzone is stratigraphically near the original Missourian-Virgilian boundary. It is recommended that the stratigraphic level containing the base of the *Pseudaktubites stainbrooki* Subzone be adopted as the official base of the Virgilian Stage. Recognition of the upper subzone of the *Pseudaktubites* Zone (*Pseudaktubites stainbrooki* Subzone) within the Colony Creek Shale Member in north-central Texas places the base of the Virgilian within the upper part of the Canyon Group and substantially below the current position at the Canyon-Cisco group boundary. *Shumardites*, a taxon previously used to mark the base of the Virgilian Stage, appears in early middle Virgilian strata; consequently, the revised *Shumardites* Zone represents the middle-upper Virgilian interval.

Introduction

Scope of study

Ammonoid cephalopods occur in moderate to great abundance in most core shales, the dark-gray to black phosphatic shales that are interpreted to represent maximum transgressive deposits of Desmoinesian through Virgilian cyclothems in the midcontinent region of the United States. Although the vertically discontinuous nature of the marine sequences in these repetitive transgressive-regressive units precludes bed-by-bed recovery of ammonoid faunas, the large number of superposed cycles of relatively short duration (≤400,000 years; Heckel, 1986) permits the construction of a detailed zonal sequence of ammonoid taxa from the succession of offshore horizons, most of which contain ammonoid-bearing core shales. Detailed stratigraphic fieldwork and extensive collection from Middle through Late Pennsylvanian cyclothems have yielded an unusually complete record of ammonoid evolution. More than 40,000 ammonoids have been identified from over 400 localities, representing 74 stratigraphic horizons and at least 40 successive stratigraphic levels in the midcontinent region.

A wealth of paleobiologic and phylogenetic information will eventually be derived from these exhaustive collections. The detailed study of the stratigraphic distribution of ammonoid taxa permits substantial revision and refinement of ranges of ammonoid genera; these results are presented here. This new information indicates that previous ammonoid-based zonations based on ranges determined from the midcontinent region are in error and, consequently, generally accepted intercontinental correlations, most critically those with the Soviet succession, are also incorrect. A new provisional midcontinent ammonoid generic zonation based on first occurrences is presented. When systematic revisions have been completed, a more detailed species-level zonation will be possible.

Superposition and correlation of ammonoid-bearing units in the North American midcontinent cyclothemic sequence

Outcrop exposures in the North American midcontinent are limited by the combination of low topographic relief and widespread vegetative cover. No single stratigraphic section is sufficiently complete to obtain successive ammonoid faunas through several cyclothems. As a result, the true superpositional sequence of stratigraphically and geographically isolated exposures must be determined by tracing beds along the outcrop belt and by constructing a composite of several stratigraphic sections. The construction of the true superpositional order and determination of local ranges of ammonoid taxa is difficult but can be achieved with the increasing knowledge of the ultimate sedimentologic controls on Pennsylvanian cyclothemic deposition.

The glacial-eustatic model of Pennsylvanian sedimentation, first proposed by Wanless and Shepard (1936), attributes the formation of most cyclothems to rapid changes in sea level that produced geographically widespread transgressive and regressive events. Core shales, the dark-gray to black phosphatic shales that produce most midcontinent Middle and Upper Pennsylvanian ammonoid faunas, represent the maximum transgressive events (Heckel and Baesemann, 1975). Originally, Udden (1912), followed by Moore (1929) and Weller (1930), argued that the black shale (core shale, in part) represented a lagoon or coastal swamp deposit that accumulated in less than 5 m (16 ft) of water. This shallow-water depositional model prevailed until Schenk (1967, p. 1,380–1,381) suggested that the black Lake Neosho Shale Member (Altamont Limestone, Desmoinesian, northern midcontinent) had been deposited in fairly deep water [50–200 m (160–660 ft)] below a thermocline augmented by regional upwelling. Heckel (1977, 1980) further developed Schenk's model and applied it to other cyclothems of Desmoinesian–Virgilian age in the midcontinent. Heckel emphasized that the black shale facies of the cyclothem (core shale) represents the deepest-water maximum transgressive lithofacies in most cycles of marine transgression. Boardman and Malinky (1985) demonstrated a well-defined oxygen paleogradient within core shales formed by encroachment of the oxygen minimum zone from the more basinal regions to the shallow shelf regions at maximum transgression. Radiolarian- and ammonoid-bearing phosphate nodules are found consistently at the anaerobic-dysaerobic boundary layer within core shales (Boardman et al., 1984). Because these deeper-water core shales often lie only 1 m (3 ft) or so above clearly terrestrial or nearshore deposits, geologically rapid marine transgressions must have occurred. As a consequence, maximum transgressive black shales should be essentially isochronous units along the outcrop belt (Israelsky, 1949). Rapid sea-level rises of the order of magnitude necessary to form offshore core shales can be reasonably explained only by waxing and waning of glaciers in the southern hemisphere during the Middle and Upper Pennsylvanian Series, for which there is now extensive evidence (Crowell, 1978).

Lithostratigraphic correlation from the Kansas carbonate shelf area to the Oklahoma siliciclastic-dominated shelf region is a difficult procedure. Heckel (1977, 1980), Bennison (1984), and Boardman et al. (1984) have demonstrated that the regressive carbonate-dominated sediments of the Kansas shelf pinch out into a plexus of terrigenous clastic-dominated lithofacies in the Oklahoma shelf setting. In contrast, offshore core shales are developed in most cycles and can be shown by surface and subsurface mapping to be laterally continuous from Kansas to Oklahoma (Bennison, 1984; Boardman et al., 1984; Heckel, 1986). Moreover, core shales are both lithologically and faunally similar throughout their extent (Boardman et al., 1984). Consequently, correlation of the core shales provides the primary basis for determining stratigraphic relationships within Pennsylvanian cyclothemic strata. Boardman et al. (1984) related differences in the carbonate- to clastic-dominated sequences to the local paleogeography; the differences reflect change in positions of ancient deltaic systems prograding across the midcontinent seaway during high-water stillstand or various stages of regression.

To construct the composite stratigraphic ammonoid distribution charts for the northern midcontinent (figs. 1–7) and southern midcontinent (figs. 1, 8–13), we selected a series of closely spaced outcrops for which objective stratigraphic superposition could be determined. All ammonoid occurrences in these sections were documented and compared with similarly spaced sections in other areas. Critical levels, such as horizons immediately above or below provisional series and stage boundaries, were traced as far as possible along the outcrop belts to provide additional control. Isolated sections were compared with more complete sections, and summary correlations were formulated. Little lateral variation is seen within any one particular ammonoid-producing interval, usually a core shale, in terms of species present. However, because the percentages of individual species within a given assemblage vary considerably between sections, zonations based solely on percentages of certain taxa within an assemblage are considered to be unreliable, even at the level of intrabasinal correlation.

Stratigraphic sections showing the sequence of Desmoinesian (fig. 2) ammonoid-bearing formations are presented for the Oklahoma basinal regions (northwestern

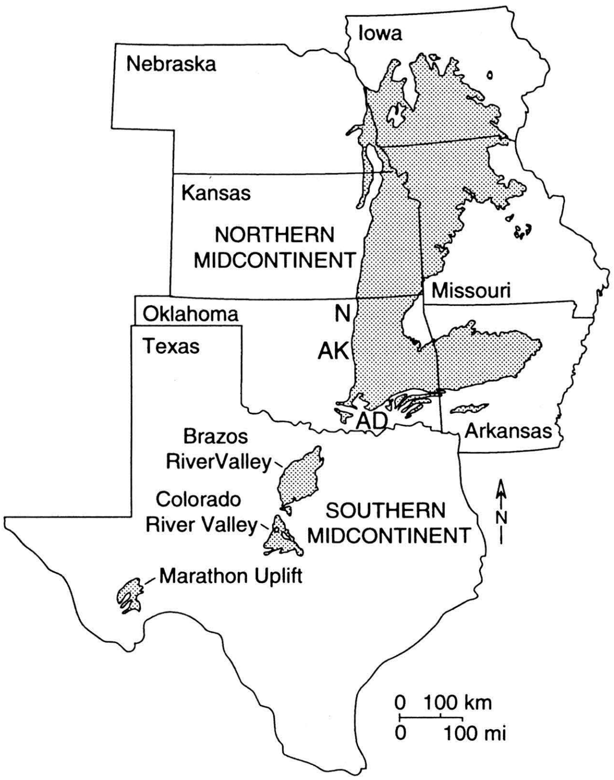


Figure 1. Generalized outcrop areas of Middle-Upper Pennsylvanian strata in the North American midcontinent. AD = Ardmore Basin; AK = Arkoma-McAlester Basin; N = northern shelf.

and southwestern edges of the Arkoma-McAlester Basin) and for the northern carbonate shelf region of the northern midcontinent. The Desmoinesian of the Ardmore Basin is shown separately (fig. 3). The stratigraphic distribution of ammonoid-bearing units in Missourian (fig. 4) and Virgilian strata (figs. 5 and 6) is given for both the Kansas shelf and the Oklahoma terrigenous detrital facies belt of Heckel (1977). A composite Kansas shelf and northernmost Oklahoma stratigraphic section showing the distribution of basal Permian ammonoids is shown in fig. 7.

Stratigraphic sections showing the sequence of ammonoid-bearing formations are presented for southern midcontinent Desmoinesian strata (fig. 8), Missourian strata (fig. 10), Virgilian strata (fig. 11), and basal Permian strata (fig. 12) using Brazos River valley (fig. 1) stratigraphic terminology. The Desmoinesian ammonoid succession from the Colorado River valley is presented separately (fig. 9) because the correlation of Desmoinesian strata from the Colorado River valley with that of the Brazos River valley succession is not completely clear. The sequence of Missourian and Virgilian ammonoid-bearing formations in the Marathon Uplift area (fig. 1) is presented in fig. 13.

Definition and placement of Desmoinesian–Virgilian stage boundaries in the midcontinent region

Ammonoid ranges must be carefully determined relative to precise and consistent definitions of existing stage and series boundaries to properly correlate these units on an interbasinal and intercontinental basis. In the midcontinent area the distinct Desmoinesian–Virgilian outcrop belts (northern midcontinent, north-central Texas, and Marathon Uplift; fig. 1) cannot be directly traced interregionally by surface mapping. The outcrop areas must be accurately correlated to produce a composite ammonoid range chart for the entire midcontinent. We followed a multitaxon integrated approach using fusulinids, conodonts, and brachiopods, in preference to ammonoids, to correlate stage and series boundaries to avoid circular reasoning. The northern midcontinent serial nomenclature (Desmoinesian, Missourian, Virgilian) is used because it has priority over southern midcontinent serial nomenclature [Strawn, Canyon, and Cisco; see Brown (1959) for a summary].

Cheney et al. (1945, p. 131, chart 1, and p. 140, chart 2) advocated a tripartite subdivision of the Pennsylvanian wherein each subdivision contains two provincial series. However, Cheney gave no classificatory designation of the terms Lower Pennsylvanian (Springer, Morrow), Middle Pennsylvanian (Lampasas, Desmoines), and Upper Pennsylvanian (Missouri, Virgil). Moore and Thompson (1949) argued that, because no formal rank for the Lower, Middle, and Upper Pennsylvanian had been designated by Cheney et al. (1945), a geography-based provincial series nomenclature was preferable. Moore and Thompson (1949) proposed that the Lower Pennsylvanian of Cheney be designated the Ardian Series (type area in the Ardmore Basin of south-central Oklahoma), the Middle Pennsylvanian be designated the Oklan Series (type area in the Arkoma Basin of eastern Oklahoma), and the Upper Pennsylvanian be designated the Kawvian Series (type area in the Kaw valley = Kansas River valley in northeastern Kansas) and that the previously existing series (Springer, Morrow, Atoka, Des Moines, Missouri, and Virgil) be lowered in rank to stages. The provincial series usage proposed by Moore and Thompson (1949) is similar to that used in Europe, wherein Namurian, Westphalian, and Stephanian are provincial series designations for the upper Carboniferous (Silesian) subsystem.

Because of various problems in definition, the geography-based serial nomenclature of Moore and Thompson (1949) has been disregarded by many North American workers, who use Lower, Middle, and Upper Pennsylvanian as series terms. The current official stratigraphic correlation chart of the Kansas Geological Survey (Zeller et al., 1968) designates the Lower, Middle, and Upper Pennsylvanian as provincial series and the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian as stages. This approach is also favored by Lane and West (1984, p. 96). For the purposes of this bulletin, we accept the nomenclature of the Kansas Geological Survey.

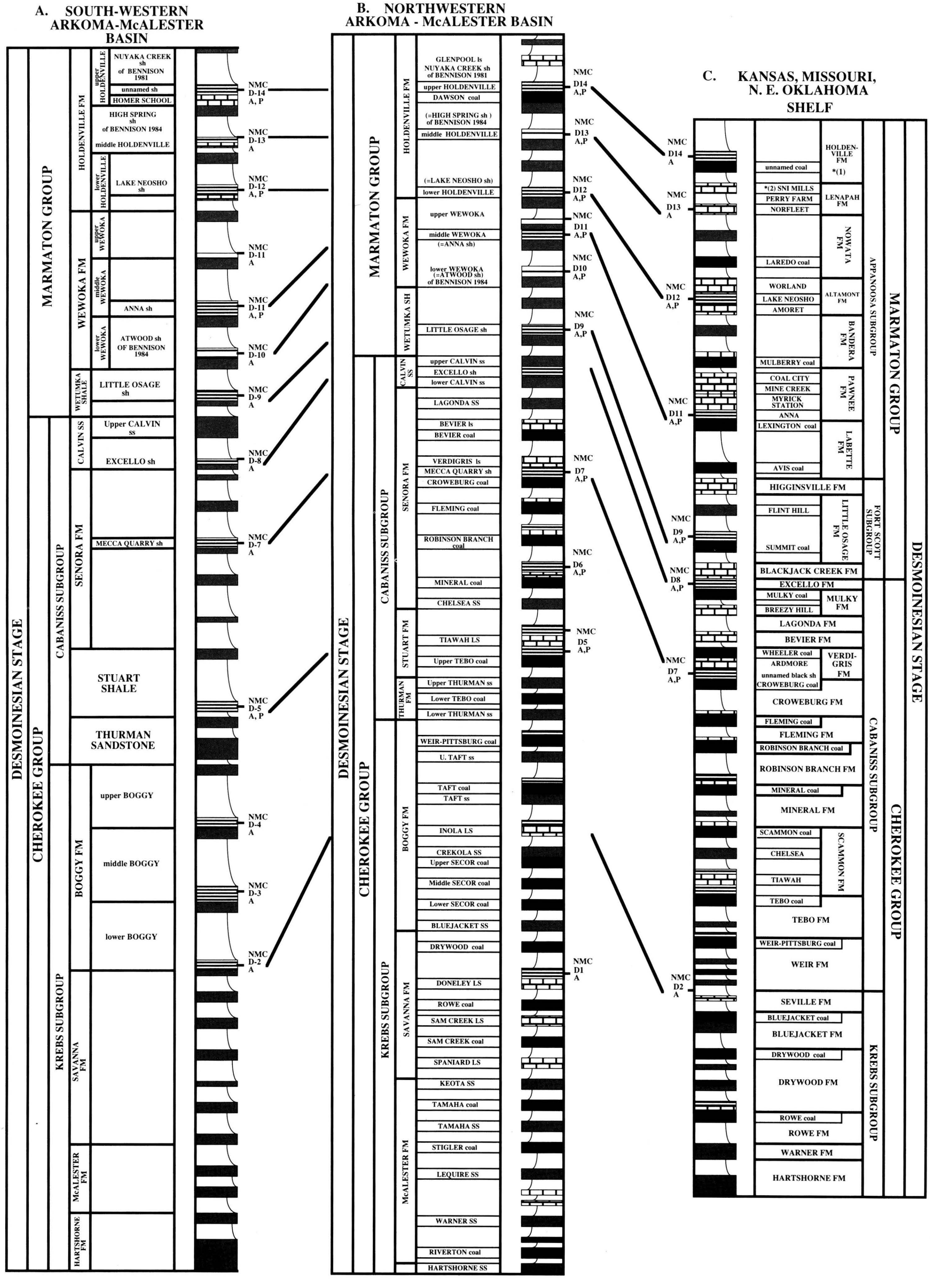
Desmoinesian Stage

The Desmoinesian Stage, originally defined as the Des Moines Formation by Keyes (1893), was regarded as a series by Keyes (1896) and used in that manner by Moore et al. (1944). Although Keyes (1896) did not designate a precise type section, the type area was given as the exposures along the Des Moines River in central Iowa. The widespread unconformity separating the Middle Pennsylvanian from the Mississippian was recognized as the lower boundary; the Bethany Limestone (= Hertha Limestone of modern usage) marked the upper boundary. According to Moore (1932), the base of the type Desmoinesian coincided with the base of the Cherokee Shale. However, Thompson (1934, p. 296) described *Fusulinella iowensis* occurring without *Fusulina* (*Beedeina* of current usage) from a bed in the lower part of the Cherokee Shale, about 90 ft (27 m) below the White Breast coal (correlated with the Croweburg coal bed; Heckel, 1986). Later, Thompson (1942, p. 40) reported that the same bed that contained *Fusulinella iowensis* also yielded a primitive species of *Fusulina* (= *Beedeina* of current usage).

Based on Thompson's earlier findings, Moore et al. (1944) placed the lower part of the Cherokee Shale into the upper Lampasan Series, which further complicated correlation of the base of the Desmoinesian Series. The Lampasan Series was originally defined by Cheney (1940) to include all post-Morrow, pre-Strawn (Desmoinesian) beds in north-central Texas. Spivey and Roberts (1946), rejected the Lampasan Series because the topmost beds (Caddo Pool Limestone) of the Lampasan contained the Desmoinesian fusulinids *Wedekindellina* and *Fusulina*. Spivey and Roberts (1946) proposed that the post-Morrowan and pre-Desmoinesian interval be called the Atokan Series, based on the Atoka Formation of the Arkoma-McAlester Basin. The Atokan Series of Spivey and Roberts includes all strata from the top of the Wapanucka Limestone (not shown) to the base of the Hartshorne Sandstone (fig. 2) in the Arkoma-McAlester Basin. The Hartshorne Sandstone has been used subsequently to mark the base of the Desmoinesian Series (or Stage) in the midcontinent area, except in Iowa (Oakes, 1953).

Moore and Thompson (1949, p. 291) defined the Atokan Stage to include all strata containing the fusulinids *Profusulinella* at the base and *Fusulinella* below the first occurrence of *Fusulina (Beedeina)* at the top. In the Arkoma-McAlester Basin region the basal Desmoinesian interval from the Hartshorne Sandstone to the Spaniard Limestone Member of the Savanna Formation (fig. 2) is fluvial and deltaic in origin and lacks fusulinids. Waddell (1966) correlated the abundantly fossiliferous Lester and Frensley limestone members of the Ardmore Basin of southern Oklahoma (fig. 3) with the relatively unfossiliferous lowest Desmoinesian strata in the Arkoma-McAlester Basin (Hartshorne and McAlester Formations). Waddell (1966) reported that the Lester and Frensley limestone members possess more primitive species of *Fusulina* (*Beedeina*) than does the Spaniard Limestone Member, which contains the first Desmoinesian fusulinids in the Arkoma-McAlester Basin. *Fusulina* (*Beedeina*) *novamexicana*, which occurs in the Spaniard Limestone Member, appears in the Pumpkin Creek Limestone Member of the Ardmore Basin, which overlies the Frensley Limestone Member (fig. 3) (Waddell, 1966). *Fusulina* (*Beedeina*) *insolata* was recovered from a thin limestone bed 150 ft (46 m) below the more massive

Figure 2 (facing page). Stratigraphic distribution of ammonoid faunas in Desmoinesian strata of (A) the southwestern Arkoma-McAlester Basin, Oklahoma, (B) the northwestern Arkoma-McAlester Basin, Oklahoma, and (C) the northern shelf areas of the northern midcontinent region. Lithostratigraphic nomenclature used in this figure is a composite of many sources, including but not limited to Bennison (1984), Bennison et al.(1981, 1984), Branson (1954), Heckel (1984), Moore (1932, 1936), Seawright and Howe (1961), and Zeller et al. (1968). NMC D1–D14 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules. The Lost Branch formation is a new name proposed by P. H. Heckel (1991).



A. SOUTH-WESTERN ARKOMA-McALESTER BASIN
B. NORTHWESTERN ARKOMA - McALESTER BASIN
C. KANSAS, MISSOURI, N. E. OKLAHOMA SHELF
DESMOINESIAN STAGE
MARMATON GROUP
CHEROKEE GROUP
CABANISS SUBGROUP
KREBS SUBGROUP
HOLDENVILLE FM
upper HOLDENVILLE
NUYAKA CREEK sh of BENNISON 1981
unnamed sh
HOMER SCHOOL
HIGH SPRING sh of BENNISON 1984
middle HOLDENVILLE
lower HOLDENVILLE
LAKE NEOSHO sh
WEWOKA FM
upper WEWOKA
middle WEWOKA
ANNA sh
lower WEWOKA
ATWOOD sh OF BENNISON 1984
WETUMKA SHALE
LITTLE OSAGE sh
CALVIN SS
Upper CALVIN ss
EXCELLO sh
SENORA FM
MECCA QUARRY sh
STUART SHALE
THURMAN SANDSTONE
BOGGY FM
upper BOGGY
middle BOGGY
lower BOGGY
SAVANNA FM
McALESTER FM
HARTSHORNE FM
NMC D-14 A, P
NMC D-13 A
NMC D-12 A, P
NMC D-11 A
NMC D-11 A, P
NMC D-10 A
NMC D-9 A
NMC D-8 A
NMC D-7 A
NMC D-5 A, P
NMC D-4 A
NMC D-3 A
NMC D-2 A
GLENPOOL ls NUYAKA CREEK sh of BENNISON 1981
upper HOLDENVILLE
DAWSON coal
(=HIGH SPRING sh) of BENNISON 1984
middle HOLDENVILLE
(=LAKE NEOSHO sh)
lower HOLDENVILLE
upper WEWOKA
middle WEWOKA (=ANNA sh)
lower WEWOKA (=ATWOOD sh) of BENNISON 1984
WETUMKA SH
LITTLE OSAGE sh
upper CALVIN ss
EXCELLO sh
lower CALVIN ss
LAGONDA SS
BEVIER ls
BEVIER coal
VERDIGRIS ls
MECCA QUARRY sh
CROWEBURG coal
FLEMING coal
ROBINSON BRANCH coal
MINERAL coal
CHELSEA SS
STUART FM
TIAWAH LS
Upper TEBO coal
THURMAN FM
Upper THURMAN ss
Lower TEBO coal
Lower THURMAN ss
WEIR-PITTSBURG coal
U. TAFT ss
TAFT coal
TAFT ss
INOLA LS
CREKOLA SS
Upper SECOR coal
Middle SECOR coal
Lower SECOR coal
BLUEJACKET SS
DRYWOOD coal
DONELEY LS
ROWE coal
SAM CREEK LS
SAM CREEK coal
SPANIARD LS
KEOTA SS
TAMAHA coal
TAMAHA SS
STIGLER coal
LEQUIRE SS
WARNER SS
RIVERTON coal
HARTSHORNE SS
NMC D14 A,P
NMC D13 A,P
NMC D12 A,P
NMC D11 A,P
NMC D10 A,P
NMC D9 A,P
NMC D7 A,P
NMC D6 A,P
NMC D5 A,P
NMC D1 A
unnamed coal
HOLDEN-VILLE FM *(1)
*(2) SNI MILLS
PERRY FARM
NORFLEET
LENAPAH FM
NOWATA FM
LAREDO coal
WORLAND
LAKE NEOSHO
AMORET
ALTAMONT FM
BANDERA FM
MULBERRY coal
COAL CITY
MINE CREEK
MYRICK STATION
ANNA
PAWNEE FM
LEXINGTON coal
AVIS coal
LABETTE FM
APPANOOSA SUBGROUP
HIGGINSVILLE FM
FLINT HILL
SUMMIT coal
LITTLE OSAGE FM
FORT SCOTT SUBGROUP
BLACKJACK CREEK FM
EXCELLO FM
MULKY coal
BREEZY HILL
MULKY FM
LAGONDA FM
BEVIER FM
WHEELER coal
ARDMORE
unnamed black sh
CROWEBURG coal
VERDI-GRIS FM
CROWEBURG FM
FLEMING coal
FLEMING FM
ROBINSON BRANCH coal
ROBINSON BRANCH FM
MINERAL coal
MINERAL FM
SCAMMON coal
CHELSEA
TIAWAH
TEBO coal
SCAMMON FM
TEBO FM
WEIR-PITTSBURG coal
WEIR FM
SEVILLE FM
BLUEJACKET coal
BLUEJACKET FM
DRYWOOD coal
DRYWOOD FM
ROWE coal
ROWE FM
WARNER FM
HARTSHORNE FM
NMC D14 A
NMC D13 A
NMC D12 A,P
NMC D11 A,P
NMC D9 A,P
NMC D8 A,P
NMC D7 A,P
NMC D2 A

upper part of the Lester Limestone Member, and Waddell (1966) tentatively placed the Atokan-Desmoinesian boundary at that stratigraphic level. Thompson (1948, p. 96–97) thought that *Fusulina* (*Beedeina*) *insolata* represented the most primitive species and probable root stock of *Fusulina* (*Beedeina*); he found *?Fusulina insolata* co-occurring with *Fusulinella* in the upper part of the Cuchillo Negro Formation in the Derry Hills of New Mexico.

Northward from the Arkoma-McAlester Basin area (Kansas and Missouri), lower Desmoinesian strata (Hartshorne and Warner sandstones) are present but are characterized by fluvial-deltaic-dominated complexes similar to coeval deposits in the Arkoma-McAlester Basin. Field evidence indicates that most lower Desmoinesian marine strata above the Warner Sandstone Member and below the Rowe coal (upper two-thirds of the McAlester Formation and lower two-thirds of the Savanna Formation; fig. 2), including the Spaniard Limestone Member, are missing by nondeposition or erosion northward from the Arkoma-McAlester Basin (Moore et al., 1944; Oakes, 1953).

The Hartshorne-Warner interval has not yet been positively identified in the type Desmoinesian area in Iowa. However, until recently the type Desmoinesian had received little attention. Ravn et al. (1984) proposed a number of new formational and member rank designations for Cherokee Group strata in Iowa but attempted few correlations with the remainder of the midcontinent region. Ravn et al. (1984) also demonstrated that the position of the base of the Cherokee Group in Iowa varies considerably because of fluvial channel development within the lower Cherokee Group that locally cuts out earlier strata. This channeling is commonly associated with remnant Mississippian paleohighs. The Cherokee Group terminology in Iowa is not illustrated here because of the paucity of ammonoids from this region.

For the purposes of this bulletin we conditionally accept the base of the Hartshorne Sandstone, where present, to represent the base of the Desmoinesian Stage in the midcontinent. As discussed, Moore and Thompson (1949) placed the Atokan-Desmoinesian biostratigraphic boundary at the first occurrence of *Beedeina* (= *Fusulina* of older usage). Here, we consider the first occurrence of *Beedeina*, specifically the most primitive species, *B. insolata*, to be the most reliable criterion by which to identify the base of the Desmoinesian outside the Arkoma-McAlester Basin. Shaver (1984) used the first occurrence of *Fusulinella iowensis* to characterize the base of the Desmoinesian in Iowa and in the

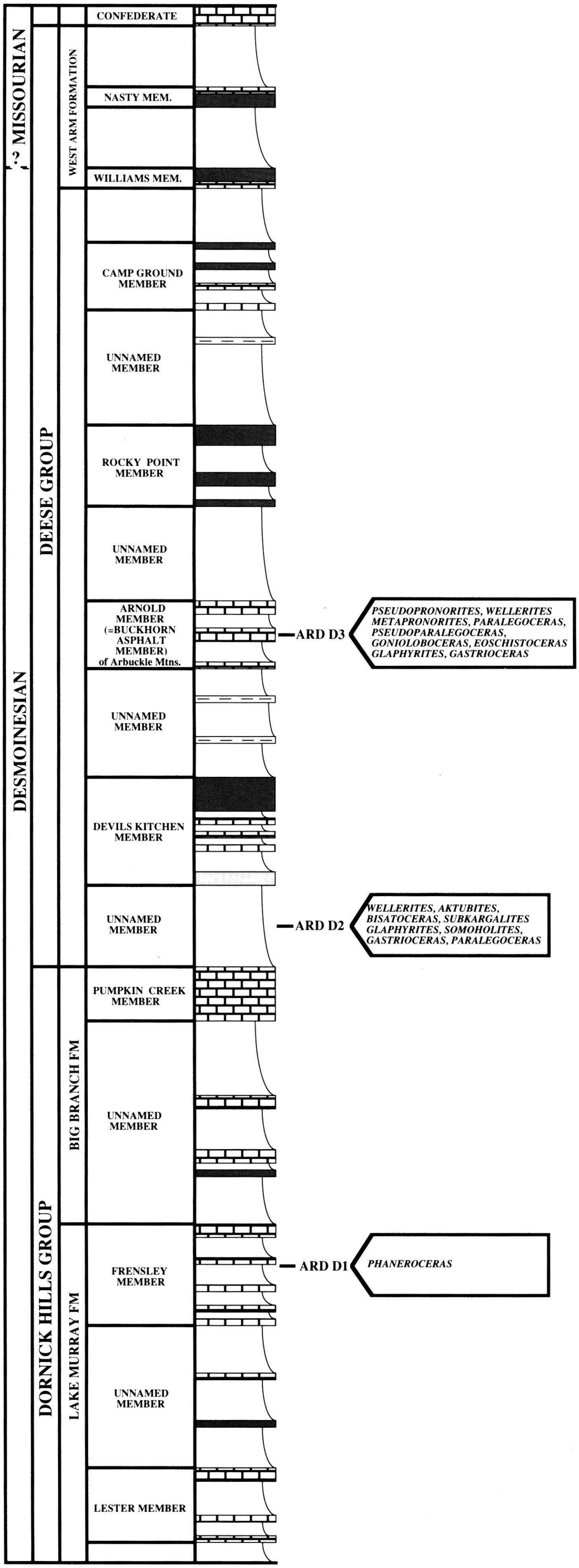


Figure 3. Stratigraphic distribution of ammonoid faunas in Desmoinesian strata of the Ardmore Basin and Arbuckle Mountains. Lithostratigraphic nomenclature used in this figure is based largely on the work of Waddell (1966). NMC ARD D1–D3 are ammonoid-bearing intervals.

Illinois Basin. In the Illinois Basin *F. iowensis* occurs without *Beedeina* (Douglass, 1979). If the report of a primitive species of *Beedeina* occurring with *F. iowensis* in Iowa is correct, then the correlation of the *F. iowensis*–bearing strata between the two regions may be in error. The *F. iowensis*–bearing strata in Illinois may be older than those of Iowa, as evidenced by the lack of primitive *Beedeina* in the Illinois section.

Conodonts show considerable promise for correlation of the base of the Desmoinesian but, unfortunately, they have not been studied sufficiently in the critical regions of the type Desmoinesian area in Iowa and in the type Atokan area of the Arkoma-McAlester Basin region. The last occurrence of the conodont genus *Idiognathoides* (Grayson et al., 1985) and the first occurrence of *Neognathodus medexultimus* (Merrill, 1975) traditionally have been used to recognize the base of the Desmoinesian. Grayson and Merrill (1987), however, report that *Idiognathoides* may range into lower Desmoinesian strata in north-central Texas.

Correlation of the Atokan-Desmoinesian boundary from the northern midcontinent to the southern midcontinent (Texas) is especially difficult. In the Brazos River valley (northern outcrop belt in north-central Texas; fig. 1) upper Atokan and basal Desmoinesian sediments are present only in the subsurface. In the Colorado River valley (southern outcrop belt exposed in north-central Texas; fig. 1) latest Atokan and earliest Desmoinesian strata are exposed continuously only in the eastern two-thirds of the Colorado River valley. These exposures are complicated further by tectonic deformation associated with the Llano Uplift (Grayson et al., 1985).

The traditional Atokan-Desmoinesian boundary in the Colorado River valley lies at the contact of the Smithwick Shale (upper Bend Group) and the lower Strawn Group (fig. 8). Fusulinids are sporadically present in the Colorado River valley succession but have not been adequately studied. Grayson et al. (1985) located the Atokan-Desmoinesian boundary based on the last occurrence of *Idiognathoides* and the presence of *Gondolella laevis*, a species characteristic of Merrill's (1975) early Desmoinesian *Neognathodus medexultimus–N. medadultumus* Zone. Grayson et al. (1985) placed the Atokan-Desmoinesian boundary within the lower Strawn Group in the Colorado River valley, although they did not have a complete continuous section in which the boundary was present. Although additional work will be necessary in the Colorado River valley area to arrive at a precise correlation of the Atokan-Desmoinesian boundary, we provisionally accept Grayson's interpretation of the Atokan-Desmoinesian boundary.

Missourian Stage

The Missourian Stage was defined originally by Keyes (1893) as a terrane (formation) with its type area in northwestern Missouri and later was elevated to series rank (Keyes, 1896). In the original definition unnamed beds (now the Bethany Falls Limestone Member) marked the base of the Missourian, and the base of the Wabaunsee Formation (base of the Florena Shale at that time; Council Grove Group, Wolfcampian, of modern usage, not illustrated) marked the top. Moore (1932) redefined the base of the series to correspond with a regional unconformity at the base of the Pleasanton Shale (= Seminole Formation of Oklahoma). Although the Pleasanton Shale (now a group) lies below the original Desmoinesian-Missourian (Middle-Upper Pennsylvanian) boundary, it contains a fauna of Missourian aspect with few Desmoinesian taxa. In this bulletin the base of the Pleasanton Group (fig. 4) is used as the Desmoinesian-Missourian boundary.

Faunal and floral aspects of the Desmoinesian-Missourian (Middle-Upper Pennsylvanian) biostratigraphic boundary have been summarized recently by Boardman et al. (1991b). Historically, this boundary has been characterized variously by the extinction of the chonetid brachiopod *Mesolobus* (Dunbar and Condra, 1932; Moore and Thompson, 1949); the extinction of the ammonoids *Wellerites* (Ramsbottom and Saunders, 1985) and *Gonioglyphioceras* (Boardman et al., 1989c); the appearance of the ammonoids *Parashumardites* (Ramsbottom and Saunders, 1985) and *Pennoceras* (Boardman et al., 1989c); the last occurrence of the fusulinid *Fusulina* (*Beedeina*) (Stewart, 1968); the appearance of the fusulinids *Triticites* (Douglass, 1987) and *Eowaeringella* (Stewart, 1968); the last occurrence of the conodonts *Neognathodus* (Heckel, 1984, p. 44), *Idiognathodus* cf. *I. concinnus*, and *I. antiquus* (Barrick and Boardman, 1989); the appearance of the conodont *I. sagittalis* (Kozitskaya et al., 1978; Boardman et al., 1991b); the first occurrence of the pseudozygopleuriid microgastropod *Plocezyga* (*Plocezyga*) *costata* (Anderson and Boardman, 1989); and the great reduction in *Lycospora* in conjunction with the extinction of *Thymospora* and *Cappasporites* (Phillips et al., 1985, p. 88).

In the northern midcontinent the extinction events of *Mesolobus*, *Gonioglyphioceras*, *Fusulina* (*Beedeina*), *Neognathodus*, *Idiognathodus* cf. *I. concinnus*, *I. antiquus*, *Thymospora*, and *Cappasporites* occurs at Moore's (1932) Desmoinesian-Missourian boundary (base of the Pleasanton), as does the great reduction of *Lycospora* (Phillips et al., 1985). According to Boardman et al. (1989c), the ammonoid *Wellerites* does not range above the lower Holdenville Formation (late but not latest Desmoinesian). The appearances of *I. sagittalis* and *Pennoceras* coincide with the base of the Pleasanton Shale (Boardman et al., 1991b). Recently, the appearance of *Plocezyga* (*Plocezyga*) *costata* has been identified in the basal Missourian Coffeyville Formation in Seminole County, Oklahoma (Anderson, personal communication, 1991). *Eowaeringella* occurs in the Bethany Falls Limestone Member of the Swope Limestone, which lies stratigraphically above the base of the Pleasanton Shale (Thompson, 1957; Stewart, 1968) (fig. 4). Moreover, although *Eowaeringella* has been cited often as an early Missourian index, Stewart (1968) demonstrated that in certain ranges in western North America (e.g., Big Hatchet Mountains of New Mexico) *Eowaeringella* occurs with the Desmoinesian taxon *Fusulina* (*Beedeina*), thus limiting its utility as a reliable lower Missourian indicator. *Triticites* first occurs in the Winterset Member of the Dennis Limestone (fig. 4). The most reliable biostratigraphic events for identifying the base of the Missourian Stage are the apparently simultaneous extinctions of *Beedeina*, *Mesolobus*, *Neognathodus*, *Thymospora*, and *Cappasporites* and the great reduction of *Lycospora*, followed by appearances of *Pennoceras*, *I. sagittalis*, and *Plocezyga* (*Plocezyga*) *costata*.

Based on the extinction of *Neognathodus*, *Mesolobus*, and *Beedeina* and the appearance of *I. sagittalis* (as *I. lobatus*; Barrick and Boardman, 1989), the Desmoinesian-Missourian boundary in north-central Texas is recognized at the base of a sandy limestone bed (Bath Bend bed; Boardman et al., 1989b) that lies 15–25 ft (4.6–7.6 m) above the Village Bend Limestone Member of the East Mountain Shale (in the Strawn Group; fig. 8).

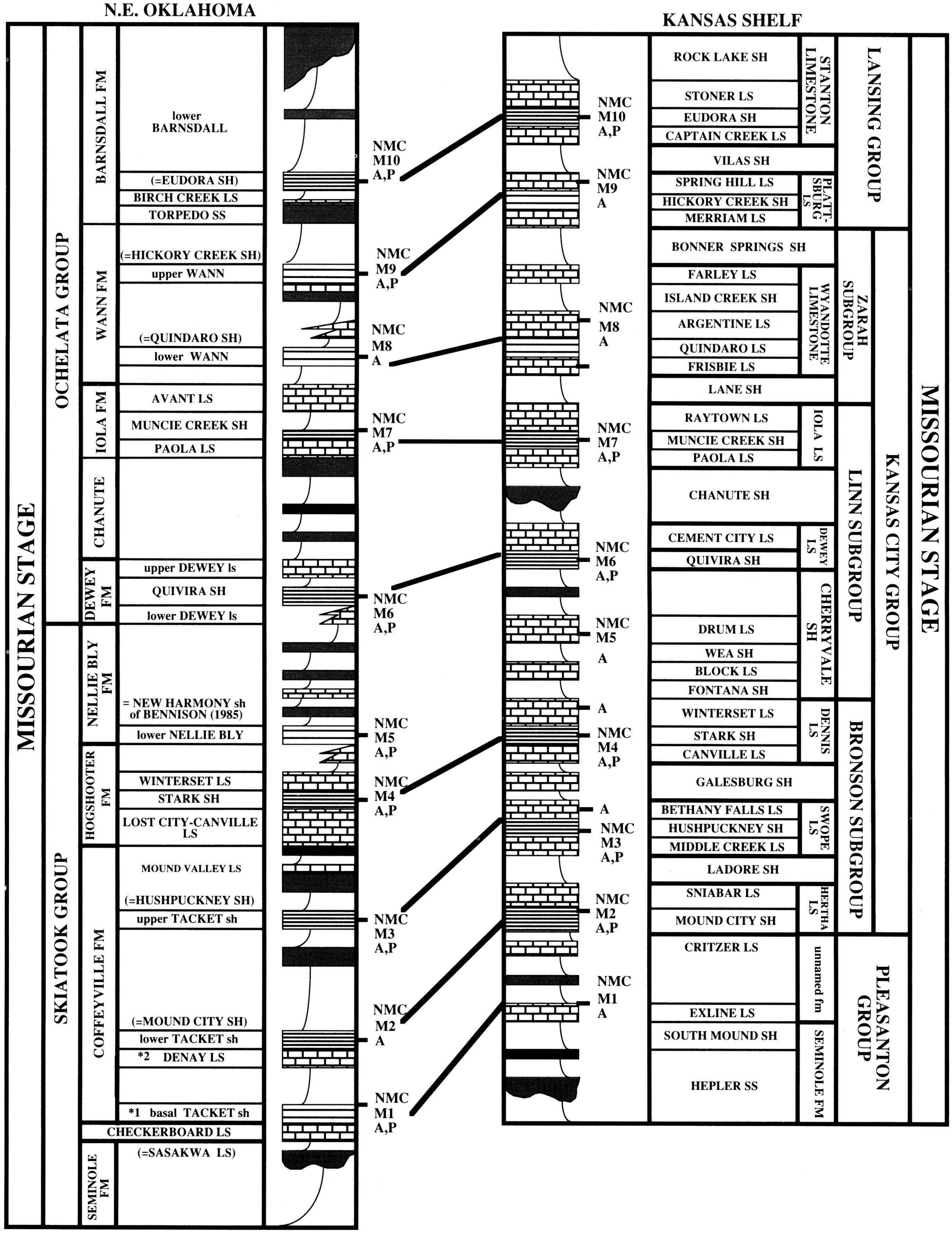
Virgilian Stage

The provincial Virgilian Series was erected by Moore (1932) as a subdivision of the original Missourian Series. Moore argued that the Missourian Series, as originally defined, contained a widespread unconformity with a substantial faunal break that required the erection of a new series. The type area for the Virgilian was designated by Moore (1936) as "exposures along the Verdigris River from west of Madison, Kansas, to Virgil, Kansas, and southeastward to central Wilson County, Kansas" (p. 143). The lower boundary of the series was placed at what was thought to be a regional unconformity within the original Missourian Series, at the top of the Iatan Limestone Member. The regional unconformity was thought to coincide with the base of the Tonganoxie Sandstone Member. No specific faunal data was presented by Moore (1932) as criteria for his perceived Missourian-Virgilian faunal break.

O'Connor (1963) recommended that the Pedee Group, which contained the Weston Shale and the Iatan Limestone, be eliminated and that the Weston Shale and overlying Iatan Limestone be placed as members in the Stranger Formation of the Douglas Group. This revision shifted the Missourian-Virgilian stage boundary downward to a position at the top of the upper member of the Stanton Limestone (South Bend Limestone Member). O'Connor's revision was based largely on unpublished stratigraphic information detailing the limited geographic distribution of Moore's unconformity and the difficulty in physically tracing this boundary. O'Connor presented no paleontologic evidence to support his boundary revision. At present there is no consensus among midcontinent state geological surveys as to the position of the Missourian-Virgilian boundary. The Missouri Geological Survey (Thompson, 1979) officially recognizes the Pedee Group and places the base of the Virgilian Stage at the top of the Iatan Limestone Member, following Moore (1932). The Oklahoma Geological Survey (Fay et al., 1979) also recognizes the older Missourian-Virgilian boundary (base of Cheshewalla Sandstone Member, which is thought to correlate with the Tonganoxie Sandstone Member). However, the Iatan Limestone Member is highly discontinuous in Kansas and is known only from scattered localities in Oklahoma (Zeller et al., 1968; Heckel, personal communication, 1988), adding a potential problem for using the top of the Iatan Limestone Member as the Missourian-Virgilian boundary throughout the midcontinent.

The Nebraska and Kansas geological surveys recognize the top of the South Bend Limestone Member as the Missourian-Virgilian boundary. However, there is a slight discrepancy in the stratigraphic positions advocated by the two geological surveys. In Nebraska the South Bend Member of the Stanton Limestone consists of a thin "transgressive" limestone, an offshore core shale, and a thicker "regressive" limestone (fig. 5). The base of the Virgilian is placed at the top of the "regressive" limestone of the South Bend Limestone Member in Nebraska. However, in Kansas, the "regressive" limestone is replaced by an offshore core shale followed by a thick prodeltaic shale facies. In Kansas the Missourian-Virgilian boundary is placed at the top of the "transgressive" limestone part of the South Bend Limestone Member (Zeller et al., 1968). As a result of this discrepancy, the Missourian-Virgilian boundary lies in two different stratigraphic positions, both associated with the South Bend Limestone Member of the Stanton Limestone. Since O'Connor's downward revision for the Missourian-Virgilian

Figure 4 (facing page). Stratigraphic distribution of ammonoid faunas in Missourian strata of Oklahoma and Kansas, Nebraska, Missouri, and Iowa. Lithostratigraphic nomenclature used in this figure for the Oklahoma region is based largely on accepted formational usage by the Oklahoma Geological Survey. However, the bed designations are based on correlations with the Kansas region based on our work with considerable input from A. P. Bennison (geological consultant, Tulsa, Oklahoma) and Philip H. Heckel (University of Iowa). Lithostratigraphic nomenclature for the Kansas region is based on Zeller et al. (1968) and incorporates modifications made by Philip H. Heckel (University of Iowa). NMC M1–M10 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules. The basal Tacket shale member is present as a separate lithologic unit south of Tulsa County, Oklahoma. The Denay Limestone Member is present only in the southern part of the study area in south-central Oklahoma.


N.E. OKLAHOMA
MISSOURIAN STAGE
OCHELATA GROUP
SKIATOOK GROUP
BARNSDALL FM
WANN FM
IOLA FM
CHANUTE
DEWEY FM
NELLIE BLY FM
HOGSHOOTER FM
COFFEYVILLE FM
SEMINOLE FM
lower BARNSDALL
(=EUDORA SH)
BIRCH CREEK LS
TORPEDO SS
(=HICKORY CREEK SH)
upper WANN
(=QUINDARO SH)
lower WANN
AVANT LS
MUNCIE CREEK SH
PAOLA LS
upper DEWEY ls
QUIVIRA SH
lower DEWEY ls
= NEW HARMONY sh of BENNISON (1985)
lower NELLIE BLY
WINTERSET LS
STARK SH
LOST CITY-CANVILLE LS
MOUND VALLEY LS
(=HUSHPUCKNEY SH)
upper TACKET sh
(=MOUND CITY SH)
lower TACKET sh
*2 DENAY LS
*1 basal TACKET sh
CHECKERBOARD LS
(=SASAKWA LS)
NMC M10 A,P
NMC M9 A,P
NMC M8 A
NMC M7 A,P
NMC M6 A,P
NMC M5 A,P
NMC M4 A,P
NMC M3 A,P
NMC M2 A
NMC M1 A,P
KANSAS SHELF
NMC M10 A,P
NMC M9 A
NMC M8 A
NMC M7 A,P
NMC M6 A,P
NMC M5 A
A
NMC M4 A,P
A
NMC M3 A,P
NMC M2 A,P
NMC M1 A
ROCK LAKE SH
STONER LS
EUDORA SH
CAPTAIN CREEK LS
VILAS SH
SPRING HILL LS
HICKORY CREEK SH
MERRIAM LS
BONNER SPRINGS SH
FARLEY LS
ISLAND CREEK SH
ARGENTINE LS
QUINDARO LS
FRISBIE LS
LANE SH
RAYTOWN LS
MUNCIE CREEK SH
PAOLA LS
CHANUTE SH
CEMENT CITY LS
QUIVIRA SH
DRUM LS
WEA SH
BLOCK LS
FONTANA SH
WINTERSET LS
STARK SH
CANVILLE LS
GALESBURG SH
BETHANY FALLS LS
HUSHPUCKNEY SH
MIDDLE CREEK LS
LADORE SH
SNIABAR LS
MOUND CITY SH
CRITZER LS
EXLINE LS
SOUTH MOUND SH
HEPLER SS
STANTON LIMESTONE
PLATTSBURG LS
WYANDOTTE LIMESTONE
IOLA LS
DEWEY LS
CHERRYVALE SH
DENNIS LS
SWOPE LS
HERTHA LS
unnamed fm
SEMINOLE FM
LANSING GROUP
ZARAH SUBGROUP
LINN SUBGROUP
BRONSON SUBGROUP
KANSAS CITY GROUP
PLEASANTON GROUP
MISSOURIAN STAGE

boundary, Pabian and Strimple (1978) recommended moving the Missourian-Virgilian boundary downward to the top of the lower bed of the South Bend Limestone Member of Nebraska, based on faunal replacement in crinoids.

The development of thicker-walled *Triticites* (e.g., *T. cullomensis*) has been used traditionally to characterize Virgilian strata (Moore and Thompson, 1949). However, distinction between transitional *Triticites* species found near the currently defined Missourian-Virgilian boundary is vague. The more definitive Virgilian fusulinid *T. cullomensis* first appears in the Lecompton Limestone (Shawnee Group, early to middle Virgilian; Moore et al., 1944) (fig. 4). According to Ross (1965, p. 1,158), a significant evolutionary event in fusulinids—the appearance of early representatives of fusiform and thickly fusiform lineages (e.g., *Triticites primarius*)—occurs just below the presently defined Missourian-Virgilian boundary. These forms appear in the basal beds of the Rock Lake Shale Member, which immediately overlies the Stoner Limestone Member (Stanton Limestone, upper Missourian; fig. 4). Additional biostratigraphic events within this cyclothem include the first appearance of the conodonts *Streptognathodus simulator* and *S. firmus*, which occur in the Eudora Shale Member of the Stanton Limestone (fig. 4). Significantly, the appearance of *S. simulator* has been used to define the Kasimovian-Gzhelian boundary in the former Soviet Union (Barskov et al., 1987, p. 140). Another stratigraphic level that might be used to mark the base of the Virgilian Stage is the South Bend Limestone Member of the northern midcontinent (fig. 5). The South Bend Member is marked by the first appearance of *Triticites newelli* (Thompson, 1957). For the purposes of determining stratigraphic ranges of ammonoids, we use the base of the lower ("transgressive" limestone) part of the South Bend as the provisional boundary.

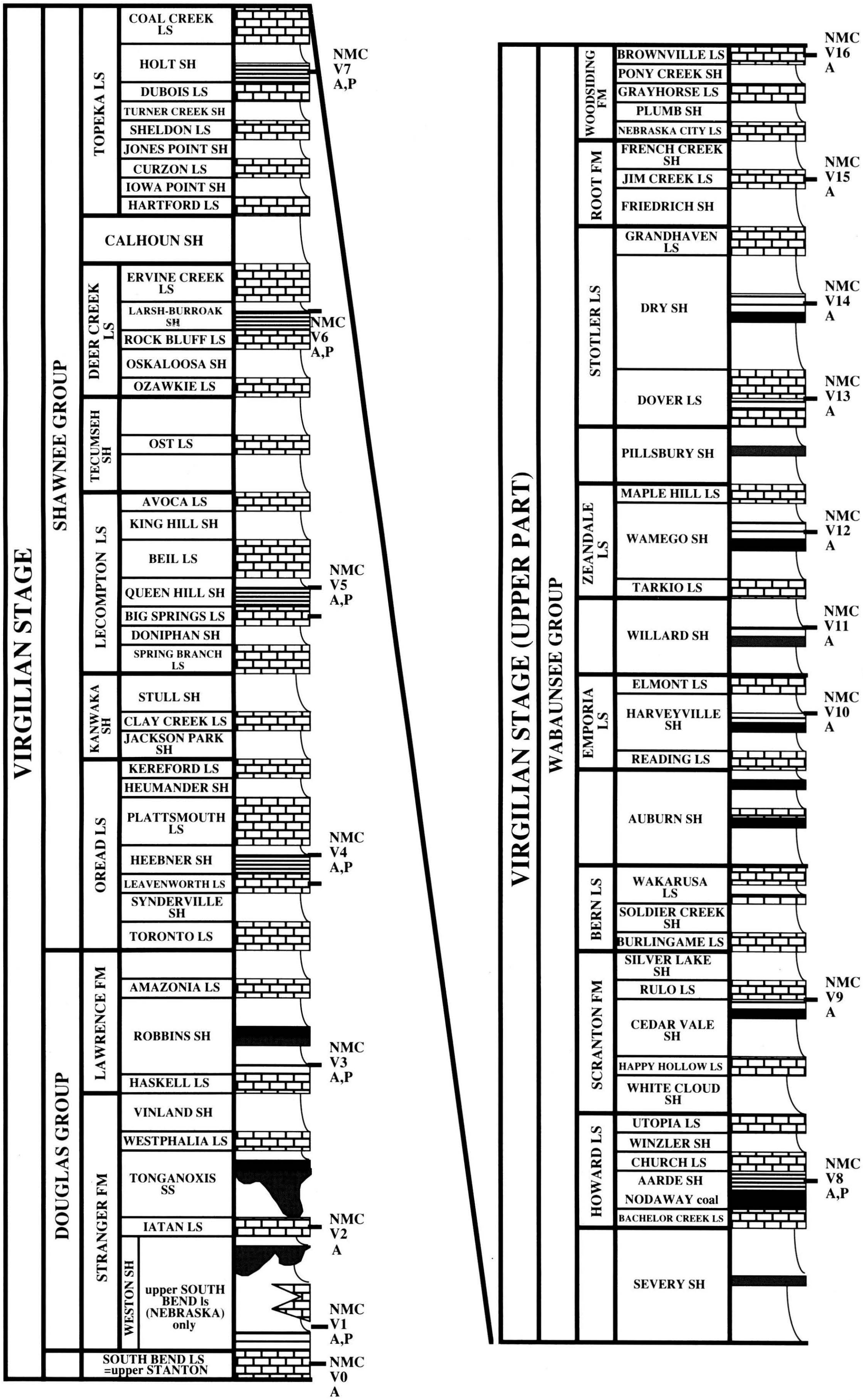
In north-central Texas the Missourian-Virgilian boundary has historically been placed at the top of the Home Creek Limestone Member, which coincides with the Canyon-Cisco Group boundary (fig. 11) (Brown, 1959). Based on unspecified fusulinid evidence, Moore (1936, p. 144) had placed the Missourian-Virgilian boundary in north-central Texas at the top of the Ranger Limestone Member, which lies one formation lower stratigraphically (fig. 11). Later, Moore et al. (1944) correlated the Missourian-Virgilian boundary with the top of the Home Creek Limestone Member (fig. 11). Ross (1965, p. 1,160) presented a chart that placed the Missourian-Virgilian boundary at the base of the upper fossiliferous horizon of the Placid Shale Member in north-central Texas (fig. 11), at a level only slightly below that identified by Moore (1936). The basis for Ross's (1965, p. 1,164) recorrelation was the occurrence of *Triticites newelli* and *T. iatensis* in the Ranger Limestone Member and presumably the underlying Placid Shale Member. Both taxa first occur in early Virgilian strata in the northern midcontinent and the Glass Mountains. This level also approximates the South Bend–Iatan interval of the northern midcontinent based on fusulinids (Ross, 1965, p. 1,160).

Boardman et al. (1989b) presented ammonoid evidence that further supports recorrelation of the Missourian-Virgilian boundary to a position substantially below the Canyon-Cisco boundary. They reported *Emilites incertus*, *?Aktubites stainbrooki* (herein referred to as *Pseudaktubites stainbrooki*), *Neopronorites*, and *Vidrioceras conlini* from the base of the Colony Creek Shale Member (upper Canyon Group) of north-central Texas. Significantly, both *Pseudaktubites stainbrooki* and *V. conlini* have been recovered in lower Virgilian strata in Kansas (basal Robbins Shale Member; fig. 5). *Emilites incertus* has been found only in definitively Virgilian strata in the Glass Mountains. *Neopronorites* has been found only in Virgilian and younger strata in the Glass Mountains and in Gzhelian equivalents in the southern Urals. In addition, undescribed crinoids from the Colony Creek Shale Member have been tentatively identified as early Virgilian taxa by Roger K. Pabian (personal communication, 1985). For the purposes of this bulletin, we follow Ross (1965) in recognizing the upper part of the Placid Shale Member as the correlated position of the Missourian-Virgilian boundary in north-central Texas (fig. 11).

Base of the Permian System (Asselian Stage)

Originally, the upper boundary of the Virgilian Stage (correlated base of the Permian System) was placed by Moore (1936) at a perceived major unconformity just above the Brownville Limestone Member. Moore, however, did not demonstrate a faunal change immediately above and below the boundary. Because of the previous lack of a consistent faunal definition in the type Permian area of the former Soviet Union, North American fusulinid workers have correlated the Carboniferous-Permian (Pennsylvanian-Permian) boundary at a number of different stratigraphic levels. Most fusulinid workers place the correlated level of the Pennsylvanian-Permian boundary at the first appearance of *Schwagerina* (Kozur, 1979, p. 579). In the northern midcontinent the first appearance of *Schwagerina* would correspond to a position some 200 ft (60 m) higher than the

Figure 5 (facing page). Stratigraphic distribution of ammonoid faunas in Virgilian strata of the northern midcontinent (exclusive of Oklahoma). Lithostratigraphic nomenclature used in this figure for the northern midcontinent area exclusive of Oklahoma is based largely on Zeller et al. (1968). NMC V1–V16 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules. The upper limestone in the upper Stanton Limestone (= South Bend interval) is observed only in Nebraska.


VIRGILIAN STAGE
SHAWNEE GROUP
DOUGLAS GROUP
TOPEKA LS
COAL CREEK LS
HOLT SH
DUBOIS LS
TURNER CREEK SH
SHELDON LS
JONES POINT SH
CURZON LS
IOWA POINT SH
HARTFORD LS
NMC V7 A,P
CALHOUN SH
DEER CREEK LS
ERVINE CREEK LS
LARSH-BURROAK SH
ROCK BLUFF LS
OSKALOOSA SH
OZAWKIE LS
NMC V6 A,P
TECUMSEH SH
OST LS
LECOMPTON LS
AVOCA LS
KING HILL SH
BEIL LS
QUEEN HILL SH
BIG SPRINGS LS
DONIPHAN SH
SPRING BRANCH LS
NMC V5 A,P
KANWAKA SH
STULL SH
CLAY CREEK LS
JACKSON PARK SH
OREAD LS
KEREFORD LS
HEUMANDER SH
PLATTSMOUTH LS
HEEBNER SH
LEAVENWORTH LS
SYNDERVILLE SH
TORONTO LS
NMC V4 A,P
LAWRENCE FM
AMAZONIA LS
ROBBINS SH
HASKELL LS
NMC V3 A,P
STRANGER FM
VINLAND SH
WESTPHALIA LS
TONGANOXIS SS
IATAN LS
NMC V2 A
WESTON SH
upper SOUTH BEND ls (NEBRASKA) only
NMC V1 A,P
SOUTH BEND LS =upper STANTON
NMC V0 A
VIRGILIAN STAGE (UPPER PART)
WABAUNSEE GROUP
WOODSIDING FM
BROWNVILLE LS
PONY CREEK SH
GRAYHORSE LS
PLUMB SH
NEBRASKA CITY LS
NMC V16 A
ROOT FM
FRENCH CREEK SH
JIM CREEK LS
FRIEDRICH SH
NMC V15 A
STOTLER LS
GRANDHAVEN LS
DRY SH
DOVER LS
NMC V14 A
NMC V13 A
PILLSBURY SH
ZEANDALE LS
MAPLE HILL LS
WAMEGO SH
TARKIO LS
NMC V12 A
WILLARD SH
NMC V11 A
EMPORIA LS
ELMONT LS
HARVEYVILLE SH
READING LS
NMC V10 A
AUBURN SH
BERN LS
WAKARUSA LS
SOLDIER CREEK SH
BURLINGAME LS
SCRANTON FM
SILVER LAKE SH
RULO LS
CEDAR VALE SH
HAPPY HOLLOW LS
WHITE CLOUD SH
NMC V9 A
HOWARD LS
UTOPIA LS
WINZLER SH
CHURCH LS
AARDE SH
NODAWAY coal
BACHELOR CREEK LS
NMC V8 A,P
SEVERY SH

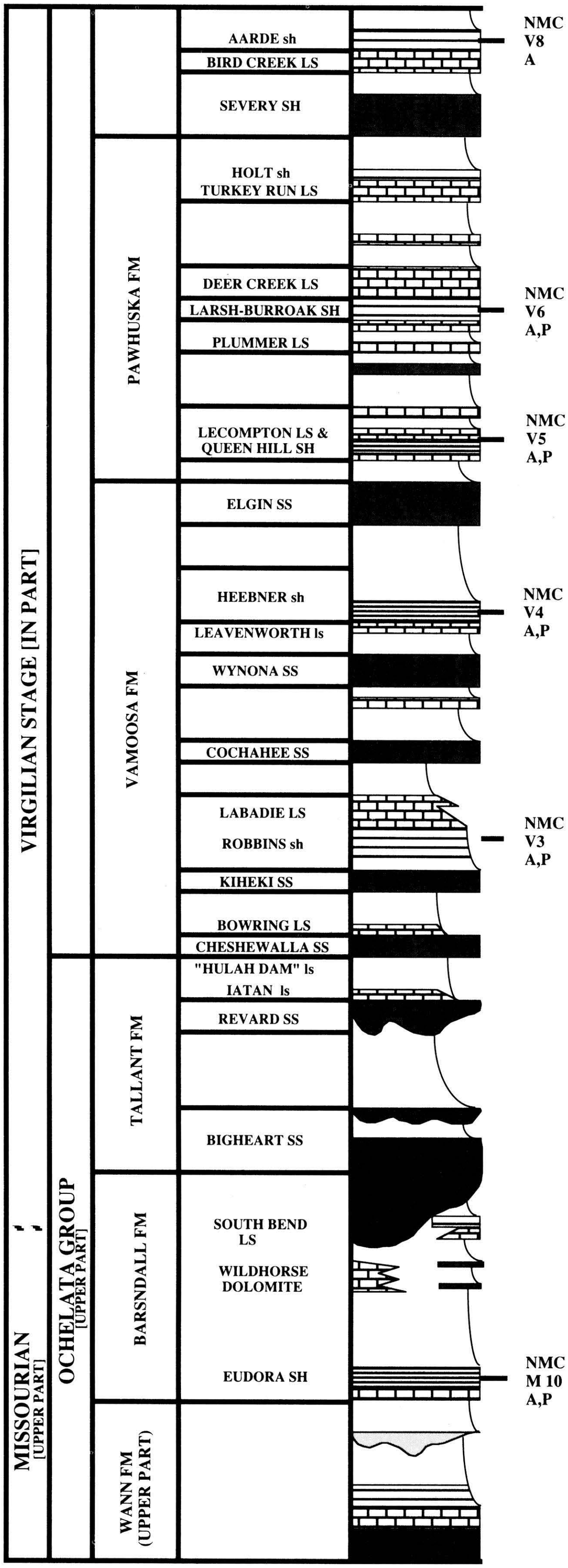
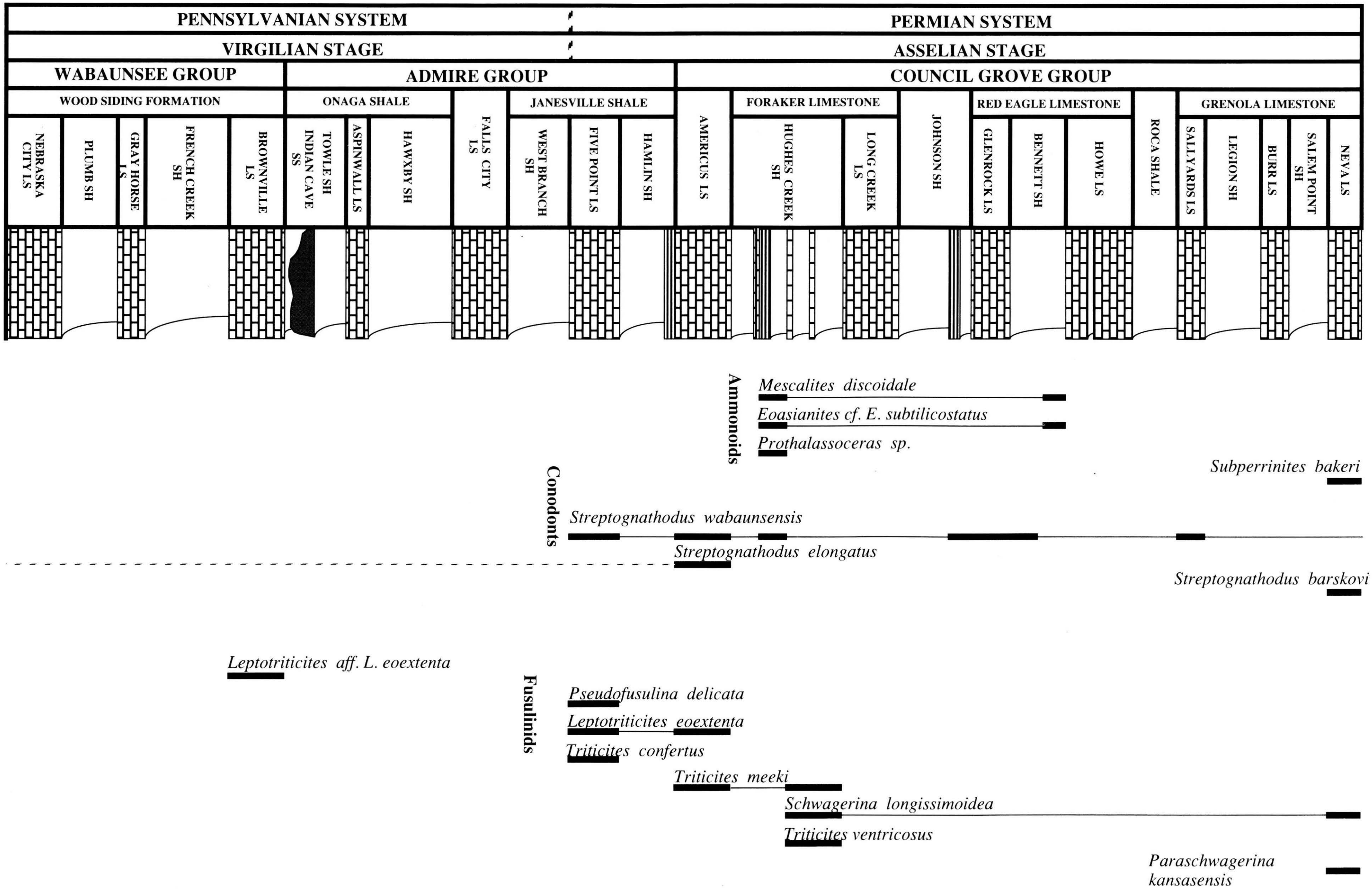


Figure 6. Stratigraphic distribution of ammonoid faunas in Virgilian strata of the northern midcontinent (Oklahoma). Lithostratigraphic nomenclature used in this figure for the Virgilian strata in Oklahoma is based on accepted stratigraphic nomenclature by the Oklahoma Geological Survey with the exception of the placement of the Missourian-Virgilian boundary and the correlation of the Wann and Barnsdall Formations. The previous Missourian-Virgilian boundary was placed at the base of the Cheshewalla Sandstone Member, which was thought to be contiguous with the Tonganoxie Sandstone Member of southern Kansas. The Tonganoxie marked the base of the Virgilian until O'Connor's (1963) downward revision of the Missourian-Virgilian boundary. The Oklahoma Geological Survey has not officially recognized this boundary revision in subsequent stratigraphic columns. As discussed in this bulletin, the base of the South Bend Limestone Member is used to mark the provisional base of the Virgilian in all regions of the northern midcontinent. Previous correlations placed the Birch Creek Limestone Member in the same stratigraphic position with the South Bend Limestone Member. We have subsequently identified the Birch Creek in its type area and instead correlate this limestone with the upper part of the Wann Formation in its type area. As a result of this recorrelation, the upper part of the type Wann Formation is regarded as being physically contiguous with the lower Stanton (= Captain Creek Limestone, Eudora Shale, and Stoner Limestone Members of Kansas) and as being in the same stratigraphic position as most of the type Barnsdall Formation. Therefore the upper part of the Wann Formation is shown on this diagram as the Barnsdall Formation. Formal resolution of this problem, however, lies with the Oklahoma Geological Survey. NMC V1–V8 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules.

Figure 7 (facing page). Stratigraphic distribution of ammonoid, fusulinid, and conodont faunas in the Carboniferous-Permian boundary strata in the northern midcontinent. Lithostratigraphic nomenclature is based on accepted stratigraphic nomenclature by the Kansas Geological Survey (Zeller et al., 1968). The Gearyian Stage, however, is not used because we prefer to use the Asselian Stage defined in the former Soviet Union. Fusulinid data are based on reports by Thompson (1954) and Douglass (1963). Conodont data are based on reports by Gunnell (1933), Perlmutter (1975), and Movschovitch et al. (1979). Ammonoid data are based on reports by Gordon (1963), Furnish and Glenister (1971), and Holterhoff and Pabian (1989).


PENNSYLVANIAN SYSTEM
PERMIAN SYSTEM
VIRGILIAN STAGE
ASSELIAN STAGE
WABAUNSEE GROUP
ADMIRE GROUP
COUNCIL GROVE GROUP
WOOD SIDING FORMATION
ONAGA SHALE
JANESVILLE SHALE
FORAKER LIMESTONE
RED EAGLE LIMESTONE
GRENOLA LIMESTONE
NEBRASKA CITY LS
PLUMB SH
GRAY HORSE LS
FRENCH CREEK SH
BROWNVILLE LS
TOWLE SH INDIAN CAVE SS
ASPINWALL LS
HAWXBY SH
FALLS CITY LS
WEST BRANCH SH
FIVE POINT LS
HAMLIN SH
AMERICUS LS
HUGHES CREEK SH
LONG CREEK LS
JOHNSON SH
GLENROCK LS
BENNETT SH
HOWE LS
ROCA SHALE
SALLYARDS LS
LEGION SH
BURR LS
SALEM POINT SH
NEVA LS
Ammonoids
Mescalites discoidale
Eoasianites cf. E. subtilicostatus
Prothalassoceras sp.
Subperrinites bakeri
Conodonts
Streptognathodus wabaunsensis
Streptognathodus elongatus
Streptognathodus barskovi
Leptotriticites aff. L. eoextenta
Fusulinids
Pseudofusulina delicata
Leptotriticites eoextenta
Triticites confertus
Triticites meeki
Schwagerina longissimoidea
Triticites ventricosus
Paraschwagerina kansasensis

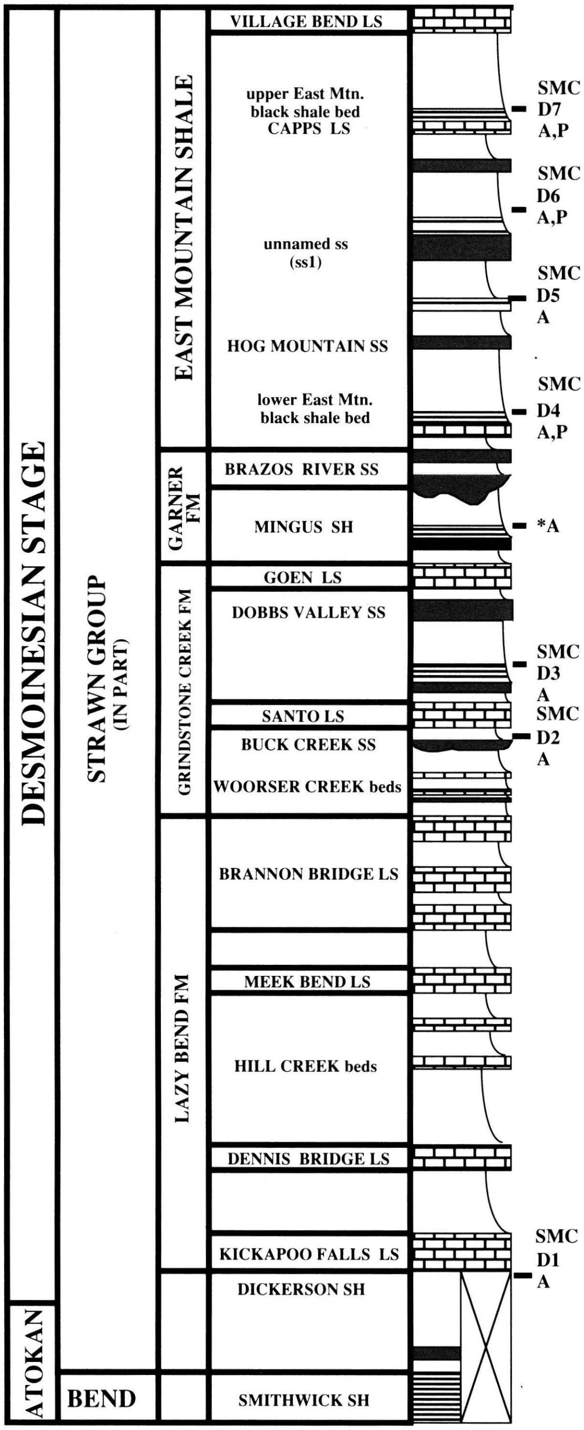


Figure 8. Stratigraphic distribution of ammonoid faunas in Desmoinesian strata of the Brazos River valley in north-central Texas. Lithostratigraphic nomenclature is based largely on Plummer and Moore (1922). SMC D1–D7 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules; an asterisk indicates unidentifiable ammonoid protoconches.

Brownville Limestone Member, in the Hughes Creek Shale Member (fig. 7; Thompson, 1954, p. 14). Although the stratigraphic interval from the top of the Brownville Limestone Member to the base of the Hughes Creek Shale Member does not contain *Schwagerina*, Thompson (1954) retained Moore's boundary because he correlated this interval to other early Wolfcampian units bearing *Schwagerina* based on advanced species of *Triticites* and *Dunbarinella*.

Other workers place the level of the Permian-Pennsylvanian boundary at the first appearance of *Pseudofusulina* (a genus closely related to *Schwagerina*). The first appearance of *Pseudofusulina* in the northern midcontinent occurs in the Five Point Limestone Member, which occurs in the upper part of the Admire Group (fig. 7; Douglass, 1963). Wilde (1971) recommended placing the Pennsylvanian-Permian boundary even lower, at a position corresponding to the appearance of *Leptotriticites*, which first occurs in the Brownville Limestone Member (fig. 5; Douglass, 1963). Still other workers have advocated moving the Permian-Pennsylvanian boundary upward to a position corresponding to the first occurrence of *Pseudoschwagerina* (Ross, 1963, p. 43). In the northern midcontinent *Pseudoschwagerina* first appears in the Florence Limestone Member (not illustrated).

Historically, the base of the Asselian Stage has been placed at the top of the Orenburgian Stage, which corresponds to the base of the *Sphaeroschwagerina fusiformis–S. vulgaris* Zone. The *S. fusiformis–S. vulgaris* Zone occurs in the lower part of the Sokolyegorsky Horizon. This zone is further distinguished by the appearance of *Occidentoschwagerina*, which is thought to represent the root stock of *Pseudoschwagerina*. Neither the nominate taxa of the *S. fusiformis–S. vulgaris* Zone nor *Occidentoschwagerina* has been reported from the continental United States.

The official base of the Asselian Stage (basal Permian) was recently lowered to correspond to the base of the *Daixina bosbytauensis–D. robusta* Zone (Bogoslovskaya and Popov, 1986). A potential Carboniferous-Permian boundary stratotype section (Samara Luka) with appropriate paleontologic documentation was proposed by Muravyev et al. (1984). This newly proposed Carboniferous-Permian boundary level was accepted as a result of decisions made at a plenary session of the Interdepartmental Stratigraphic Committee (ISC) Commission on the Carboniferous and Permian Systems in the USSR in 1984. In an apparent reversal of this decision lowering the base of the Permian, the Commission on the Permian System of the ISC of the USSR passed a resolution on June 12, 1990, placing the Carboniferous-Permian boundary at the level corresponding to the changeover from the *Shumardites-Vidrioceras* Zone to the *Svetlanoceras-Juresanites* ammonoid genozone (Davydov et al., 1990). With this decision the base of the Asselian once more coincides with the base of the *S. fusiformis–S. vulgaris* fusulinid zone.

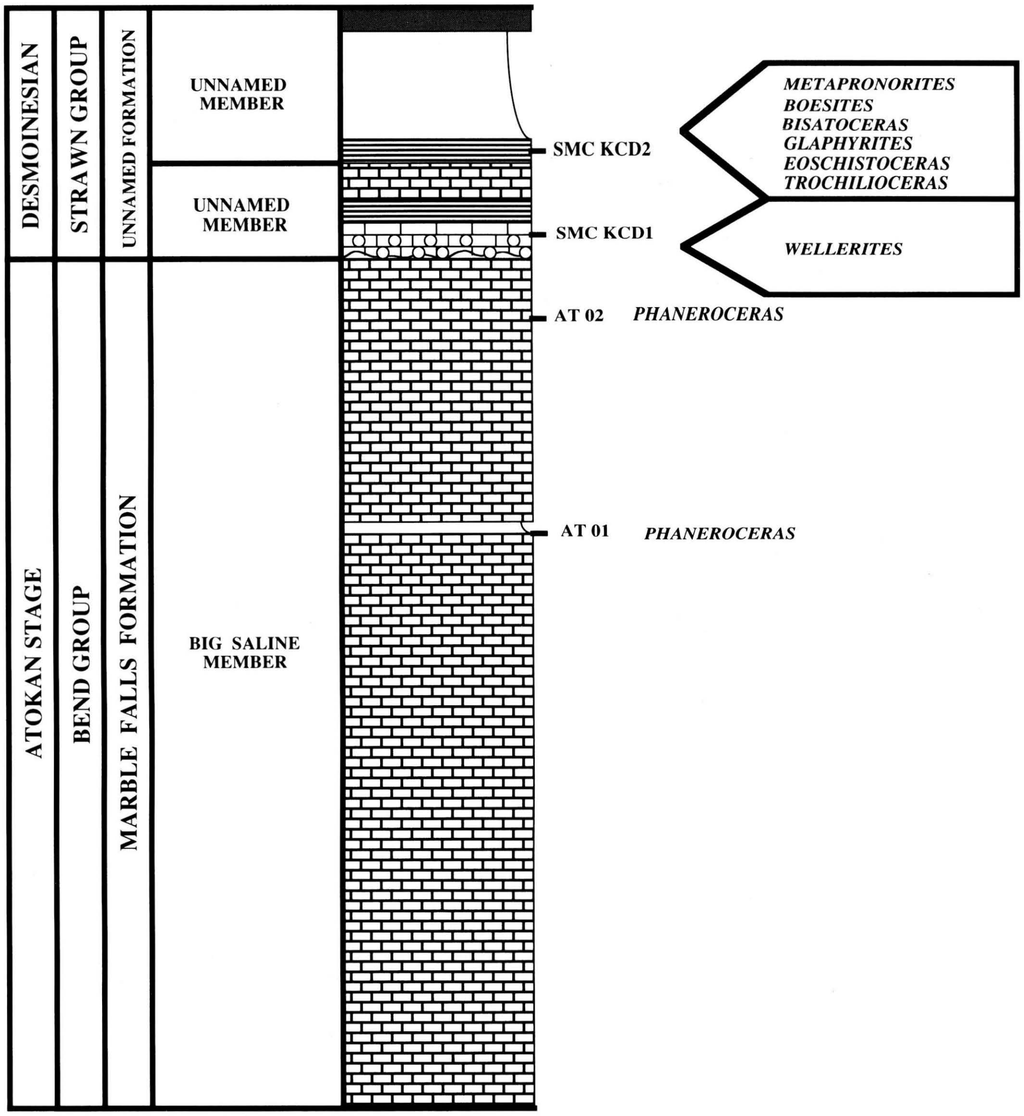
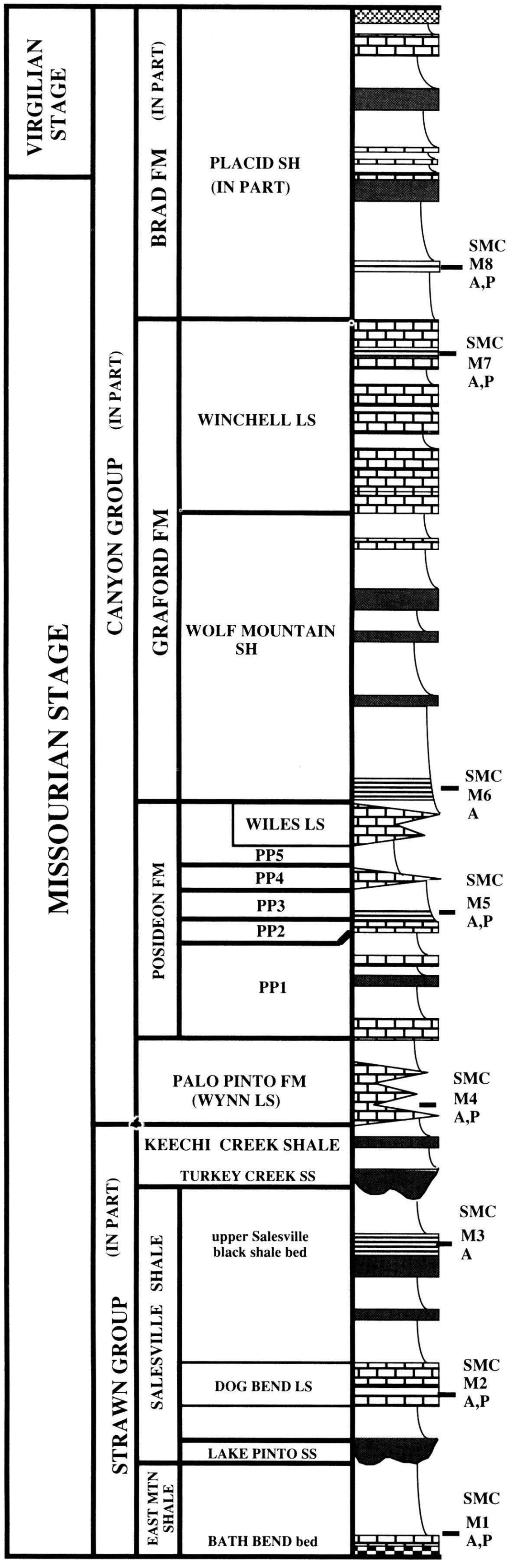


Figure 9. Stratigraphic distribution of ammonoid faunas in Desmoinesian strata of the Llano uplift region in Kimble County, Texas. The lithostratigraphic nomenclature used in this figure reflects informal usage based largely on the findings of Plummer (1945). SMC KC D1 and D2 are ammonoid-bearing intervals.

Some workers [e.g., Ross (1963)] still advocate placement of the base of the Asselian at the base of the *Sphaeroschwagerina moelleri–Schwagerina fecunda* Zone (near the top of the Asselian, as currently used). In addition to the nominate taxa, this zone marks the first appearances of inflated schwagerinids, including both *Paraschwagerina* and *Pseudoschwagerina*, and the appearance of the ammonoid *Juresanites*. Neither *Sphaeroschwagerina moelleri* nor *Schwagerina fecunda* has been reported in North America. However, the genera *Paraschwagerina* and *Pseudoschwagerina* are abundant in North America, although they do not necessarily appear at the same stratigraphic level. For example, in the northern midcontinent *Paraschwagerina* appears in the Neva Limestone Member, whereas *Pseudoschwagerina* first appears substantially higher in the Florence Limestone Member (fig. 7).

The highly endemic nature of late Carboniferous and Early Permian fusulinid faunas has been well documented by Ross (1979). Ross placed the late Carboniferous–Early Permian strata of the continental United States in the midcontinent province and the Canadian Arctic, the former Soviet Union, and Asia in the Eurasian-Arctic province. Nevertheless, fusulinid workers have offered detailed correlations between the two regions, based largely on the



presumed evolutionary equivalence of counterpart species and genera. Such practices have led to highly contradictory correlations. Wilde (1971) places the entire Gzhelian and upper part of the Kasimovian within the Permian, whereas Ross and Ross (1987) correlate the upper part of the Kasimovian with basal Virgilian strata and place the entire Gzhelian within the uppermost Carboniferous. A refined interregional biostratigraphic correlation of late Carboniferous and Early Permian strata based on fusulinid faunas between the former Soviet Union and the North American midcontinent probably will never be attainable. However, analysis of North American and Soviet late Carboniferous and Early Permian conodont faunas suggests that morphotypic species of *Idiognathodus* and *Streptognathodus* are probably cosmopolitan in distribution, potentially allowing a highly refined biostratigraphic correlation (Barrick and Boardman, 1989; Barskov and Alekseev, 1976; Barskov et al., 1981, 1987; Chernykh and Resthetkova, 1987; Kosenko, 1975; Kozitskaya et al., 1978).

The base of the *Daixina bosbytauensis–D. robusta* Zone in the former Soviet Union lies within the Noginsky Horizon and has been characterized by the upper part of the range of the conodonts *Streptognathodus elongatus* and *S. simplex* occurring below *S. wabaunsensis* (Movschovitsch et al., 1979). However, Akhmetshina et al. (1984) reported *S. wabaunsensis* from strata containing the *D. bosbytauensis–D. robusta* Zone. The appearance of *S. wabaunsensis* represents a significant event in conodont evolution that has been reported at apparently similar stratigraphic levels throughout the world. The first appearance of *S. wabaunsensis* in the North American midcontinent occurs in the Five Point Limestone Member (Perl'mutter, 1975), a level that also marks the first midcontinent appearance of *Pseudofusulina* (fig. 7). This stratigraphic level is not favored by most Soviet ammonoid workers because it dissects strata containing the Orenburgian ammonoid fauna, resulting in the upper part of the *Shumardites* Zone being assigned to the basal Asselian (Bogoslovskaya and Popov, 1986). The stratigraphic level corresponding to the appearance of the conodont *S. wabaunsensis* is characterized only by the appearance of *Vidrioceras borissiaki*.

According to Davydov et al. (1990) the appearance of *Streptognathodus flangulatus* and *S. asselicus* approximates the base of the *Sphaeroschwagerina vulgaris–S. fusiformis* Zone. A changeover in ammonoid faunas, in-

Figure 10. Stratigraphic distribution of ammonoid faunas in Missourian strata of north-central Texas. The lithostratigraphic nomenclature used in this figure is based on several works, including but not limited to Plummer and Moore (1922), Lee et al. (1938), Cheney (1940), and Laury (1982). SMC M1–M8 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules.

cluding the extinctions of *Uddenites*, *Uddenoceras*, *Prouddenites*, *Vidrioceras*, *Marathonites*, and *Shumardites* in conjunction with the first appearance of *Prostacheoceras*, *Svetlanoceras*, and *Artinskia kazakhstanica*, occurs at the same stratigraphic level (Bogoslovskaya and Popov, 1986). Accordingly, both Bogoslovskaya and Davydov (personal communications, 1990) have argued that this level should be used as the base of the Asselian Stage.

Other workers have proposed that the base of the Asselian Stage be placed stratigraphically higher, at the base of the *Streptognathodus barskovi* Zone, which occurs within strata marked by the upper part of the *Sphaeroschwagerina vulgaris–S. fusiformis* Zone and just below the stratigraphic level that approximates the base of the *Sphaeroschwagerina moelleri–Schwagerina fecunda* fusulinid zone (Davydov et al., 1990). *S. barskovi* has an apparently cosmopolitan distribution and has been documented in both North America and the former Soviet Union (Movschovitch et al., 1979). The first documented *S. barskovi* occurs in the Neva Limestone Member of the northern midcontinent in association with *Paraschwagerina*, based on the data of Movschovitch et al. (1979) and Thompson (1954).

It is our position that the base of the Five Point Limestone Member, which contains the appearances of *Streptognathodus wabaunsensis* and *Pseudofusulina*, be used as the provisional base of the Asselian boundary in the midcontinent until a formal boundary stratotype is selected in the former Soviet Union. However, it seems highly probable that a higher level will ultimately be adopted.

In north-central Texas various positions for the Pennsylvanian-Permian boundary have been proposed. The Waldrip 1, Waldrip 3, and Gouldbusk limestones have all been suggested as possible levels based on the first appearances of *Leptotriticites*, *Schwagerina*, and *Pseudoschwagerina*, respectively. We consider the base of the Waldrip 3 limestone (which is probably correlative with the Five Point Limestone Member of Kansas) to be the tentative level of the base of the Wolfcampian Stage (Asselian) in north-central Texas.

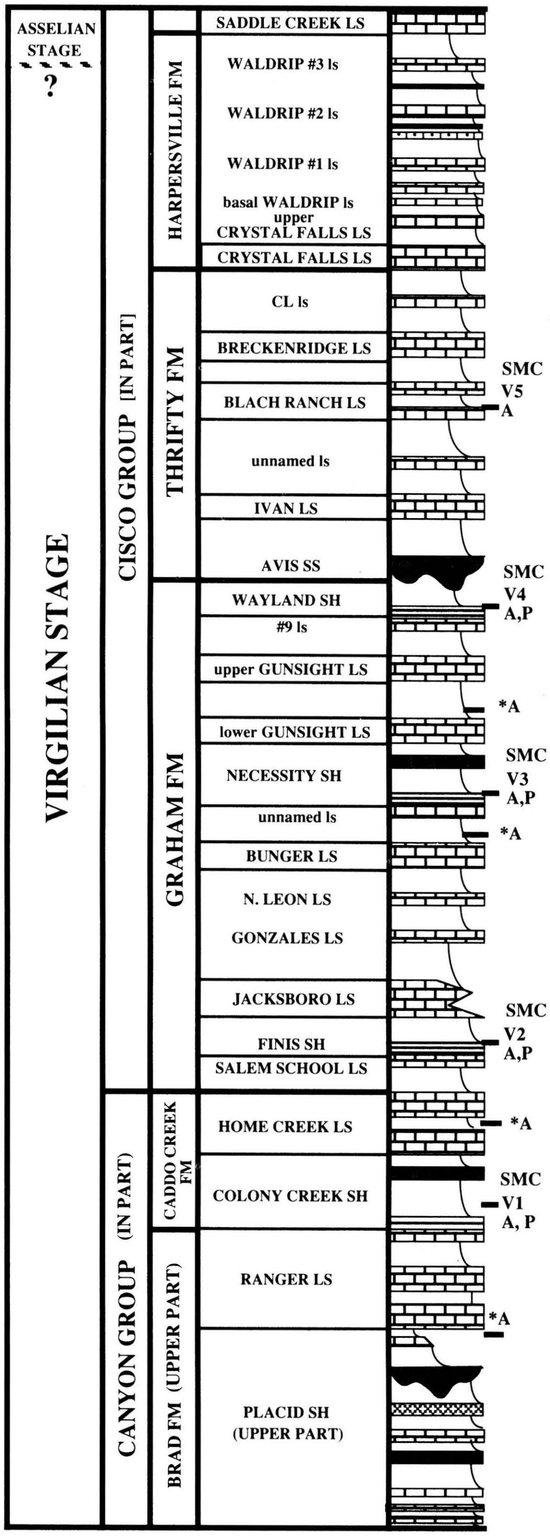


Figure 11. Stratigraphic distribution of ammonoid faunas in Virgilian strata of north-central Texas. Lithostratigraphic nomenclature is based on a combination of several works, including Plummer and Moore (1922), Lee et al. (1938), Brown (1960, 1962), and Laury (1982). SMC V1–V5 are ammonoid-bearing intervals. A = ammonoid occurrences; P = phosphate nodules. An asterisk indicates unidentifiable ammonoid protoconches.

Midcontinent Desmoinesian–Virgilian ammonoid faunas

The distribution of ammonoid genera in the northern and southern midcontinent regions is summarized on two range charts (figs. 14 and 15) for Desmoinesian–Virgilian strata. The synonymy showing placement of ammonoid species within specific genera is presented in appendix 1. Examples of many of these taxa are illustrated in plates 1–5. On range charts the stratigraphic range of each genus is shown as a heavy line that is keyed by an interval number to charts showing the actual occurrences in different geographic regions (figs. 2–13). Within each midcontinent region the interval number implies correlation with all stratigraphic levels having the same number (e.g., the Arkoma Basin NMC D5 ammonoid-bearing horizon corresponds with northern shelf NMC D5 ammonoid-bearing horizon in the northern midcontinent). However, northern midcontinent ammonoid-bearing horizon numbers do not necessarily correspond with the same number in the southern midcontinent region (north-central Texas) (e.g., horizon NMC D5 of the northern midcontinent does not necessarily entail a correlation with horizon SMC D5 from the southern midcontinent). This discrepancy derives at least in part from paleogeography: The northern midcontinent ammonoid succession is more complete (i.e., there are more ammonoid-bearing horizons) because its outcrop belt is situated in a geographic area corresponding to the middle to outer shelf region of the Middle and Late Pennsylvanian seaway; by contrast, the southern midcontinent outcrop belt is situated in a geographic area corresponding to the Pennsylvanian middle to inner shelf. Pennsylvanian ammonoids were evidently much more abundant in the offshore middle to outer shelf region than in the middle to inner shelf (Boardman et al., 1984). The composite Desmoinesian–Virgilian ammonoid generic-level range chart (fig. 16) utilizes data from both regions of the midcontinent. Where ranges from the midcontinent have been extended using information from other geographic areas, the range extensions are signified by dashed lines (see caption to fig. 16).

Localities used in this study are documented in appendix 2. In addition, specific occurrences of ammonoids obtained from previous workers and utilized in this bulletin are listed in appendix 3.

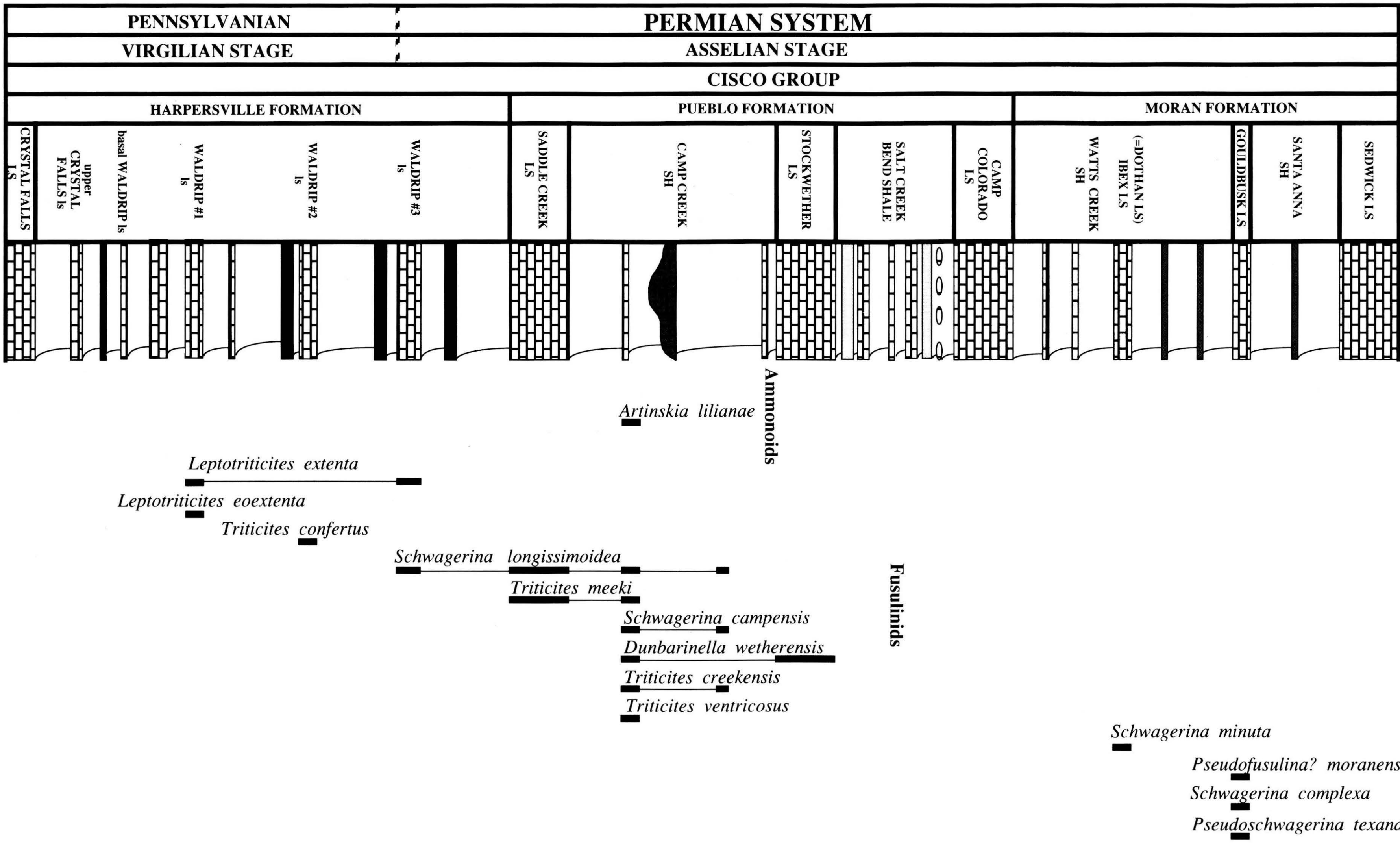
The Middle and Upper Pennsylvanian stages are subdivided into informal subdivisions for purposes of collective discussion of ammonoid faunas. These informal stage subdivisions are correlated within the various areas of the midcontinent on the basis of fusulinids. The Desmoinesian Stage is subdivided into lower, middle, and upper Desmoinesian, corresponding to the Krebs Subgroup (Cherokee Group), the Cabaniss Subgroup (Cherokee Group), and the Marmaton Group, respectively. The Missourian Stage consists of the lower, middle, and upper Missourian, corresponding to the Pleasanton-Bronson interval, the Linn-Zarah subgroups, and the lower part of the Lansing Group, respectively. The Virgilian Stage is subdivided into lower, middle, and upper Virgilian, corresponding to the uppermost part of the Lansing-Douglas Groups, the Shawnee Group, and the Wabaunsee Group, respectively.

Desmoinesian ammonoid faunas

Considered collectively, early Desmoinesian ammonoid faunas are similar to late Atokan faunas in that both are characterized by the association of *Paralegoceras* and *Gastrioceras* (figs. 2 and 14, horizons NMC D1–D4; fig. 3, horizons NMC OKARD D1–D3). Atokan faunas, however, are generally characterized by *Eowellerites* and *Phaneroceras,* whereas Desmoinesian faunas are generally characterized by *Wellerites* and *Pseudoparalegoceras.* However, it should be noted that Miller and Furnish (1958) reported the first appearance of *Pseudoparalegoceras* in the Atokan part of the Magdalena Formation of the Sierra Diablo Mountains of West Texas (not illustrated). Moreover, Unklesbay (1962) reported *Phaneroceras williamsi* (as *Pseudoparalegoceras*) from the Desmoinesian Frensley Limestone Member of the Ardmore Basin (fig. 3, horizon NMC OKARD D1). The occurrences of an Atokan *Pseudoparalegoceras* and a Desmoinesian *Phaneroceras* raise doubt concerning their use as generic-level biostratigraphic indicators. Early Desmoinesian faunas are characterized by the appearance of *Wellerites* (fig. 3, horizon NMC OKARD D2; fig. 9, SMC KC D1), *Pseudoparalegoceras brazoense* (figs. 2 and 14, horizon NMC D2; fig. 3, horizon NMC OKARD D3; figs. 8 and 15, horizon SMC D1), *Eoschistoceras* (fig. 3, horizon NMC OKARD D3), and *Aktubites* (fig. 3, horizon NMC OKARD D2).

The unnamed black shale above the Doneley Limestone Member of the Arkoma-McAlester Basin has yielded only a single specimen of *Gastrioceras* (fig. 14, horizon NMC D1). The faunas from the lower Boggy Formation of the Arkoma-McAlester Basin (fig. 14, horizon NMC D2; appendix 2, localities OKD–53 and OKD–54) and the Devil's

Figure 12 (facing page). Stratigraphic distribution of ammonoid and fusulinid faunas in Carboniferous-Permian boundary strata of north-central Texas. Lithostratigraphic nomenclature used in this figure for the Virgilian strata of north-central Texas is based on a combination of several works, including Plummer and Moore (1922), Lee et al.(1938), and Brown (1960, 1962). Fusulinid data are based on Thompson (1954). Ammonoid data are based on Miller and Youngquist (1947).


PENNSYLVANIAN
PERMIAN SYSTEM
VIRGILIAN STAGE
ASSELIAN STAGE
CISCO GROUP
HARPERSVILLE FORMATION
PUEBLO FORMATION
MORAN FORMATION
CRYSTAL FALLS LS
upper CRYSTAL FALLS ls
basal WALDRIP ls
WALDRIP #1 ls
WALDRIP #2 ls
WALDRIP #3 ls
SADDLE CREEK LS
CAMP CREEK SH
STOCKWETHER LS
SALT CREEK BEND SHALE
CAMP COLORADO LS
WATTS CREEK SH
IBEX LS (=DOTHAN LS)
GOULDBUSK LS
SANTA ANNA SH
SEDWICK LS
Ammonoids
Artinskia lilianae
Fusulinids
Leptotriticites extenta
Leptotriticites eoextenta
Triticites confertus
Schwagerina longissimoidea
Triticites meeki
Schwagerina campensis
Dunbarinella wetherensis
Triticites creekensis
Triticites ventricosus
Schwagerina minuta
Pseudofusulina? moranensis
Schwagerina complexa
Pseudoschwagerina texana

Kitchen member (Deese Formation) of the eastern Ardmore Basin (fig. 3, horizon NMC OKARD D2; appendix 2, locality OKARD D1) are diverse and appear to represent a single fauna that includes representatives of *Gastrioceras*, *Bisatoceras*, *Wellerites*, *Paralegoceras*, *Wiedeyoceras*, *Politoceras*, *Aktubites*, and *Pseudoparalegoceras*. The Buckhorn Asphalt of the northern end of the Arbuckle Mountains (western part of the Mill Creek Syncline; fig. 3, horizon NMC OKARD D3; appendix 2, locality OKARD D2), which has been correlated with the upper part of the Boggy Formation on the basis of fusulinids (Ham, 1955, p. 46), contains *Gastrioceras*, *Gonioloboceras*, *Paralegoceras*, *Metapronorites*, *Pseudoparalegoceras*, *Wellerites*, and *Eoschistoceras*.

Early Desmoinesian ammonoids from the Brazos River valley in north-central Texas are known only from the Dickerson Shale. This unit contains only *Pseudoparalegoceras* and *Glaphyrites* (fig. 15, horizon SMC D1).

Undifferentiated early Desmoinesian strata exposed in the extreme western end of the Llano Uplift (Kimble County), Texas, have yielded only *Wellerites* and represent the type locality for this important index taxon (fig. 9, SMC KC D1). This locality (UT 134–T–5; appendix 2, locality TXD–10) was originally described as the ?Barnett Formation (Mississippian) by Plummer and Scott (1937, p. 407) and more recently as the Marble Falls Limestone (Barnes, 1981). However, Grayson and Merrill (1987) discovered the Desmoinesian fusulinid *Wedekindellina* in apparently correlative beds 1 mi (1.6 km) to the northeast (UT–134–T–2; appendix 2, locality TXD–12). These early Desmoinesian strata unconformably overlie limestones that constitute the type section of the Big Saline member of the Marble Falls Limestone (Atokan) (UT–134–T–2) and presumably overlie coeval deposits at locality UT–134–T–1. We have collected three ammonoid-bearing horizons in the same vicinity (fig. 9) that range in age from late Atokan to middle Desmoinesian. Because no specimens of *Wellerites* have been obtained in situ in the area, the horizon in which *Wellerites* occurs remains uncertain.

Middle Desmoinesian ammonoid faunas differ somewhat from early Desmoinesian ammonoid faunas, reflecting a moderate faunal changeover (figs. 2 and 14, horizons NMC D5–D8; figs. 8 and 15, horizon SMC D2; fig. 9, horizon SMC KC D2). Within the North American midcontinent *Paralegoceras*, *Aktubites*, and *Pseudoparalegoceras* apparently became extinct by middle Desmoinesian time and *Politoceras politum* became exceedingly abundant, as did *Goniolobeceratoides* and *Wiedeyoceras*. *Owenoceras* appeared near the end of middle Desmoinesian time (fig. 14, horizon NMC D8).

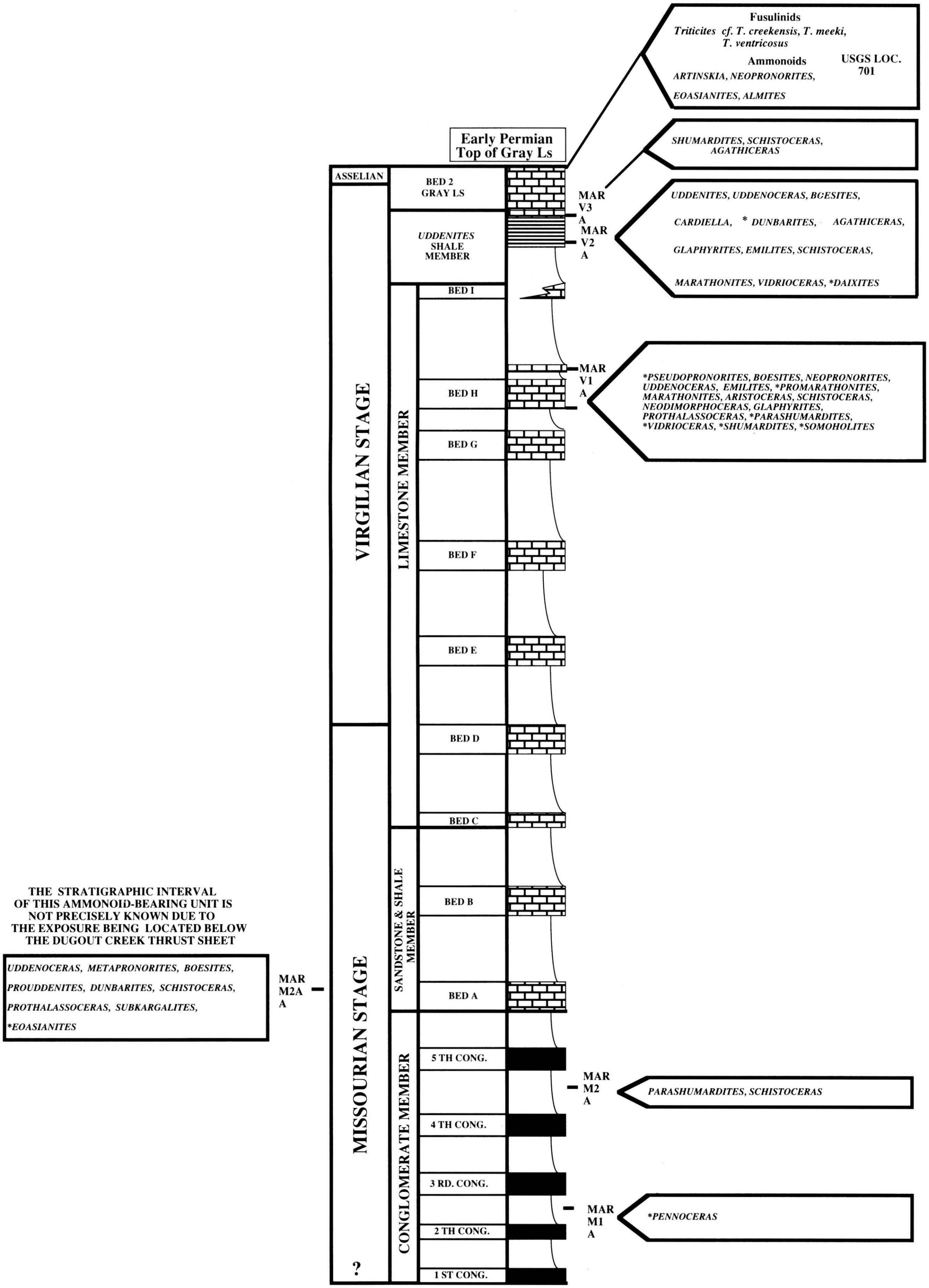
Middle Desmoinesian ammonoid faunas from the northern midcontinent are characterized by a moderately low diversity assemblage, including *Wiedeyoceras*, *Goniolobeceratoides*, *Bisatoceras*, *Maximites*, *Politoceras*, and *Glaphyrites* with sporadic occurrences of *Owenoceras* (fig. 14, horizons NMC D5–D8). The schistoceratid ammonoids *Wellerites* and *Eoschistoceras* have not been recovered from middle Desmoinesian strata in the northern midcontinent, but their absence may be due to unfavorable ecologic conditions because they are abundant in both lower and upper Desmoinesian strata in that region. *Eoschistoceras* is present in the Grindstone Creek Formation [= upper Millsap Lake Formation of Plummer and Scott (1937, 1938)] in north-central Texas (figs. 8 and 15, horizon SMC D2), a unit that we correlate with the middle Desmoinesian based on the presence of the fusulinid *Wedekindellina*.

Ammonoids have been reported from the northern shelf area of the northern midcontinent (fig. 2) by Miller and Owen (1939) in the Seville, Verdigris, and Excello formations [middle to upper Cherokee Group; from western Missouri as shales associated with the Jordan, Tebo (= Croweburg), and Mulky coals, respectively]. The Cherokee Group fauna includes representatives of *Glaphyrites*, *Politoceras*, *Wiedeyoceras*, *Owenoceras*, *Bisatoceras*, *Goniolobeceratoides*, and *Maximites*. In the Arkoma-McAlester Basin we have discovered middle Desmoinesian ammonoids in the Stuart Shale and several members of the Senora Formation (fig. 14, horizons NMC D5–D8). Except for the absence of *Owenoceras*, faunas in the Arkoma Basin are similar to those of the northern shelf.

Middle Desmoinesian ammonoids from the Brazos River valley in north-central Texas are poorly known and have been reported only from shale below the Santo Limestone Member of the Grindstone Creek Formation [= upper Millsap Lake Formation of Plummer and Scott (1937, 1938)]. The Grindstone Creek ammonoid fauna contains *Glaphyrites* and *Eoschistoceras* (fig. 15, horizon SMC D2). Ammonoids of probable middle Desmoinesian age are also present in the Colorado River valley in Kimble County (fig. 9, horizon SMC KC D2, locality UT–134–T–5; appendix 2, locality TXD–11;). The ammonoid-bearing shale was originally mapped as Smithwick (Atokan) and was later correlated with the Strawn Group (Desmoinesian) by Plummer (1945, p. 252) and more recently as ?Smithwick by Barnes (1981). Ammonoids from this interval include *Metapronorites*, *Boesites*, *Glaphyrites*, *Trochilioceras*, *Bisatoceras*, and *Eoschistoceras*.

Based largely on data from the Arkoma-McAlester Basin, late Desmoinesian ammonoid faunas contrast strongly

Figure 13 (facing page). Stratigraphic distribution of ammonoid faunas in Missourian, Virgilian, and basal Asselian strata of the Marathon Uplift region in West Texas. Lithostratigraphic nomenclature is based on Ross (1967). SMC MAR M1, M2, and M2A and SMC MAR V1 and V2 are ammonoid-bearing intervals; A = ammonoid occurrences; an asterisk indicates new report. Fusulinid data from USGS Locality 701 are based on Wilde (1977). Ammonoid data from USGS Locality 701 are based on Furnish and Glenister (1977).


Fusulinids
Triticites cf. T. creekensis, T. meeki, T. ventricosus
Ammonoids
ARTINSKIA, NEOPRONORITES, EOASIANITES, ALMITES
USGS LOC. 701
SHUMARDITES, SCHISTOCERAS, AGATHICERAS
UDDENITES, UDDENOCERAS, BOESITES, CARDIELLA, * DUNBARITES, AGATHICERAS, GLAPHYRITES, EMILITES, SCHISTOCERAS, MARATHONITES, VIDRIOCERAS, *DAIXITES
*PSEUDOPRONORITES, BOESITES, NEOPRONORITES, UDDENOCERAS, EMILITES, *PROMARATHONITES, MARATHONITES, ARISTOCERAS, SCHISTOCERAS, NEODIMORPHOCERAS, GLAPHYRITES, PROTHALASSOCERAS, *PARASHUMARDITES, *VIDRIOCERAS, *SHUMARDITES, *SOMOHOLITES
Early Permian
Top of Gray Ls
ASSELIAN
VIRGILIAN STAGE
MISSOURIAN STAGE
?
BED 2 GRAY LS
UDDENITES SHALE MEMBER
LIMESTONE MEMBER
SANDSTONE & SHALE MEMBER
CONGLOMERATE MEMBER
BED I
BED H
BED G
BED F
BED E
BED D
BED C
BED B
BED A
5 TH CONG.
4 TH CONG.
3 RD. CONG.
2 TH CONG.
1 ST CONG.
MAR V3 A
MAR V2 A
MAR V1 A
MAR M2 A
MAR M1 A
MAR M2A A
PARASHUMARDITES, SCHISTOCERAS
*PENNOCERAS
THE STRATIGRAPHIC INTERVAL OF THIS AMMONOID-BEARING UNIT IS NOT PRECISELY KNOWN DUE TO THE EXPOSURE BEING LOCATED BELOW THE DUGOUT CREEK THRUST SHEET
UDDENOCERAS, METAPRONORITES, BOESITES, PROUDDENITES, DUNBARITES, SCHISTOCERAS, PROTHALASSOCERAS, SUBKARGALITES, *EOASIANITES

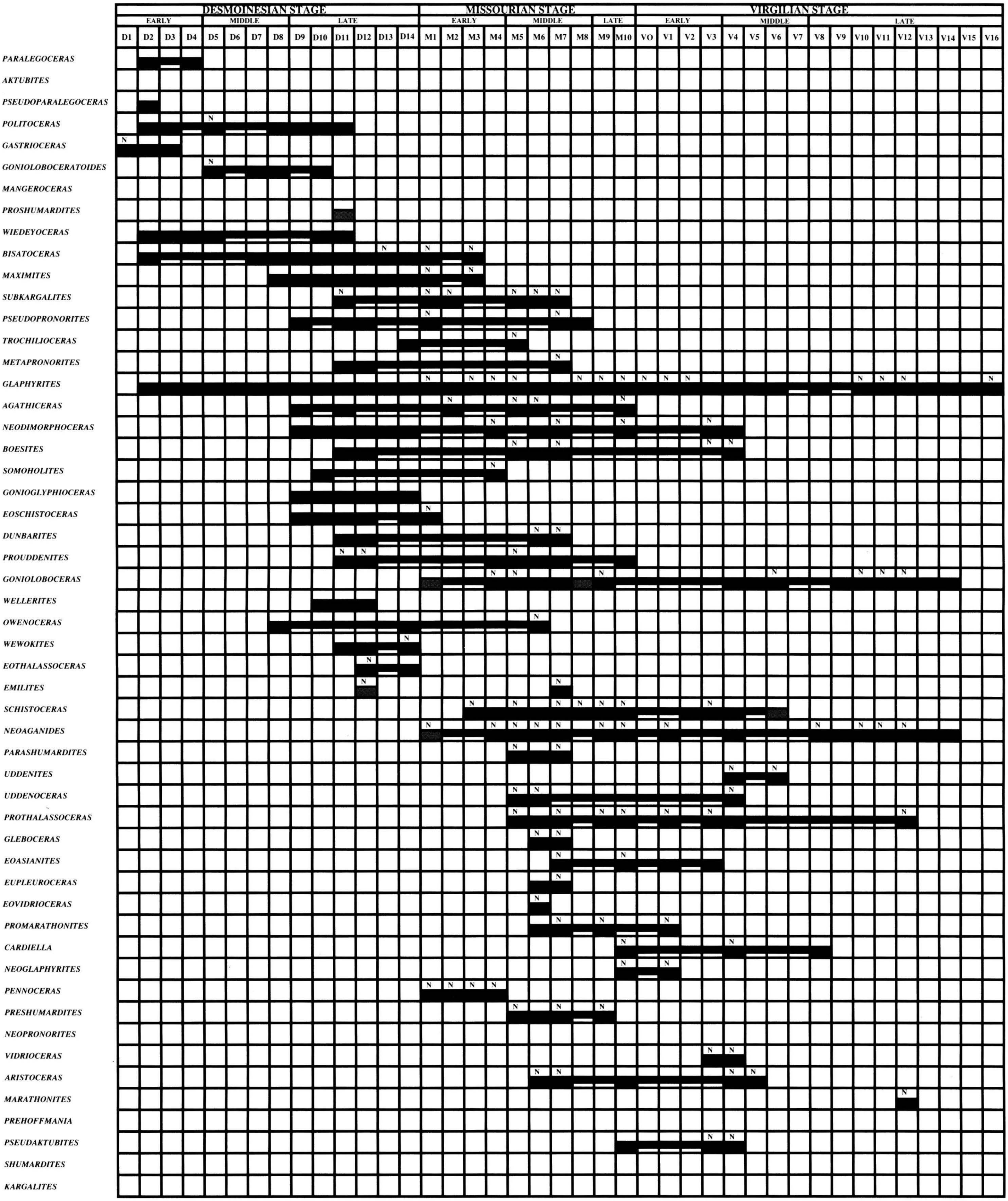


Figure 14. Generic-level ammonoid range chart for the northern midcontinent. This generic-level ammonoid range chart for the northern midcontinent is based on ammonoid occurrences illustrated in figs. 2, 4, 5, and 6. A solid bar indicates an actual occurrence; a half-bar indicates range through; a stippled bar indicates a questionable occurrence; N indicates a new reported occurrence.

with middle Desmoinesian faunas because of several extinctions, the appearance of new genera, and an overall increase in diversity (figs. 2 and 14, horizons NMC D9–14; figs. 8 and 15, horizons SMC D3–D7). *Goniolobоceratoides* and *Politoceras* are absent through apparent extinction in the lower part of the Marmaton Group (fig. 14, horizons NMC D10 and NMC D11, respectively). Critical new taxa appear in various members of the Marmaton Group: *Gonioglyphioceras* (fig. 14, horizon NMC D9); *Dunbarites*, *Prouddenites*, and *Wewokites* (fig. 14, horizon NMC D11); and *Eothalassoceras* (fig. 14, horizon NMC D12). Late Desmoinesian ammonoid faunas from the northern midcontinent are dominated by *Gonioglyphioceras*, *Bisatoceras*, *Neodimorphoceras*, *Wellerites*, *Eoschistoceras*, *Glaphyrites*, *Maximites*, and *Gonioglyphioceras* with sporadic occurrences of *Wiedeyoceras*, *Somoholites*, *Pseudopronorites*, *Metapronorites*, *Trochilioceras*, *Owenoceras*, *Wewokites*, *Boesites*, *Agathiceras*, and *Eothalassoceras* and rare early occurrences of *Subkargalites*, *Dunbarites*, *?Emilites*, and *Prouddenites* (fig. 14, horizons NMC D9–D14).

In the Arkoma Basin area of the northern midcontinent, late Desmoinesian ammonoids have been recovered from the Wetumka Shale, the Wewoka Formation (three members), and the Holdenville Formation (three members) (fig. 2, horizons NMC D9–D14). We have discovered a major new ammonoid fauna from the Wetumka Shale near Holdenville, Oklahoma, that includes *Pseudopronorites*, *Eoschistoceras*, *Gonioglyphioceras*, *Wellerites*, *Bisatoceras*, *Glaphyrites*, *Agathiceras*, *Neodimorphoceras*, and *Maximites* (fig. 14, horizon NMC D9; appendix 2, localities OKD–13 and OKD–14). Significantly, the Wetumka fauna marks the first appearance of *Gonioglyphioceras* and *Neodimorphoceras* in the northern midcontinent and the reappearance of *Wellerites*, which has not been recovered from middle Desmoinesian ammonoid faunas in the Arkoma Basin. Ammonoids from the members of the Wewoka Formation were summarized by Unklesbay (1962); the component genera are summarized in fig. 14 (horizons NMC D10–D12). The most significant faunal break during late Desmoinesian time occurs in the middle shale member (Anna shale bed) of the Wewoka Formation. The middle Wewoka shale is distinguished by the appearance of *Prouddenites*, *Wewokites*, and *Dunbarites*. *Eothalassoceras* first appears in the lower Holdenville (= Lake Neosho shale bed) (fig. 14, horizon NMC D12). Two newly discovered ammonoid faunas from the middle and upper members of the Holdenville Formation (figs. 2 and 14, horizons NMC D13 and D14) in the Arkoma Basin are similar to Wewoka faunas but lack *Wellerites*, probably because of extinction.

Ammonoids from late Desmoinesian strata in the northern shelf area (fig. 2) of the northern midcontinent are spotty in distribution. Only relatively undiagnostic taxa such as *Glaphyrites* have been recovered from the Little Osage Shale (= Wetumka Shale), the middle Wewoka Formation (Anna shale bed), and the Lenapah Limestone [middle Holdenville = High Spring shale of Bennison (1984)]. A significant new ammonoid fauna has been recovered from the Lake Neosho Shale Member of the Altamont Limestone (= lower Holdenville) at the basin-shelf transition near Tulsa, Oklahoma (fig. 2, horizon NMC D12; appendix 2, localities OKD–05 and OKD–06). The Tulsa assemblage is similar to that of the lower Holdenville (Lake Neosho) in the Arkoma-McAlester Basin in that it contains *Bisatoceras*, *Glaphyrites*, *Eothalassoceras*, *Gonioglyphioceras*, *Wellerites*, *Metapronorites*, *Neodimorphoceras*, *Maximites*, and *Eoschistoceras*; however, it differs by not containing *Dunbarites*, *Prouddenites*, *Pseudopronorites*, *Wewokites*, and *?Emilites* (appendix 2, localities OKD–04, OKD–08, OKD–30, and OKD–31).

Miller and Owen (1937) reported ammonoids from bullions (concretions) within the "Seminole" Formation (northern shelf area) at Collinsville, in northeastern Oklahoma (fig. 2, horizon NMC D14; appendix 2, locality OKD–02). Miller and Owen (1937) considered the Collinsville fauna to be the earliest Missourian ammonoid fauna in North America, despite the predominance of typically Desmoinesian taxa (*Owenoceras*, *Maximites*, *Eoschistoceras*, *Bisatoceras*, and *Gonioglyphioceras*) in that assemblage. Their assignment of the Collinsville locality to the Missourian rather than to the Desmoinesian was predicated on mapping at that time by the Oklahoma Geological Survey. More recently, Krumme (1981), Bennison (1984), Boardman and Mapes (1984b), and Heckel (1984) have demonstrated that the Collinsville ammonoid-bearing unit, which directly overlies the Dawson coal, does not correlate with the Seminole Formation (Pleasanton Group, Missourian Stage) but with the upper portion of the Holdenville Formation (upper part of the Marmaton Group, Desmoinesian Stage) (figs. 2 and 14, NMC D14) based on lithostratigraphic correlation and surface mapping. The Collinsville ammonoid fauna is nearly identical with newly discovered faunas from the upper member of the Holdenville Formation in the type area of that formation (appendix 2, locality OKD–01). Both contain *Maximites*, *Eoschistoceras*, *Owenoceras*, *Eothalassoceras*, *Glaphyrites*, *Bisatoceras*, and *Gonioglyphioceras*. However, the upper Holdenville of the Arkoma Basin contains *Neodimorphoceras* and *Wewokites*, which have not been recovered at Collinsville, and *Trochilioceras* has not yet been recovered in the Arkoma Basin sections. A similar, although slightly less diverse, fauna (*Glaphyrites*, *Eoschistoceras*, *Eothalassoceras*, and *Neodimorphoceras*) occurs in the Holdenville Formation of west-central Missouri (appendix 2, locality MID–01).

Plummer and Scott (1937) reported late Desmoinesian ammonoids from an unnamed interval near the base of the East Mountain Shale (Strawn Group) in north-central Texas (fig. 8, horizon SMC D4). They also recovered ammonoids a few feet below the top of the formation and considered these ammonoids to be Desmoinesian (fig. 10, horizon SMC M1). We now correlate this upper interval [= Bath

Bend bed of Boardman et al. (1989d)] with basal Missourian strata in the northern midcontinent, based largely on conodonts [following Merrill et al. (1987)]. Ammonoids have also been recovered from two newly discovered intervals in the East Mountain Shale (figs. 8 and 14, horizons SMC D5 and D6). The Desmoinesian part of the East Mountain Shale contains *Somoholites*, *Bisatoceras*, *Eoschistoceras*, *Wewokites*, *Gonioglyphioceras*, *Wellerites*, *Glaphyrites*, *Neodimorphoceras*, *Agathiceras*, and *?Gastrioceras*. This assemblage compares favorably with the late Desmoinesian ammonoid faunas recovered from the Marmaton Group of the Arkoma Basin. Plummer and Scott (1938) reported ammonoids from near Millsap, Texas (appendix 2, locality TXD–02), in the Millsap Lake Formation (= Grindstone Creek Formation of more recent usage). This horizon (fig. 8, horizon SMC D3), which contains *Wellerites*, *Neodimorphoceras*, *?Eoschistoceras*, *Bisatoceras*, and *Somoholites*, is judged to be late Desmoinesian based on its stratigraphic position immediately above the extinction of the fusulinid *Wedekindellina*.

Missourian ammonoid faunas

The Desmoinesian-Missourian stage boundary, as currently defined, is characterized by a relatively minor turnover in the composition of ammonoid faunas. *Gonioglyphioceras* (fig. 14, horizon NMC D14; fig. 15, horizon SMC D6) and *Wellerites* (fig. 14, horizon NMC D12; fig. 15, horizon SMC D4) are missing from early Missourian faunas because of apparent extinction at or slightly below the Desmoinesian-Missourian boundary.

The most significant event at the Desmoinesian-Missourian boundary is the appearance of *Pennoceras* (fig. 14, horizon NMC M1) near the base of the lowest Missourian marine interval. Early Missourian ammonoid faunas in the northern midcontinent are dominated by *Pennoceras*, *Eoschistoceras*, *Schistoceras*, *Bisatoceras*, *Glaphyrites*, and *Subkargalites*, based on new collections from the basal Tacket Shale Member (= Exline Limestone), lower Tacket Shale Member (= Mound City Shale Member), upper Tacket Shale Member (= Hushpuckney Shale Member), and Stark-Winterset member from Oklahoma and southern Kansas (figs. 4 and 14, horizons NMC M1–M4). Several typically Desmoinesian taxa, including *Bisatoceras*, *Eoschistoceras*, and *Maximites* (fig. 14, horizons NMC M1–M3), persist in these early Missourian faunas. Slightly higher in the Missourian, *Schistoceras* first appears (fig. 14, horizon NMC M3). A profound changeover in ammonoid faunas takes place between the Hushpuckney (Swope) and the Stark-Winterset (Dennis) of the northern midcontinent (figs. 4 and 14, horizons NMC M3 and M4), where *Eoschistoceras*, *Bisatoceras*, *Pennoceras*, and *Maximites* become extinct and *Schistoceras*, *Gonioloboceras*, *Glaphyrites*, *Prouddenites*, and *Preshumardites* become dominant in the faunal assemblage.

In the southern midcontinent (Texas) early Missourian ammonoids have been obtained from the uppermost member of the East Mountain Shale (Bath Bend bed), two ammonoid-bearing units in the Salesville Shale (figs. 10 and 15, horizons SMC M2 and M3), and the Palo Pinto–Keechi Creek interval (figs. 10 and 15, horizon SMC M4). The Bath Bend bed contains the first questionable appearance of *Pennoceras* along with *Eoschistoceras* and *Glaphyrites*. A shale between two ledges of the Dog Bend Limestone Member of the Salesville Shale contains juvenile specimens of *Pennoceras*, *?Eoschistoceras*, and *Glaphyrites* (figs. 10 and 15, horizon SMC M2). The ammonoid-bearing unit near the top of the Salesville Shale contains *Schistoceras*, *Eoschistoceras*, *Glaphyrites*, and *Subkargalites* (figs. 10 and 15, horizon SMC M3). The abrupt faunal transition that characterizes the upper part of the lower Missourian section in the northern midcontinent occurs in Texas between the upper Salesville and the Palo Pinto–Keechi Creek interval (fig. 10, horizons SMC M3 and M4). This transition is marked by the extinction of *Eoschistoceras*. Significantly, the Palo Pinto–Keechi Creek fauna is the first Missourian ammonoid fauna to contain abundant *Gonioloboceras*.

Middle Missourian ammonoid faunas are markedly distinct from early Missourian faunas because the early Missourian index taxon *Pennoceras* and persistent Desmoinesian elements such as *Bisatoceras*, *Maximites*, and *Eoschistoceras* are missing because of apparent extinction (figs. 4 and 14, horizons NMC M5–M8; figs. 10 and 15, horizons SMC M5–M6; fig. 13, horizons TX MAR M2 and M1A). Middle Missourian ammonoid faunas are characterized by appearance of *Parashumardites* (fig. 13, horizon MAR M2; fig. 14, horizon NMC M5; fig. 15, horizon SMC M5), *Gleboceras* (fig. 14, horizon NMC M6), *Aristoceras* (fig. 14, horizon NMC M6; fig. 15, horizon SMC M5), *Preshumardites* (fig. 13, horizon MAR M1A; fig. 14, horizon NMC M6; fig. 15, horizon SMC M5), *Eovidrioceras* (fig. 14, horizon NMC M6), *Uddenoceras* (fig. 13, horizon MAR M1A; fig. 14, horizon NMC M5), *Promarathonites* (fig. 14, horizon NMC M6; fig. 15, horizon SMC M5), *Emilites* (fig. 14, horizon NMC M7), and *Neoaganides* (fig. 14, horizon NMC M5) along with the continued presence of *Glaphyrites*, *Trochilioceras*, *Gonioloboceras*, *Schistoceras*, *Neodimorphoceras*, *Dunbarites*, and *Prouddenites*. A significant new ammonoid fauna from the basal member of the Nellie Bly Formation [= New Harmony shale of Bennison et al. (1984); Tulsa, Osage, and Washington counties, Oklahoma; appendix 2, localities OKM–11, OKM–18, OKM–19, OKM–35, OKM–44, OKM–45, and OKM–46] is characterized by the first northern midcontinent occurrence of *Prothalassoceras*, *Uddenoceras*, *Parashumardites*, and *Preshumardites* (figs. 4 and 14, horizon NMC M5).

The richest middle Missourian ammonoid-producing horizon in the North American continent occurs in the Quivira Shale Member [= Nellie Bly Formation of Miller and Cline (1934)] (fig. 4). This horizon has been mapped as uppermost Nellie Bly where the lower Dewey [Wekiwa limestone of Bennison (1984)] is thin or missing. The Quivira Shale Member has yielded a large number of middle Missourian ammonoids (Miller and Cline, 1934) and was used by previous workers to characterize the entire Missourian. The Quivira ammonoid fauna is significant in that it includes the first appearances of *Gleboceras*, *Eovidrioceras*, *Promarathonites*, *Eupleuroceras*, and *Aristoceras* (fig. 14, horizon NMC M6; appendix 2, localities OKM–09, OKM–10, OKM–48, and OKM–49). The Muncie Creek Shale Member, which lies approximately 100 ft (30 m) above the Quivira Shale Member (fig. 4), has previously yielded only a few ammonoids from the Kansas City region (Miller and Furnish, 1940c). However, this interval contains a large undescribed ammonoid fauna with more than 15 genera in the Sand Springs and Ramona, Oklahoma, region (fig. 14, horizon NMC M7; appendix 2, localities OKM–05, OKM–06, OKM–07, OKM–08, OKM–23, OKM–30, OKM–47, and OKM–50). The Muncie Creek Shale Member has yielded the first Missourian occurrence of *Emilites* and numerous specimens of *Gleboceras*. Although the Quindaro-Wyandotte interval of the Kansas City region and the equivalent lower Wann Formation of northern Oklahoma have yielded rare ammonoids, they include no significant first occurrences.

In north-central Texas middle Missourian ammonoid-producing intervals occur in the Posideon shale (fig. 10, horizon SMC M5) and the lower Wolf Mountain Shale Member (= Lake Bridgeport Shale; fig. 10, horizon SMC M6). Collectively, these units have yielded a rich diverse fauna, including representatives of *Aristoceras*, *Parashumardites*, *Preshumardites*, *Prouddenites*, *Schistoceras*, *Goniolobocera*s, *Neoaganides*, *Agathiceras*, *Neodimorphoceras*, *Pseudopronorites*, *Metapronorites*, *Boesites*, *Subkargalites*, and *Promarathonites*. So far, no representatives of *Eupleuroceras*, *Dunbarites*, *Gleboceras*, *Emilites*, *Uddenites*, *Uddenoceras*, or *Eovidrioceras* have been recovered (fig. 15, horizons SMC M5 and M6).

Late Missourian ammonoid faunas from the northern midcontinent are characterized by the first occurrence of *Eoasianites*, *Cardiella*, and *Neoglaphyrites* (figs. 4 and 14, horizon NMC M10), along with a continuance of middle Missourian elements, including *Glaphyrites*, *Prouddenites*, *Schistoceras*, *Neodimorphoceras*, *Neoaganides*, *Promarathonites*, *Boesites*, *Prothalassoceras*, and *Gonioloboceras*. Significant new late Missourian ammonoid faunas have been recovered in the northern midcontinent from the upper member of the Wann Formation (= Hickory Creek Shale Member; appendix 2, localities OKM–03 and OKM–41) and the Barnsdall Formation (= Eudora Shale Member;

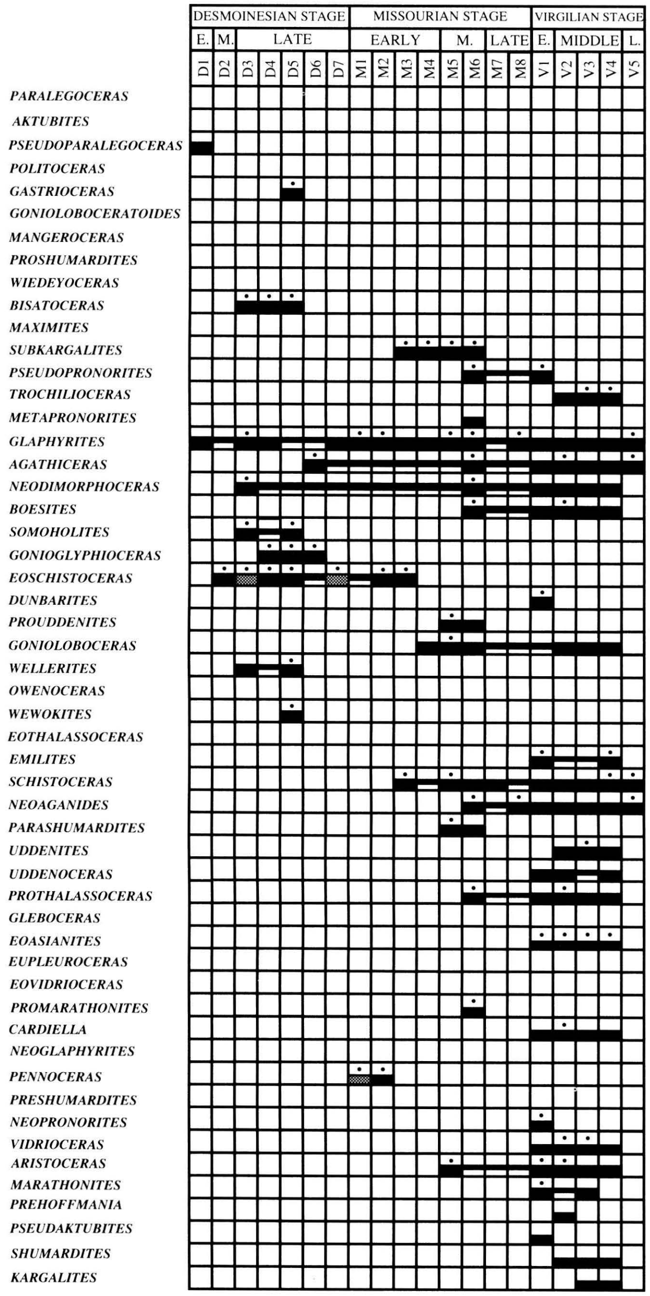


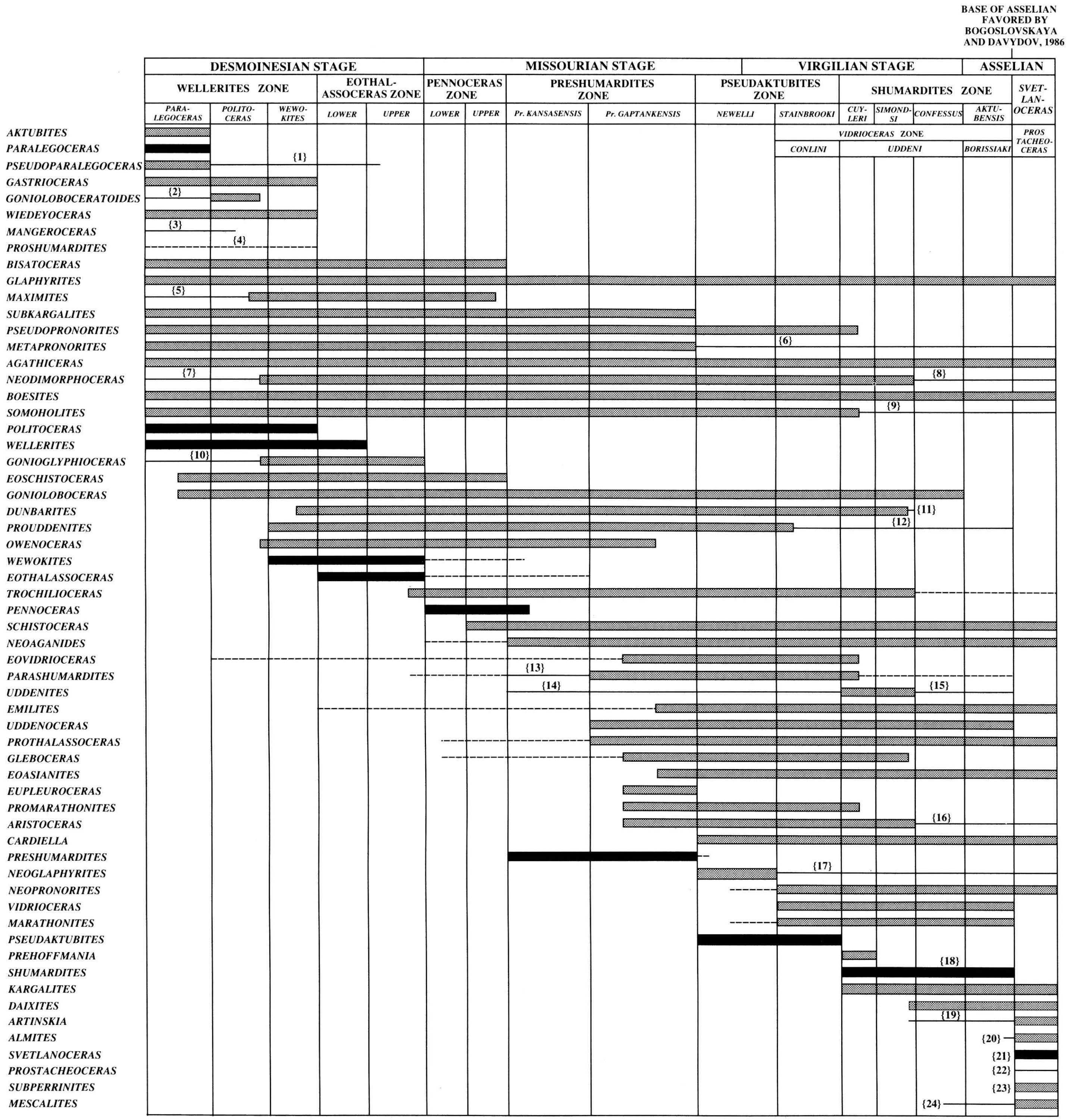
Figure 15. Generic-level ammonoid range chart for the southern midcontinent, based on ammonoid occurrences illustrated in figs. 8, 10, and 11. A solid bar indicates an actual occurrence; a half-bar indicates range through; a stippled bar indicates a questionable occurrence; filled circle indicates a new reported occurrence.

appendix 2, localities OKM–02, OKM–17, OKM–69, KSM–01, KSM–02, KSM–03, KSM–17, KSM–18, and KSM–19) from northernmost Oklahoma and southernmost Kansas (fig. 4, horizons NMC M9–M11). We consider the changeover in ammonoid faunas that occurs between the Hickory Creek Shale Member and the Eudora Shale Member to represent a potentially significant biostratigraphic event that warrants consideration in the selection of a paleontologically significant Missourian-Virgilian boundary.

Ammonoids were reported by Miller and Furnish (1940b) from an unnamed shale below the Wildhorse Dolomite Member (Nelagoney Formation) from the southern part of Osage County in northern Oklahoma (fig. 6, horizon NMC M10; appendix 2, locality OKM–69). The ammonoid-bearing shale contains *Pseudaktubites newelli*, *Prouddenites*, *Cardiella*, *Aristoceras*, *Glaphyrites*, *Neodimorphoceras*, *Schistoceras*, *Neoaganides*, and *Prothalassoceras*. The precise correlation of the Wildhorse Dolomite Member and the unnamed underlying shale has been a source of controversy for many years based on the lenticularity of the resistant Wildhorse dolomite that caps the hills in southern Osage County, Oklahoma. Based on preliminary mapping by the U.S. Geological Survey, Beckwith (1930) correlated the Wildhorse Dolomite Member with the Labadie Limestone Member of northern Osage County, Oklahoma. The Labadie Member is considered to correlate with the Haskell Limestone Member of Kansas (fig. 5). However, Beckwith (1930, p. 228–229) stated that the correlation of the Wildhorse with the Labadie was tentative because the Wildhorse occurred stratigraphically lower in the section.

Oakes (1951, 1952) mapped the Wildhorse Dolomite Member and underlying shale with the upper part of the Barnsdall Formation and correlated the entire Barnsdall Formation with the South Bend Limestone Member and lower Weston Shale Member of Kansas. Unklesbay (1962) correlated the shale below the Wildhorse with the Missourian Wann Formation, Ochelata Group. The Oklahoma Geological Survey currently maps the unnamed shale below the Wildhorse Dolomite Member as the upper part of the Barnsdall Formation (fig. 6). We agree with the correlation of the Wildhorse and underlying shale to the Barnsdall Formation. However, we consider the Barnsdall Formation of southern Osage County to be stratigraphically equivalent to the upper Wann Formation of Washington County, Oklahoma, and with the Eudora Shale Member of the Stanton Limestone of Kansas based on field relationships and identical conodont faunas (first appearance of *Idiognathodus simulator* and *Streptognathodus firmus*). Moreover, the South Bend Limestone Member and basal Weston Shale Member of Kansas appear to be present only in the northernmost part of Osage County, Oklahoma. Where the South Bend and basal Weston are present in Oklahoma, they occur in the upper Barnsdall Formation immediately underlying the Bigheart Sandstone Member of the overlying Tallant

Figure 16 (facing page). Composite generic-level ammonoid range chart for the North American midcontinent, based on data from figures 2–15. A solid bar indicates the ranges of critical genera used as zonal indexes. A stippled bar is used to show ranges of ammonoid genera within the North American midcontinent. Solid lines are range extensions based on ranges determined outside the midcontinent. Dashed lines are probable range extensions based on phylogenetic inferences unless otherwise noted as being a questionable occurrence. (1) Based on ammonoids from Cape Chayka (Yugorskiy Peninsula) (Ruzhencev, 1975). (2) Based on ammonoids from the Canadian Arctic (Nassichuk, 1975). (3) Based on ammonoids from the Appalachian Basin (Mapes et al., 1993). (4) Based on a questionable occurrence reported by Beghtel (1962). (5) Based on ammonoids from the Canadian Arctic (Nassichuk, 1975). (6) Based on ammonoids from the Permian of Timor (Haniel, 1915; Librovitch, 1938). (7) Based on ammonoids from Atokan equivalents in Japan (Nishida, 1971) and from the Atokan of the Canadian Arctic (Nassichuk, 1975). (8) Based on ammonoids from Orenburgian strata in the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (9) Based on ammonoids from Permian strata in Timor (Haniel, 1915; Ruzhencev, 1938) and from Orenburgian strata (both Gzhelian and Asselian) (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (10) Based on ammonoids from early Desmoinesian strata in the Appalachian Basin (Mapes et al., 1993). (11) Based on Orenburgian ammonoids from the southern Urals (Bogoslovskaya and Popov, 1986). (12) Based on Orenburgian ammonoids (both Gzhelian and Asselian) from the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (13) Based on ammonoids from Zhigulian (Kasimovian) strata in the southern Urals (Ruzhencev, 1950). (14) Based on ammonoids from Zhigulian (Kasimovian) strata (Ruzhencev, 1950). (15) Based on ammonoids from Orenburgian strata (both Gzhelian and Asselian) in the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (16) Based on Orenburgian ammonoids (both Gzhelian and Asselian) (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (17) Based on Asselian ammonoids from the southern Urals (Bogoslovskaya and Popov, 1986). (18) Based on Orenburgian (Gzhelian) ammonoids from the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (19) Based on Orenburgian (Gzhelian) ammonoids from the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). (20) Based on Orenburgian (Gzhelian) ammonoids from the southern Urals (Bogoslovskaya and Popov, 1986). (21) Based on Asselian ammonoids from the southern Urals (Bogoslovskaya and Popov, 1986). (22) Based on Asselian ammonoids from the southern Urals (Bogoslovskaya and Popov, 1986). (23) Based on Asselian ammonoids from the Bursum Formation (Laborcita of recent usage) of the Sacramento Mountains, New Mexico (Tharalson, 1984). (24) Based on Gzhelian ammonoids from the Karawanken Mountains of Yugoslavia (Kullman and Ramovs, 1980).



Formation. The Bigheart appears to truncate the underlying beds progressively and completely removes the South Bend–Weston sequence a short distance south of the Kansas-Oklahoma border.

Late Missourian ammonoid faunas from north-central Texas are poorly known. These faunas include only *Neoaganides*, *Eoasianites*, *Gonioloboceras*, *Schistoceras*, and *Glaphyrites* (fig. 15, horizons SMC M7 and M8).

Virgilian ammonoid faunas

Early Virgilian ammonoid faunas are characterized by the first appearance of *Pseudaktubites stainbrooki* (fig. 5, horizon NMC V3; figs. 11 and 15, horizon SMC V1), *Vidrioceras conlini*, *Marathonites*, and *Neopronorites* (fig. 15, horizon SMC V1) and the continued presence of *Dunbarites*, *Pseudopronorites*, *Emilites*, *Uddenoceras*, *Glaphyrites*, *Neodimorphoceras*, *Agathiceras*, *Boesites*, *Neoaganides*, *Schistoceras*, *Prothalassoceras*, *Eoasianites*, and *Cardiella* (figs. 14 and 15). Few major generic-level changeovers occur within Virgilian ammonoid faunas; however, rapid speciation within *Shumardites* and *Vidrioceras* make possible refined biostratigraphic subdivisions of the Virgilian Stage.

Early Virgilian ammonoids from the Douglas Group of the northern midcontinent are poorly known and have previously been reported only from the Iatan Limestone Member (fig. 5, horizon NMC V2), which contains only the ubiquitous *Schistoceras*. Important new ammonoid faunas are reported herein from the basal Weston Shale Member and Robbins Shale Member of Kansas (fig. 5, horizons NMC V1 and V3; appendix 2, localities KSV–05, KSV–06, KSV–07, KSV–25, and KSV–26). The Weston Shale Member has thus far yielded *Neoaganides*, *Neoglaphyrites*, *Eoasianites*, *Glaphyrites*, *Promarathonites*, and *Subkargalites* (fig. 14, horizon NMC V1), whereas the Robbins Shale Member contains *Boesites*, *Prothalassoceras*, *Eoasianites*, *Neodimorphoceras*, *Glaphyrites*, *Schistoceras*, *Cardiella*, *Vidrioceras conlini*, and *Pseudaktubites stainbrooki* (fig. 14, horizon NMC V3).

Plummer and Scott (1937) reported *Uddenoceras* (as *Uddenites*), *Cardiella* (as *Vidrioceras*), *Trochilioceras*, and *Pseudaktubites* (as *Preshumardites*) from the Colony Creek Shale Member (Canyon Group) of north-central Texas (figs. 11 and 15, horizon SMC V1; appendix 2, locality TXV–52). Boardman and Mapes (1984a) and Boardman et al. (1989c) reported an extensive ammonoid fauna in the Colony Creek Shale Member from new localities in both the Brazos and Colorado River valleys that includes a number of taxa of Virgilian aspect: *Vidrioceras conlini*, *Emilites incertus*, *?Neopronorites*, *Aristoceras*, *Uddenoceras harlani*, *Marathonites*, and *Pseudaktubites stainbrooki* (figs. 1 and 15, horizon SMC V1; appendix 2, localities TXV–46, TXV–49, and TXV–50). They concluded that the Colony Creek Shale Member is early Virgilian in age based on comparisons with newly discovered early Virgilian ammonoid faunas from the type Virgilian area of Kansas. Ross's (1965, p. 1,160) fusulinid-based correlation of the Colony Creek Shale Member with the lower Virgilian Douglas Group of the northern midcontinent provides further corroboration for an early Virgilian age assignment.

Middle and early Virgilian ammonoid faunas are comparable with two minor exceptions (figs. 5, 6, and 14, horizons NMC V4–V6; figs. 11 and 15, horizons SMC V2–V4; fig. 13, horizon MAR V1): *Vidrioceras*, *Shumardites*, and *Kargalites* first appear in the early to middle Virgilian, and *Pseudopronorites* is missing because of apparent extinction by the end of middle Virgilian time (fig. 13, horizon MAR V1; fig. 15, horizon SMC M2).

Ammonoids are exceedingly abundant in certain middle Virgilian ammonoid-bearing units in north-central Texas. The Finis, Necessity–Bluff Creek, and Wayland shale members (Graham Formation, Cisco Group) have all yielded more than 20 species of ammonoids (Smith, 1903; Plummer and Scott, 1937; Miller and Downs, 1950), an exceptionally high diversity (figs. 11 and 15, horizons SMC V2–V4). Among the most important taxa present in these intervals are *Vidrioceras*, *Shumardites*, *Marathonites*, *Kargalites*, *Emilites*, *Uddenites*, and *Uddenoceras*.

Only sporadic occurrences of ammonoids have been reported from the middle Virgilian Shawnee Group of the northern midcontinent (figs. 5 and 14, horizons NMC V4–V6). The only major fauna reported thus far is known from the Heebner Shale Member of Oklahoma and Kansas. Ammonoids from the Heebner Member in Kansas were reported by Unklesbay (1954), and Heebner (= Vamoosa) ammonoids were first reported from Oklahoma by Unklesbay (1962). The Heebner ammonoid fauna is similar to the middle Virgilian ammonoid assemblage from the southern midcontinent in that it contains *Vidrioceras*, *Uddenites*, *Uddenoceras*, *Aristoceras*, *Prothalassoceras*, *Schistoceras*, *Cardiella*, *Trochilioceras*, *Gonioloboceras*, *Neoaganides*, *Neodimorphoceras*, and *Glaphyrites* but dissimilar in that it lacks *Shumardites* and *Emilites* (fig. 14, horizon NMC V4).

Late Virgilian ammonoid faunas from the midcontinent are poorly known and usually exhibit low diversities (figs. 5 and 14, horizons NMC V7–V13; figs. 10 and 15, horizon SMC V5; fig. 13, horizon MAR V2). Thus far, only *Neoaganides*, *Glaphyrites*, *Gonioloboceras*, *Marathonites*, *Prothalassoceras*, and *Cardiella* have been reported from late Virgilian strata in the northern midcontinent (fig. 14, horizons NMC V7–V14). The best late Virgilian ammonoid fauna from the northern midcontinent has been recovered from the Wamego Shale Member (figs. 6 and 14, horizon NMC V12; appendix 2, locality KSV–1). This newly discovered horizon has yielded *Neoaganides*, *Glaphyrites*, *Gonioloboceras*, *Marathonites*, and *Prothalassoceras*.

Late Virgilian ammonoids from north-central Texas are also poorly known. Only one specimen each of *Schistoceras*, *Agathiceras*, and *Neoaganides* have been recovered, all of which came from the Blach Ranch limestone member and associated shale (figs. 10 and 15, horizon SMC V5).

Asselian ammonoid faunas

Basal Permian (Admire Group of the northern midcontinent and equivalents) ammonoids are essentially unknown from North America. The single exception is the Indian Cave Sandstone of Nebraska that has yielded specimens of *Agathiceras* (R. K. Pabian, personal communication, 1990). However, locally abundant ammonoids have been recovered from the lower half of the Council Grove Group and equivalent strata from Kansas and Oklahoma (fig. 7), north-central Texas (fig. 12), Marathon Uplift (fig. 13), and northern Sacramento Mountains of New Mexico (fig. 17). Unfortunately, these ammonoids have with a few notable exceptions received little attention (Miller, 1932; Miller and Youngquist, 1947; Furnish and Glenister, 1971, 1977; Tharalson, 1984). No effort has been made so far to obtain systematic stratigraphic collections from any region of the North American midcontinent.

Collectively, the Lower Permian pre-*Streptognathodus barskovi* and pre-*Pseudoschwagerina* ammonoid faunas from North America contain *Artinskia*, *Neopronorites*, *Agathiceras*, *Glaphyrites*, *Eoasianites*, *Prothalassoceras*, *Mescalites*, *Almites*, *Emilites*, and *Subperrinites* (figs. 7, 12, 13, and 17). The most diverse fauna is known from the Bursum (Laborcita) Formation of New Mexico, which has yielded *Artinskia*, *Glaphyrites*, *Eoasianites*, *Mescalites*, *Almites*, *Emilites*, and *Subperrinites*.

Furnish and Glenister (1971) illustrated *Eoasianites* and *Mescalites* from the Bennett Shale Member of the Red Eagle Limestone of northern Oklahoma. Earlier, Gordon (1963) reported *Glaphyrites* from the Bennett Shale Member of northern Kansas. Recently, Holterhoff and Pabian (1989) reported *Mescalites discoidale*, *Prothalassoceras* sp., and *Eoasianites* cf. *E. subtilicostatus* (identifications by B. F. Glenister) from the Bennett Shale Member of southeastern Nebraska. However, Holterhoff (personal communication, 1991) now considers this locality to belong to the Hughes Creek Shale Member of the Foraker Limestone.

Only a single ammonoid has been recovered from the lowermost Permian of north-central Texas. Miller and Youngquist (1947) described *Artinskia lilianae* from the lower part of the Camp Creek Shale Member of the Pueblo Formation in the Colorado River valley of north-central Texas.

Ammonoid faunas from the Glass Mountains, West Texas

Missourian faunas

Early Missourian ammonoids are present in the lower part of the Gaptank Formation of the Marathon region in West Texas (Conglomerate Member; fig. 13, horizon MAR M1). King (1938) reported ammonoids from a limestone and shale sequence between the second and third conglomerate at two localities 2 mi (3 km) southeast of Gaptank. Although no faunal list was given, Girty (1938) considered the fauna to be Desmoinesian. Only one of the two collections has been located by the U.S. Geological Survey (Mackenzie Gordon, Jr., personal communication, 1988). According to Gordon, this collection contains only *Pennoceras*, thereby suggesting an early Missourian age.

The upper part of the Conglomerate Member of the Gaptank Formation (limestone and shale between the fourth and fifth conglomerate beds; fig. 13, horizon MAR M2), in the Marathon Uplift region has yielded *Parashumardites* and *Schistoceras*. Based on the presence of distinctive fusulinids, including *Triticites irregularis*, from these ammonoid-bearing beds, Ross (1965) correlated this interval with early to middle Missourian strata in the northern midcontinent. In addition, a large late middle Missourian ammonoid fauna has been recovered from an unnamed isolated limestone block (probably an allochthonous shelf edge block that was part of a debris flow into the basin) within the Dugout Creek beds member of the Gaptank Formation (fig. 13, horizon MAR M2A; appendix 2, locality TX MAR M1). This ammonoid fauna, first reported by Miller (1930), contains *Prouddenites*, *Uddenoceras*, *Metapronorites*, *Boesites*, *Eoasianites*, *Preshumardites gaptankensis*, *Prothalassoceras*, *Schistoceras*, and *Subkargalites* (fig. 13, horizon MAR M2A). Based on the presence of *Preshumardites gaptankensis*, this fauna is clearly middle to late Missourian. In addition, we have recovered elements of the *Streptognathodus gracilis* conodont faunal interval of Barrick and Boardman (1989) in the Dugout Creek beds, further corroborating a middle to late Missourian age.

Virgilian faunas

Böse (1917) described ammonoids from the *Uddenites* Shale Member, Wolfcamp Formation, at the Saddle locality within the Wolfcamp Hills region of the Glass Mountains, Marathon Uplift, West Texas (fig. 13, horizon MAR V2; appendix 2, locality TX MAR V–03) which he considered to be Early Permian in age. However, King (1938), based largely on the findings of Plummer and Scott (1937), assigned the *Uddenites* Shale Member to the Late Pennsylvanian Gaptank Formation. Bostwick (1962) placed the *Uddenites* Shale Member back into the Wolfcamp Formation based on his identification of the fusulinid *Schwagerina* from the superjacent Gray Limestone Member [= bed J of Ross (1965)] and the presence of Wolfcampian species of *Triticites* within the *Uddenites* Shale Member. Based on more detailed collections from the Gray Limestone Member, Ross (1965) demonstrated that Bostwick's identification of *Schwagerina* and advanced species of *Triticites* was in error and concluded that the Gray Limestone Member (bed J) and the underlying *Uddenites* Shale Member were early late Virgilian in age. Recently, Wilde (1977) reported *Triticites* cf. *T creekensis*, *T. meeki*, and *T. ventricosus* from the uppermost part of the Gray Limestone Member (USGS Collection 701 from Wolf Camp). These fusulinid species

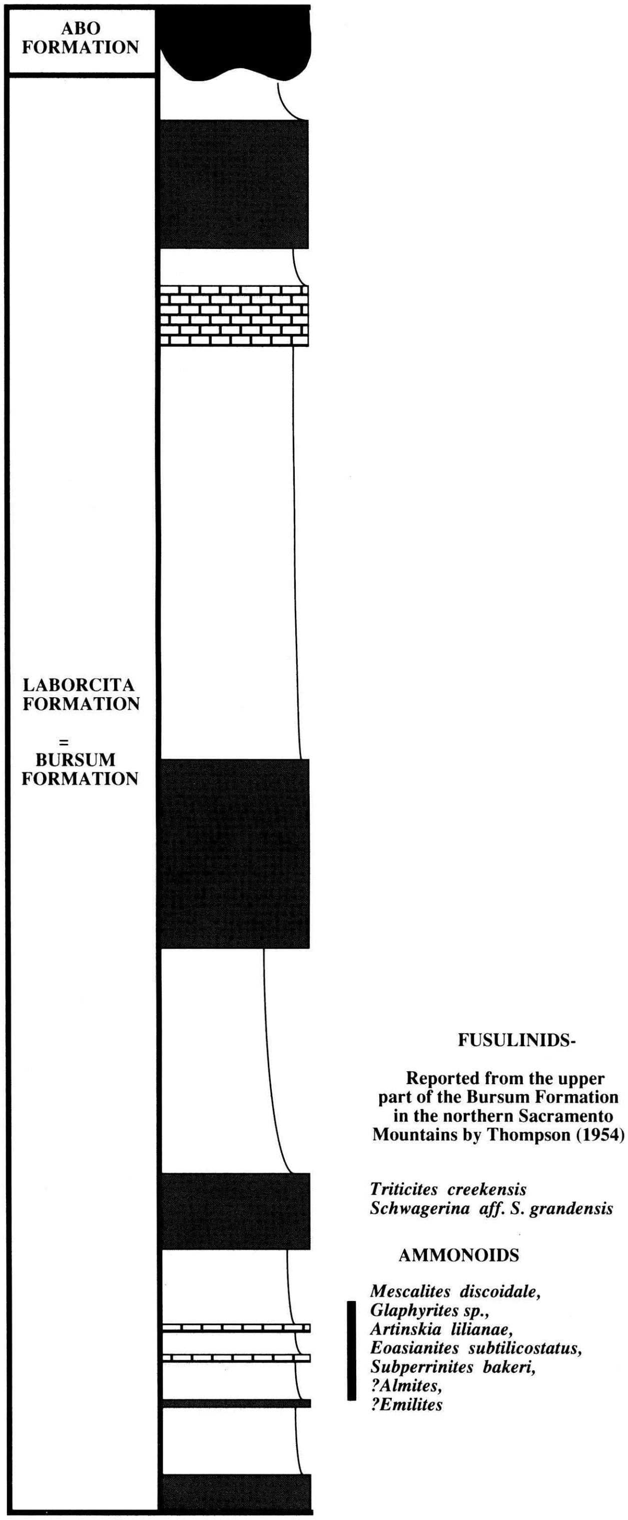


Figure 17. Stratigraphic distribution of ammonoids in lower Asselian strata exposed at the Tularosa shale pit, Bursum Formation (= Laborcita Formation). Lithostratigraphic nomenclature is based on Otte (1959). Fusulinid data are based on Thompson (1954). Ammonoid data are based on Miller (1932), Furnish and Glenister (1971), Tharalson (1984), and our new unpublished collections.

are known only from Early Permian strata of north-central Texas (Camp Creek Shale Member) and Kansas (Hughes Creek Shale Member) (Thompson, 1954). Furnish and Glenister (1977) reported several Permian ammonoid taxa (*Artinskia*, *Neopronorites*, *Almites*, and *Eoasianites*) from the same bed (USGS 701). Ross (1977) noted that the uppermost part of the Gray Limestone Member is a limestone conglomerate and suggested that its fauna might be mixed.

The *Uddenites* Shale Member ammonoid fauna resembles faunas from the Graham Formation and Colony Creek Shale Member of north-central Texas; nearly all genera of ammonoids (with the exception of *Daixites*) present in the Gaptank Formation (*Uddenites* Shale Member) occur in north-central Texas. However, the *Uddenites* Shale Member of the Gaptank Formation is probably younger than the Graham Formation of north-central Texas based on the co-occurrence of advanced *Vidrioceras uddeni*, *V. irregulare*, and *Daixites* cf. *D. meglitzkyi*. Fusulinid data from Ross (1965, p. 1,160 and 1,165) also indicate that the *Uddenites* Shale Member (uppermost Gaptank) fauna is of late but not latest Virgilian age (= lower Wabaunsee equivalent of the northern midcontinent).

A second locality that yielded ammonoids from the *Uddenites* Shale Member was described by Smith (1929) from limestone beds 4.5 to 5.5 mi (7.2–8.9 km) northeast of Wolf Camp (appendix 2, localities TX MAR V–01 and TX MAR V–02). Although the *Uddenites* Shale Member cannot be traced continuously from one locality to the other, Smith reasoned that, because both faunas contained *Uddenites*, they were of equivalent age. Keyte et al. (1927), followed by Smith (1929) and King (1931), correlated the ammonoid-bearing locality 4.5–5.5 mi (7.2–8.9 km) northeast of Wolf Camp with the *Uddenites* Shale Member of the Wolfcamp Formation. Interestingly, Keyte (1927, plate 31) presented a stratigraphic cross section that shows the *Uddenites* ammonoid zone occurring at different stratigraphic positions below the top of the Gaptank Formation. The base of the first limestone immediately overlying the *Uddenites* ammonoid zone at a particular locality was arbitrarily set as a stratigraphic datum. Although the *Uddenites* fauna was recovered within 25 ft (7.6 m) of the top of the Gaptank Formation at the Saddle locality at Wolf Camp, it occurs 150–200 ft (46–61 m) below the top of the Gaptank Formation at Smith's locality. This supposed discrepancy was attributed to variable downcutting by the Gaptank-Wolfcamp unconformity. The validity of Keyte et al.'s (1927) correlation rested solely on the presumed equivalence of the *Uddenites*-bearing horizons at these two isolated exposures.

Ross (1965) mapped the Gaptank Formation in detail from its type section at Gap Tank southwestward toward the Wolfcamp Hills. He mapped Smith's ammonoid-bearing horizon 4.5–5.5 mi (7.2–8.9 km) northeast of Wolf Camp as part of the H limestone bed of the Limestone Member of the Gaptank Formation. Ammonoids from the *Uddenites* Shale Member of the Gaptank Formation exposed at the Saddle locality occur near the top of a thick shale sequence and just below the Gray Limestone Member [limestone bed J of Ross (1965)]. The intervening I limestone bed that lies stratigraphically between the H and J limestones is prominent at Smith's locality, 4.5–5.5 mi (7.2–8.9 km) northeast of Wolf Camp; but the I limestone is absent at the Saddle locality. Based on previously published analyses of their respective ammonoid faunas, Ross (1965) concluded that the *Uddenites*-bearing limestone at this locality was stratigraphically equivalent to the *Uddenites* Shale Member exposed at the famous Saddle locality near Wolf Camp. To account for the notable absence of the I limestone at the Saddle locality, Ross (1967) suggested that the I limestone bed was never deposited or was truncated by a post–I limestone and pre–J limestone erosional event. Using fusulinids, Ross correlated the *Uddenites* Shale Member and the H limestone with the middle part of the Graham Formation of north-central Texas and the Shawnee Group of the northern midcontinent.

The ammonoid fauna recovered from the H limestone bed is similar to but unquestionably distinct from that of the *Uddenites* Shale Member. Both faunas contain representatives of *Uddenoceras*, *Boesites*, *Aristoceras*, *Glaphyrites*, *Shumardites*, *Vidrioceras*, *Marathonites*, *Emilites*, and *Schistoceras*. However, the H limestone fauna also includes *Vidrioceras conlini*, *Neopronorites*, *Pseudopronorites*, *Somoholites*, *Parashumardites*, and *Neodimorphoceras*, which are not present in the *Uddenites* Shale Member, and the *Uddenites* Shale Member contains *Uddenites*, *Daixites*, *Agathiceras*, *Prothalassoceras*, *Dunbarites*, and *Cardiella*, which are not present in the H limestone.

The two faunas differ markedly at the species level. Böse (1917) originally reported two species of *Uddenites* from *Uddenites* Shale Member exposures at the Saddle locality near Wolf Camp: *U. schucherti* and *U. minor*. Smith (1929) illustrated specimens attributed by him to *U. schucherti* from the locality 4.5–5.5 mi (7.2–8.9 km) northeast of Wolf Camp. Miller and Furnish (1940a) later determined that specimens of *Uddenites schucherti* figured by Smith (1929) from the locality northeast of Wolf Camp actually belonged to a third new species (*U. oweni*). They reported that *U. harlani*, previously known only from the Colony Creek Shale Member of north-central Texas, occurred with *U. oweni* at Smith's locality. Miller and Furnish (1957) reanalyzed the species of *Uddenites* from Smith's locality (*U. oweni*) and suggested that the degree of sutural difference separating *U. oweni* from *U. schucherti* warranted a generic-level distinction. Accordingly, they proposed the new genus *Uddenoceras* (type species *U. oweni*) to accommodate *U. oweni* and *U. harlani*. As a result of the taxonomic revision by Miller and Furnish (1940a, 1957), we conclude that no species of *Uddenites* or *Uddenoceras* are in common at the two localities. We have a number of specimens of *Uddenoceras* in our collections from the original Saddle locality, but they are clearly distinct from either *Uddenoceras* species present at Smith's locality.

Vidrioceratid species in the H limestone and the *Uddenites* Shale Member are also distinct. The H limestone contains *Vidrioceras conlini* and the morphologically primitive *V. uddeni*, whereas the *Uddenites* Shale Member contains *V. irregulare* and the morphologically advanced *V. uddeni*. *Vidrioceras conlini* is known from the early Virgilian Colony Creek and basal Robbins Shale Members and from the early to middle Virgilian Finis and Heebner shales of the North American midcontinent. The stratigraphically highest Virgilian ammonoid-bearing strata in north-central Texas contains primitive *V. uddeni* but no representatives of *V. irregulare*, suggesting that the ammonoid fauna from the *Uddenites* Shale Member is younger than the middle Virgilian ammonoid faunas of north-central Texas.

Marathonitids from Smith's locality also are decidedly more primitive than their counterparts from the *Uddenites* Shale Member at the Saddle locality. Böse (1917) described *Cardiella* (as *Marathonites*) *sulcatus*, *Marathonites vidriensis*, and *Marathonites jpsmithi* from the *Uddenites* Shale Member at the Saddle locality. Smith (1929) also reported *M. jpsmithi* from the locality northeast of Wolf Camp; however, reexamination of marathonitid material from both the Saddle and Smith localities reveals no species in common to both localities. The species of *Marathonites* from Smith's locality is distinct from both *M. vidriensis* and *M. jpsmithi*. Species of *Marathonites* from the Saddle locality have decidedly more advanced sutural configurations than their counterparts from Smith's locality. An undescribed species of *Marathonites* from Smith's locality (plate 2, no. 2) has no geniculate coiling at maturity, whereas *M. jpsmithi* from the Saddle locality has pronounced geniculate coiling at maturity (plate 2, nos. 1 and 3).

Finally, the shumarditid taxa present in the H limestone also demonstrate the probable diachronous age for the *Uddenites* Shale Member and the H limestone bed, Limestone Member of the Gaptank Formation. We have recovered *Shumardites* cf. *S. simondsi* from the Saddle locality. The H limestone contains *Parashumardites*, a taxon previously known from only Missourian or Kasimovian strata, and *Shumardites* cf. *S. cuyleri*. Based on the preponderance of evidence, we conclude that the ammonoid fauna from the H limestone is probably early to middle Virgilian, whereas that of the *Uddenites* Shale Member is probably late Virgilian.

Late Moscovian–Gzhelian ammonoid faunas from the former Soviet Union and comparisons with Desmoinesian–Virgilian North American faunas

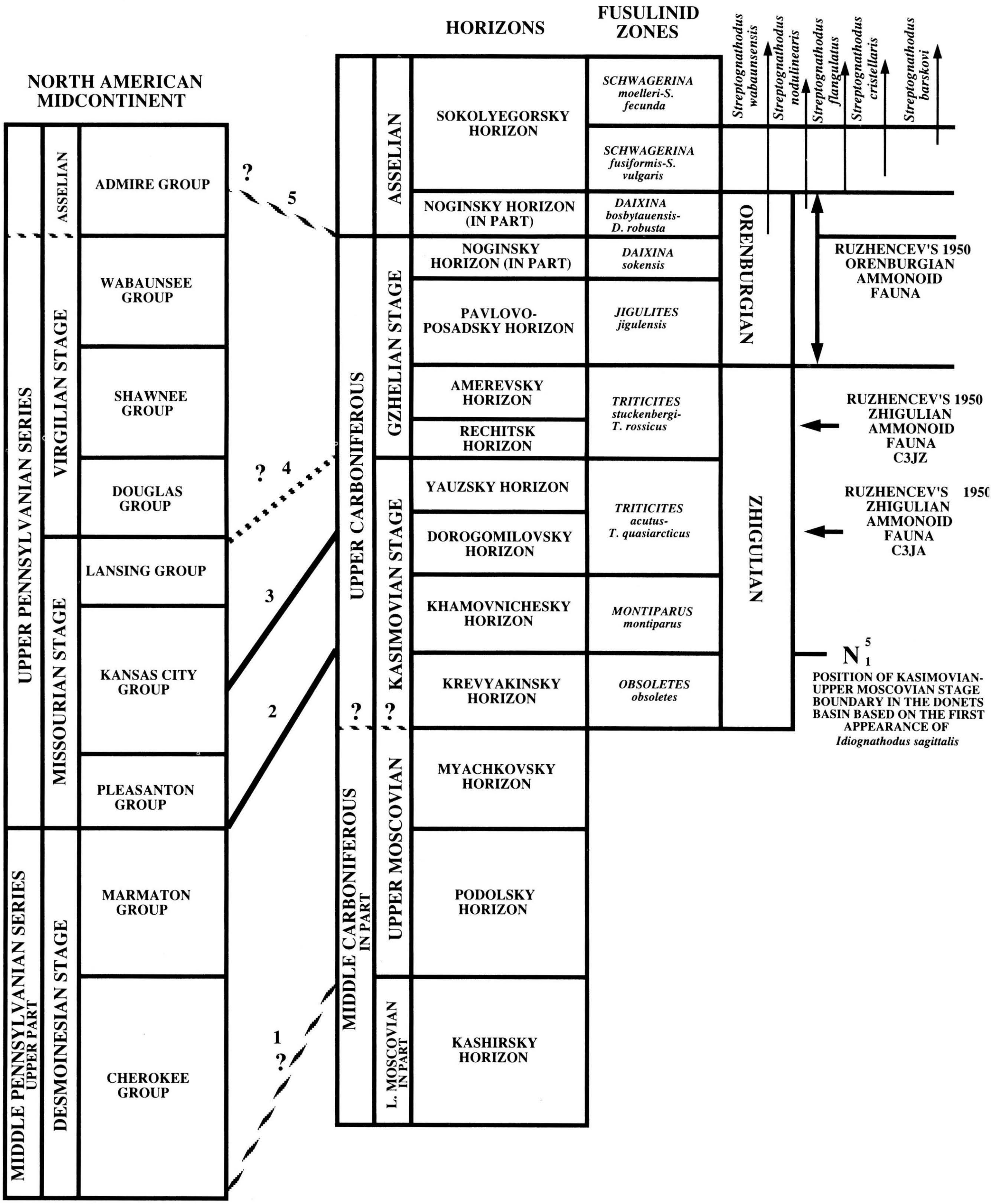
Upper Moscovian strata, including the Podolsky and Myachkovsky horizons (fig. 18), have traditionally been correlated with Desmoinesian strata of North America. Late Moscovian (Desmoinesian) ammonoids have been recovered from the southern Urals, the Donetz Basin, and the Moscow Basin in the former Soviet Union, but these occurrences are sparse (Ruzhencev, 1965). Late Moscovian ammonoid faunas in the former Soviet Union are dominated by *Pseudoparalegoceras*, *Wellerites*, *Eoschistoceras*, and *Aktubites* (Ruzhencev, 1962). The best stratigraphically controlled late Moscovian ammonoid faunas in the former Soviet Union are found in the Moscow Basin. There, the Podolsky Horizon (lower part of the upper Moscovian; fig. 18) has yielded *Pseudoparalegoceras* and *Eoparalegoceras* (Ruzhencev, 1974, p. 322). *Eoparalegoceras* has not been recovered from North America, and *Pseudoparalegoceras* is inconclusive as a zonal indicator. In North America *Pseudoparalegoceras* has not been recovered from strata younger than lower Desmoinesian in age (fig. 16). However, it is believed that this taxon gave rise to *Dunbarites*, which first appears in the late Desmoinesian (fig. 16). If this phylogenetic interpretation is correct, then *Dunbarites* must either have arisen earlier, that is, in early to middle Desmoinesian time, or *Pseudoparalegoceras* must actually extend as high as the late Desmoinesian. *Pseudoparalegoceras* and *Dunbarites*, in association with the fusulinid *Protriticites*, were reported by Ruzhencev (1974, p. 315) from Cape Chayka, suggesting that *Pseudoparalegoceras* might actually range through the Desmoinesian.

The Podolsky Horizon contains the first appearance of the fusulinid *Fusulina* in association with *Fusulinella* and is thought to be early Desmoinesian in age (Solovieva et al., 1984, p. 85). According to Ross and Ross (1987), the base of the upper Moscovian is drawn at the first appearance of *Fusulina*, whereas the North American Atokan-Desmoinesian boundary is drawn at the first appearance of *Beedeina*. *Fusulina* appears only in lower Missourian strata in North America (Bethany Falls Limestone Member; Thompson, 1957). However, *Fusulina* and *Beedeina* may actually have different ranges in the two regions (Ross, 1979). According to Ross (1979), *Beedeina* is rare and appears above the first appearance of *Fusulina* in the former Soviet Union. An alternative view is expressed by Ivanova et al. (1975), who showed that *Fusulina* and *Beedeina* have the same stratigraphic appearance in the former Soviet Union.

Solovieva et al. (1984) reported that the boundary between the *Neognathodus bothrops* and *N. medadultimus* conodont zones occurs stratigraphically below the Podolsky Horizon, within the Kashirsky Horizon, which is thought to correspond to the Atokan Stage (fig. 18). However, according to Merrill (1975), the *N. bothrops–N. medadultimus* zonal boundary coincides with the Atokan-Desmoinesian stage boundary in North America.

Ruzhencev (1974) reported *Eoschistoceras* from limestones near the top of the Myachkovsky Horizon in the

Figure 18 (facing page). Correlation between the northern North American midcontinent and the Moscow Basin and southern Urals. The stratigraphic position of the late Carboniferous ammonoid faunas presented by Ruzhencev (1950) is shown here to illustrate the faunas' position relative to the new serial nomenclature used by Soviet scientists. (1) The correlation of the basal Desmoinesian portion of the Cherokee Group with the Lower-Upper Moscovian boundary is provisional and is based on a correlation of the first appearance of *Beedeina* in North America and the first appearance of *Fusulina* in the former Soviet Union. (2) Although there is a general tendency to correlate the base of the Kasimovian with the Desmoinesian-Missourian boundary, conodont and palynomorph data suggest that the Desmoinesian-Missourian boundary is younger than the Moscovian-Kasimovian boundary. The extinction of the conodont *Neognathodus* occurs within the lower part of the Kasimovian (Barskov et al., 1987). The first appearance of *Idiognathodus sagittalis* occurs in the Khamovnichesky Horizon of the former Soviet Union and in the basal Missourian strata of the North American midcontinent (Boardman et al., 1991). In addition, palynomorph data indicate that the base of the Missourian Stage is actually slightly younger than the base of the Kasimovian Stage, based on the works of Phillips et al. (1985) and Peppers (1985, 1988), thereby supporting the conodont evidence. (3) Ammonoid faunas and fusulinid faunas from the middle part of the Kansas City Group are similar to that of the upper Kasimovian [Zhigulian, in part, of Ruzhencev (1950)], based in part on the first appearance of *Triticites irregularis*. (4) Correlation of the Gzhelian-Kasimovian boundary with the uppermost Missourian is predicated on the first appearance of the conodont *Streptognathodus simulator*, which first appears at the base of the Gzhelian in the former Soviet Union (Barskov et al., 1987) and in the Eudora Shale Member (late Missourian) of the northern North American midcontinent. (5) The correlation of the Gzhelian-Asselian boundary of the former Soviet Union with the Virgilian-Wolfcampian (Asselian) is in considerable doubt. The first appearance of *Streptognathodus wabaunsensis* occurs in the Five Point Limestone Member of the Admire Group and in strata containing the *Daixina bosbytauensis–D. robusta* Zone of the former Soviet Union, which currently officially marks the base of the Asselian Stage of the Permian System.


NORTH AMERICAN MIDCONTINENT
UPPER PENNSYLVANIAN SERIES
MIDDLE PENNSYLVANIAN SERIES UPPER PART
ASSELIAN
VIRGILIAN STAGE
MISSOURIAN STAGE
DESMOINESIAN STAGE
ADMIRE GROUP
WABAUNSEE GROUP
SHAWNEE GROUP
DOUGLAS GROUP
LANSING GROUP
KANSAS CITY GROUP
PLEASANTON GROUP
MARMATON GROUP
CHEROKEE GROUP
HORIZONS
FUSULINID ZONES
UPPER CARBONIFEROUS
MIDDLE CARBONIFEROUS IN PART
ASSELIAN
GZHELIAN STAGE
KASIMOVIAN STAGE
UPPER MOSCOVIAN
L. MOSCOVIAN IN PART
SOKOLYEGORSKY HORIZON
NOGINSKY HORIZON (IN PART)
NOGINSKY HORIZON (IN PART)
PAVLOVO-POSADSKY HORIZON
AMEREVSKY HORIZON
RECHITSK HORIZON
YAUZSKY HORIZON
DOROGOMILOVSKY HORIZON
KHAMOVNICHESKY HORIZON
KREVYAKINSKY HORIZON
MYACHKOVSKY HORIZON
PODOLSKY HORIZON
KASHIRSKY HORIZON
SCHWAGERINA moelleri-S. fecunda
SCHWAGERINA fusiformis-S. vulgaris
DAIXINA bosbytauensis-D. robusta
DAIXINA sokensis
JIGULITES jigulensis
TRITICITES stuckenbergi-T. rossicus
TRITICITES acutus-T. quasiarcticus
MONTIPARUS montiparus
OBSOLETES obsoletes
Streptognathodus wabaunsensis
Streptognathodus nodulinearis
Streptognathodus flangulatus
Streptognathodus cristellaris
Streptognathodus barskovi
ORENBURGIAN
ZHIGULIAN
RUZHENCEV'S 1950 ORENBURGIAN AMMONOID FAUNA
RUZHENCEV'S 1950 ZHIGULIAN AMMONOID FAUNA C3JZ
RUZHENCEV'S 1950 ZHIGULIAN AMMONOID FAUNA C3JA
N 5 1
POSITION OF KASIMOVIAN-UPPER MOSCOVIAN STAGE BOUNDARY IN THE DONETS BASIN BASED ON THE FIRST APPEARANCE OF *Idiognathodus sagittalis*
1
2
3
4
5
?

Moscow Basin (fig. 18). Correlation based solely on this taxon is difficult because *Eoschistoceras* ranges from the early Desmoinesian to the early Missourian in North America (fig. 16). Based on the presence of the fusulinids *Fusulina* and *Fusulinella* and species of the conodont *Neognathodus*, Solovieva et al. (1984) correlated the entire Myachkovsky Horizon (M8–N2) with the upper Desmoinesian. In contrast, Ruzhencev (1974, p. 322) concluded that the top of the Myachkovsky Horizon was Kasimovian (Zhigulian) in age. Ruzhencev's rationale for a Kasimovian age assignment was based on ammonoids from the Myachkovsky Horizon of the Moscow Basin and those from supposedly correlative strata at Cape Chayka.

Librovitch (1947) and later Ruzhencev (1974) reported a fairly large ammonoid fauna from limestones at Cape Chayka (Yugorskiy Peninsula) that includes *Glaphyrites* (as *Eoasianites* aff. *E. kansasensis*), *Dunbarites*, *Eoshumardites* (as *Shumardites*), *Pseudoparalegoceras*, and *Daixites*. Ruzhencev (1974, p. 322) correlated the Cape Chayka ammonoid fauna with that of the Myachkovsky Horizon, concluding that both were Zhigulian in age (= Kasimovian of more recent usage). He based this age assignment on the presence of *Dunbarites* and the fusulinid *Protriticites* in the Cape Chayka exposure. Ruzhencev considered both of these taxa to be restricted to the Zhigulian (Missourian) Stage.

Ruzhencev (1965) was aware that Furnish and Beghtel (1961) had reported *Dunbarites* from the late Desmoinesian Wewoka Formation of Oklahoma and went so far as to recommend changing the age assignment of the Wewoka Formation to Zhigulian (Missourian) based on the occurrence of *Dunbarites*. In support of his new age assignment for the Wewoka, Ruzhencev (1965) cited the appearance of *Agathiceras*, *Neodimorphoceras*, *Eoschistoceras*, and *Eothalassoceras* in the Wewoka Formation as representing a major faunal turnover. Some of these genera, however, actually appear elsewhere much lower stratigraphically. *Agathiceras* appears in the Smithwick Shale (Atokan) of central Texas, where it occurs with *Eowellerites* and *Paralegoceras* (Boardman and Mapes, unpublished collections). *Agathiceras* has also been reported from Japan in beds containing Atokan foraminifers (Nishida, 1971). In the northern midcontinent *Neodimorphoceras* appears in the Wetumka Shale in direct association with *Politoceras* (fig. 14, horizon NMC D10). Moreover, Nassichuk (1975) reported *Neodimorphoceras* from unequivocally Atokan strata (dated independently by foraminifers) on Ellesmere Island. *Eoschistoceras* appears in the early Desmoinesian Buckhorn Asphalt in association with *Pseudoparalegoceras*, *Paralegoceras*, and *Wellerites*. Besides the ammonoid evidence, the Wewoka Formation is clearly late Desmoinesian in age based on the presence of the fusulinid *Beedeina* and several species of the conodont *Neognathodus*. These same taxa are also used to characterize late Moscovian strata (Solovieva et al., 1984).

The use of the first appearance of the fusulinid *Protriticites* as a Kasimovian (Missourian) indicator is not favored by most Soviet workers [e.g., Solovieva et al. (1984)]. In the Moscow Basin *Protriticites* first occurs in late Moscovian strata in association with the characteristic Desmoinesian fusulinids *Fusulina* and *Fusulinella* (Makhlina et al., 1984, p. 8). The Cape Chayka ammonoid fauna, which includes the ammonoids *Dunbarites* and *Pseudoparalegoceras* in association with the fusulinid *Protriticites*, should probably be considered late Moscovian (Desmoinesian) rather than Kasimovian (Missourian), as advocated by Ruzhencev (1974). Lower Kasimovian strata are characterized by the first appearance of *Obsoletes obsoletes* and *Protriticites pseudomontiparus* (Makhlina et al., 1984, p. 8).

Shchegolev and Kozitskaya (1984, p. 110) reported that the Moscovian-Kasimovian boundary lies within the N4–N5 limestone beds (fig. 18) in the Donetz Basin, corresponding to the first appearance of the conodont *Idiognathodus sagittalis*, the fusulinid *Obsoletes obsoletes*, and the extinction of the conodont *Neognathodus inequalis*. They correlated the base of the Kasimovian in the Donetz Basin to the base of the Khamovnichesky Horizon (fig. 18) in the Moscow Basin based on the first appearance of *I. sagittalis* in that succession. Most Soviet workers place the base of the Kasimovian Stage at the base of the Krevyakinsky Horizon in the Moscow Basin (fig. 18). However, *Neognathodus dilatus* persists into the lower part of the Krevyakinsky Horizon (Barskov et al., 1987, p. 140), suggesting that the base of the Kasimovian, as currently interpreted by most Soviet workers, may not coincide with the base of the Missourian Stage but instead corresponds to some position within the late Desmoinesian. We follow Solovieva et al. (1984) in regarding the entire Myachkovsky Horizon (M8–N2) to be of late but probably not latest Moscovian (Desmoinesian) age.

Popov (1960) reported the late Carboniferous ammonoids *Bisatoceras*, *Owenoceras*, *Eoshumardites*, and *Yakutoceras* from the Orulgansky mountain range of the Soviet Arctic and concluded that the ammonoids were Orenburgian in age. Ruzhencev (1975, p. 162), with no evidence to the contrary, categorically stated that these collections were "astratigraphic," representing more than one horizon and age. He also stated that the only ammonoid that was correctly placed stratigraphically within the upper Moscovian–Orenburgian interval was the poorly known taxon *Eoshumardites*. Ruzhencev (1975) was uncertain whether to refer this ammonoid fauna to the Moscovian or to the Zhigulian, but he favored a Zhigulian age assignment. Popov (1970) maintained that *Eoshumardites* occurred stratigraphically below *Phaneroceras* in the Orulgansky range, thereby concluding that *Eoshumardites* was definitely Moscovian in age. We tentatively accept the analysis of Popov (1970).

Late Moscovian ammonoids are rare in the Donetz Basin but include *Donetzoceras cambriense* (Aisenverg et al., 1975), a species that has been reported from the Westphalian C of Britain (Calver, 1968). However, based on palynomorphs, Peppers (1988) now considers the ammonoid-bearing strata containing *D. cambriense* in Britain to correspond to an Atokan (lower Moscovian) age.

Recently, Popov (1979) reported Kasimovian ammonoids from the Dombass region of the former Soviet Union, including *Gonioloboceras parvum* from the M10 interval, and *Gonioglyphioceras krynkense* from the N1 interval. Popov considered both of these occurrences to correspond to a Kasimovian age. Because most Soviet workers [e.g., Shchegolev and Kozitskaya (1984, p. 10)] favor a stratigraphically higher position for the Moscovian-Kasimovian boundary [between the N4 and N5 intervals in the Donetz Basin and the equivalent horizon in the Dombass region (N2–N3 level)], both of these occurrences are now considered to be Moscovian in age. A late Moscovian (Desmoinesian) age for the Dombass occurrence seems more consistent with the midcontinent ranges of these genera.

Kasimovian (Zhigulian) faunas from the Uralian region of the former Soviet Union have been extensively studied by Ruzhencev (1950, 1957, 1974, 1975). Two Zhigulian ammonoid faunas were reported by Ruzhencev (1950) from the Urals (fig. 18). The first of these faunas occurs in Ruzhencev's C3JA horizon and includes nine genera. This fauna is similar to typical Missourian ammonoid faunas in the North American midcontinent, as it includes *Metapronorites*, *Gleboceras*, *Glaphyrites*, *Parashumardites*, and *Subkargalites*. This fauna probably best corresponds to a middle but not late middle Missourian age. The presence of *Triticites*, including *T. irregularis*, in the C3JA ammonoid horizon is also compatible with a middle Missourian age.

The second of Ruzhencev's Zhigulian ammonoid faunas occurs in the C3JZ horizon (fig. 18). This horizon has produced 12 genera and is characterized by *Neopronorites*, *Uddenites*, *Uddenoceras* (as *Uddenites*), *Aristoceras*, and *Prothalassoceras*. The occurrence of *Aristoceras* with *Neopronorites* suggests a Virgilian (Gzhelian) correlation based on North American midcontinent range data (fig. 16). Only one of the species present in the C3JZ horizon also occurs in the C3JA horizon; by contrast, 11 species occur in both the C3JZ and the Orenburgian (upper Gzhelian–lower Asselian) fauna (fig. 18). Based on the fusulinid *Triticites stuckenbergi*, which occurs in the same stratigraphic interval containing the C3JZ ammonoid fauna, most Soviet workers [e.g., Muravyev et al. (1984), Bogoslovskaya (1984), and Bogoslovskaya and Popov (1986)] now refer this fauna to the lower Gzhelian (lower Virgilian). However, the absence of representatives of the rapidly evolving genera *Shumardites* and *Vidrioceras* precludes direct comparison with North American Virgilian ammonoid faunas. Most of the remaining ammonoids are generalized long-ranging taxa that have been insufficiently compared at the species level with North American counterparts.

Ruzhencev (1950) described diverse Orenburgian (uppermost Gzhelian and lowermost Asselian; fig. 18) ammonoid faunas from the Uralian region of the former Soviet Union that contain at least 22 genera. Ruzhencev (1950) considered the entire Orenburgian Stage to be latest Carboniferous (Virgilian) in age. The Orenburgian Stage was recently abandoned by most Soviet researchers when it was shown to correlate with the late Gzhelian to early Asselian stages in the proposed hypostratotype for the Gzhelian Stage and the Permian-Carboniferous boundary stratotype section (Samara Luka) by Muravyev et al. (1984) and Bogoslovskaya and Popov (1986). The Orenburgian ammonoid fauna is similar to North American Virgilian ammonoid faunas in that both contain *Neopronorites*, *Emilites*, *Aristoceras*, *Vidrioceras*, *Marathonites*, *Shumardites*, and *Daixites*. In contrast, Soviet Orenburgian faunas also contain *Artinskia*. *Daixites* has not been reported previously from the United States, but Nassichuk and Henderson (1986) recovered it with a typical Orenburgian fauna from Asselian strata in the Canadian Arctic. *Artinskia* has been recovered in North America only from rocks that are correlated with the Permian. North American occurrences of *Artinskia* are in the Camp Creek Shale Member (Pueblo Formation) of north-central Texas (Miller and Youngquist, 1947, fig. 12) and the Bursum Formation of New Mexico (Furnish and Glenister, 1971, fig. 16). It should be stressed that no prolecanitids have been recovered from the uppermost Virgilian or lowermost Asselian strata in the North American midcontinent.

Ample evidence exists that the Soviet Orenburgian ammonoid faunas of the southern Urals are slightly younger than the diverse ammonoid assemblages from the Virgilian Graham Formation and the H limestone bed of the Gaptank Formation of the Marathon Uplift. However, it is possible that the less diverse assemblages from late Virgilian (Wabaunsee) strata in the northern midcontinent and the ammonoid fauna from the *Uddenites* Shale Member of the Gaptank Formation might be comparable in age with the Soviet lower Orenburgian (upper Gzhelian) faunas. *Shumardites confessus*, from the latest Gzhelian *Daixina sokensis* Zone of the southern Urals (fig. 18), is slightly more advanced in terms of sutural complexity than its North American Virgilian counterpart, *S. simondsi*, the most advanced North American species of *Shumardites*. The early Asselian species *S. aktubensis* is difficult to assess because the suture of the holotype, as illustrated by Ruzhencev (1950), is presumably immature. Furthermore, sutures of the Soviet species of *Vidrioceras* (*V. borissiaki*, recovered from early Asselian strata containing the *D. bosbytauensis*–*D. robusta* Zone; fig. 18) are considerably more advanced than those of its North American Virgilian equivalents *V. uddeni* and *V. irregulare*.

Zakharov (1978) reported several new ammonoid occurrences from late Carboniferous strata of Karachatyr (south Fergana). He reported *Emilites incertus* and *Vidrioceras* *bidens* Zakharov from Kasimovian strata. We consider these occurrences to be of potentially great biostratigraphic value but have reservations concerning the taxonomic treatment of reported taxa. Uncertainty surrounds Zakharov's assignment of *V. bidens* to the genus *Vidrioceras*. The ventrad U_2 umbilical lobe of *V. bidens* is distinctly more advanced than that of any species of *Vidrioceras*, with the possible exception of the most advanced species *V. borissiaki*. We tentatively refer *V. bidens* to the genus *Subkargalites*. The sutures of *Emilites incertus* presented by Zakharov (1978) illustrate a closer relationship to Missourian species of *Emilites* (e.g., *E. bennisoni* Mapes and Boardman).

Zakharov (1978) reported *Emilites plummeri* and *Vidrioceras conlini* from middle to lower upper Gzhelian strata of Karachatyr. The fusulinid-based correlations of these ammonoid-bearing strata indicate a middle Gzhelian age based on *Daixina asiatica*. Uncertainty also surrounds some taxonomic assignments within this fauna. The conch proportions of *E. plummeri* reported by Zakharov (1978) are incompatible with that species and are actually much closer to *E. incertus*. We have reservations about the middle Gzhelian specimens of *Vidrioceras* being attributed to *Vidrioceras conlini*. *Vidrioceras conlini* (Miller and Downs, 1950) is decidedly more primitive than specimens assigned to the species by Zakharov. Zakharov's illustrated specimens of *V. conlini* clearly indicate an advanced *Vidrioceras* with a distinctly tripartite umbilical lobe, whereas *Vidrioceras conlini* (Miller and Downs, 1950) shows no tripartition of the umbilical lobe. Zakharov's (1978) specimens of *V. conlini* should probably be referred to *V. uddeni* or possibly a new species of *Vidrioceras*. This middle to lower upper Gzhelian ammonoid fauna seems to compare well to that of the *Uddenites* Shale Member of the Gaptank Formation, and the two faunas may be correlative.

Ammonoid zonation

Previous zonations

Several previous Middle and Upper Pennsylvanian (Desmoinesian–Virgilian) ammonoid zonations have been proposed for interbasinal stage-level correlations (fig. 19; Miller, 1938; Unklesbay, 1954; Ruzhencev and Bogoslovskaya, 1971; Ramsbottom and Saunders, 1985; Bogoslovskaya, 1984). Although these zonations have proven useful for generalized worldwide correlation, the zones have not been rigorously defined with ranges of critical taxa tested against an objective standard. The North American midcontinent, with its unparalleled succession of Desmoinesian–Virgilian ammonoid faunas, provides the standard against which to test the accuracy and applicability of the various zonal schemes.

The presence of *Wellerites* (Ramsbottom and Saunders, 1985), the joint occurrence of *Wellerites* and *Pseudoparalegoceras* (Ruzhencev and Bogoslovskaya, 1971), and a combination of *Owenoceras* and *Wellerites* (wherein *Owenoceras* and *Wellerites* represent the early and late Desmoinesian, respectively; Unklesbay, 1954) have been used to characterize the Desmoinesian Stage (fig. 19). However, the actual ranges of these taxa in the midcontinent (fig. 16), as demonstrated here, indicate that none of these zones accurately characterizes the Desmoinesian Stage. *Wellerites* apparently became extinct in late but not latest Desmoinesian time (fig. 16). *Owenoceras* ranges from the latest middle Desmoinesian through the middle Missourian (fig. 16). In North America the ranges of *Wellerites* and *Pseudoparalegoceras* overlap only in the early Desmoinesian (fig. 16).

The presence of *Prouddenites* (Miller, 1938) and *Parashumardites* (Ramsbottom and Saunders, 1985), the co-occurrence of *Parashumardites* and *Dunbarites* (Ruzhencev and Bogoslovskaya, 1971), and a combination of *Eothalassoceras* and *Prouddenites* (*Eothalassoceras* representing the early Missourian and *Prouddenites* representing middle and late Missourian; Unklesbay, 1954) have been used to characterize the Missourian Stage (fig. 19). The ranges of these taxa in the midcontinent do not support their use as stage-level generic-level zonal indicators (fig. 16). *Prouddenites* ranges from the late Desmoinesian to the late Missourian in the midcontinent (fig. 16) and from the Kasimovian into the Asselian in the Urals (Bogoslovskaya, 1984; Bogoslovskaya and Popov, 1986). The use of *Eothalassoceras* to characterize the early Missourian was based on the Collinsville, Oklahoma, fauna, which subsequently has been shown to be latest Desmoinesian in age (Boardman et al., 1989c). *Parashumardites* ranges from middle Missourian to early middle Virgilian (fig. 16). *Dunbarites* ranges from the late Desmoinesian through the late Virgilian in the North American midcontinent (fig. 16) and has been reported recently from equivalent Gzhelian strata in the southern Urals (Bogoslovskaya and Popov, 1986).

The presence of *Uddenoceras* (Miller, 1938) and *Shumardites* (Ramsbottom and Saunders, 1985), the joint occurrence of *Emilites* and *Shumardites* (Ruzhencev and Bogoslovskaya, 1971), and the co-occurrence of *Shumardites* and *Vidrioceras* (Bogoslovskaya, 1984) have been used to characterize the Virgilian Stage (fig. 19). *Uddenites* ranges from the Kasimovian (as Zhigulian) to the early Asselian in the southern Urals (Ruzhencev, 1950; Bogoslovskaya and Popov, 1986). *Shumardites* ranges from the early middle Virgilian through the early Asselian based on ranges from the North American midcontinent (fig. 16) and the southern Urals. *Emilites* ranges from the late middle Missourian (and possibly late Desmoinesian) through the Virgilian in the midcontinent region (fig. 16) and is known to range into the Asselian in the southern Urals (Movschovitsch et al., 1979). *Vidrioceras* appears in the early to middle Virgilian and ranges into the early Asselian (fig. 16).

Ammonoid-based generic-level zonation and correlation

Generic-level zones are based on a belief that a single genus or two genera used in combination can be used to characterize an entire stage. As demonstrated here, no single genus has a range that exactly coincides with both the upper and the lower boundaries of a given stage (fig. 16). An alternative approach using first-occurrence generic-level zones is proposed (figs. 19 and 20). All the zones are defined on the basis of the northern midcontinent succession with the exception of the *Shumardites* Zone, which is more fully developed in the north-central Texas area of the southern midcontinent (fig. 20).

***Wellerites* Zone** The base of the *Wellerites* Zone is defined by the first occurrence of *Wellerites*, and the top is defined by the first occurrence of *Eothalassoceras* (fig. 19). The first appearance of *Wellerites* has been used traditionally to identify the Atokan-Desmoinesian boundary. However, the upper range of *Eowellerites* and the lower range of *Wellerites* remain undetermined. *Eowellerites* has been found exclusively in Atokan strata and *Wellerites* only in Desmoinesian strata, but the evolutionary first appearance of *Wellerites* is not known because the first occurrence of this genus is in lower but presumably not lowermost Desmoinesian strata. Accordingly, the base of the *Wellerites* Zone could be extended down to the base of the Desmoinesian or into the uppermost Atokan. Therefore, although the basal part of the *Wellerites* Zone may be used to correlate early Desmoinesian strata, it cannot be used as an Atokan-Desmoinesian boundary indicator. The *Wellerites* Zone is subdivided into three subzones (figs. 19 and 20): the *Wellerites-Paralegoceras* Subzone (fig. 20, horizons NMC D2–D4), the *Politoceras* Subzone (fig. 20, horizons NMC D5–D10), and the *Wewokites* Subzone (fig. 20, horizon NMC D11).

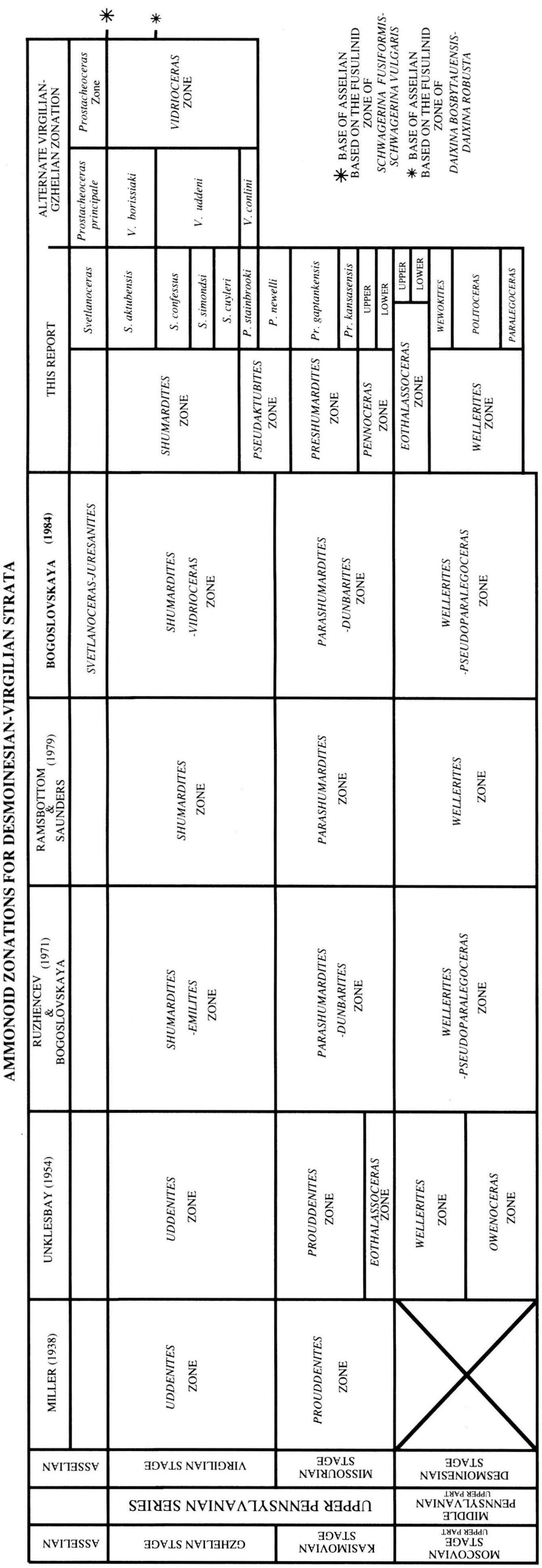


Figure 19. Proposed ammonoid-based zonations for Desmoinesian–Virgilian strata. See text for definition of zones and their relationship to series and stage boundaries.

Wellerites-Paralegoceras Subzone The base of the *Wellerites-Paralegoceras* Subzone is defined by the first appearance of *Wellerites*, and the top is defined by the extinction of *Paralegoceras* (fig. 20, horizons NMC D2–D4). This subzone encompasses lower Desmoinesian strata and is characterized by the presence of *Wellerites*, *Aktubites*, *Paralegoceras*, *Gastrioceras*, and *Pseudoparalegoceras* (fig. 20). The use of *Pseudoparalegoceras brazoense* as an indicator for the *Wellerites-Paralegoceras* Subzone seems to work well for North American ammonoid faunas. The use of *Pseudoparalegoceras* at the generic level for recognition of this subzone is not favored because *Pseudoparalegoceras* occurs in Atokan strata in North America and occurs in strata of probable late Desmoinesian age in the former Soviet Union. The presence of *Paralegoceras* and *Gastrioceras* may also be used in conjunction with *Wellerites*, *Aktubites*, or *Pseudoparalegoceras* to identify this subzone. In north-central Texas this subzone is recognized in the upper portion of the Dickerson Shale based on the occurrence of *Pseudoparalegoceras brazoense* (fig. 20, horizon SMC D1).

Politoceras Subzone The base of the *Politoceras* Subzone is defined by the extinction of *Paralegoceras*, and the top is defined by the first occurrence of *Wewokites venatus* (fig. 20, horizons NMC D5–D10). The *Politoceras* Subzone is distinguished by the acmes of *Politoceras politum* and *Wiedeyoceras*. Missing from the *Politoceras* Subzone because of apparent extinction are *Pseudoparalegoceras* and *Aktubites*. In the northern shelf area of the northern midcontinent the upper part of this subzone includes the first appearance of *Owenoceras* (figs. 14 and 20, horizon NMC D8) and the first midcontinent appearance of *Neodimorphoceras* (figs. 14 and 20, horizon NMC D9). In north-central Texas the *Politoceras* Subzone is tentatively identified in the Grindstone Creek Formation (figs. 15 and 20, horizon SMC D2) based on the presence of *Glaphyrites welleri,* which occurs in the northern midcontinent in the Mecca Quarry Shale Member and Excello Shale Member (figs. 2, 14, and 20, horizons NMC D7 and D8).

Wewokites Subzone The base of the *Wewokites* Subzone is defined by the first occurrence of *Wewokites venatus*, and the top is defined by the first occurrence of *Eothalassoceras inexpectans* (fig. 20, horizon NMC D11). The *Wewokites* Subzone interval has produced the most diverse and abundant Desmoinesian ammonoid fauna in the world (fig. 14, horizon NMC D11). The *Wewokites* Subzone is tentatively recognized in the East Mountain Shale of north-central Texas by the co-occurrence of *Wewokites* and *Wellerites* (fig. 20, horizon SMC D4). However, an alternative assignment to the lower subzone of the succeeding *Eothalassoceras* Zone cannot be ruled out. *Eothalassoceras* has not yet been recovered from north-central Texas.

***Eothalassoceras* Zone** The base of the *Eothalassoceras* Zone is defined by the first appearance of *Eothalassoceras inexpectans*, and the top is defined by the first occurrence of *Pennoceras* (fig. 20, horizons NMC D12–D14). This zone is characterized by a fauna similar to that of the *Wewokites* Zone (fig. 14, horizons NMC D12–D14). The *Eothalassoceras* Zone is subdivided into lower and upper subzones.

Lower Subzone The base of the Lower Subzone is defined by the first appearance of *Eothalassoceras inexpectans*, and the top is defined by the last occurrence of *Wellerites* (figs. 14 and 20, horizons NMC D12 and D13). The Lower Subzone has not been positively identified in north-central Texas because of the apparent absence of *Eothalassoceras* in that region.

Upper Subzone The base of the Upper Subzone is defined by the last occurrence of *Wellerites*, and the top is defined by the first occurrence of *Pennoceras* (figs. 14 and 20, horizon NMC D14). The Upper Subzone is correlated with the middle unnamed member of the East Mountain Shale, north-central Texas, based on the extinction of *Wellerites* below the first appearance of *Pennoceras* (figs. 15 and 20, horizons SMC D6 and D7).

***Pennoceras* Zone** The base of the *Pennoceras* Zone is defined by the first occurrence of *Pennoceras*, and the top is defined by the first appearance of *Preshumardites kansasensis* (fig. 20, horizons NMC M1–M3). The *Pennoceras* Zone is further distinguished by the appearance of the first abundance of marathonitid ammonoids (*Subkargalites*). Persistent Desmoinesian elements include *Eoschistoceras*, *Bisatoceras*, and *Maximites*. The presence of these holdover taxa argues against any major disconformity at the Desmoinesian-Missourian boundary, as has been postulated previously. The *Pennoceras* Zone is subdivided into two subzones.

Lower Subzone The base of the Lower Subzone is defined by the first appearance of *Pennoceras*, and the top is defined by the first occurrence of *Schistoceras missouriensis* (fig. 20, horizons NMC M1 and M2). This subzone is identified in north-central Texas by the first appearance of *Pennoceras* in the Bath Bend bed of the East Mountain Shale (fig. 20, horizon SMC M1).

Upper Subzone The base of the Upper Subzone is defined by the first appearance of *Schistoceras missouriensis*, and the top is defined by the first occurrence of *Preshumardites kansasensis* (fig. 20, horizon NMC M3). This subzone is recognized in north-central Texas by the first appearance of *S. missouriensis* in the upper part of the Salesville Shale (fig. 20, horizon SMC M3).

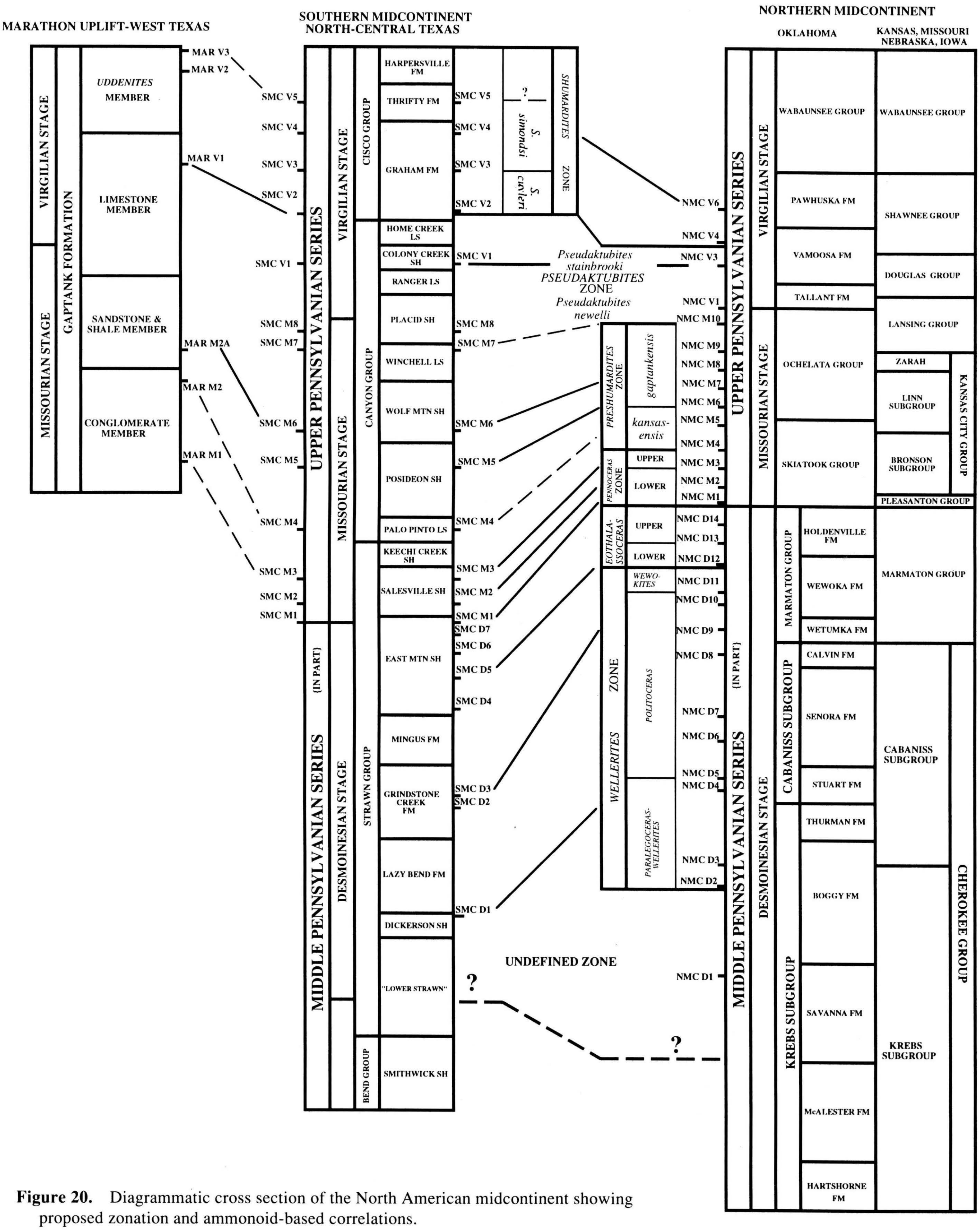


Figure 20. Diagrammatic cross section of the North American midcontinent showing proposed zonation and ammonoid-based correlations.

***Preshumardites* Zone** The base of the *Preshumardites* Zone is defined by the first occurrence of *Preshumardites*, and the top is defined by the first occurrence of *Pseudaktubites* (fig. 20, NMC horizons M4–M9). The *Preshumardites* Zone is subdivided into a lower *Preshumardites kansasensis* Subzone and an upper *Preshumardites gaptankensis* Subzone.

Preshumardites kansasensis Subzone The base of the *Preshumardites kansasensis* Subzone is defined by the first appearance of the nominate species, and the top is defined by the first occurrence of *Preshumardites gaptankensis* (fig. 20, horizon NMC M4). The *Preshumardites kansasensis* Subzone is the first typically Missourian ammonoid assemblage. Persistent Desmoinesian elements (*Maximites*, *Bisatoceras*, *Eoschistoceras*), which occur in the subjacent *Pennoceras* Zone, are replaced in the *Preshumardites kansasensis* Subzone by taxa of Missourian aspect: *Prouddenites*, *Gonioloboceras*, *Subkargalites*, and *Schistoceras*. The *Preshumardites kansasensis* Subzone has not been identified definitely in north-central Texas but can be equated to the Palo Pinto Formation based on the first part of the acme of *Gonioloboceras* and *Subkargalites* along with the extinction of *Eoschistoceras* (fig. 20, horizon SMC M4).

Preshumardites gaptankensis Subzone The base of the *Preshumardites gaptankensis* Subzone is defined by the first appearance of the nominate species, and the top is defined by the first occurrence of *Pseudaktubites newelli* (fig. 20, horizons NMC M5–M9). In addition to the nominate species, this subzone is characterized by the appearances of *Parashumardites*, *Uddenoceras*, *Aristoceras*, *Gleboceras*, *Promarathonites*, *Eupleuroceras*, and *Eoasianites* (fig. 16). This subzone has been positively identified in north-central Texas (fig. 20, horizons SMC M5 and M6) by the occurrence of the nominate species in addition to the appearances of *Aristoceras*, *Parashumardites*, and *Promarathonites*.

***Pseudaktubites* Zone** The base of the *Pseudaktubites* Zone is defined by the first appearance of *Pseudaktubites* (fig. 20, horizons NMC M10–V3), and the top is defined by the first appearance of *Shumardites* (fig. 20, horizons SMC M7–V1). The base of the *Pseudaktubites* Zone occurs at the base of the lower Barnsdall Formation (stratigraphic equivalent of the Eudora Shale Member of the Stanton Limestone) at a position slightly below the provisional base of the Virgilian Stage. The *Pseudaktubites* Zone is subdivided into a lower *Pseudaktubites newelli* Subzone and an upper *Pseudaktubites stainbrooki* Subzone.

Pseudaktubites newelli Subzone The base of the *Pseudaktubites newelli* Subzone is defined by the first appearance of *Pseudaktubites newelli* (fig. 20, horizon NMC M10), and the top is defined by the first appearance of *Pseudaktubites stainbrooki* (fig. 20, horizon NMC V3). The *Pseudaktubites newelli* Subzone is distinguished by the first occurrences of *Cardiella* and *Neoglaphyrites*. In northernmost Oklahoma and Kansas *Neoglaphyrites* is especially prominent in the Eudora Shale Member of the Stanton Limestone and the basal Weston Shale Member of the Stranger Formation. In north-central Texas, strata of probable *P. newelli* Subzone age have produced only a small number of indeterminate juvenile ammonoids. Although this fauna includes new faunal elements, such as *Cardiella* and *Neoglaphyrites*, it contains a number of typically Missourian taxa, such as *Prouddenites primus*.

Pseudaktubites stainbrooki Subzone The base of the *Pseudaktubites stainbrooki* Subzone is defined by the first appearance of *Pseudaktubites stainbrooki* (fig. 20, horizons NMC V3 and SMC V1), and the top is defined by the first appearance of *Shumardites cuyleri* (fig. 20, horizon SMC V2). The *Pseudaktubites stainbrooki* Subzone has been identified in the Colony Creek Shale Member of north-central Texas, based on the first appearance of the nominate species. The *Pseudaktubites stainbrooki* Subzone fauna is distinguished by the first appearance of a large number of important Virgilian taxa, including *Neopronorites*, *Vidrioceras conlini*, *Marathonites*, *Uddenoceras harlani*, and *Emilites incertus*.

***Shumardites* Zone** The base of the *Shumardites* Zone is defined by the first appearance of *Shumardites*, and the top is provisionally placed at the first appearance of *Prostacheoceras* (fig. 20, horizon SMC V2 and above). Ammonoid faunas within this zone are taxonomically similar to those of the subjacent *Pseudaktubites* Zone, except that *Shumardites* has replaced *Pseudaktubites*. The *Shumardites* Zone is further distinguished by the first appearance of *Vidrioceras uddeni*. The *Shumardites* Zone is subdivided into the *S. cuyleri* Subzone, the *S. simondsi* Subzone, the *S. confessus* Subzone, and the *S. aktubensis* Subzone.

Shumardites cuyleri Subzone The base of the *Shumardites cuyleri* Subzone is defined by the first appearance of *S. cuyleri*, and the top is defined by the first appearance of *S. simondsi* (fig. 20, horizon SMC V2). This subzone has been tentatively identified in the H limestone bed of the Limestone Member of the Gaptank Formation in the Marathon Uplift region (fig. 13, horizon MAR V1). In addition, the *S. cuyleri* Subzone has been identified in the Heebner Shale Member of the Oread Limestone in the northern midcontinent based on the first appearance of *Vidrioceras uddeni* (fig. 20, horizon NMC V4), in association with *V. conlini*.

Shumardites simondsi Subzone The base of the *Shumardites simondsi* Subzone is defined by the first appearance of *S. simondsi*, and the top is defined by the first appearance of *S. confessus* (fig. 20, horizons SMC V3 and V4 at base; fig. 18 at top). The *S. simondsi* Subzone has been identified in the *Uddenites* Shale Member of the Gaptank Formation of the Marathon Uplift based on the presence of the nominate species (figs. 13 and 20, horizon MAR V2). Ammonoid faunas representing the *S. simondsi* Subzone have not yet been positively identified in the northern midcontinent but may equate to the low-diversity assemblages from the upper Shawnee and lower Wabaunsee strata.

Shumardites confessus Subzone The base of the *Shumardites confessus* Subzone is defined by the first appearance of *S. confessus*, and the top is defined by the first appearance of *Vidrioceras borissiaki* (fig. 18). The *S. confessus* Subzone is defined in the southern Urals and is presently unknown in North America but may be present in Wabaunsee Group strata.

Shumardites aktubensis Subzone The base of the *Shumardites aktubensis* Subzone is defined by the first appearance of the nominate species, and the top is defined by the first appearance of *Svetlanoceras primore* and *Prostacheoceras principale* (fig. 18). The *S. aktubensis* Subzone is defined in the southern Urals and is presently unknown in North America but may be present in the uppermost Wabaunsee or lower Admire Group.

Alternative Virgilian (Gzhelian) zonation

Because of the apparently cosmopolitan distribution of vidrioceratids and because of their importance in potentially marking the base of the Virgilian (Gzhelian) and Asselian stages (*Vidrioceras conlini* and *V. borissiaki*), we propose an alternative Virgilian (Gzhelian) zonation based on *Vidrioceras*. Three subzones based on species of *Vidrioceras* are used. The *Vidrioceras conlini* and *Vidrioceras uddeni* subzones are defined in north-central Texas but are equally well developed in the northern midcontinent. The *Vidrioceras borissiaki* Subzone was defined by Bogoslovskaya and Popov (1986) based on the succession in the Ural Mountains.

***Vidrioceras* Zone** The base of the *Vidrioceras* Zone is marked by the first occurrence of *Vidrioceras*, and the top is defined by the appearance of *Prostacheoceras*. The *Vidrioceras* Zone is subdivided into the *V. conlini* Subzone, the *V. uddeni* Subzone, and the *V. borissiaki* Subzone (fig. 16).

Vidrioceras conlini Subzone The base of the *Vidrioceras conlini* Subzone is defined by the first appearance of the nominate taxon, and the top is defined by the appearance of *Vidrioceras uddeni* (figs. 16 and 19). The *Vidrioceras conlini* Subzone occupies the same stratigraphic interval as the *Pseudaktubites stainbrooki* Subzone defined in the northern midcontinent (basal Robbins Shale Member–Heebner Shale Member) and identified in north-central Texas (Colony Creek Shale Member–Finis Shale Member) (fig. 20).

Vidrioceras uddeni Subzone The base of the *Vidrioceras uddeni* Subzone is defined by the first appearance of the nominate taxon, and the top is defined by the appearance of *Vidrioceras borissiaki* (figs. 16 and 19). The *Vidrioceras uddeni* Subzone is distinguished further by the appearance of *Shumardites* (*S. cuyleri*) and the continued presence of *V. conlini* in the lowermost part (fig. 16). The upper part of the *Vidrioceras uddeni* Subzone is marked by the appearances of *Shumardites simondsi* and *Vidrioceras irregulare*. The *V. uddeni* Subzone is present in the Finis, Necessity, and Wayland shale members of north-central Texas, the H limestone bed and the *Uddenites* Shale Member of the Marathon Uplift, the Heebner Shale Member of the northern midcontinent, and probably in the south Fergana region of Kazakhstan.

Vidrioceras borissiaki Subzone The base of the *Vidrioceras borissiaki* Subzone is defined by the appearance of the nominate taxon, and the top is defined by the appearance of *Prostacheoceras* (*P. primore*) (figs. 16, 18, and 19). This subzone, defined by Bogoslovskaya and Popov (1986), currently marks the base of the Asselian, as formally utilized in the former Soviet Union. Near the top of the *Vidrioceras borissiaki* Subzone *Almites* first appears (Bogoslovskaya and Popov, 1986). This subzone has not been positively identified outside the former Soviet Union.

Correlation of North American stage and series boundaries

The base of the Desmoinesian Stage has traditionally been placed at the changeover from *Eowellerites* to *Wellerites* (Ramsbottom and Saunders, 1985). Although *Eowellerites* has not been recovered from demonstrably Desmoinesian strata and *Wellerites* has not been recovered from Atokan strata, both the upper limit to the range of *Eowellerites* and the base of the range of *Wellerites* remain unknown. The first ammonoid-bearing interval above the base of the Desmoinesian contains only *Gastrioceras*, which occurs in both Atokan and Desmoinesian strata. At this time the base of the Desmoinesian cannot be confidently identified by means of ammonoids, and the first appearance of *Wellerites* should not be used as an indicator of the Atokan-Desmoinesian boundary. Despite the difficulty of boundary recognition, early Desmoinesian strata can be correlated using the *Wellerites-Paralegoceras* Subzone of the redefined *Wellerites* Zone.

In areas with sufficient ammonoid faunas the Middle-Upper Pennsylvanian series boundary (equivalent to the Desmoinesian-Missourian stage boundary) is best recognized by ammonoids. In both regions of the North American midcontinent *Pennoceras* and the conodont *Idiognathodus sagittalis* generally first appear within the first 20 ft (6 m) of the initial marine transgression after the major extinction event that resulted in the range termination of the fusulinid *Beedeina*, the conodont *Neognathodus*, and the chonetid brachiopod *Mesolobus*. Unfortunately, no ammonoids have been recovered to date from Kasimovian strata below the Dorogomilovsky Horizon (fig. 18) in the former Soviet Union.

There is no consistent, widely used biostratigraphic indicator for the base of the Virgilian as currently defined. The base of the *Pseudaktubites newelli* Subzone occurs one cycle below the current provisional Missourian-Virgilian boundary in the northern midcontinent. However, the *P. newelli* Subzone has not been recognized in the southern midcontinent. No significant change in ammonoid faunas takes place across the provisional Missourian-Virgilian boundary in the northern midcontinent. The basal Weston Shale Member ammonoid fauna is virtually identical to that of the underlying Eudora Shale Member except that it has a slightly lower diversity. However, the *Pseudaktubites stainbrooki* Subzone, which is well developed in both the northern and southern midcontinent, is distinguished by the first appearance of the typically Virgilian taxa *Vidrioceras conlini*, *Marathonites*, *Neopronorites*, *Emilites incertus*, and *Uddenoceras harlani*, suggesting that this faunal break may represent a more suitable level for placement of the Missourian-Virgilian boundary (Boardman et al., 1989a). Significantly, the base of the *P. stainbrooki* Subzone occurs only slightly above the level of Moore's (1932) Missourian-Virgilian boundary in the northern midcontinent.

Other ammonoid faunas from North America

Appalachian Basin

Only sporadic occurrences of Desmoinesian–Virgilian ammonoids have been reported from the Appalachian Basin. The following discussion of ammonoid distribution in the Appalachian Basin is summarized by Mapes et al. (1993).

Desmoinesian ammonoids have been reported from only four stratigraphic intervals in the Appalachian Basin. The stratigraphically lowest Desmoinesian ammonoid-bearing interval occurs near the base of the Allegheny Group (fig. 21, horizon APP D1) in the Putnam Hill Limestone Member. This assemblage is similar to early Desmoinesian faunas from the midcontinent in that it contains *Aktubites*, *Gastrioceras*, *Wellerites*, and *Eoschistoceras*. The Putnam Hill fauna differs from midcontinent early Desmoinesian faunas by lacking *Paralegoceras* and *Pseudoparalegoceras* and by containing *Gonioglyphioceras*, which appears in late Desmoinesian strata in the midcontinent. The gonioloboceratid *Mangeroceras* is apparently endemic to the Appalachian Basin. The co-occurrence of *Aktubites*, *Gastrioceras*, and *Wellerites* in the Putnam Hill fauna suggests reference to the early Desmoinesian *Wellerites* Zone (*Wellerites-Paralegoceras* Subzone). The Putnam Hill Limestone Member contains the appearance of *Beedeina* (*B. leei*) in the Appalachian Basin (Douglass, 1987). *Beedeina leei* occurs in lower Desmoinesian strata (basal Boggy Formation; fig. 2) in the northern midcontinent, thus corroborating an early Desmoinesian age for the Putnam Hill.

The Vanport limestone contains *Aktubites*, *Glaphyrites*, and *Mangeroceras* (fig. 21, horizon APP D2). The joint occurrence of *Aktubites* and *Mangeroceras* suggests that the Vanport is close in age to the underlying Putnam Hill Limestone Member. Douglass (1979, p. 19) reports *Wedekindellina* and *Beedeina* from this unit, indicating an early to middle Desmoinesian age. The Columbiana limestone and associated shale contain *Somoholites*, *Wellerites*, and *Gonioglyphioceras*, which are relatively undiagnostic at the generic level for interbasinal correlation (fig. 21, horizon APP D3). Fusulinids from this interval are rare and include undiagnostic specimens of *Beedeina* (Douglass, 1979, p. 19). The highest Allegheny ammonoid-producing interval occurs in the Washingtonville shale. The Washingtonville shale contains a moderately diverse assemblage of ammonoids, including *Maximites*, *Somoholites*, *Wellerites*, *Gonioglyphioceras*, and *Glaphyrites*. The occurrence of *Gonioglyphioceras gracile* and *Glaphyrites jonesi* in both the Washingtonville shale and Marmaton Group (late Desmoinesian) strata of the northern midcontinent suggests that the Washingtonville is probably also late Desmoinesian in age. The Washingtonville shale has so far produced no diagnostic fusulinids (Douglass, 1979). Considered together, the Vanport, Columbiana, and Washingtonville marine bands cannot be precisely zoned because of the paucity of ammonoids. However, the presence of *Wellerites* in the highest of these intervals (Washingtonville shale), suggests that all these faunas are older than the upper part of the *Eothalassoceras* Zone.

Missourian ammonoid faunas from the Appalachian Basin, like those of the Desmoinesian, are poorly represented and stratigraphically spotty in distribution. The lowest Missourian ammonoid-producing interval occurs in the lower Brush Creek limestone (and overlying shale) of the lower part of the Conemaugh Group in both Ohio and Pennsylvania (fig. 21, horizon APP M1). The fauna of the lower Brush Creek limestone and associated shale includes *?Neoaganides*, *Neodimorphoceras*, *Eoschistoceras*, *Schistoceras*, *Pennoceras*, *Gonioloboceras*, and *Glaphyrites*. The presence of *Pennoceras*, *Eoschistoceras*, and *Schistoceras* in the lower Brush Creek fauna suggests reference to the upper part of the early Missourian *Pennoceras* Zone. The upper Brush Creek limestone and associated shale contain only *Pennoceras* and *Neoaganides*, which are not sufficiently diagnostic for interbasinal correlation (fig. 21, horizon APP M2). However, the first appearance of *Triticites* (*T. ohioensis*) from the Brush Creek limestone of southern Ohio (Douglass, 1979, p. 18) in conjunction with *Pennoceras* suggests that the Brush Creek limestone might be latest early Missourian in age. The Cambridge limestone, which lies near the middle of the Conemaugh Group, has produced only *Schistoceras* (fig. 21, horizon APP M3). *Preshumardites* has been reported from the Carnahan Run marine unit (fig. 21, horizon APP M4) in Pennsylvania by Saunders (1971). The Portersville shale, which according to Busch (1984) is equivalent to the Carnahan Run shale, contains *Neoaganides*, *Subkargalites*, and *Gonioloboceras* (fig. 21, horizon APP M5). The combined Carnahan Run–Portersville marine band fauna suggests reference to the late middle Missourian *Preshumardites* Zone.

The only Virgilian ammonoid-producing interval in the Appalachian Basin occurs in the Ames limestone in eastern Ohio (upper Conemaugh Group; fig. 21, horizon APP V1). The Ames limestone has produced only the relatively undiagnostic ammonoid *Schistoceras*, which precludes an ammonoid-based interbasinal correlation between the Ames and the midcontinent. However, the Ames contains *Triticites cullomensis*, which indicates a middle to early middle Virgilian age for this unit (Douglass, 1979, p. 18).

Illinois Basin

Although the Illinois Basin contains an excellent Desmoinesian through middle Virgilian section, few ammonoids have been recovered from those units. As is the case in the Appalachian Basin, a multitaxial approach for

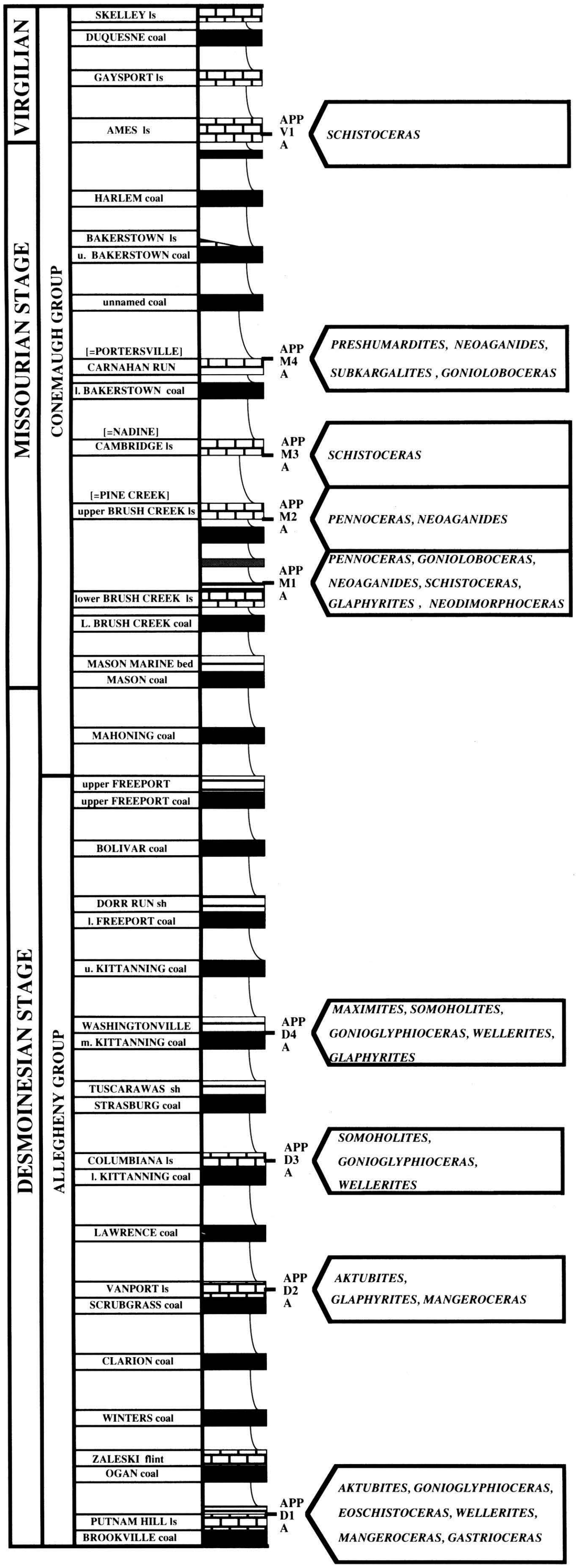


Figure 21. Stratigraphic distribution of ammonoid faunas in Desmoinesian–Virgilian strata in the Appalachian Basin. This figure is based largely on the Mapes et al. (1993) report on the ammonoids of the Appalachian Basin.

biostratigraphic correlation is necessary because of the paucity of data for any one taxonomic group.

Desmoinesian strata from the Illinois Basin have yielded only three genera of ammonoids: *Wiedeyoceras*, *Gonioglyphioceras*, and *Glaphyrites*. Plummer and Scott (1937) reported *Gastrioceras* from shale above the Rock Island coal (fig. 22, horizon ILL A0). Zangerl and Richardson (1963) reported *Paralegoceras* and *Pseudopronorites* from the Logan Quarry Shale, a probable correlative of the shale over the Rock Island coal in Indiana. The Illinois Geological Survey considers these units to be early Desmoinesian in age, based on the first appearance of *Fusulinella iowensis* (Shaver, 1984). However, we refer these occurrences to the late Atokan based on the first appearance of *Beedeina*, somewhat higher in the Illinois succession (Curlew Limestone Member; fig. 22). As a result of the reassignment of the Logan Quarry Shale to the Atokan, no early Desmoinesian ammonoids are known from the Illinois Basin.

Middle Desmoinesian strata in the Illinois Basin have produced only *Wiedeyoceras*, *Glaphyrites*, and *Gonioglyphioceras*. Saunders and Richardson (1979) reported *Wiedeyoceras* from the Mazon Creek interval (fig. 22, horizon ILL D1). Plummer and Scott (1937) reported *Wiedeyoceras* (as *Anthracoceras wanlessi*) from black shale overlying the Colchester (no. 2) coal (fig. 22, horizon ILL D3; probable Croweburg equivalent of the northern midcontinent). Wanless (1958) reported *Wiedeyoceras* (as *Beyrichoceras wanlessi*) and *Glaphyrites* (as *Eoasianites welleri*) from the Excello Shale Member overlying the Summum (no. 4) coal (fig. 22, horizon ILL D4).

Late Desmoinesian ammonoids reported from the Illinois Basin include *Wiedeyoceras*, *Glaphyrites*, and *?Gastrioceras*. Wanless (1958) reported *Wiedeyoceras* (as *Beyrichoceras wanlessi*) and *Glaphyrites* (as *Eoasianites welleri*) from black shale overlying the Springfield (no. 5) coal (fig. 22, horizon ILL D4). Miller and Gurley (1896) reported *Gastrioceras montgomeryense* questionably identified with the shale above the Danville (no. 7) coal (fig. 22, horizon ILL D5). In addition, Miller and Gurley (1896) recorded *Glaphyrites* (as *Goniatites*) from unknown strata of the Carbondale Group. Because of the paucity of ammonoid taxa in any one of these ammonoid-producing intervals, no precise correlations to the midcontinent are now possible; however, the acme of *Wiedeyoceras* in ammonoid-bearing intervals ILL D1–D4 suggests reference to the *Politoceras* Subzone of the *Wellerites* Zone. Ammonoid-bearing interval ILL D5 is considered too generalized for correlation.

Glaphyrites (as *Goniatites globulosus*) was reported by Meek and Worthen (1860) from the Upper Coal Measures (probably Missourian) in the Illinois Basin, without a locality or stratigraphic interval. Miller and Gurley (1896) reported two additional Illinois ammonoid occurrences of probable Missourian age: *Schistoceras* (as *Goniatites fultonensis*) and *Preshumardites* (as *Goniatites illinoisensis*), both without reference to precise locality or stratigraphic interval.

Canadian Arctic

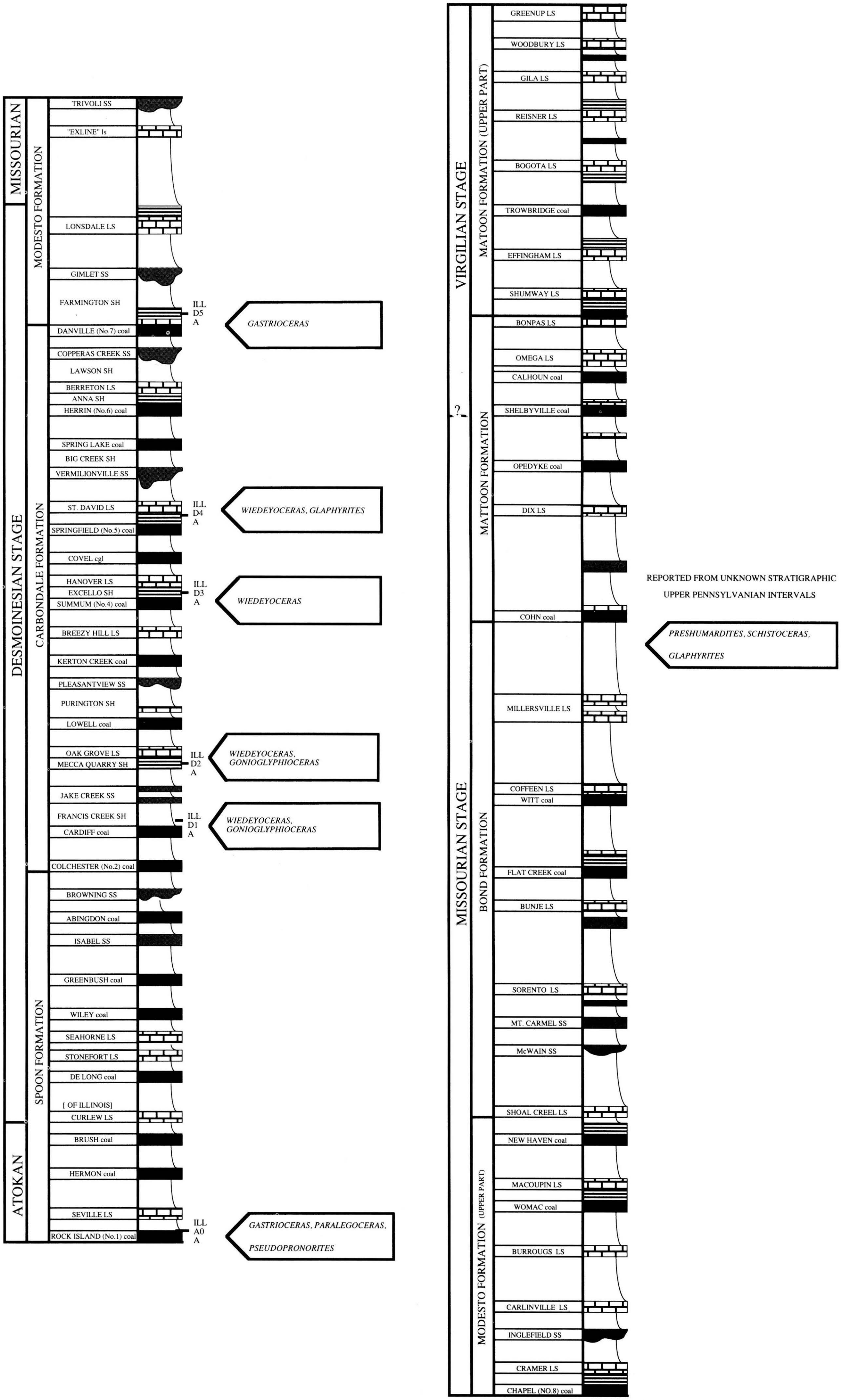
Nassichuk (1975) described abundant Atokan ammonoids from the Hare Fiord Formation on Ellesmere Island in the Canadian Arctic. One collection, including *Gastrioceras*, *Diaboloceras*, and *Bisatoceras*, was associated with a variety of foraminifers that Mamet (1975) concluded were of late Moscovian and hence Desmoinesian age. Nassichuk (1984, p. 166), however, concluded that the ammonoids were Atokan in age. Nassichuk (1975) also reported *Boesites*, *Metapronorites*, *Bisatoceras*, and *Somoholites* from the Desmoinesian portion of the Canyon Fiord Formation on Ellesmere Island. The Nansen Formation on Axel Heiberg Island has produced *Bisatoceras* cf. *B. greenei*, a widespread element in several middle Desmoinesian ammonoid faunas from the midcontinent, suggesting possible reference to the *Wellerites* Zone. Nassichuk (1975) also reported a single Missourian ammonoid, *Parashumardites*, from the Nansen Formation on Ellesmere Island. Earlier, Nassichuk (1971) had described a Missourian occurrence of *Metapronorites* from the Yukon.

New Mexico

Despite the abundance of Middle and Upper Pennsylvanian strata exposed in a large number of mountain ranges in New Mexico, few ammonoids have been recovered. Only two occurrences have been documented. Miller and Furnish (1940c) illustrated *Pseudoparalegoceras brazoense* from the probable early Desmoinesian part of the Magdalena Limestone from San Miguel County, New Mexico.

One of the first Late Pennsylvanian ammonoids reported from North America (*Gonioloboceras goniolobum*) was described from the Coal Measures of New Mexico by Meek (1877). The exact provenance of Meek's specimen remains uncertain (Furnish and Glenister, 1971). In addition, we have obtained specimens of *Neoaganides*, *?Eoschistoceras*, and *Glaphyrites* from late Desmoinesian strata exposed in the Sacramento Mountains.

Figure 22 (facing page). Stratigraphic distribution of ammonoid faunas in Desmoinesian-Missourian strata of the Illinois Basin. The ammonoid distribution in the Illinois Basin is based largely on the works of Wanless (1957, 1958) and Saunders and Richardson (1979).



MISSOURIAN
DESMOINESIAN STAGE
ATOKAN
MODESTO FORMATION
CARBONDALE FORMATION
SPOON FORMATION
TRIVOLI SS
"EXLINE" ls
LONSDALE LS
GIMLET SS
FARMINGTON SH
DANVILLE (No.7) coal
COPPERAS CREEK SS
LAWSON SH
BERRETON LS
ANNA SH
HERRIN (No.6) coal
SPRING LAKE coal
BIG CREEK SH
VERMILIONVILLE SS
ST. DAVID LS
SPRINGFIELD (No.5) coal
COVEL cgl
HANOVER LS
EXCELLO SH
SUMMUM (No.4) coal
BREEZY HILL LS
KERTON CREEK coal
PLEASANTVIEW SS
PURINGTON SH
LOWELL coal
OAK GROVE LS
MECCA QUARRY SH
JAKE CREEK SS
FRANCIS CREEK SH
CARDIFF coal
COLCHESTER (No.2) coal
BROWNING SS
ABINGDON coal
ISABEL SS
GREENBUSH coal
WILEY coal
SEAHORNE LS
STONEFORT LS
DE LONG coal
[OF ILLINOIS]
CURLEW LS
BRUSH coal
HERMON coal
SEVILLE LS
ROCK ISLAND (No.1) coal
ILL D5 A
GASTRIOCERAS
ILL D4 A
WIEDEYOCERAS, GLAPHYRITES
ILL D3 A
WIEDEYOCERAS
ILL D2 A
WIEDEYOCERAS, GONIOGLYPHIOCERAS
ILL D1 A
WIEDEYOCERAS, GONIOGLYPHIOCERAS
ILL A0 A
GASTRIOCERAS, PARALEGOCERAS, PSEUDOPRONORITES
VIRGILIAN STAGE
MISSOURIAN STAGE
?
MATOON FORMATION (UPPER PART)
MATTOON FORMATION
BOND FORMATION
MODESTO FORMATION (UPPER PART)
GREENUP LS
WOODBURY LS
GILA LS
REISNER LS
BOGOTA LS
TROWBRIDGE coal
EFFINGHAM LS
SHUMWAY LS
BONPAS LS
OMEGA LS
CALHOUN coal
SHELBYVILLE coal
OPEDYKE coal
DIX LS
COHN coal
MILLERSVILLE LS
COFFEEN LS
WITT coal
FLAT CREEK coal
BUNJE LS
SORENTO LS
MT. CARMEL SS
McWAIN SS
SHOAL CREEL LS
NEW HAVEN coal
MACOUPIN LS
WOMAC coal
BURROUGS LS
CARLINVILLE LS
INGLEFIELD SS
CRAMER LS
CHAPEL (NO.8) coal
REPORTED FROM UNKNOWN STRATIGRAPHIC UPPER PENNSYLVANIAN INTERVALS
PRESHUMARDITES, SCHISTOCERAS, GLAPHYRITES

California

Gordon (1964) reported Middle Pennsylvanian ammonoids from California. These include late Atokan or early Desmoinesian occurrences of *Bisatoceras* cf. *B. greenei* and *Pseudopronorites* (as *Stenopronorites*) from the Tihvipah Limestone near Rest Spring. In addition, Gordon (1964) reported *?Paralegoceras texanum* presumably from the Atokan part of the Bird Spring Formation of the Providence Mountains.

Oregon

Miller and Furnish (1940c) described *Somoholites merriami* (as *Eoasianites merriami*) from the upper Mills Ranch inlier in the upper Crooked River Basin in southeastern Crook County, Oregon. They considered this specimen to be of either Late Pennsylvanian or Early Permian age. However, Saunders (1971) reported this same species from lower Atokan strata from Oklahoma and therefore concluded that the Oregon specimen was also probably Atokan.

Ammonoid faunas from areas other than North America and the former Soviet Union

China

Despite the vast amount of Middle and Late Pennsylvanian strata exposed in mainland China, few late Carboniferous (Desmoinesian–Virgilian) ammonoids have been reported. Ruan and Zhou (1987, p. 170) described *Maximites sinensis* Ruan and Zhou from the upper Yanghukou Formation of probable Moscovian or Desmoinesian age. Yang (1978) reported *Owenoceras bellilineatum shuichengense* Yang from an isolated outcrop of Moscovian or Zhigulian (Desmoinesian or Missourian) strata exposed on a road from Shuicheng to Jiepai. Sheng (1981) described a late Carboniferous fauna (probably late Gzhelian–early Asselian; Orenburgian equivalent) from the upper Auertu Formation of northern Tianshan, Xinjiang, that includes *Neopronorites carboniferous*, *Prouddenites* cf. *P. primus*, *Somoholites glomerosus*, *Glaphyrites parangulatus*, *Eoasianites* cf. *E. millsi*, and *Glaphyrites qijiangouensis*. Sheng (1981) also reported *Glaphyrites* cf. *G. oblatus* and *Gonioloboceras welleri* from the correlative Tamugang Formation and *?Paralegoceras* from a lower Upper Carboniferous locality near Shuangjingzi.

The former Yugoslavia

Kullman and Ramovs (1980) reported *Agathiceras*, *Schistoceras*, and *Mescalites* from uppermost Gzhelian strata in the Karawanken Mountains of the former Yugoslavia. Their Gzhelian age assignment was predicated on the occurrence of the fusulinid *Rugosofusulina alpina antiqua* (Schellwen). This occurrence is extremely important because it raises doubt concerning the utility of *Mescalites* as an Asselian index.

Spain

Important upper Westphalian through Cantabrian ammonoid faunas have been recently documented in the Cantabrian Mountains of northern Spain. Upper Westphalian C ammonoid occurrences have been summarized by Wagner-Gentis (1971) and include *Phaneroceras kesslerense* [as *Bisatoceras* (*Phanoceras*) cf. *B. williamsi* and as *Pseudoparalegoceras kesslerense*] from limestones of Podolskian age (= early Desmoinesian) near Las Branas and *Politoceras politum?* and *Pseudoparalegoceras* sp. from the Pando Formation of upper Westphalian C age at a locality near Prioro.

Wagner-Gentis (1971) illustrated Westphalian D ammonoids from Spain, including *Glaphyrites angulatus* and *Aktubites trifidus* from the basal beds of the Abismo Limestone (upper Podolskian or lower Myachkovian) near Santa María de Redondo, *Glaphyrites micromphalus* Wagner-Gentis from the basal Abismo Limestone exposed near San Juan de Redondo, *Eoparalegoceras inflatum* from lower Westphalian D (Podoloskian) strata near Peña Tremaya, and *Boesites eotexanus* Wagner-Gentis from post-Leonian strata (Myachkovian) near Casavegas.

A few poorly preserved ammonoids have been recovered from upper Cantabrian strata (probably early Missourian). These were reported by Wagner-Gentis (1970) and include *?Neodimorphoceras*, *?Aristoceras*, and *?Eoasianites*.

Argentina

Closs (1969) described *Eoasianites* (*Glaphyrites*) *rionegrensis* from Carboniferous strata in Argentina. He regarded the strata yielding this species to be of probable Atokan age.

Summary

New detailed collections of ammonoid cephalopods from a succession of cyclothemic intervals of Desmoinesian through Virgilian age in the North American midcontinent permit a reevaluation of their utility in effecting biostratigraphic correlation in Middle and Late Pennsylvanian strata. Remapping of critical ammonoid-bearing stratigraphic intervals, based in part on the traceability of the core shale facies of cyclothems, clarifies a number of misconceptions concerning the distribution of important index taxa relative to stage and series boundaries. The ammonoid fauna from the "Seminole Formation" at Collinsville, Oklahoma, which has been widely used to characterize early Missourian strata, is late Desmoinesian in age, based on a recorrelation of the ammonoid-bearing interval to the stratigraphically lower uppermost Holdenville Formation.

Previous ammonoid zonations that have used the ranges of individual genera to characterize an entire stage are misleading because the actual range of any ammonoid genus seldom, if ever, coincides with both the top and the bottom boundaries of a stage. Continuous faunal change at the generic level characterizes ammonoid faunas from Middle and Upper Pennsylvanian cyclothems in the North American midcontinent. The first occurrences of ammonoid genera as biostratigraphic markers provide sufficient information to characterize Middle and Upper Pennsylvanian series and stage boundaries and to identify and correlate biostratigraphic intervals within stages.

Six high-confidence zones, based largely on the first occurrence of ammonoid genera, are proposed for the Desmoinesian, Missourian, and Virgilian stages: *Wellerites* Zone, *Eothalassoceras* Zone, *Pennoceras* Zone, *Preshumardites* Zone, *Pseudaktubites* Zone, and the *Shumardites* Zone. Fifteen subzones of lesser confidence, using first occurrences of ammonoid genera and species, are also suggested.

The generic-level zonation proposed here permits reliable correlations to be effected both within the North American midcontinent region and with other basins in North America. The base of the Cisco Group in north-central Texas often has been cited as corresponding to the base of the Virgilian Stage in that region. Because the Finis Shale Member contains the first appearance of *Shumardites*, the base of the Virgilian was thought to also correspond to the base of the *Shumardites* Zone. Recorrelations presented here demonstrate that the base of the *Shumardites* Zone corresponds to an early middle Virgilian age. The famous *Uddenites* Shale Member of the Gaptank Formation has been most recently correlated with the ammonoid-bearing interval in the H limestone located 4.5–5.5 mi (7.2–8.9 km) northeast of Wolf Camp, and both of these have been considered to be Permian in age (Cooper and Grant, 1972). Reevaluation of their respective ammonoid faunas indicates that the locality northeast of Wolf Camp is early middle Virgilian in age (*Shumardites cuyleri* Subzone) and that the *Uddenites* Shale Member is early late Virgilian in age (upper part of *Shumardites* Zone).

The base of the Desmoinesian has traditionally been placed at the changeover from *Eowellerites* to *Wellerites* (Ramsbottom and Saunders, 1985). Because both the upper range of *Eowellerites* and the lower range of *Wellerites* remain unknown, the base of the Desmoinesian Stage cannot be confidently identified using these genera. Although the first occurrence of *Wellerites* should not be used to mark the base of the Desmoinesian, the *Wellerites-Paralegoceras* Subzone is useful in correlating early Desmoinesian strata.

The base of the Upper Pennsylvanian Series (base of the Missourian Stage) is readily identified using the first appearance of *Pennoceras* in association with the typically Desmoinesian taxa *Eoschistoceras* and *Bisatoceras*. This level is also readily identified by the appearance of the conodont *Idiognathodus sagittalis*. This level corresponds to the base of the Khamovnichesky Horizon in the Moscow Basin and the N_1^5 Horizon of the Donetz Basin. The currently used base of the Kasimovian in the Moscow Basin corresponds to the latest Desmoinesian upper Holdenville (Lost Branch formation) in the North American midcontinent, based on the occurrence of *Idiognathodus nodocarinatus* Jones (= *I.* aff. *I. excelsus*) and the upper range of species of *Neognathodus*.

The base of the *Pseudaktubites* Zone occurs slightly below the currently used Missourian-Virgilian boundary (as accepted by the Kansas, Nebraska, and Iowa geological surveys). The appearances of *Vidrioceras conlini*, *Marathonites*, and *Neopronorites* within the upper part of the *Pseudaktubites* Zone (*Pseudaktubites stainbrooki* Subzone) are readily correlatable biostratigraphic events that mark the transition from typically Missourian to typically Virgilian ammonoid faunas. We suggest that the base of the *Pseudaktubites stainbrooki* Subzone be used to define the base of the Virgilian. The *Shumardites* Zone is restricted to middle and late Virgilian strata.

The base of the Asselian as formally used in the former Soviet Union (strata containing the base of the *Daixina bosbytauensis–D. robusta* Zone) is marked only by the appearance of the ammonoid *Vidrioceras borissiaki*. The base of the *Schwagerina fusiformis–S. vulgaris* Zone is marked by a major changeover in ammonoid faunas, including the extinctions of *Uddenites*, *Uddenoceras*, *Prouddenites*, *Vidrioceras*, *Marathonites*, and *Shumardites* and the appearances of *Prostacheoceras*, *Svetlanoceras*,

and *Artinskia kazakhstanica*. The base of the *Schwagerina moelleri–Pseudofusulina fecunda* Zone corresponds only to the appearance of *Juresanites*. In terms of ammonoids, the best level for the base of the Asselian corresponds to the base of the *Schwagerina fusiformis–S. vulgaris* Zone. However, in terms of worldwide correlation, the current base of the Asselian is also a strong candidate because of the cosmopolitan distribution of *Streptognathodus wabaunsensis*. By contrast, the use of the *Schwagerina moelleri–Pseudofusulina fecunda* Zone to define the base of the Permian is not favored because the major changeover in ammonoid faunas occurs below this level; moreover, the ammonoid *Juresanites* is apparently restricted in distribution. Placement of the Carboniferous-Asselian boundary at the base of strata containing the *Schwagerina moelleri–Pseudofusulina fecunda* Zone or the "equivalent" *Streptognathodus barskovi* Zone would effectively relegate the appearances of the typically Permian taxa *Prostacheoceras*, *Svetlanoceras*, and *Subperrinites* to the Carboniferous.

Review of Moscovian-Gzhelian ammonoid distributions from the former Soviet Union indicates that the zonation proposed here can be used to correlate North American series and stage boundaries on a worldwide basis. Additional studies of the systematics of Middle and Late Pennsylvanian ammonoids should yield a more refined species-level zonation and should contribute further to our understanding of ammonoid evolution, paleoecology, and paleogeographic distribution.

Revision of the family Shumarditidae Plummer & Scott, 1937

D. R. Boardman II, D. M. Work, and R. H. Mapes

Abstract As currently defined, the Upper Carboniferous ammonoid family Shumarditidae Plummer & Scott is almost certainly polyphyletic. The family concept is emended to include *Preshumardites* Plummer & Scott, 1937, *Pseudaktubites* gen. nov. (type species, *Preshumardites stainbrooki* Plummer & Scott, 1937), and *Shumardites* Smith, 1903. Early Permian (Sakmarian) species previously assigned to *Preshumardites* are reassigned to *Andrianovia* gen. nov. (type species, *?Preshumardites sakmarae* Ruzhencev, 1938). *Aktubites* Ruzhencev, 1955, *Eoshumardites* Popov, 1960, and *Parashumardites* Ruzhencev, 1939[a], previously included in the Shumarditidae, are assigned to the new family Parashumarditidae. *Eovidrioceras inexpectans* gen. nov., sp. nov. is included and is interpreted as the ancestor of the cyclolobacean family Vidrioceratidae Plummer & Scott, 1937.

Introduction to the shumarditid and somoholitid problem

As originally defined, Shumarditidae Plummer & Scott, 1937, included three genera: *Shumardites* Smith, 1903; *Perrinites* Böse, 1917; and *Preshumardites* Plummer & Scott, 1937. As such, the familial concept included a variety of globose ammonoids with simple pouched to trifid lobes and discoidal forms with advanced pseudo-ammonitic sutures. Working with an unusually complete sequence of taxa from Texas, Plummer and Scott (1937) proposed a detailed species-level phylogeny: *Preshumardites gaptankensis* → *Preshumardites stainbrooki* → *Shumardites cuyleri* → *Shumardites simondsi* → *Perrinites* spp. The taxonomic position of several species of *Shumardites* that differ from the type species *S. simondsi* Smith, 1903, by their possession of tripartite umbilical lobes [e.g., *S. sellardsi* Plummer & Scott, 1937, *S. fornicatus* Plummer & Scott, 1937, and *S. senex* Miller & Cline, 1934] was clarified by Ruzhencev (1939a) with the erection of *Parashumardites*. Elias (1938) proposed *Properrinites* Elias to include the primitive *Perrinites* species *P. bosei* Plummer & Scott, 1937, *P. bakeri* Plummer & Scott, 1937, and *Properrinites plummeri* Elias, 1938. Miller and Furnish (1940a) established the Perrinitidae to accommodate *Properrinites* and *Perrinites*. They further reduced the scope of the Shumarditidae, synonymizing *Preshumardites* Plummer & Scott, 1937, with the Sakmarian somoholitid *Neoshumardites* Ruzhencev, 1936. Ruzhencev (1955) established *Aktubites* (type species, *A. trifidus* Ruzhencev) for a similar taxon from the upper Moscovian (lower Desmoinesian) of the southern Urals, which he interpreted as the proximate ancestor to the Kasimovian-Gzhelian (Missourian-Virgilian) genus *Parashumardites*. Ruzhencev (1955) accepted the early Virgilian (Gzhelian) *Preshumardites stainbrooki* as the proximate ancestor to *Shumardites cuyleri* Plummer & Scott (Ruzhencev's *Postaktubites cuyleri*) but included the species within *Aktubites*, further obscuring the close phylogenetic connection between that taxon and *Preshumardites gaptankensis*. The most recent discussion of the family, by Ruzhencev and Bogoslovskaya (1978), essentially reflects Ruzhencev's earlier (1955) analysis (i.e., *Aktubites trifidus* → *Parashumardites*; advanced *Aktubites*, *A. stainbrooki* →

Shumardites → *Perrinites*) but adds a third branch lineage: *Aktubites* → *Eoshumardites* Popov, 1960 (type species, *Eoshumardites lenensis* Popov).

Extensive new collections from the North American midcontinent and the Appalachians provide a stratigraphically objective succession of shumarditid taxa that confirms the fundamental validity of Plummer and Scott's (1937) *Preshumardites* → *Shumardites* lineage. Analysis of newly recovered specimens of *Preshumardites gaptankensis* reaffirms the shumarditid affinities of that taxon and link it to the *"Aktubites" stainbrooki* → *Shumardites cuyleri* lineage. Moreover, detailed sutural comparisons of *Aktubites trifidus* and *"Aktubites" stainbrooki* reveal fundamental sutural differences between these taxa. The new shumarditid genus *Pseudaktubites* is therefore established to accommodate *Preshumardites stainbrooki* Plummer & Scott and a slightly more primitive species, *Pseudaktubites newelli* sp. nov. (figs. 23–25). This new species provides the morphologic and stratigraphic link between *Preshumardites gaptankensis* and *Pseudaktubites stainbrooki*.

Taxonomic position of *Preshumardites* Plummer & Scott, 1937 The taxonomic position of the ancestral Missourian shumarditid *Preshumardites* Plummer & Scott, 1937 (type species, *Gastrioceras gaptankense* Miller, 1930) has been controversial and involves confusion with a homeomorphic Artinskian somoholitid, *Neoshumardites* Ruzhencev, 1936 (type species, *N. triceps* Ruzhencev). Although a number of researchers (Miller and Furnish, 1940a; Saunders, 1971) have regarded *Neoshumardites* as a senior synonym of *Preshumardites* based on sutural grounds, Ruzhencev and Bogoslovskaya (1978) recognized both genera, stressing the presence of strong longitudinal lirae on all Permian species of *Preshumardites* (e.g., *Preshumardites sakmarae* Ruzhencev, 1938) as the basis for distinction from *Neoshumardites*, which lacks longitudinal ornament. Ruzhencev and Bogoslovskaya (1978) stipulated that assignment of the Permian species to *Preshumardites* was conditional and dependent on ultimate discovery of longitudinal ornament in the Missourian type species; in its absence a new genus would be required to accommodate the lirate Permian species.

Two recently recovered specimens of *Preshumardites gaptankensis* from the middle Missourian Wolf Mountain Shale Member (Graford Formation) of north-central Texas (SUI 55603, 55412), which preserve shell ornament, provide clarification on the generic concept of *Preshumardites*. Both specimens exhibit transverse growth lamellae that trace broad ventral salients, and longitudinal lirae are absent. Moreover, additional, seemingly fundamental differences in ventral lobe configuration separate the Sakmarian *Preshumardites sakmarae* group from the Missourian type species; *P. gaptankensis* and other Missourian species of *Preshumardites* [*P. illinoisensis* (Miller & Gurley, 1896), *P. grafordensis* Miller & Furnish, 1940, and *P. kansasensis* (Miller & Gurley, 1896)] are characterized by extraordinarily broad ventral lobes with strongly attenuate, medially inflated ventral prongs and high secondary ventral saddles, whereas all Permian species currently assigned to *Preshumardites* [*P. sakmarae* Ruzhencev; *P. bogoslovski* Andrianov, 1985; *P. gorbunovi* Andrianov, 1985; and *P.* sp. 1 Andrianov, 1985] are distinguished by proportionally narrower, medially constricted ventral lobes with narrow, attenuate ventral prongs and moderately high secondary ventral saddles (fig. 23). Significantly, no Virgilian-Asselian representatives of *Preshumardites* have been recovered that might bridge these stratigraphically isolated groups of species. Accordingly, *Andrianovia* gen. nov. (type species, *Preshumardites sakmarae* Ruzhencev, 1938) is established herein for Sakmarian somoholitid species previously included in *Preshumardites* (fig. 23). Although Ruzhencev's (1962) derivation of *Andrianovia sakmarae* from the Gzhelian *Somoholites glomerosus* seems plausible, the precise origin of the earliest *Preshumardites*, *P. kansasensis* (Miller & Gurley), is not known.

Taxonomic position of *Aktubites* Ruzhencev, 1955 Miller and Sturgeon (1946, p. 387, fig. 2A) figured as *Neoshumardites* sp. an ammonoid from the lower Desmoinesian Vanport limestone (Allegheny Group) of Ohio that bears a strong resemblance to the Virgilian *Preshumardites stainbrooki*. Assignment to *Neoshumardites* was based on a previous analysis by Miller and Furnish (1940a) in which both *Preshumardites stainbrooki* and *Shumardites cuyleri* were reassigned to *Neoshumardites*. Ruzhencev (1955) subsequently established *Aktubites* (type species, *A. trifidus* Ruzhencev) for a similar late Moscovian (early Desmoinesian) species from the southern Urals, including Miller and Sturgeon's early Desmoinesian *Neoshumardites* sp. and the early Virgilian *Preshumardites stainbrooki*. This effectively extended the range from the late Moscovian into the Gzhelian (early Desmoinesian–early Virgilian). Ruzhencev (1955) derived the Missourian (Kasimovian) shumarditid *Parashumardites* from the Moscovian species *Aktubites trifidus*; *Aktubites (Postaktubites) cuyleri* (= *Shumardites cuyleri*) was derived from the Virgilian (Gzhelian) species *Aktubites stainbrooki*.

Miller and Sturgeon's (1946, fig. 2A) suture of *Neoshumardites* sp. represents the only previously illustrated internal suture of true Moscovian (Desmoinesian) *Aktubites*. However, direct examination of their Vanport limestone specimen and of subsequently collected representatives of *Aktubites trifidus* from the lower Desmoinesian (Moscovian) Putnam Hill Limestone Member of Ohio reveals a critical inaccuracy in the internal lateral lobe portion of Miller and Sturgeon's (1946, fig. 2A) figured suture of *Neoshumardites* sp.: The crest of the secondary subdivision ($I_1/I_{2(d)}$) is higher than the saddle that bounds the ventrad subdivision ($I_{2(v)}/I_1$), a pattern confirmed in the Putnam Hill representatives of *Aktubites trifidus* (fig. 25). By contrast, in the early Virgilian *Aktubites stainbrooki* this pattern is reversed; the crest of the secondary subdivision ($I_{2(v)}/I_1$) is higher than the saddle that bounds the dorsad subdivision (I_1/I_{2d}) (figs. 23 and 24). These seemingly minor differences in sutural ontogeny, although incipient in *Aktubites trifidus* and *"Aktubites" stainbrooki*, are increasingly prominent during the subsequent phylembryogenesis of their respective descendant taxa, suggesting a fairly high level of phylogenetic separation (fig. 23). Accordingly, *Pseudaktubites* gen. nov. is established to accommodate *Aktubites stainbrooki* (type species) and *Pseudaktubites newelli* sp. nov., a slightly more primitive species that establishes a stratigraphic and morphologic link between *Preshumardites gaptankensis* and *Pseudaktubites stainbrooki*. The *Aktubites* (*A. trifidus*) → *Parashumardites* → *Properrinites* lineage is considered phylogenetically distinct, and both *Aktubites* and *Parashumardites* are included in the new family Parashumarditidae, a position that more accurately reflects their true phylogenetic position.

Systematic paleontology

Superfamily Shumarditaceae Plummer & Scott, 1937
Family Shumarditidae Plummer & Scott, 1937

Diagnosis Shumarditaceans that lack second-order subdivision of sutural elements and that are characterized by prominently pouched to incipiently trifid primary external and internal lateral lobes (L and I); during phylogeny the outer (ventral) subdivision of the I complex [$(I_{2(v)}I_1, I_{2(d)})$], that is, ($I_{2(v)}$) is larger than the inner two subdivisions ($I_{2(d)}$ and I_1), and the secondary subdivision ($I_{2(v)}/I_1$) is higher than the saddle that bounds the dorsad subdivision ($I_1/I_{2(d)}$).

Composition *Preshumardites* Plummer & Scott, 1937, *Pseudaktubites* gen. nov., and *Shumardites* Smith, 1903.

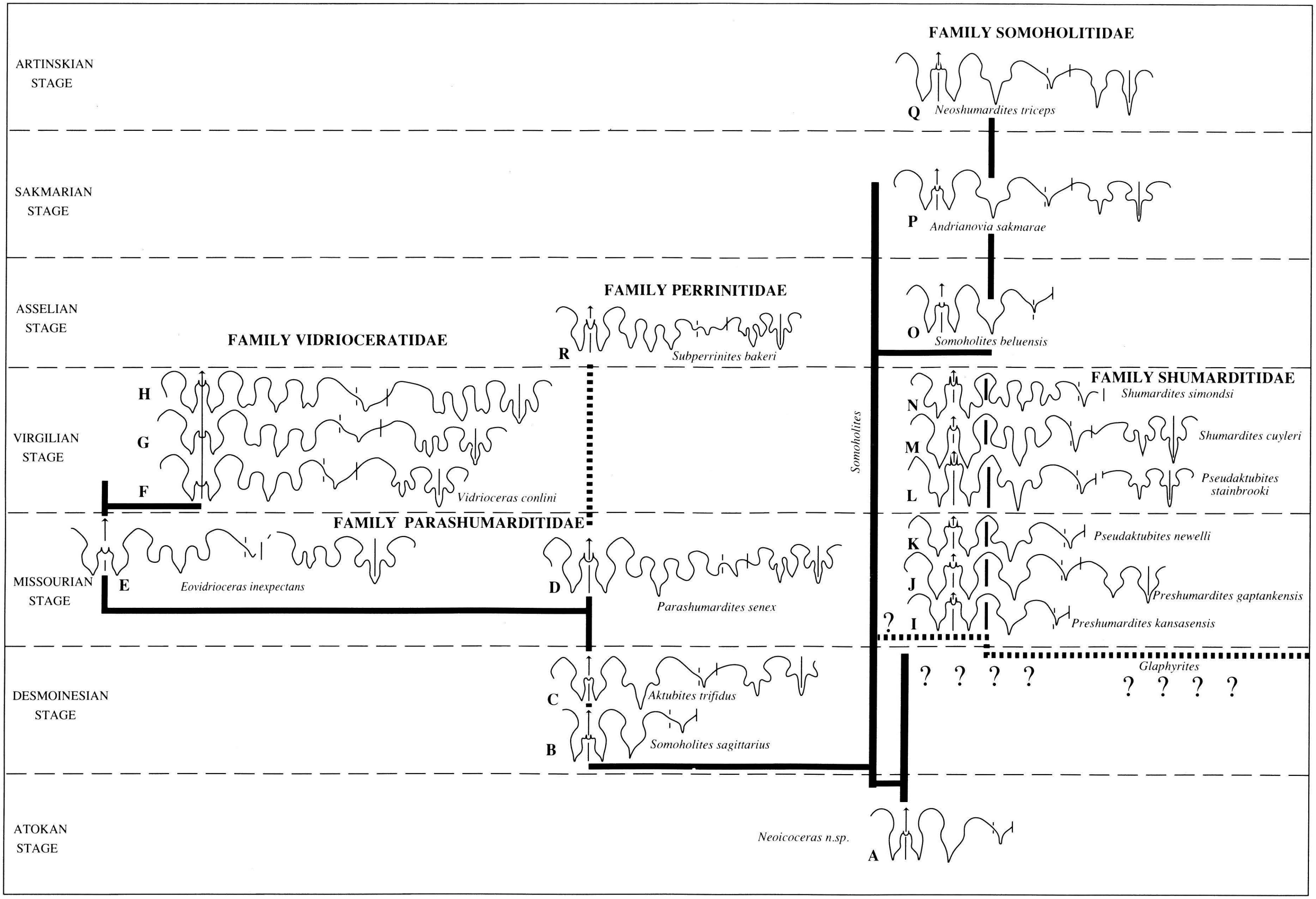
Discussion The diagnosis excludes *Aktubites* Ruzhencev, 1955, and *Parashumardites* Ruzhencev, 1937, taxa whose high secondary subdivision ($I_1/I_{2(d)}$) links them to the later perrinitid lineage (*Aktubites* → *Parashumardites* → *Subperrinites* ...). Both genera are included with *Eoshumardites* Popov, 1960, and *Eovidrioceras* gen. nov. in the new family Parashumarditidae.

Age Middle Missourian (Kasimovian) to late Virgilian (Gzhelian).

Genus *Pseudaktubites* Boardman, Work & Mapes, gen. nov.

Type species *Preshumardites stainbrooki* Plummer & Scott, 1937, from the early Virgilian Colony Creek Shale

Figure 23 (facing page). Interpretation of phylogeny in the Shumarditidae, Perrinitidae, Vidrioceratidae, and Somoholitidae. (A) *Neoicoceras* sp. nov. from the Smithwick Shale, Bend Group (late Atokan), central Texas; based on SUI 55526 at a diameter of 20.7 mm. (B) *Somoholites sagittarius* Saunders from the Columbiana limestone, Allegheny Group (early Desmoinesian), Ohio; based on holotype OSU 18736 at a diameter of 28 mm. (C) *Aktubites trifidus* Ruzhencev from the Putnam Hill limestone, Allegheny Group (early Desmoinesian), Ohio; based on hypotype OSU 30723 at a diameter of 10.2 mm. (D) *Parashumardites senex* (Miller) from the Quivira Shale Member, Dewey Formation, Ochelata Group (middle Missourian), Oklahoma; based on SUI 48382 at a diameter of 17.6 mm. (E) *Eovidrioceras inexpectans* gen. nov., sp. nov. from the Quivira Shale Member, Dewey Formation, Ochelata Group (middle Missourian), Oklahoma; based on holotype SUI 55406 at a diameter of 13.9 mm. (F) *Vidrioceras conlini* Miller & Downs from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55529 at a diameter of 8.5 mm. (G) *Vidrioceras conlini* Miller & Downs from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55685 at a diameter of 9.3 mm. (H) *Vidrioceras conlini* Miller & Downs from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55536 at a diameter of 17 mm. (I) *Preshumardites kansasensis* (Miller & Gurley) from the Winterset Limestone Member, Dennis Limestone, Kansas City Group (middle Missourian), Kansas City, Missouri; based on holotype UC 6219 at a diameter of 24.1 mm. (J) *Preshumardites gaptankensis* (Miller) from the Gaptank Formation (middle Missourian), Marathon Uplift, West Texas; based on topotype SUI 34138 at a whorl height of 15 mm [modified from Saunders (1971, text fig. 6B)]. (K) *Pseudaktubites newelli* gen. nov., sp. nov. from shale below the Wildhorse Dolomite Member, Barnsdall Formation, Ochelata Group (late Missourian), Oklahoma; based on holotype SUI 34137 at a diameter of 31 mm. (L) *Pseudaktubites stainbrooki* (Plummer & Scott) from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55531 at an estimated diameter of 48 mm. (M) *Shumardites cuyleri* Plummer & Scott from the Finis Shale Member, Graham Formation, Cisco Group (early middle Virgilian), north-central Texas; based on hypotype JPC 3596 (reposited in the U.S. National Museum) at an estimated conch height of 25 mm [modified from Miller and Downs (1950, fig. 10B)]. (N) *Shumardites simondsi* Smith from the Wayland Shale Member, Graham Formation, Cisco Group (middle Virgilian), north-central Texas; based on hypotype UT P–2391 at an estimated diameter of 56 mm. (O) *Somoholites beluensis* (Haniel) from the Somohole beds (Sakmarian), Indonesian Timor; based on hypotype MTHD 12704 at a diameter of 21 mm [modified from Saunders (1971, text fig. 3B)]. (P) *Andrianovia sakmarae* (Ruzhencev) from Sakmarian strata, Orenburgian District, southern Urals; based on specimen 318/342 at a diameter of 15.3 mm [modified from Ruzhencev (1951, fig. 41b)]. (Q) *Neoshumardites triceps* Ruzhencev from (Artinskian) strata, Aktubinsk District, southern Urals; at a conch height of 23 mm [modified from Ruzhencev (1956, text figs. 43d,e)].


ARTINSKIAN STAGE
SAKMARIAN STAGE
ASSELIAN STAGE
VIRGILIAN STAGE
MISSOURIAN STAGE
DESMOINESIAN STAGE
ATOKAN STAGE
FAMILY SOMOHOLITIDAE
Q Neoshumardites triceps
P Andrianovia sakmarae
O Somoholites beluensis
FAMILY PERRINITIDAE
R Subperrinites bakeri
FAMILY VIDRIOCERATIDAE
H
G
F Vidrioceras conlini
FAMILY PARASHUMARDITIDAE
E Eovidrioceras inexpectans
D Parashumardites senex
C Aktubites trifidus
B Somoholites sagittarius
A Neoicoceras n.sp.
Somoholites
FAMILY SHUMARDITIDAE
N Shumardites simondsi
M Shumardites cuyleri
L Pseudaktubites stainbrooki
K Pseudaktubites newelli
J Preshumardites gaptankensis
I Preshumardites kansasensis
Glaphyrites
? ? ? ?
? ? ? ?

Member of the Caddo Creek Formation (Canyon Group), north-central Texas; original designation herein.

Diagnosis Primitive shumarditid characterized by incipient trifurcation of the primary external and internal lateral lobes (L, I).

Sutural formula $(V_1V_1)(L_2L_1L_2)U:(I_2I_1I_2)(D_2D_1D_2)$.

Comparisons *Pseudaktubites* most closely resembles *Aktubites*, from which it may be distinguished on the basis of the symmetry of the incipient subdivision of the internal lateral lobe; in *Pseudaktubites* the crest of the secondary internal subdivision ($I_{2(v)}/I_1$) is higher than the saddle that bounds the dorsad subdivision ($I_1/I_{2(d)}$), whereas in *Aktubites* the crest of the dorsad subdivision ($I_1/I_{2(d)}$) is higher (figs. 23 and 25). Although incipient in *Pseudaktubites*, this relatively subtle feature is considered fundamental because it anticipates the later shumarditid progression (*Pseudaktubites* → *Shumardites*) and serves to distinguish it from the parallel lineage *Aktubites* → *Parashumardites* → *Properrinites* and the later perrinitids (fig. 23).

Pseudaktubites, particularly the advanced species *P. stainbrooki*, can be distinguished from primitive species of *Shumardites* by its tridentate, incompletely subdivided lateral and internal lateral lobes. In addition, the asymmetry of the internal lateral lobe complex is considerably more extreme in *Shumardites* (e.g., *S. cuyleri*, figs. 26E–F).

Pseudaktubites closely resembles its probable ancestor, *Preshumardites*, in overall conch form and sutural configuration. Both genera present virtually identical ventral lobe configurations and cannot be distinguished on this character at diameters less than 30 mm. However, incipient tripartition of the lateral lobes in even the most primitive *Pseudaktubites* species (*P. newelli* sp. nov.) represents a slight advance over the prominently pouched lateral lobes of *Preshumardites* (figs. 24B–D).

Species composition and distribution *Pseudaktubites stainbrooki* (Plummer & Scott, 1937) from the early Virgilian Colony Creek Shale Member, Caddo Creek Formation (Canyon Group), north-central Texas; and from the early Virgilian basal Robbins Shale Member, Lawrence Formation (Douglas Group) eastern Kansas.

Pseudaktubites newelli sp. nov. from an unnamed late Missourian shale below the Wildhorse Dolomite Member, Barnsdall Formation (Ochelata Group), Oklahoma. We correlate this shale with the Eudora Shale Member, Stanton Limestone (Lansing Group), of Kansas.

Age Latest Missourian (Kasimovian) to early Virgilian (Gzhelian).

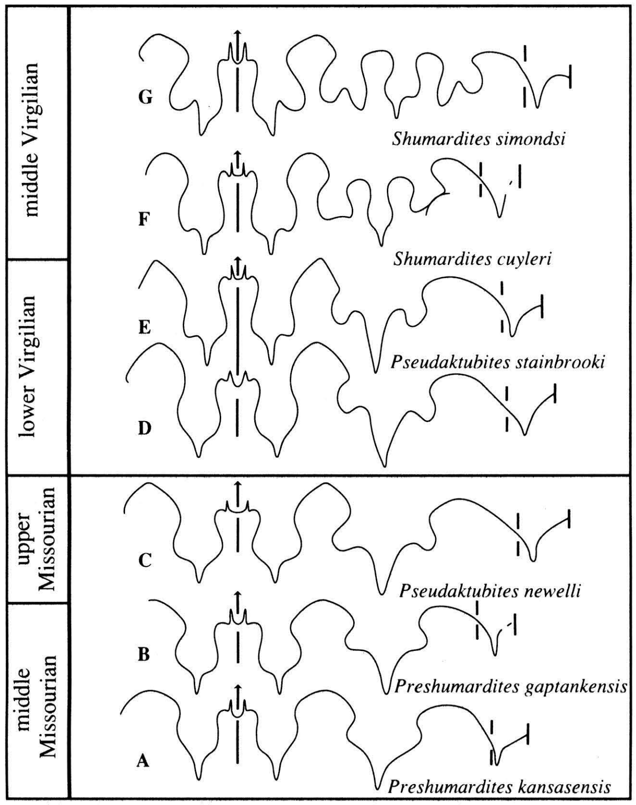


Figure 24. Interpretation of phylogeny of the family Shumarditidae. (A) *Preshumardites kansasensis* (Miller & Gurley) from the Winterset Limestone Member, Dennis Limestone, Kansas City Group (middle Missourian), Kansas City, Missouri; based on holotype UC 6219 at a diameter of 24.1 mm. (B) *Preshumardites gaptankensis* (Miller) from the Wolf Mountain Shale Member, Graford Formation, Canyon Group (middle upper Missourian), north-central Texas; based on hypotype SUI 55604 at a diameter of 37.8 mm. (C) *Pseudaktubites newelli* gen. nov., sp. nov. from shale below the Wildhorse Dolomite Member, Barnsdall Formation, Ochelata Group (late Missourian), Oklahoma; based on holotype SUI 34137 at a diameter of 31 mm. (D) *Pseudaktubites stainbrooki* (Plummer & Scott) from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55413 at a diameter of 20 mm. (E) *Pseudaktubites stainbrooki* (Plummer & Scott) from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55531 at an estimated diameter of 48 mm. (F) *Shumardites cuyleri* Miller & Downs from the Finis Shale Member, Graham Formation, Cisco Group (early middle Virgilian), north-central Texas; based on hypotype SUI 55638 at an estimated diameter of 62 mm. (G) *Shumardites simondsi* Smith from the Wayland Shale Member, Graham Formation, Cisco Group (middle Virgilian), north-central Texas; based on hypotype UT P–2391 at an estimated diameter of 56 mm.

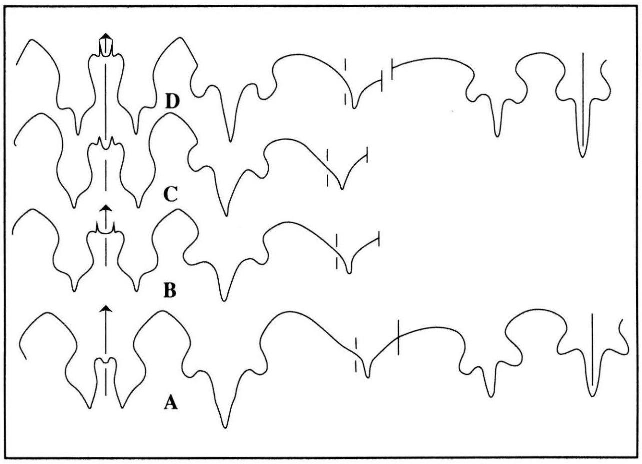


Figure 25. Sutures of *Aktubites* and *Pseudaktubites*. (A) *Aktubites trifidus* Ruzhencev from the Putnam Hill limestone, Allegheny Group (early Desmoinesian), Ohio; based on hypotype OSU 30723 at a diameter of 10.2 mm. (B) *Pseudaktubites newelli* gen. nov., sp. nov. from shale below the Wildhorse Dolomite Member, Barnsdall Formation, Ochelata Group (late Missourian), Oklahoma; based on holotype SUI 34137 at a diameter of 31 mm. (C) *Pseudaktubites stainbrooki* (Plummer & Scott) from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55413 at a diameter of 20 mm. (D) *Pseudaktubites stainbrooki* (Plummer & Scott) from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas; based on hypotype SUI 55531 at an estimated diameter of 48 mm.

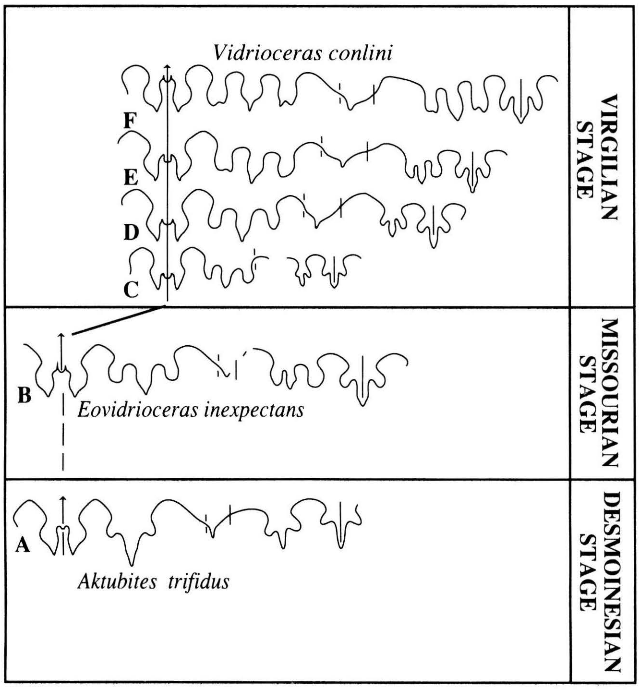


Figure 26. Origin of the Family Vidrioceratidae. (A) *Aktubites trifidus* Ruzhencev from the Putnam Hill limestone, Allegheny Group (early Desmoinesian), Ohio; based on hypotype OSU 30723 at a diameter of 10.2 mm. (B) *Eovidrioceras inexpectans* gen. nov., sp. nov. from the Quivira Shale Member, Dewey Formation, Ochelata Group (middle Missourian), Oklahoma; based on holotype SUI 55406 at a diameter of 13.9 mm. (C–F) Sutural ontogeny of *Vidrioceras conlini* Miller & Downs from the Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (early Virgilian), north-central Texas. (C) Early juvenile stage based on hypotype SUI 55685 at an estimated diameter of 6 mm. (D) Late juvenile stage based on hypotype SUI 55529 at a diameter of 8.5 mm. (E) Early mature stage based on hypotype SUI 55685 at an estimated diameter of 9.3 mm. (F) Late mature stage based on hypotype SUI 55536 at a diameter of 17 mm.

***Pseudaktubites stainbrooki* (Plummer & Scott), 1937** (pl. 1, figs. 13–15; figs. 23L, 24D,E, 25C,D, 26E; table 1)

Preshumardites stainbrooki Plummer & Scott, 1937, pp. 292–293; fig. 46B; pl. 23, figs. 13–15.

Neoshumardites stainbrooki (Plummer & Scott); Miller and Furnish, 1940a, p. 77.

Neoshumardites stainbrooki (Plummer & Scott); Miller and Sturgeon, 1946, p. 387.

Aktubites stainbrooki (Plummer & Scott); Ruzhencev, 1955, pp. 1,107–1,110.

?Aktubites stainbrooki (Plummer & Scott); Boardman, Mapes, and Work, 1989b, pp. 201–203, 206, 207, 210; pl. 4, figs. 13–15.

Discussion The species is adequately diagnosed and described by Plummer and Scott (1937, pp. 292–293); numerous newly recovered specimens have yielded additional sutural details discussed previously under the generic heading. Conch dimensions and proportions are listed in table 1.

Occurrence *Pseudaktubites stainbrooki* characterizes the early Virgilian *P. stainbrooki* Subzone, which is widely developed in the Colony Creek Shale Member of the Caddo Creek Formation (Canyon Group) throughout the Brazos (locality TXV–52) and Colorado (localities TXV–46 and TXV–49) River valleys of north-central Texas. The species has been recovered from an equivalent level in the basal Robbins Shale Member of the Lawrence Formation (Douglas Group) in eastern Kansas (localities KSV–05, KSV–06, and KSV–11).

Repository The holotype (UT–1440–X3) is reposited at the University of Texas, Austin. Hypotypes (SUI 53413 and 55531) and selected measured specimens (SUI 55421,

Table 1. Conch dimensions and proportions for representatives of *Pseudaktubites* and *Eovidrioceras*

Specimen Number	Horizon	Locality	D	W	H	U	W/D	H/D	U/D	H/W
***Pseudaktubites stainbrooki* (Plummer & Scott)**										
SUI 55614	Robbins Shale Member	KSV–05	48.0	26.2	24.1		0.55	0.50		0.92
SUI 55531	Colony Creek Shale Member	TXV–49								
Holotype[a]	Colony Creek Shale Member	TXV–52	37.5	23.6	18.0	7.3	0.63	0.48	0.19	0.76
SUI 55613	Robbins Shale Member	KSV–11	32.0	23.5	14.6	7.7	0.73	0.46	0.24	0.62
SUI 55620	Colony Creek Shale Member	TXV–49	26.5	17.2	11.2	7.9	0.65	0.42	0.30	0.65
SUI 55629	Colony Creek Shale Member	TXV–49	25.3	15.9	12.3	6.0	0.63	0.49	0.20	0.78
UT–1440–TX3	Colony Creek Shale Member	TXV–49	25.0							
SUI 55617	Robbins Shale Member	KSV–05	24.0							
SUI 55628	Colony Creek Shale Member	TXV–49	21.6							
SUI 55421	Robbins Shale Member	KSV–05	21.4	16.8	8.0	3.8	0.79	0.37	0.18	0.48
SUI 55413	Colony Creek Shale Member	TXV–49	20.6	15.3	9.4	4.0	0.74	0.46	0.20	0.61
SUI 55619	Colony Creek Shale Member	TXV–49	17.3	15.8	10.3	4.5	0.91	0.59	0.26	0.65
SUI 55626	Colony Creek Shale Member	TXV–49	15.9	13.4	7.9	5.0	0.84	0.50	0.31	0.59
SUI 55618	Colony Creek Shale Member	TXV–46	14.6	13.0	6.7	3.3	0.89	0.46	0.23	0.52
SUI 55624	Colony Creek Shale Member	TXV–49	13.8	11.0	6.0	3.2	0.79	0.43	0.23	0.55
SUI 55623	Colony Creek Shale Member	TXV–49	12.9	11.0	5.0	3.7	0.85	0.39	0.29	0.45
SUI 55630	Colony Creek Shale Member	TXV–49	11.4	9.2	4.7	3.9	0.81	0.41	0.34	0.51
SUI 55622	Colony Creek Shale Member	TXV–49	11.0	9.6	5.0	3.9	0.87	0.45	0.35	0.52
SUI 55621	Colony Creek Shale Member	TXV–49	10.5	10.0	4.9	3.2	0.95	0.47	0.30	0.49
SUI 55627	Colony Creek Shale Member	TXV–49	10.4	9.4	3.8	4.8	0.90	0.37	0.46	0.41
SUI 55625	Colony Creek Shale Member	TXV–49	10.2	8.9	4.2	3.2	0.87	0.41	0.31	0.47
***Pseudaktubites newelli* Boardman, Work & Mapes gen. nov., sp. nov.**										
SUI 34137	Barnsdall Formation	OKM–69	34.0	18.0	17.4	6.7	0.53	0.51	0.20	0.97
SUI 55633	Barnsdall Formation	OKM–69	30.0	19.0	13.9		0.63	0.46		0.73
SUI 55634	Barnsdall Formation	OKM–69	24.4		10.0	7.3		0.41	0.30	
SUI 55635	Barnsdall Formation	OKM–69	15.0	14.5	7.0		0.97	0.48		0.48
***Eovidrioceras inexpectans* Boardman, Work & Mapes gen. nov., sp. nov.**										
SUI 55406	Quivira Shale Member	OKM–10	14.7	11.5	6.1	4.6	0.78	0.41	0.31	0.53

All measurements in millimeters.

a. Holotype first reposited at Texas Tech University; currently reposited at The Memorial Museum, University of Texas, Austin.

55613, 55614, 55617–55630) are reposited at the Department of Geology, University of Iowa, Iowa City.

Age Early Virgilian (Gzhelian).

***Pseudaktubites newelli* Boardman, Work & Mapes, sp. nov.** (pl. 1, fig. 8; figs. 23K, 24C, 25B; table 1)

Neoshumardites sp., Miller & Furnish, 1957, p. L61, fig. 83.

Neoshumardites gaptankensis (Miller, 1930), Saunders, 1971, pp. 115–116, pl. 23, fig. 8.

Diagnosis Primitive *Pseudaktubites* distinguished by an incipiently trifid external lateral lobe, morphologically transitional between *Preshumardites gaptankensis* and *Pseudaktubites stainbrooki*.

Description Conch globular to subdiscoidal (W/D = 0.53–0.97) with moderately narrow umbilicus (U/D = 0.2–0.3) and strongly depressed to equidimensional whorls (H/W ≈ 0.5–1.0). Conch ornament preserved on paratype SUI 55633 consists of transverse growth lamellae that form a prominent ventral salient. External suture distinguished by symmetric, medially inflated prongs of the ventral lobe that approximate width of the first lateral saddle. The first lateral lobe is conspicuously tridentate.

Discussion *Pseudaktubites newelli* is regarded as transitional between *Preshumardites gaptankensis* and *Pseudaktubites stainbrooki*. Although the ventral lobe of *Pseudaktubites newelli* is virtually indistinguishable from that of *Preshumardites gaptankensis*, a condition that previously led to its identification with that species (Saunders, 1971), it can be distinguished on the basis of its incipiently tridentate lateral lobe, which represents a slight advance over the pouched lateral lobe of *Preshumardites gaptankensis* (figs. 24B–C). *P. newelli* can be distinguished from *P. stainbrooki* by the pouched prongs of the ventral lobe and the slightly less advanced lateral lobe at diameters greater than 30 mm (figs. 24C–E).

Occurrence The holotype and three additional paratypes of *Pseudaktubites newelli* were recovered from an unnamed shale below the late Missourian Wildhorse Dolomite Member, currently included in the lower part of the Barnsdall Formation (Ochelata Group), Oklahoma (locality OKM–69).

Repository Holotype (SUI 34137) and three unfigured paratypes (SUI 55633–55635) are reposited at the Department of Geology, University of Iowa, Iowa City.

Age Latest Missourian (Kasimovian).

Family Parashumarditidae Boardman, Work & Mapes, fam. nov.

Diagnosis Shumarditaceans characterized by tridentate to incipiently trifid primary external and internal lateral lobes (L and I); the inner (dorsal) subdivision of the I complex [$(I_{2(v)}I_1I_{2(d)})$], that is, $(I_{2(d)})$ is larger than the outer two subdivisions ($I_{2(v)}$ and I_1) and the secondary subdivision $(I_1/I_{2(d)})$ is higher than the saddle that bounds the ventral subdivision $(I_{2(v)}/I_1)$. The primary umbilical lobe (U) is undivided to trifid. The prongs of the ventral lobe (V_1) are simple or bidentate.

Composition *Aktubites* Ruzhencev, 1955; *Parashumardites* Ruzhencev, 1939a; *Eoshumardites* Popov, 1960; *Eovidrioceras* Boardman, Work, & Mapes gen. nov.

Discussion Taxa in this family are united by shared asymmetry of the dorsal subdivision of the internal lateral lobe $(I_{2(d)})$, which is markedly larger than the ventrad division $(I_{2(v)})$ of the I complex [i.e., $(I_{2(v)}I_1I_{2(d)})$], and secondary saddles $I_1/I_{2(d)}$ that are higher than saddle $I_{2(v)}/I_1$. These characters, which represent new criteria for separation from the parallel shumarditid lineage, were first noted by Tharalson (1984) in *Parashumardites* and *Properrinites* (= *Subperrinites* Tharalson, 1984). New observations on the internal suture of *Aktubites* presented herein link that taxon to the later perrinitid progression (*Aktubites* → *Parashumardites* → *Properrinites* → *Perrinites*). Similarly, the new parashumarditid genus *Eovidrioceras* establishes a phyletic connection between *Aktubites* and *Vidrioceras*, root stock of the Vidrioceratidae and the Cyclolobaceae.

Eoshumardites Popov, 1960, is an enigmatic genus from the Moscovian (?) of Verkhoyan in the Russian Far East, which Ruzhencev (1975) included in the Shumarditidae as a derivative of *Aktubites*. *Eoshumardites* differs from other members assigned to this family by its possession of bidentate ventral prongs and essentially transverse ornament. However, the overall pattern of conch form and sutural configuration support assignment to the Parashumarditidae. This is supported by direct examination of topotypes from the Paleontological Institute in Moscow (PIM 4473/18 and PIM 4473/19), which exhibit the characteristic asymmetry of the dorsal subdivision of the internal lateral lobe $(I_{2(d)})$, shared only by members of the Parashumarditidae.

Age Lower Desmoinesian (Moscovian) to late Virgilian (Gzhelian).

Genus *Eovidrioceras* Boardman, Work & Mapes, gen. nov.

Type species *Eovidrioceras inexpectans* sp. nov. from the middle Missourian Quivira shale member, Dewey Limestone (Ochelata Group), Oklahoma; original designation herein.

Diagnosis Parashumarditids of intermediate advancement characterized by a combination of undivided prongs of the ventral lobe (V_1), nearly complete isolation of the three subdivisions of the primary external and internal lateral lobes, and an undivided primary umbilical lobe (U).

Sutural formula $(V_1V_1)(L_2L_1L_2)U{:}(I_2I_1I_2)(D_2D_1D_2)$.

Discussion *Vidrioceras conlini* Miller & Downs, 1950, exhibits sutural features of mature *Eovidrioceras* in its early ontogeny and is believed to have evolved from that taxon (figs. 23 and 26).

Species composition and distribution *Eovidrioceras inexpectans* sp. nov. from the middle Missourian (Kasimovian) Quivira shale member, Dewey Limestone (Ochelata Group), Oklahoma.

Eovidrioceras bulakensis (Popov, 1992) from the Karachatyr range, near Karaganda, Kazakhstan, was referred previously to *Shumardites* and was dated as Gzhelian (Popov, 1992); however, overall faunal analysis suggests reference to the pre-Gzhelian (Kasimovian, Missourian) Stage.

Eovidrioceras inexpectans Boardman, Work & Mapes
(pl. 1, figs. 17, 21; figs. 23E, 26B; table 1)

Diagnosis As for genus.

Description *Eovidrioceras inexpectans* is based on the holotype (SUI 55406), a calcitic phragmocone that attains a diameter of 14.7 mm. The conch is subglobose (W/D = 0.78) with a moderately wide umbilicus (U/D = 0.31) and depressed whorls (H/W = 0.53). Three growth constrictions are deeply incised across the flanks and venter of the final whorl, forming a high, rounded ventral salient.

The external suture is characterized by asymmetrically arcuate, bluntly pointed prongs of the ventral lobe and a broadly tridentate, incompletely subdivided lateral lobe. The internal lateral lobe is incipiently trifid with a high crest of the third internal lateral saddle ($I_1/I_{2(d)}$) and nondigitate I_2 elements.

Discussion The close phylogenetic link between *Eovidrioceras inexpectans* and primitive *Vidrioceras* (e.g., *V. conlini* Miller & Downs) is evident from fig. 26. The ventral lobe of *E. inexpectans* at 14 mm diameter is virtually identical with similar growth stages of *V. conlini*. At this stage the suture resembles that of *V. conlini* of a diameter of 9 mm.

Eovidrioceras inexpectans closely resembles *E. bulakensis* (Popov) but differs from it at similar diameters by having a slightly narrower conch (W/D = 0.78 vs. W/D = 0.86) and a wider umbilicus (U/D = 0.31 vs. U/D = 0.23). In addition, *E. bulakensis* has a slightly more advanced ventral lobe than *E. inexpectans*.

Occurrence The holotype of *Eovidrioceras inexpectans* was recovered from the middle Missourian (Kasimovian) Quivira shale member, Dewey Limestone (Ochelata Group) of northern Oklahoma (OKM–10).

Repository The holotype (SUI 55406) is reposited at the Department of Geology, University of Iowa, Iowa City.

Plates 1–5

Plate 1. (1, 2) *Preshumardites kansasensis* (Miller & Gurley), holotype UC 6219; ?Winterset Limestone Member, Dennis Limestone, Kansas City Group (Missourian); Kansas City, Jackson County, Missouri; dorsal and lateral views, respectively, ×1.5. (3, 4) *Preshumardites kansasensis* (Miller and Gurley), hypotype SUI 55411, Winterset Limestone Member, Dennis Limestone, Kansas City Group (Missourian); Lee's Summit, Jackson County, Missouri (Locality MIM–01); dorsal and lateral views, respectively, ×1.5. (5) *Somoholites* cf. *S. sagittarius* Saunders, SUI 55536; Grindstone Creek Formation, Strawn Group (Desmoinesian); 0.8 km east of Millsap, Parker County, Texas (Locality TXD–02); ventral view, ×2. (6, 7) *Neoicoceras* sp. nov., SUI 55526, Smithwick Shale, Bend Group (Atokan); 5.8 km east-southeast of Rochelle, McCulloch County, Texas (Locality TXA–02); dorsal and lateral views, respectively, ×1.7. (8) *Pseudaktubites newelli* Boardman, Work & Mapes, holotype SUI 34137; unnamed shale below Wildhorse Dolomite Member, Barnsdall Formation, Ochelata Group (Missourian); 24.2 km west of Skiatook, Osage County, Oklahoma (Locality OKM–69); lateral view, ×1.6. (9–11) *Preshumardites gaptankense* (Miller), hypotype SUI 55412; Wolf Mountain Shale Member, Graford Formation, Canyon Group (Missourian); exposure on east shore of Lake Bridgeport, 2.6 km north of US–380, Wise County, Texas (Locality TXM–43). (9) Enlargement showing ventral ornament, ×2.7. (10, 11) Lateral and ventral views, respectively, ×1.6. (12, 16) *Aktubites trifidus* Ruzhencev, hypotype OSU 30724; Putnam Hill limestone, Allegheny Group (Desmoinesian); Canfield Township, Mahoning County, Ohio; ventral and lateral views, respectively, ×2. (13–15) *Pseudaktubites stainbrooki* (Plummer and Scott), hypotype SUI 55413; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km north of Brownwood, Brown County, Texas (Locality TXV–49); ventral, lateral, and dorsal views, respectively, ×2. (17, 21) *Eovidrioceras inexpectans* Boardman, Work & Mapes, holotype SUI 55406; Quivira Shale Member, Dewey Formation, Ochelata Group (Missourian); 2 km northwest of Wekiwa, Osage County, Oklahoma (Locality OKM–10); lateral and dorsal views, respectively, ×2. (18) *Parashumardites* sp. nov., SUI 55390; H limestone bed, Limestone Member, Gaptank Formation (Virgilian); 5.5 miles (8.8 km) northeast of Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V2); lateral view, ×2. (19, 20) *Vidrioceras conlini* Miller & Downs, hypotype SUI 55407; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km north of Brownwood, Brown County, Texas (Locality TXV–49); dorsal and lateral views, respectively, ×2.

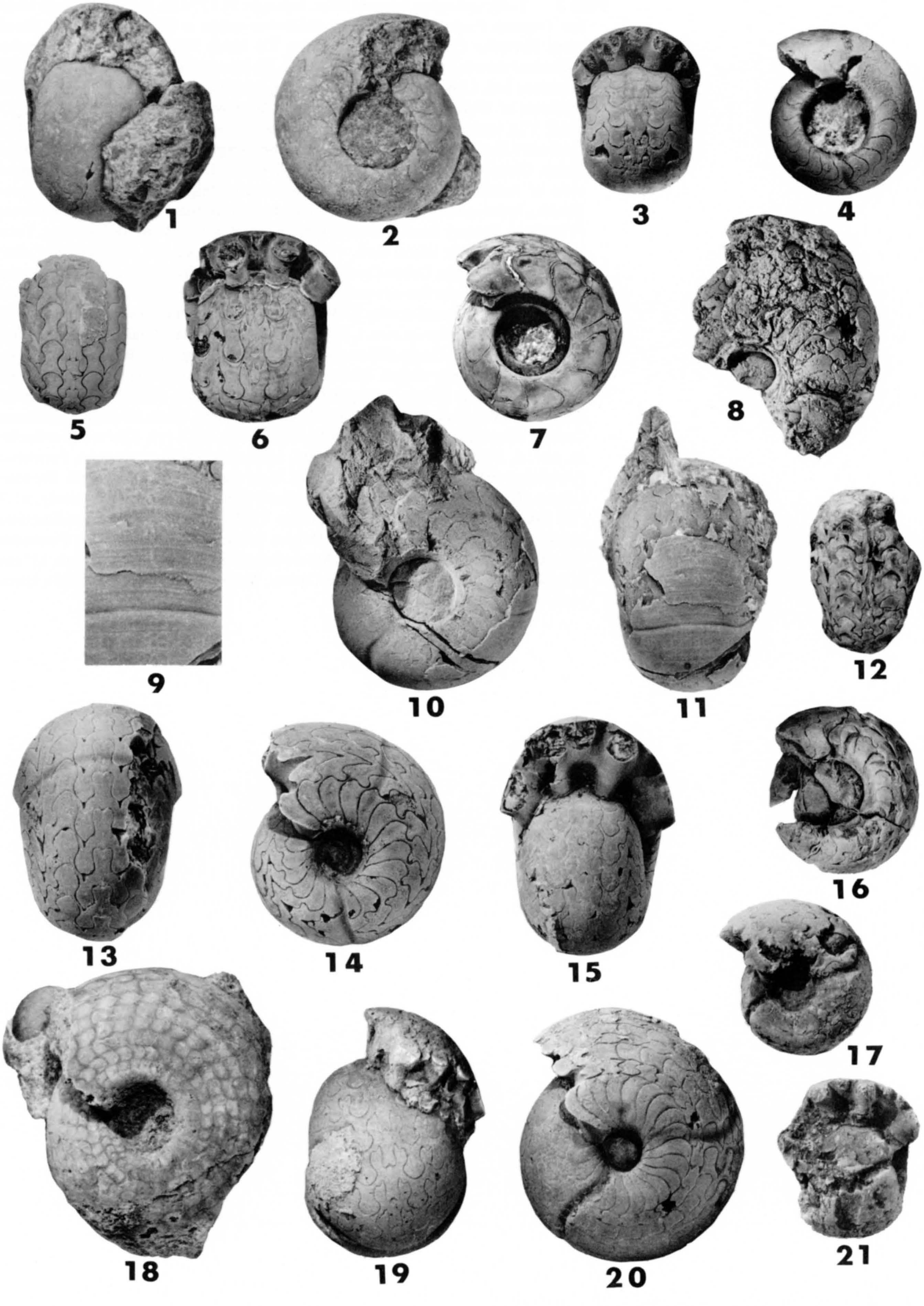

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Plate 2. (1) *Marathonites jpsmithi* Böse, topotype SUI 55428; *Uddenites* Shale Member, Gaptank Formation (Virgilian); *Uddenites* saddle at Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V3); lateral view of mature individual showing geniculate coiling, ×2.1. (2) *Marathonites* sp. nov., SUI 55430; H limestone bed, Limestone Member, Gaptank Formation (Virgilian); 5.5 mi (8.9 km) northeast of Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V2); lateral view, ×2. (3) *Marathonites jpsmithi* Böse, topotype SUI 55432; *Uddenites* Shale Member, Gaptank Formation (Virgilian); *Uddenites* saddle at Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V3); lateral view of mature individual showing geniculate coiling, ×2.1. (4) *Cardiella ganti* (Smith), hypotype SUI 55429; Finis Shale Member, Graham Formation, Cisco Group (Virgilian), Ramsey Ranch 4 mi (6.4 km) southeast of Jacksboro, Jack County, Texas (Locality TXV–54); lateral view, ×1.7. (5, 6) *Cardiella* sp. nov., SUI 48208; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 18 km (11 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); lateral and ventral views, respectively, ×3. (7–9) *Promarathonites* sp. nov. 1, UT P2407; Wolf Mountain Shale Member, Graford Formation, Canyon Group (Missourian); clay pit at Bridgeport, Wise County, Texas (Locality TXM–06); dorsal, lateral, and ventral views, respectively, ×2.5. (10) *Cardiella sulcatus* (Böse), holotype UT 34262; *Uddenites* Shale Member, Gaptank Formation (Virgilian); *Uddenites* saddle at Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V3); lateral view, ×2.7. (11, 12) *Promarathonites* sp. nov. 2, SUI 55431; H limestone bed, Limestone Member, Gaptank Formation (Virgilian); 5.5 mi (8.9 km) northeast of Wolf Camp, Glass Mountains, Brewster County, Texas (Locality TX MAR V2); lateral and dorsal views, respectively, ×1.7. (13) *Subkargalites hargisi* (Böse), hypotype YPM 12938B; allochthonous limestone block of Dugout Creek beds, below Dugout Creek Overthrust, Gaptank Formation (Missourian); 2.5 mi (4 km) south of Arnold Ranch, and 4.5 mi (7.2 km) south, 15° east of Lenox, Glass Mountains, Brewster County, Texas (Locality TX MAR M1); lateral view, ×2.4.

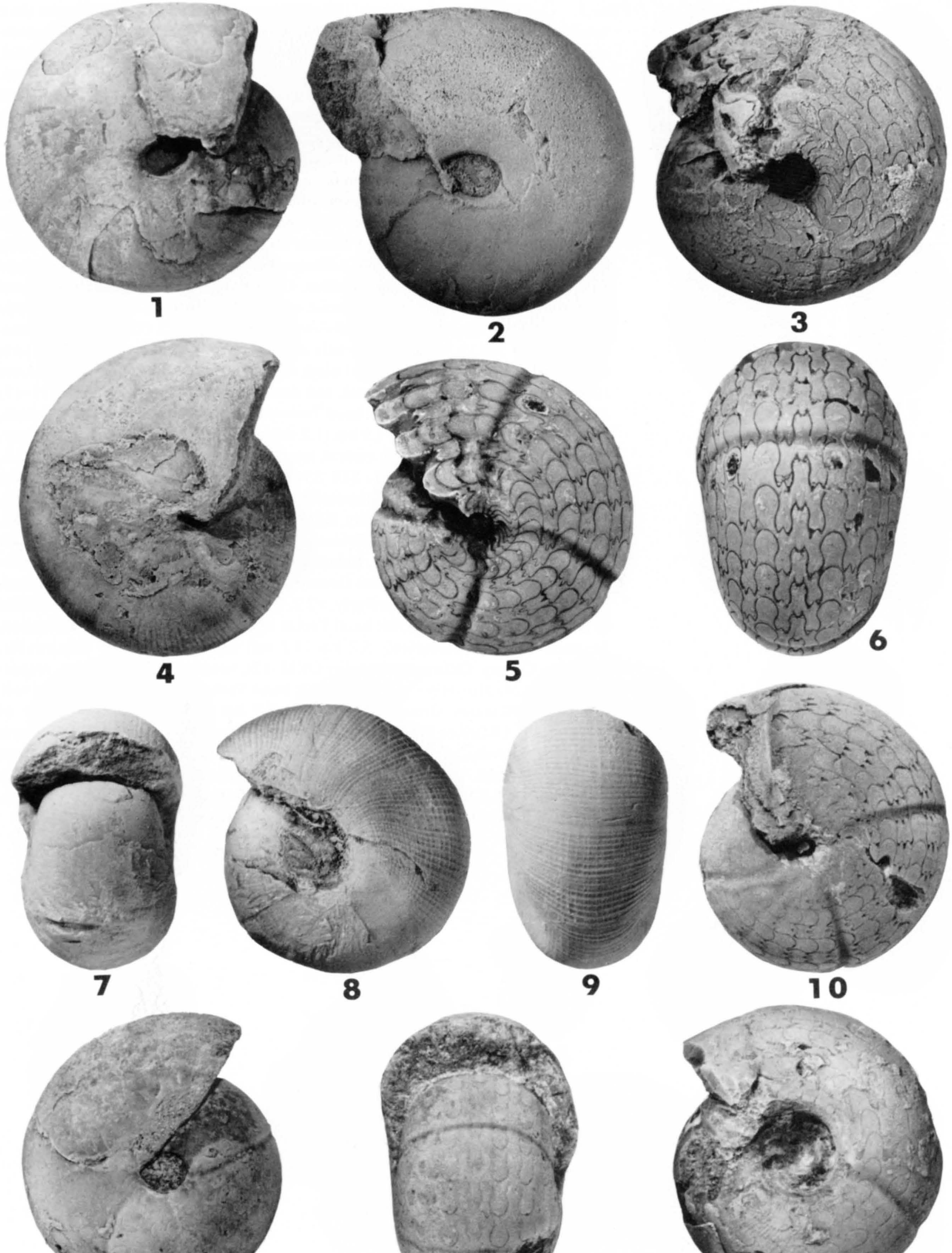
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Plate 3. (1–3) *Subkargalites hargisi* (Böse), hypotype SUI 55398; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 5.2 km south-southeast of Haydenville, Okfuskee County, Oklahoma (Locality OKM–12); lateral, dorsal, and ventral views, respectively, ×4.3. (4, 5) *Bisatoceras primum* Miller & Owen, hypotype SUI 55395; lower Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); Tackett Mound, Labette County, Kansas (Locality KSM–07); lateral and ventral views, respectively, ×2.6. (6–8) *Pennoceras* sp. nov., SUI 55433; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 1.9 km (1.2 mi) north of Sasakwa, Seminole County, Oklahoma (Locality OKM–15); ventral, lateral, and dorsal views, respectively, ×2.6. (9) *Bisatoceras* sp., SUI 55396; upper Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 7.3 km (4.5 mi) east-northeast of Mason, Okfuskee County, Oklahoma (Locality OKM–37); lateral view, ×3. (10, 11) *Bisatoceras primum* Miller & Owen, hypotype SUI 55391; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 11 km (6.8 mi) northeast of Wewoka, Hughes County, Oklahoma (Locality OKM–39); lateral and dorsal views, respectively, ×4.3. (12–14) *?Pennoceras* sp. nov., SUI 55435; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 1.9 km (1.2 mi) north of Sasakwa, Seminole County, Oklahoma (Locality OKM–16); ventral, lateral, and dorsal views, respectively, ×2.5. (15–17) *Pennoceras* sp. nov. 1, SUI 55436; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 1.9 km (1.2 mi) north of Sasakwa, Seminole County, Oklahoma (Locality OKM–16); ventral, lateral, and dorsal views, respectively, ×2.8. (18–20) *Pennoceras* sp. nov. 1, SUI 55438; Mound City shale member, Hertha Limestone, Kansas City Group (Missourian); 12 km (7.5 mi) south-southeast of Xenia, Bourbon County, Kansas (Locality KSM–15); ventral, lateral, and dorsal views, respectively, ×2.6. (21, 25, 26) *Pennoceras* sp. nov. 2, SUI 55437; ?Stark shale member, Hogshooter Formation, Skiatook Group (Missourian); railroad cut southwest of South Coffeyville, Nowata County, Oklahoma (Locality OKM–61); ventral, lateral, and dorsal views, respectively, ×2.2. (22, 23) *Eoschistoceras unicum* (Miller & Owen), hypotype SUI 55506; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 5.2 km (3.2 mi) south-southeast of Haydenville, Okfuskee County, Oklahoma (Locality OKM–12); ventral and lateral views, respectively, ×1. (24) *Maximites* sp., SUI 55503; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 5.2 km (3.2 mi) south-southeast of Haydenville, Okfuskee County, Oklahoma (Locality OKM–12); ventral and lateral views, respectively, ×1. (27, 28) *Eoschistoceras unicum* (Miller & Owen), hypotype SUI 55507; basal Tacket shale member, Coffeyville Formation, Skiatook Group (Missourian); 5.2 km (3.2 mi) south-southeast of Haydenville, Okfuskee County, Oklahoma (Locality OKM–12); lateral and dorsal views, respectively, ×2.5.

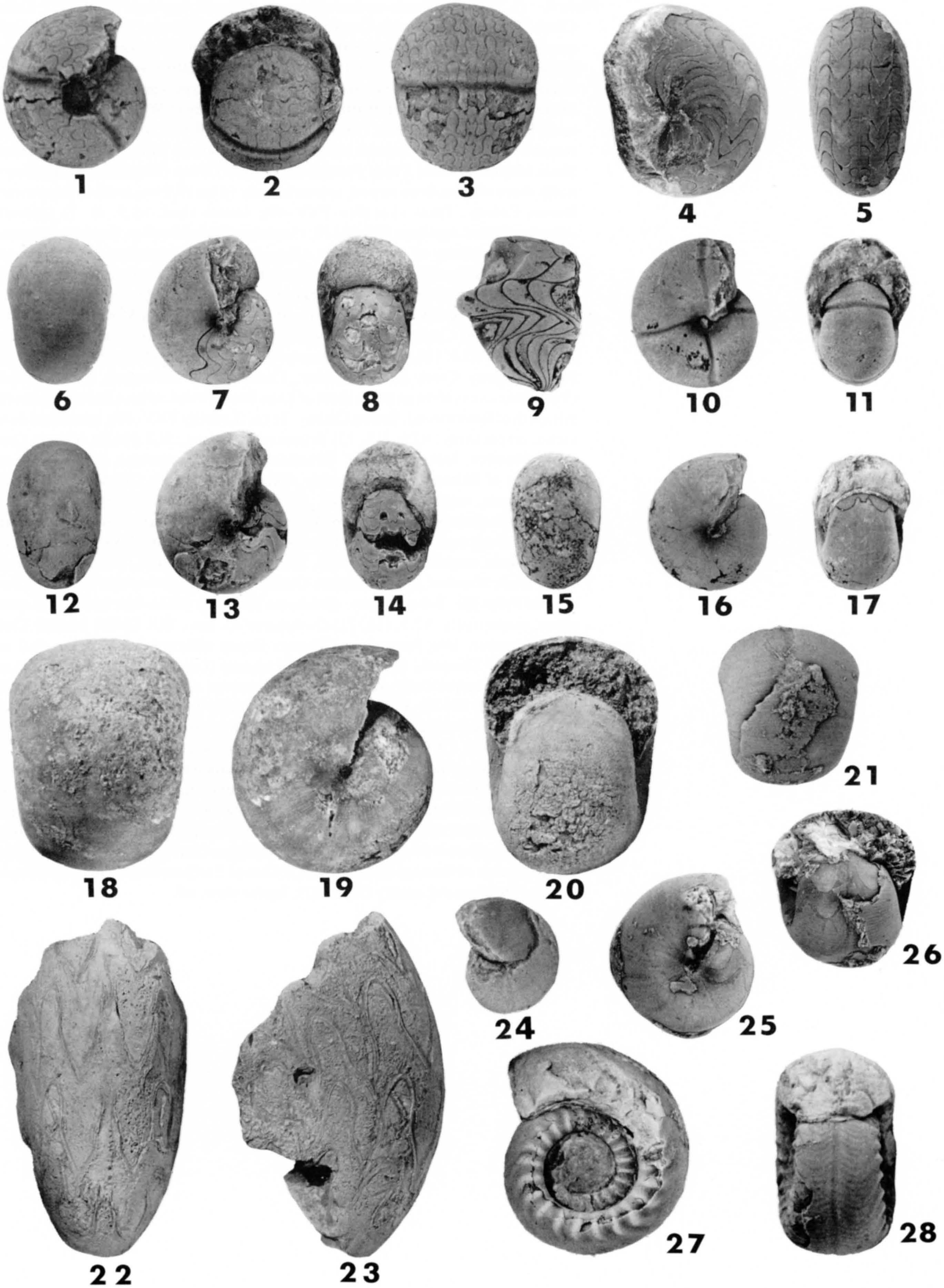
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Plate 4. (1, 2) *Uddenoceras harlani* (Plummer & Scott), hypotype SUI 54877; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km (9.9 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); ventral and lateral views, respectively, ×2. (3, 4) *Uddenoceras* aff. *U. oweni* (Miller & Furnish), hypotype SUI 55377; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains, Brewster County, West Texas (Locality TX MAR V3); lateral and ventral views, respectively, ×2.5. (5) *Boesites texanus* (Böse), hypotype SUI 55341; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km (9.9 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); lateral view, ×2.5. (6, 7) *Uddenites schucherti* Böse, topotype SUI 55374; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains–Marathon Uplift, Brewster County, Texas (Locality TX MAR V3); lateral and dorsal views, respectively, ×2.6. (8, 9) *Daixites* cf. *D. meglitzkyi* Ruzhencev, SUI 55366; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains–Marathon Uplift, Brewster County, Texas (Locality TX MAR V3); dorsal and lateral views, respectively, ×2.5. (10, 11) *Pseudopronorites kansasensis* (Newell), hypotype SUI 54878; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km (9.9 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); lateral and dorsal views, respectively, ×2.6. (12, 13) *Aristoceras* sp. nov., SUI 55425; Muncie Creek Shale Member, Iola Formation, Ochelata Group (Missourian); 9.6 km (6.0 mi) southwest of Skiatook, Osage County, Oklahoma (Locality OKM–50); dorsal and ventral views, respectively, ×3. (14, 19) *Wewokites venatus* (Girty), topotype SUI 55424; Anna shale bed, middle Wewoka Formation, Marmaton Group (Desmoinesian); 4.8 km (3.0 mi) west of Okmulgee County, Oklahoma (Locality OKD–10); dorsal and lateral views, respectively, ×2.6. (15, 20) *Gleboceras* sp. nov., SUI 55422, Muncie Creek Shale Member, Iola Formation, Ochelata Group (Missourian); 6.8 km (4.2 mi) west of Prattville, Tulsa County, Oklahoma (Locality OKM–06); lateral and dorsal views, respectively, ×2.5. (16, 21) *Gleboceras* sp. nov., SUI 55426; Muncie Creek Shale Member, Iola Formation, Ochelata Group (Missourian); 9.6 km (6.0 mi) southwest of Skiatook, Osage County, Oklahoma (Locality OKM–50); dorsal and lateral views, respectively, ×2.5. (17, 18) *Aristoceras caddoense* (Plummer & Scott), hypotype SUI 55525; Bluff Creek Shale Member (= Necessity Shale), Graham Formation, Cisco Group (Virgilian); 17.4 km (10.8 mi) south of Bangs, Brown County, Texas (Locality TXV–22); ventral and lateral views, respectively, ×2.5. (22–24) *Neoglaphyrites* sp. nov., SUI 55416; Barnsdall Formation (= upper Wann of Washington County, Oklahoma, and Eudora Shale Member of Kansas) (Missourian); 2.4 km (1.5 mi) north of Copan, Washington County, Oklahoma (Locality OKM–02); lateral, dorsal, and ventral views, respectively, ×1.5. (25) *Neoglaphyrites* sp. nov., SUI 55416; Barnsdall Formation (= upper Wann of Washington County, Oklahoma, and Eudora Shale Member of Kansas) (Missourian); 2.4 km (1.5 mi) north of Copan, Washington County, Oklahoma (Locality OKM–02); lateral view, ×2.

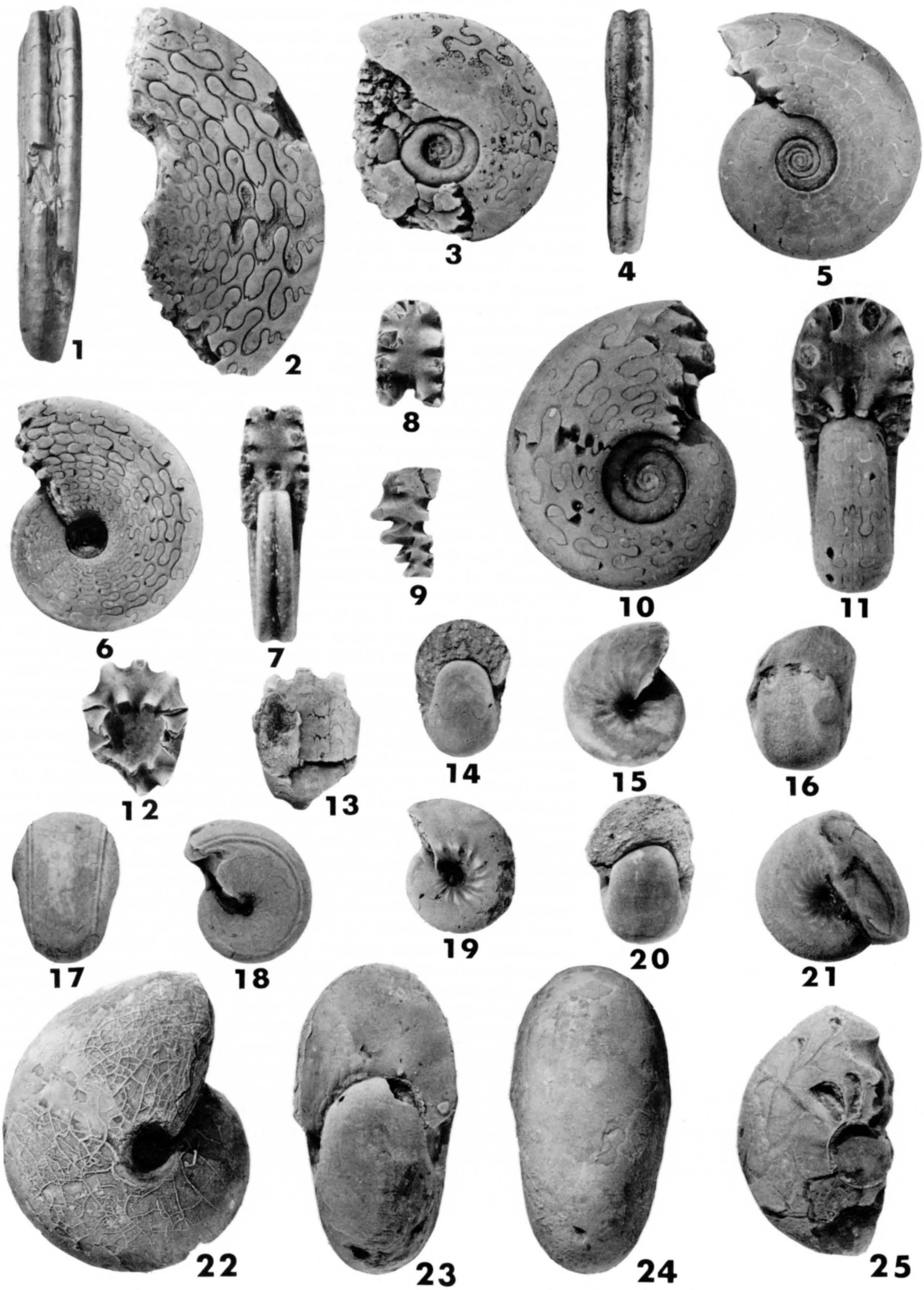
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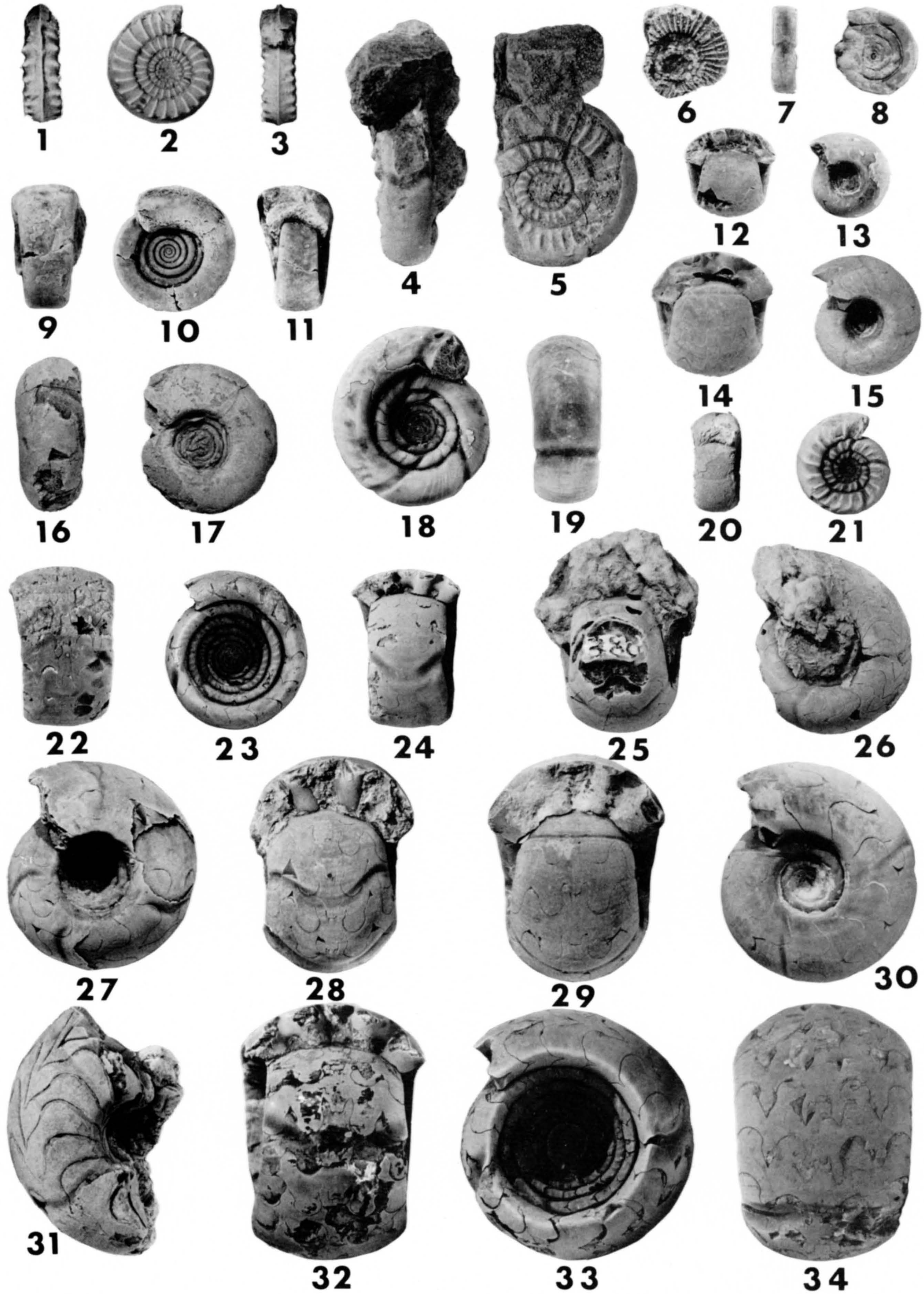
Plate 5. (1–3) *Eupleuroceras bellulum* Miller & Cline, hypotype SUI 55520; Quivira Shale Member, Dewey Formation, Ochelata Group (Missourian); 2 km (1.2 mi) northwest of Wekiwa, Osage County, Oklahoma (Locality OKM–10); ventral, lateral, and dorsal views, respectively, ×3. (4, 5) *Eoasianites* sp. nov. 1, holotype SUI 55389; allochthonous limestone block of Dugout Creek beds, below Dugout Creek Overthrust, Gaptank Formation (Missourian); 2.5 mi (4 km) south of Arnold Ranch and 4.5 mi (7.2 km) south, 15° east of Lenox, Glass Mountains, Brewster County, Texas (Locality TX MAR M1); ventral and lateral views, respectively, ×2.5. (6) *Prehoffmania milleri* Plummer & Scott, holotype UT 11119; presumably from the Finis Shale Member, Graham Formation, Cisco Group (Virgilian); 2.4 km (1.5 mi) east of Caddo, Stephens County, Texas (Locality TXV–32); lateral view, ×3. Additional ammonoid collections numbering some 3,000 specimens from the type locality of *Prehoffmania milleri* have failed to yield additional material of this enigmatic taxon. (7, 8) *Trochilioceras tenuosum* Plummer & Scott, topotype SUI 55521; Finis Shale Member, Graham Formation, Cisco Group (Virgilian); 1.3 km (0.8 mi) northeast of Cundiff, Jack County, Texas (Locality TXV–45); ventral and lateral views, respectively, ×3. (9–11) *?Dunbarites* (probably a new genus), SUI 57036; Excello Formation, Cherokee Group (Desmoinesian); 4.8 km (3.0 mi) south of Renick, Randolph County, Missouri (Locality MID–20); ventral, lateral, and dorsal views, respectively, ×2.5. (12, 13) *Glaphyrites modestus* (Böse), topotype SUI 55522; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains, Brewster County, West Texas (Locality TX MAR V3); dorsal and lateral views, respectively, ×2.2. (14, 15) *Glaphyrites modestus* (Böse), topotype SUI 55524; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains, Brewster County, West Texas (Locality TX MAR V3); dorsal and lateral views, respectively, ×2.2. (16, 17) *Trochilioceras* sp. nov., SUI 48379; New Harmony shale bed, basal Nellie Bly Formation, Skiatook Group (Missourian); 2 km (1.2 mi) northwest of Prattville, Tulsa County, Oklahoma (Locality OKM–19); ventral and lateral views, respectively, ×1.5. (18, 19) *Trochilioceras prone* (Miller & Owen), topotype SUI 57037; Nuyaka Creek black shale bed, upper part of Holdenville Formation, Marmaton Group (Desmoinesian); 1.2 km (0.7 mi) south of Collinsville, Tulsa County, Oklahoma (Locality OKD–02); lateral and ventral views, respectively, ×2.5. (20, 21) *Eoasianites* sp. nov. 2, SUI 55405; Muncie Creek Shale Member, Iola Formation, Ochelata Group (Missourian); approximately 6 km (3.7 mi) west-southwest of Wekiwa, Tulsa County, Oklahoma (Locality OKM–08); dorsal and lateral views, respectively, ×3. (22–24) *Eoasianites* sp. nov. 3, SUI 55408; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km (9.9 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); ventral, lateral, and dorsal views, respectively, ×2. (25, 26) *Glaphyrites modestus* (Böse), holotype UT P380; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains, Brewster County, West Texas (Locality TX MAR V3); dorsal and lateral views, respectively, ×2. (27, 28) *Glaphyrites* sp. nov. 1 [= *Glaphyrites kansasensis* of Plummer and Scott (1937)], UT P260; Wolf Mountain Shale Member, Graford Formation, Canyon Group (Missourian); 12.8 km (8.0 mi) north of Palo Pinto, Palo Pinto County, Texas; lateral and dorsal views, respectively, ×2. (29, 30) *Glaphyrites* sp. nov. 2 [= *Glaphyrites kansasensis* of Plummer and Scott (1937)], UT P1889; Wayland Shale Member, Graham Formation, Cisco Group (Virgilian); 2.8 km (1.7 mi) east of Fife, McCulloch County, Texas (Bureau of Economic Geology Locality UT 153–T–10; Locality TXV–03 in this bulletin); dorsal and lateral views, respectively, ×2. (31) *Glaphyrites ruzhencevi* (Miller & Furnish), topotype UT 9707; *Uddenites* Shale Member, Gaptank Formation (Virgilian); vicinity of Wolf Camp, Glass Mountains, Brewster County, West Texas (Locality TX MAR V3); lateral view, ×2. (32–34) *Eoasianites* sp. nov. 3, SUI 55481; Colony Creek Shale Member, Caddo Creek Formation, Canyon Group (Virgilian); excavation on north shore of Lake Brownwood, approximately 16 km (9.9 mi) north of Brownwood, Brown County, Texas (Locality TXV–49); dorsal, lateral, and ventral views, respectively, ×2.2.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Appendixes

Appendix 1: Synonymy

Listed in what follows are the species included within the genera in the range determinations used throughout the text of this bulletin. Placement of the species into specific genera does not imply that we subscribe to the taxonomic integrity of the species in question. An asterisk indicates a species described from outside North America.

Order Prolecanitida Miller & Furnish, 1954
- Suborder Prolecanitina Miller & Furnish, 1954
  - Superfamily Prolecanitaceae Hyatt, 1884
    - Family Daraelitidae Tchernow, 1907
      - Genus *Boesites* Miller & Furnish, 1940[b]
        - *Daraelites texanus* Böse, 1919 (type species)
        - **Boesites eotexanus* Wagner-Gentis, 1971
        - *Daraelites girtyi* Plummer & Scott, 1937
        - **Boesites primoris* Ruzhencev, 1950
  - Superfamily Medlicottiaceae Karpinsky, 1889
    - Family Pronoritidae Frech, 1901
      - Genus *Stenopronorites* Schindewolf, 1934
        - **Pronorites cyclolobus uralensis* Karpinsky, 1889 (type species)
      - Genus *Metapronorites* Librovitch, 1938
        - **Pronorites timorensis* Haniel, 1915 (type species)
        - **Metapronorites cuneilobatus* Ruzhencev, 1949
        - *Pronorites pseudotimorensis* Miller, 1930
        - *Stenopronorites simplex* Chatelain, 1984, nom. nud.
        - *Metapronorites stelcki* Nassichuk, 1975
      - Genus *Pseudopronorites* Nassichuk, 1975
        - *Pronorites arkansasensis* Smith, 1896 (type species)
        - *Pronorites kansasensis* Newell, 1936
      - Genus *Neopronorites* Ruzhencev, 1936
        - **Parapronorites permicus* Tchernow, 1907 (type species)
        - *Parapronorites boesei* Smith, 1929
        - **Neopronorites carboniferus* Ruzhencev, 1949
        - **Neopronorites prior* Ruzhencev, 1949
        - *Neopronorites* sp. nov. (Colony Creek Shale Member)
    - Family Medlicottiidae Karpinsky, 1889
      - Subfamily Uddenitinae Miller & Furnish, 1940[a]
        - Genus *Prouddenites* Miller, 1930
          - *Prouddenites primus* Miller, 1930 (type species)
          - *Prouddenites grafordensis* Plummer & Scott, 1937
          - *Prouddenites mapesi* Chatelain, 1984, nom. nud.
          - *Prouddenites primus clinei* Miller & Furnish, 1940[c]
          - *Prouddenites primus kleihegi* Miller & Furnish, 1940[c]
          - **Prouddenites terminalis* Ruzhencev, 1950
          - **Prouddenites ferganensis* Popov, 1992, nom. nud.
        - Genus *Daixites* Ruzhencev, 1941[b]
          - **Daixites meglitzkyi* Ruzhencev, 1941[b] (type species)
          - **Daixites antipovi* Ruzhencev, 1950
          - **Daixites ustritskyi* Ruzhencev, 1974
          - **Daixites karachatyrensis* Popov, 1992, nom. nud.
          - *Daixites* sp. nov. (*Uddenites* Shale Member)
        - Genus *Uddenites* Böse, 1919
          - *Uddenites schucherti* Böse, 1919 (type species)
          - **Uddenites convexus* Ruzhencev, 1949
          - **Uddenites ferganensis* Ruzhencev, 1957
          - *Uddenites minor* Böse, 1919
          - **Uddenites postsakmarensis* Ruzhencev, 1949
          - **Uddenites sakmarensis* Ruzhencev, 1939
          - *Uddenites serratus* Plummer & Scott, 1937
          - **Uddenites tuberculatus* Ruzhencev, 1949
          - **Uddenites dastarensis* Popov, 1992, nom. nud.
        - Genus *Uddenoceras* Miller & Furnish, 1954
          - *Uddenites oweni* Miller & Furnish, 1940[a] (type species)
          - *Uddenites harlani* Plummer & Scott, 1937
          - **Uddenites orenburgensis* Ruzhencev, 1949
          - *Uddenoceras* sp. nov. (*Uddenites* Shale Member)
      - Subfamily Medlicottiinae Karpinsky, 1889
        - Genus *Artinskia* Karpinsky, 1926
          - **Goniatites falx* Eichwald, 1857 (type species)
          - **Artinskia irinae* Ruzhencev, 1938

Order Goniatitida Hyatt, 1884
- Suborder Tornoceratina Wedekind, 1918
  - Superfamily Cheilocerataceae Frech, 1897
    - Family Maximitidae Ruzhencev, 1960
      - Genus *Maximites* Miller & Furnish, 1957
        - *Imitoceras cherokeensis* Miller & Owen, 1939 (type species)
        - *Maximites oklahomensis* Beghtel, 1962, nom. nud.
        - *Maximites oklahomensis* Frest, Glenister & Furnish, 1981
        - **Maximites sinensis* Ruan and Zhou, 1987
    - Family Pseudohaloritidae Ruzhencev, 1957
      - Genus *Neoaganides* Plummer & Scott, 1937
        - *Neoaganides grahamense* Plummer & Scott, 1937 (type species)
        - **Neoaganides rectilobatus* Ruzhencev, 1950

Suborder Goniatitina Hyatt, 1884
Superfamily Goniatitaceae Haan, 1825
Family Goniatitidae Haan, 1825
Subfamily Agathiceratidae Arthaber, 1911
Genus *Proshumardites* Rauser-Tschernoussova, 1928
**Proshumardites karpinskii* Rauser-Tschernoussova, 1928 (type species)
Proshumardites primus Plummer & Scott, 1937
Genus *Agathiceras* Gemmellaro, 1887
**Agathiceras suessi* Gemmellaro, 1887 (type species)
Agathiceras ciscoense Smith, 1903
Agathiceras frechi Böse, 1919
**Goniatites uralicus* Karpinsky, 1874
Superfamily Glaphyritaceae Ruzhencev & Bogoslovskaya, 1971
Family Glaphyritidae Ruzhencev & Bogoslovskaya, 1971
Genus *Glaphyrites* Ruzhencev, 1936
Gastrioceras modestum Böse, 1919 (type species)
**Glaphyrites acutus* Liang, 1957
**Glaphyrites aktubensis* Ruzhencev, 1950
Gastrioceras angulatum Girty, 1911
Glaphyrites anguloumbilicatus Plummer & Scott, 1937
**Glaphyrites boreus* Ruzhencev, 1974
Gastrioceras clinei clinei Miller & Owen, 1937
Gastrioceras clinei warei Miller & Owen, 1937
Glaphyrites digitus Chatelain, 1984, nom. nud.
Ambiguites gargantuum Smith, 1938
Goniatites globulosus Meek & Worthen, 1860
Goniatites globulosus var. *excelsum* Meek, 1876
Gastrioceras hyattianus Girty, 1911
Gastrioceras jonesi Miller & Owen, 1937
**Glaphyrites lineatus* Ruzhencev, 1950
**Glaphyrites micromphalus* Wagner-Gentis, 1971
Gastrioceras millsi Miller & Cline, 1934
Glaphyrites moorei Miller & Owen, 1939
**Glaphyrites multicavus* Ruzhencev, 1950
**Glaphyrites parangulatus* Sheng, 1981
**Glaphyrites pararhymnus* Ruzhencev, 1950
**Glaphyrites qijiangouensis* Sheng, 1981
**Glaphyrites rhymnus* Ruzhencev, 1950
Eoasianites ruzencevi Miller & Furnish, 1940[a]
**Glaphyrites sakmarensis* Ruzhencev, 1950
**Glaphyrites striatus* Ruzhencev, 1950
Proemilites strimplei Chatelain, 1984, nom. nud.
Goniatites subcavus Miller & Gurley, 1896
**Glaphyrites submodestus* Ruzhencev, 1950
Gastrioceras welleri Smith, 1903
Eoasianites wilsoni Miller, 1951
Glaphyrites sp. nov. 1 (Wolf Mountain Shale Member, Graford Formation)
Glaphyrites sp. nov. 2 (Wayland Shale Member, Graham Formation)
Family uncertain
Genus *Neoglaphyrites* Ruzhencev, 1938
**Neoglaphyrites bashkiricus* Ruzhencev, 1938 (type species)
Neoglaphyrites sp. nov. (Eudora and basal Weston Shale Members)
Superfamily Pseudoparalegocerataceae Librovitch, 1957
Family Pseudoparalegoceratidae Librovitch, 1957
Genus *Pseudoparalegoceras* Miller, 1934
**Gastrioceras russiense* Tzwetsev, 1888 (type species)
Pseudoparalegoceras brazoense Plummer & Scott, 1937
Gastrioceras buckhornensis Smith, 1938
**Pseudoparalegoceras tzwetaevae* Ruzhencev, 1951
Genus *Phaneroceras* Plummer and Scott, 1937
Phaneroceras compressum Hyatt, 1891 (type species)
Phaneroceras williamsi Unklesbay & Palmer, 1958
Genus *Eoparalegoceras* Delépine, 1939
**Eoparalegoceras clariondi* Delépine, 1939 (type species)
**Eoparalegoceras inflatum* Delépine, 1950
**Eoparalegoceras orlovkense* Popov, 1979
Family Dunbaritidae Miller & Furnish, 1957
Genus *Dunbarites* Miller & Furnish, 1940[c]
Paralegoceras rectilaterale Miller, 1930 (type species)
Dunbarites lidae Beghtel, 1962, nom. nud.
**Dunbarites larus* Ruzhencev, 1974
Dunbarites sp. nov. 1 (Colony Creek Shale Member)
Superfamily Neodimorphocerataceae Furnish & Knapp, 1966
Family Neodimorphoceratidae Furnish & Knapp, 1966
Genus *Neodimorphoceras* Schmidt, 1925
Dimorphoceras texanum Smith, 1903 (type species)
**Neodimorphoceras daixense* Ruzhencev, 1947
Dimorphoceras lenticulare Girty, 1911
Dimorphoceras oklahomae Girty, 1911
Neodimorphoceras plummerae Plummer & Scott, 1937
Genus *Politoceras* Librovitch, 1946
Goniatites politus Shumard, 1858 (type species)
Shuichengoceras loeblichi Beghtel, 1962, nom. nud.
Genus *Schuichengoceras* Yin, 1935
**Schuichengoceras yohi* Yin, 1935 (type species)
Superfamily Gastriocerataceae Hyatt, 1884
Family Gastrioceratidae Hyatt, 1884
Genus *Gastrioceras* Hyatt, 1884
**Conchyliolithus Nautilithes Ammonites (listeri)* Martin, 1809 (type species)
Gastrioceras acarium Beghtel, 1962, nom. nud.
Gastrioceras glenisteri Nassichuk, 1975

**Gastrioceras kutejnikovense* Popov, 1979
**Gastrioceras lupinum* Popov, 1979
Gastrioceras montgomeryense Miller & Gurley, 1896
Genus *Owenoceras* Miller & Furnish, 1954
Neoglyphioceras bellilineatum Miller & Owen, 1939 (type species)
Gastrioceras retiferum Miller & Owen, 1937
**Owenoceras bellilineatum shuichengense* Yang, 1978
Superfamily Thalassocerataceae Hyatt, 1900
Family Bisatoceratidae Miller & Furnish, 1957
Genus *Bisatoceras* Miller & Owen, 1937
Bisatoceras primum Miller & Owen, 1937 (type species)
Bisatoceras bransoni Chatelain, 1984, nom. nud.
Bisatoceras greenei Miller & Owen, 1939
Bisatoceras milleri Beghtel, 1962, nom. nud.
Bisatoceras milleri Chatelain, 1984, nom. nud.
Family Thalassoceratidae Hyatt, 1900
Genus *Eothalassoceras* Miller & Furnish, 1940[a]
Prothalassoceras inexpectans Miller & Owen, 1937 (type species)
Genus *Prothalassoceras* Böse, 1919
Prothalassoceras welleri Böse, 1919 (type species)
**Prothalassoceras bashkiricum* Ruzhencev, 1950
**Prothalassoceras inflatum* Ruzhencev, 1950
**Prothalassoceras jaikense* Ruzhencev, 1950
Prothalassoceras kingorum Miller, 1930
Superfamily Schistocerataceae Schmidt, 1929
Family Schistoceratidae Schmidt, 1929
Genus *Paralegoceras* Hyatt, 1884
Goniatites iowensis Meek & Worthen, 1860 (type species)
Goniatites texanus Shumard, 1863
Genus *Eoschistoceras* Ruzhencev, 1952[b]
**Eoschistoceras turkestanicum* Ruzhencev, 1952[b] (type species)
Paralegoceras discus, Smith, 1938
Pintoceras postvenatum Plummer & Scott, 1937
Paraschistoceras strawnense Plummer & Scott, 1937
Schistoceras unicum Miller & Owen, 1937
Genus *Schistoceras* Hyatt, 1884
Goniatites missouriense Miller & Faber, 1892 (type species)
Paraschistoceras costiferum Plummer & Scott, 1937
Schistoceras divercostatum Böse, 1919
Schistoceras fultonensis Miller and Gurley, 1896
Ammonites hildrethi Morton, 1836
Schistoceras hyatti Smith, 1903
**Paraschistoceras optatum* Ruzhencev, 1950
Schistoceras reticulatum Miller, 1930
Schistoceras smithi Böse, 1919
**Schistoceras suburalensis* Ruzhencev, 1950
**Schistoceras uralensis* Ruzhencev, 1950

Family Welleritidae Plummer & Scott, 1937
Genus *Wellerites* Plummer & Scott, 1937
Wellerites mohri Plummer & Scott, 1937 (type species)
Walkerites plummeri Smith, 1938
**Wellerites russiensis* Ruzhencev, 1952[a]
Walkerites vulgaris Smith, 1938
Superfamily Goniolobocerataceae Spath, 1934
Family Wiedeyoceratidae Ruzhencev & Bogoslovskaya, 1978
Genus *Wiedeyoceras* Miller, 1932
Eumorphoceras santijohanis Wiedey, 1929 (type species)
**Wiedeyoceras clarum* Popov, 1979
Wiedeyoceras graffhami Beghtel, 1962, nom. nud.
Anthracoceras missouriense Miller & Owen, 1939
Anthracoceras oklahomense Miller & Owen, 1939
Gleboceras okmulgeensis Chatelain, 1984, nom. nud.
**Wiedeyoceras tenue* Popov, 1979
Anthracoceras wanlessi Plummer & Scott, 1937
Family Goniolobоceratidae Spath, 1934
Genus *Gonioloboceras* Hyatt, 1900
Goniatites goniolobus Meek, 1877 (type species)
Gonioloboceras bicanaliculatum Smith, 1938
Gonioloboceras bridgeportense Plummer & Scott, 1937
Gonioloboceras gracellenae Miller & Cline, 1934
Goniatites parrishi Miller & Gurley, 1896
**Gonioloboceras parvum* Popov, 1979
Wiedeyoceras pingue Miller & Cline, 1934
Gonioloboceras schmidti Elias, 1962
Gonioloboceras welleri Smith, 1903
Genus *Gonioloboceratoides* Nassichuk, 1975
Gonioloboceratoides curvatus Nassichuk, 1975 (type species)
Gonioloboceratoides eliasi Nassichuk, 1975
Genus *Gonioglyphioceras* Plummer & Scott, 1937
Gonioloboceras welleri gracile Girty, 1911 (type species)
Eudissoceras collinsvillense Miller & Owen, 1937
**Gonioglyphioceras krynkense* Popov, 1979
Genus *Mescalites* Furnish & Glenister, 1971
Mescalites discoidale Furnish & Glenister, 1971 (type species)
Genus *Mangeroceras* Sturgeon, Windel, Mapes & Hoare, 1982
Mangeroceras canfieldense Sturgeon, Windel, Mapes & Hoare, 1982 (type species)
Superfamily Neoicocerataceae Hyatt, 1900
Family Neoicoceratidae Hyatt, 1900
Genus *Neoicoceras* Hyatt, 1900
Goniatites elkhornensis Miller & Gurley, 1896 (type species)

Neoicoceras sp. nov. (Smithwick Formation)
Genus *Trochilioceras* Plummer & Scott, 1937
Trochilioceras tenuosum Plummer & Scott, 1937 (type species)
Gastrioceras prone Miller & Owen, 1937
Trochilioceras sp. nov. (basal Nellie Bly Formation)
Genus *Eupleuroceras* Miller & Cline, 1934
Eupleuroceras bellelum Miller & Cline, 1934 (type species)
Genus *Eoasianites* Ruzhencev, 1933
**Eoasianites subhanieli* Ruzhencev, 1933 (type species)
**Eoasianites bashkiriensis* Ruzhencev, 1950
**Eoasianites concinnus* Ruzhencev, 1950
**Eoasianites eximus* Ruzhencev, 1950
**Eoasianites kajrakiensis* Ruzhencev, 1950
**Eoasianites postconcinnus* Ruzhencev, 1950
**Eoasianites vodorezovi* Ruzhencev, 1950
Eoasianites sp. nov. 1 (Gaptank Formation)
Eoasianites sp. nov. 2 (Muncie Creek Shale Member)
Eoasianites sp. nov. 3 (Colony Creek Shale Member)
Superfamily Somoholitaceae Ruzhencev, 1938
Family Somoholitidae Ruzhencev, 1938
Genus *Somoholites* Ruzhencev, 1938
**Gastrioceras beluense* Haniel, 1915 (type species)
**Somoholites dolium* Ruzhencev, 1950
**Somoholites glomerosus* Ruzhencev, 1950
**Somoholites ikensis* Ruzhencev, 1950
**Somoholites sholakensis* Ruzhencev, 1950
Somoholites sagittarius Saunders, 1971
Somoholites bamberi Nassichuk, 1975
Genus *Neoshumardites* Ruzhencev, 1936
**Neoshumardites triceps* Ruzhencev, 1936 (type species)
**Neoshumardites triceps angustilobus* Andrianov, 1985
Andrianovia Boardman, Work & Mapes, gen. nov.
**?Preshumardites sakmarae* Ruzhencev, 1938 (type species)
**Preshumardites bogoslovski* Andrianov, 1985
**Preshumardites gorbunovi* Andrianov, 1985
Superfamily Shumarditaceae Plummer & Scott, 1937
Family Shumarditidae Plummer & Scott, 1937
Genus *Preshumardites* Plummer & Scott, 1937
Gastrioceras gaptankense Miller, 1930 (type species)
Eoasianites grafordensis Miller and Furnish, 1940[a]
Goniatites illinoisensis Miller & Gurley, 1896
?Goniatites kansasensis Miller and Gurley, 1896
Genus *Pseudaktubites* Boardman, Work & Mapes, gen. nov.
Preshumardites stainbrooki Plummer & Scott, 1937 (type species)
Pseudaktubites newelli Boardman, Work & Mapes, sp. nov.
Genus *Shumardites* Smith, 1903
Shumardites simondsi Smith, 1903 (type species)
**Shumardites aktubensis* Ruzhencev, 1950
**Shumardites confessus* Ruzhencev, 1939[c]
Shumardites cuyleri Plummer & Scott, 1937
**Shumardites librovitchi* Ruzhencev, 1939[c]
Family *Parashumarditidae* fam. nov.
Genus *Aktubites* Ruzhencev, 1955
**Aktubites trifudus* Ruzhencev, 1955 (type species)
Aktubites sp. nov. (Vanport limestone)
Genus *Parashumardites* Ruzhencev, 1939[a]
Shumardites senex Miller & Cline, 1934 (type species)
**Parashumardites eurinus* Ruzhencev, 1950
Shumardites fornicatus Plummer & Scott, 1937
**Parashumardites mosquensis* Ruzhencev, 1939[a]
Shumardites sellardsi Plummer & Scott, 1937
Genus *Eoshumardites* Popov, 1960
**Eoshumardites lenensis* Popov, 1960 (type species)
**Eoshumardites artigensis* Popov, 1970
Genus *Eovidrioceras* Boardman, Work & Mapes, gen. nov.
Eovidiroceras inexpectans Boardman, Work & Mapes, sp. nov. (type species)
**Shumardites bulakensis* Popov, 1992
Superfamily Marathonitaceae Ruzhencev, 1938
Family Marathonitidae Ruzhencev, 1938
Subfamily Kargalitinae Ruzhencev, 1960
Genus *Kargalites* Ruzhencev, 1938
**Marathonites timorensis* Haniel var. *typica* Ruzhencev, 1933 (type species)
Kargalites sp. nov. (Finis and Necessity shales)
Genus *Subkargalites* Ruzhencev, 1950
Marathonites? hargisi Böse, 1919 (type species)
Subkargalites beghteli Chatelain, 1984, nom. nud.
**Vidrioceras bidens* Zakharov, 1978
**Subkargalites neoparkeri* Ruzhencev, 1950
Vidrioceras wewokense Beghtel, 1962, nom. nud.
**Subkargalites ferganensis* Popov, 1992, nom. nud.
Genus *Cardiella* Pavlov, 1967
**Cardiella gracia* Pavlov, 1967 (type species)
Popanoceras ganti Smith, 1903
Vidrioceras moorei Plummer & Scott, 1937
Marathonites sulcatus Böse, 1919
Subfamily Marathonitinae Ruzhencev, 1938
Genus *Promarathonites* Popov, 1992
**Promarathonites maklayi* Popov, 1992 (type species)
Promarathonites sp. nov. 1
Promarathonites sp. nov. 2

Marathonites sp. Miller & Cline, 1934
Genus *Marathonites* Böse, 1919
Marathonites jpsmithi Böse, 1919 (type species)
**Marathonites uralensis* Ruzhencev, 1940[a]
Marathonites vidriensis Böse, 1919
Superfamily Adrianitaceae Schindewolf, 1931
Family Adrianitidae Schindewolf, 1931
Genus *Emilites* Ruzhencev, 1938
Paralegoceras incertum Böse, 1919 (type species)
Emilites bennisoni Mapes and Boardman, 1988
Emilites brownwoodi Mapes and Boardman, 1988
**Emilites plummeri* Ruzhencev, 1941[a]
**Emilites ruzhencevi* Popov, 1992
**Emilites benshae* Popov, 1992
Superfamily Cyclolobaceae Zittel, 1895
Family Vidrioceratidae Plummer & Scott, 1937
Genus *Vidrioceras* Böse, 1919
Vidrioceras uddeni Böse, 1919 (type species)
Vidrioceras conlini Miller & Downs, 1950
**Vidrioceras borissiaki* Ruzhencev, 1939[b]
Vidrioceras irregulare Böse, 1919
**Hypershumardites zakharovi* Popov, 1992
Superfamily uncertain
Family uncertain
Genus *Pennoceras* Miller & Unklesbay, 1942
Pennoceras seamani Miller & Unklesbay, 1942 (type species)
Pennoceras sp. nov. 1 (Coffeyville Formation)
Pennoceras sp. nov. 2 (Stark Shale)
Superfamily uncertain
Family uncertain
Genus *Wewokites* Furnish & Beghtel, 1961
Gastrioceras venatum Girty, 1911 (type species)
Wewokites newelli Unklesbay, 1962
Genus *Aristoceras* Ruzhencev, 1940[b]
**Aristoceras chkalovi* Ruzhencev, 1940[b] (type species)
**Aristoceras appressum* Ruzhencev, 1950
Prothalassoceras caddoense Plummer and Scott, 1937
Thalassoceras (Prothalassoceras) keytei Smith, 1929
**Aristoceras serum* Bogoslovskaya and Popov 1986
Aristoceras sp. nov. (Muncie Creek Shale Member)
Genus *Gleboceras* Ruzhencev, 1950
**Gleboceras mirandum* Ruzhencev, 1950 (type species)
Gleboceras sp. nov. (Muncie Creek and Quivira Shale Members)

The following genera are not accepted as valid:

Aksuites Pavlov, 1967 (*Cardiella* Pavlov, 1967)
Ambiguites Smith, 1938 (*Glaphyrites* Ruzhencev, 1936)
Bendoceras Plummer and Scott, 1937 (*Paralegoceras* Hyatt, 1884)
Eudissoceras Miller and Owen, 1937 (*Gonioglyphioceras* Plummer and Scott, 1937)
Gordonites Miller and Furnish, 1958 (*Wiedeyoceras* Miller, 1932)
Gurleyoceras Miller, 1932 (*Goniolloboceras* Hyatt, 1900)
Hypershumardites Popov, 1992
**Martites*
Metaschistoceras Plummer and Scott, 1937 (*Schistoceras* Hyatt, 1884)
Milleroceras Hyatt, 1900 (*Gonioloboceras* Hyatt, 1900)
Paraschistoceras Plummer and Scott, 1937 (*Schistoceras* Hyatt, 1884)
Pintoceras Plummer and Scott, 1937 (*Schistoceras* Hyatt, 1884)
Plummerites Miller and Furnish, 1940[a] (*Emilites* Ruzhencev, 1938)
Prehoffmania Plummer & Scott, 1937, nom. dub.
Proemilites Chatelain 1984, nom. nud. (*Glaphyrites* Ruzhencev, 1936)
Prometalegoceras Ruzhencev, 1936 (*Eoasianites* Ruzhencev, 1933)
Pronoceras Plummer, 1950, nom. nud. (*Trochilioceras* Plummer and Scott, 1937)
Strawnoceras Plummer and Scott, 1936, nom. nud. (*Pseudoparalegoceras* Miller, 1934)
Subshumardites Schindewolf, 1939 (*Parashumardites* Ruzhencev, 1939a)
Texites Smith, 1927 (*Neodimorphoceras* Schmidt, 1925)
Uralites Voinova, 1934, nom. nud., non Tchernow, 1907, nom. nud. (*Aristoceras* Ruzhencev, 1940b)
Walkerites Smith, 1938 (*Wellerites* Plummer and Scott, 1937)

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Appendix 2: Locality register for the North American midcontinent

We have verified all the following localities. An asterisk indicates a locality in which ammonoids are reported for the first time.

1. Desmoinesian of the northern midcontinent

1.1. Southwestern Arkoma–McAlester Basin (fig. 2)

Shale in upper McAlester Formation (unnumbered horizon)
Locality OKD–50 [Collection 1 (Hendricks, 1937)]: NENENW sec. 17, T. 3. N., R. 13 E., Kiowa 7$^1/_2$′ Quadrangle, Pittsburg County, Oklahoma; shale exposure in creek bed 100 ft (30 m) south of road.

Shale in middle part of Savanna Formation (unnumbered horizon)
Locality OKD–51 [Collection 3 (Hendricks, 1937)]: NENW sec. 3, T. 2 N., R. 13 E., Kiowa 7$^1/_2$′ Quadrangle, Atoka County, Oklahoma; shale exposure.

Shale in upper part of Savanna Formation (horizon NMC D1)
Locality OKD–52 [Collection 2 (Hendricks, 1937)]: SENE sec. 4, T. 2 N., R. 13 E., Kiowa 7$^1/_2$′ Quadrangle, Atoka County, Oklahoma; shale exposure.

Shale in lower part of Boggy Formation (horizon NMC D2)
Locality OKD–53 [Station 136 (Morgan, 1924)]: Center of sec. 16, T. 3 N., R. 6 E., Ahloso 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure.
Locality OKD–54 [Station 167 (Morgan, 1924)]: Fifteen-hundred feet (460 m) south and 500 ft (150 m) east of the northwest corner of sec. 27, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure. Unklesbay (1962) refers to this locality as middle Boggy.

Shale in middle part of Boggy Formation (horizon NMC D3)
Locality OKD–55 [Station 165 (Morgan, 1924)]: Center of NE sec. 22, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure. Unklesbay (1962) refers to this locality as middle Boggy.
Locality OKD–56 [Collection 3 (Hendricks, 1937)]: SWSE sec. 5, T. 4 N., R. 15 E., Hartshorne 7$^1/_2$′ Quadrangle, Pittsburg County, Oklahoma; shale exposure.

Shale in upper part of Boggy Formation (horizon NMC D4)
Locality OKD–57 [Station 91 (Morgan, 1924)]: Center of sec. 17, T. 2 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Coal County, Oklahoma; cutbank on Bois d'Arc Creek.
Locality OKD–58 [Station 162 (Morgan, 1962)]: Center of sec. 18, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Shale in Thurman Sandstone (unnumbered horizon)
Locality OKD–59 [Station 32 (Weaver, 1954)]: Four miles (6 km) south of the northeast corner of sec. 12, T. 4 N., R. 11 E., Ashland 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; roadcut and adjacent shale exposures.

Shale in Stuart Shale (horizon NMC D5)
Locality OKD–40: NWSESW sec. 16, T. 10 N., R. 15 E., Stidham 7$^1/_2$′ Quadrangle, McIntosh County, Oklahoma; hillside exposure.

Shale underlying Verdigris Limestone Member (middle Senora Formation) (horizon NMC D7)
Locality OKD–28: SWNE sec. 29, T. 7 N., R. 11 E., Lamar 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.
Locality OKD–27: NESWSE sec. 31, T. 7 N., R. 11 E., Lamar 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; roadcut.
Locality OKD–24: Center north line of NE sec. 3, T. 5 N., R. 10 E., Calvin East 7 1/2′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Calvin Sandstone (horizon NMC D8)
Weaver (1954) listed ammonoids from the Calvin Sandstone; however, the ammonoids have not been relocated, nor did Weaver list the precise localities from which the ammonoids were recovered.

Wetumka Shale (horizon NMC D9)
*Locality OKD–13: SWSWNE sec. 8, T. 7 N., R. 10 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.
*Locality OKD–14: Center north line of sec. 17, T. 7 N., R. 10 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; pond dam.
Locality OKD–15 [Locality 163 (Morgan, 1924)]: NWNWNE sec. 18, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure.
*Locality OKD–16: NWNWNE sec. 35, T. 9 N., R. 10 E., Wetumka 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; river cutbank of Wewoka Creek.
Locality OKD–60 (Kansas locality 3223): Center of the eastern half of sec. 5, T. 7 N., R. 10 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.
Locality OKD–61 (Kansas locality 2271): Center of the southern half of sec. 8, T. 7 N., R. 10 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; pond dam.
Locality OKD–62 (Unklesbay, 1962): Sec. 20, T. 2 N.,

R. 8 E., Lula 7$^1/_2$′ Quadrangle, Coal County, Oklahoma; shale exposure.

Locality OKD–63 [Station 31 (Weaver, 1954)]: Sec. 3, T. 5 N., R. 9 E., Calvin West 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; shale exposure.

Lower Wewoka Formation (= Atwood shale bed) (horizon NMC D10)

*Locality OKD–23: NWSE sec. 3, T. 6 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure adjacent to OK–48.

Locality OKD–12 [Locality 152 (Morgan, 1924)]: SWNWSW sec. 4, T. 3 N., R. 7 E., Francis 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure used for trash dump.

Locality OKD–64 [Station 204 (Morgan, 1924)]: Shale 0.5 mi (0.8 km) north and 800 ft (240 m) west of the southeast corner of sec. 6, T. 4 N., R. 8 E., Steedman 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Locality OKD–65 [Station 205 (Morgan, 1924)]: Shale 1,000 ft (300 m) south of the northwest corner of sec. 6, T. 4 N., R. 8 E., Francis 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Locality OKD–66 [Locality 2026 (Girty, 1915)]: SW sec. 32, T. 5 N., R. 8 E., Steedman 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure.

Locality OKD–67 [Locality 7193 (Girty, 1915)]: SW sec. 33, T. 5 N., R. 8 E., Steedman 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure.

Locality OKD–68 [Locality 2010 (Girty, 1915)]: Sec. 10, T. 6 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Locality OKD–69 [Locality 2001 (Girty, 1915)]: Western half of sec. 24, T. 5 N., R. 8 E., also NENW sec. 23, T. 5 N., R. 8 E., Allen 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; hillside exposure.

Middle Wewoka Formation (= Anna shale bed) (horizon NMC D11)

Locality OKD–11 [Locality 2006 (Girty, 1915)]: Northern half of sec. 5, T. 6 N., R. 9 E., Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

*Locality OKD–22: Center of SENE sec. 32, T. 7 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

*Locality OKD–37: Center of NW sec. 33, T. 7 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; spillway cut for Lake Holdenville.

Locality OKD–70 [Locality 2004 (Girty, 1915)]: SW sec. 32, T. 6 N., R. 9 E., Calvin West 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Locality OKD–71 [Locality 2021 (Girty, 1915)]: NW sec. 31, T. 7 N., R. 9 E., Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Locality OKD–72 [Station 130 (Morgan, 1924)]: Center east line of NE sec. 12, T. 3 N., R. 6 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Locality OKD–73 [Station 155 (Morgan, 1924)]: Center of NW sec. 7, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Locality OKD–74 [Station 156 (Morgan, 1924)]: One-thousand feet (300 m) south and 2,000 ft (600 m) east of the northwest corner of sec. 7, T. 3 N., R. 7 E., Stonewall 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale exposure.

Locality OKD–75 (Unklesbay, 1962): South half of SW sec. 28, T. 7 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; shale exposure.

Upper Wewoka Formation (upper unnamed member) (horizon NMC D11)

Locality OKD–07 (Beghtel, 1962): SESESE sec. 19, T. 7 N., R. 9 E., Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

*Locality OKD–33: Center of north half of NW sec. 16, T. 7 N., R. 9 E., Lake Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; roadcut on US–270.

Locality OKD–76 [Station 129 (Morgan, 1924)]: One-thousand feet (300 m) north of south line of sec. 11, T. 3 N., R. 6 E., Ahloso 7$^1/_2$′ Quadrangle, Pontotoc County, Oklahoma; shale in railroad cut.

Wewoka Formation, no designation

Locality OKD–77 [Station 46 (Ries, 1954)]: Three-tenths of a mile (0.5 km) west and 0.05 mi (0.08 km) north of the southeast corner of sec. 1, T. 10 N., R. 10 E., Okemah Southeast 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; shale exposure. Unklesbay (1962) listed this as Wewoka undesignated, but Ries (1954) mapped it as middle Wewoka.

Locality OKD–78 [Station 57 (Weaver, 1954)]: Roadcut in southwest corner of sec. 5, T. 9 N., R. 10 E., Okemah Southeast 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; shale exposure. Unklesbay (1962) listed this as Wewoka undesignated, but Ries (1954) mapped it as middle Wewoka.

Lower Holdenville Formation (Lake Neosho shale bed) (horizon NMC D12)

*Locality OKD–30: NENE sec. 3, T. 9 N., R. 9 E., Okemah Southeast 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; deep gullies near oil field storage tanks.

*Locality OKD–31: SWNE sec. 3, T. 9 N., R. 9 E., Okemah Southeast 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Middle Holdenville Formation (High Spring shale bed) (horizon NMC D13)

Locality OKD–03: SESESE sec. 1, T. 10 N., R. 9 E., also NENENE sec. 12, T. 10 N., R. 9 E., Okemah Southeast 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; hillside exposure.

Upper Holdenville Formation (Nuyaka Creek shale bed) (horizon NMC D14)

*Locality OKD–01: Center of sec. 35, T. 8 N., R. 8 E., Holdenville 7½′ Quadrangle, Hughes County, Oklahoma; gully used for trash dump.

*Locality OKD–21: Center of southern half of SENW sec. 25, T. 6 N., R. 7 E., Sasakwa 7½′ Quadrangle, Seminole County, Oklahoma; hillside exposure.

*Locality OKD–32: SWSW sec. 15, T. 10 N., R. 9 E., Okemah Southeast 7½′ Quadrangle, Okfuskee County, Oklahoma; stream cutbanks.

Holdenville Formation, no designation

Locality OKD–79 (Kansas Locality 2131): Center of southern half of sec. 14, T. 7 N., R. 8 E., Holdenville 7½′ Quadrangle, Hughes County, Oklahoma; roadcut.

Locality OKD–80 [Station 158 (Ries, 1954)]: 0.35 mi (0.56 km) east of the southwest corner of sec. 6, T. 10 N., R. 10 E., Okemah Southeast 7½′ Quadrangle, Okfuskee County, Oklahoma; shale exposure. Unklesbay (1962) listed this locality as Holdenville with no member designation; however, we regard this locality as middle Holdenville.

1.2. Northwestern Arkoma–McAlester Basin (fig. 2)

Shale over Doneley Limestone Member (Savanna Formation) (horizon NMC D1)

Locality OKD–38: Center of eastern half of NWSE sec. 10, T. 14 N., R. 18 E., Southwest Muskogee 7½′ Quadrangle, Muskogee County, Oklahoma; cutbank on north side of Corta Creek.

Shale underlying Tiawah Limestone Member (Stuart Shale) (horizon NMC D5)

Locality OKD–41: Center of SWNWSW sec. 13, T. 14 N., R. 15 E., Boynton 7½′ Quadrangle, Muskogee County, Oklahoma; shale exposure adjacent to Cane Creek.

Shale overlying Tiawah Limestone Member (Stuart Shale) (horizon NMC D5)

Locality OKD–42: Center of SWNWSW sec. 13, T. 14 N., R. 15 E., Boynton 7½′ Quadrangle, Muskogee County, Oklahoma; shale exposure adjacent to Cane Creek.

Shale overlying Mineral coal (basal Senora Formation) (horizon NMC D6)

Locality OKD–43: Center east line of SESE sec. 25, T. 14 N., R. 14 E., Okmulgee Northeast 7½′ Quadrangle, Okmulgee County, Oklahoma; coal pit.

Excello shale bed (Calvin Sandstone) (horizon NMC D8)

Locality OKD–44: SESWSE sec. 18, T. 19 N., R. 15 E., Broken Arrow 7½′ Quadrangle, Wagoner County, Oklahoma; strip pits.

Wetumka Shale (horizon NMC D9)

*Locality OKD–19: Center west line of SWSENW, sec. 7, T. 15 N., R. 14 E., Concharty Mountain 7½′ Quadrangle, Okmulgee County, Oklahoma; stream cutbank.

*Locality OKD–20: Center of southern half of northern half of SE sec. 16, T. 12 N., R. 12 E., Okmulgee Lake 7½′ Quadrangle, Okmulgee County, Oklahoma; pond dam.

Lower Wewoka Formation (= Atwood shale bed) (horizon NMC D10)

Locality OKD–81 (Unklesbay, 1962): SW sec. 10, T. 15 N., R. 12 E., Spanish Peak 7½′ Quadrangle, Okmulgee County, Oklahoma; shale exposure. Unklesbay (1962) listed this locality as Wetumka; however, it is mapped as lower Wewoka by Oakes (1963).

Middle Wewoka Formation (= Anna shale bed) (horizon NMC D11)

Locality OKD–10: SESW sec. 10, T. 13 N., R. 12 E., Okmulgee Lake 7½′ Quadrangle, Okmulgee County, Oklahoma; hillside exposure adjacent to OK–56.

Upper Wewoka Formation (upper unnamed member) (horizon NMC D11)

*Locality OKD–34: Center of sec. 18, T. 13 N., R. 12 E., Okmulgee Lake 7½′ Quadrangle, Okmulgee County, Oklahoma; lakeside exposure.

Locality OKD–17 (Unklesbay, 1962): NE sec. 2, T. 14 N., R. 12 E., Okmulgee North 7½′ Quadrangle, Okmulgee County, Oklahoma; roadcut on US–75.

Locality OKD–18 (Unklesbay, 1962): Center north line of NW sec. 31, T. 14 N., R. 13 E., Okmulgee North 7½′ Quadrangle, Okmulgee County, Oklahoma; roadcut on OK–16.

*Locality OKD–45: Center of NESE sec. 7, T. 13 N., R. 12 E., Okmulgee Lake 7½′ Quadrangle, Okmulgee County, Oklahoma; lakeside exposure.

Locality OKD–82 [Station 80 (Ries, 1954)]: Three-tenths of a mile (0.5 km) south of the northeast corner of sec. 26, T. 11 N., R. 10 E., Clearview 7½′ Quadrangle, Okfuskee County, Oklahoma; shale in roadcut. Unklesbay (1962) listed this locality as middle Wewoka; however, Ries (1954) mapped it as upper Wewoka.

Lower Holdenville Formation (Lake Neosho shale bed) (horizon NMC D12)

*Locality OKD–04: NENE sec. 11, T. 11 N., R. 10 E., Clearview 7½′ Quadrangle, Okfuskee County, Oklahoma; hillside exposure.

*Locality OKD–08: Center south line of SWSE sec. 23, T. 16 N., R. 13 E., Spanish Peak 7½′ Quadrangle, Okmulgee County, Oklahoma; hillside exposure.

Middle Holdenville Formation (High Spring shale bed) (horizon NMC D13)

*Locality OKD–36: Center of SENW sec. 21, T. 11 N., R. 10 E., Okemah 7½′ Quadrangle, Okfuskee County, Oklahoma; old abandoned railroad track. This locality is mapped as upper Holdenville by Ries (1954).

*Locality OKD–25: NWSENW sec. 36, T. 14 N., R. 11 E., Beggs 7½′ Quadrangle, Okmulgee County, Oklahoma; hillside exposure.

*Locality OKD–46: SENENE sec. 11, T. 12 N., R. 10 E., Okfuskee 7½′ Quadrangle, Okfuskee County, Oklahoma; cutbank on Cow Creek.

Upper Holdenville Formation (Nuyaka Creek shale bed) (horizon NMC D14)

*Locality OKD–47: NWSW sec. 2, T. 17 N., R. 12 E., Sapulpa South 7½′ Quadrangle, Tulsa County, Oklahoma; cutbank of Coal Creek.

*Locality OKD–48: Center east line of sec. 32, T. 12 N., R. 10 E., Okemah 7½′ Quadrangle, Okfuskee County, Oklahoma; cutbank of Nuyaka Creek. This locality is the type section for this member.

Holdenville Formation, no designation

Locality OKD–83 [Station 87 (Ries, 1954)]: One-quarter mile (0.4 km) east of the northwest corner of sec. 33, T. 11 N., R. 10 E., Okemah 7½′ Quadrangle, Okfuskee County, Oklahoma; shale exposure.

Locality OKD–84 (Unklesbay, 1962): Sec. 36, T. 11 N., R. 10 E., Clearview 7½′ Quadrangle, Okfuskee County, Oklahoma; shale exposure. Unklesbay (1962) listed this locality as Holdenville, but it is mapped as Wewoka.

Locality OKD–85 (Unklesbay, 1962): NE sec. 24, T. 15 N., R. 11 E., Lake Boren 7½′ Quadrangle, Okmulgee County, Oklahoma; shale exposure.

Locality OKD–86 (Unklesbay, 1962): Sec. 36, T. 11 N., R. 9 E., Okemah 7½′ Quadrangle, Okfuskee County, Oklahoma; shale exposure.

1.3. Northeast Oklahoma platform, Kansas, Missouri, Iowa (fig. 2)

Lower Cherokee Shale, undifferentiated

Locality IOD–01 (University of Iowa Locality): East side of SE sec. 1, T. 82 N., R. 30 W., Cooper 7½′ Quadrangle, Greene County, Iowa; strip mine.

Locality IOD–02 (University of Iowa Locality): NW sec. 29, T. 82 N., R. 29 W., Cooper 7½′ Quadrangle, Greene County, Iowa; Bussey coal mine.

Locality IOD–03 (University of Iowa Locality): NENW sec. 8, T. 70 N., R. 13 W., Ottumwa South 7½′ Quadrangle, Davis County, Iowa; strip mine.

Locality IOD–04 (University of Iowa Locality): East of center of sec. 7, T. 70 N., R. 13 W., Ottumwa South 7½′ Quadrangle, Davis County, Iowa; strip mine.

Locality IOD–05 (University of Iowa Locality): NW sec. 26, T. 76 N., R. 19 W., Knoxville 7½′ Quadrangle, Marion County, Iowa; strip mine.

Meek and Worthen (1860) Locality: Near Alpine, Wapello County, Iowa.

Shale above Jordan coal (= Seville Formation) (horizon NMC D2)

Locality MID–02 (Miller and Owens, 1939) [Locality 9 (Hoare, 1961)]: SW sec. 17, T. 41 N., R. 25 W., Gaines 7½′ Quadrangle, Henry County, Missouri; England strip pit.

Mecca Quarry shale bed [Verdigris Formation in Missouri; unnamed black shale bed underlying the Verdigris Limestone Member (Senora Formation) in northern Oklahoma] (horizon NMC D7)

Locality MID–03 (Miller and Owen, 1939): Sec. 22, T. 42 N., R. 26 W., Clinton North 7½′ Quadrangle, Henry County, Missouri; Coon Creek strip pit.

Locality MID–04 (Miller and Owen, 1939): Sec. 23, T. 42 N., R. 26 W., Clinton North 7½′ Quadrangle, Henry County, Missouri; Tillman strip pit.

Locality MID–05 (Miller and Owen, 1939): Sec. 22, T. 41 N., R. 27 W., Montrose 7½′ Quadrangle, Henry County, Missouri; Vansant strip pit.

Locality MID–06 (Miller and Owen, 1939): Sec. 9, T. 42 N., R. 25 W., Calhoun West 7½′ Quadrangle, Henry County, Missouri; Carroll strip pit.

Locality MID–07 (Miller and Owen, 1939): Sec. 10, T. 41 N., R. 27 W., Montrose 7½′ Quadrangle, Henry County, Missouri; J. G. Turk strip pit.

Locality MID–08 (Miller and Owen, 1939): Sec. 23, T. 42 N., R. 26 W., Clinton North 7½′ Quadrangle, Henry County, Missouri; West Missouri Power Company strip pit.

Locality OKD–87 (Kansas Locality 2285): SW sec. 16, T. 20 N., R. 15 E., Catoosa 7½′ Quadrangle, Rogers County, Oklahoma; shale exposure.

Excello Formation [in Missouri; Excello shale member (Cabaniss Formation) in Kansas; Excello Shale Member (Senora Formation) in northern Oklahoma] (horizon NMC D8)

Locality MID–09 (Miller and Owen, 1939): Sec. 36, T. 43 N., R. 28 W., Hartwell 7½′ Quadrangle, Henry County, Missouri; Ewing strip pit.

Locality MID–10 (Miller and Owen, 1939): Sec. 15, T. 43 N., R. 29 W., Quick City 7½′ Quadrangle, Cass County, Missouri; Lear strip pit.

Locality MID–11 (Miller and Owen, 1939): Sec. 21, T. 43 N., R. 29 W., Garden City 7½′ Quadrangle, Cass County, Missouri; Overby strip pit.

Locality MID–12 (Miller and Owen, 1939): Sec. 19, T. 42 N., R. 25 W., Calhoun West 7½′ Quadrangle, Henry County, Missouri; Houston strip pit.

Locality MID–13 (Miller and Owen, 1939): Sec. 22, T.

43 N., R. 28 W., Hartwell 7$^1/_2$′ Quadrangle, Henry County, Missouri; Shideler strip pit.

Locality MID–14 (Miller and Owen, 1939): Sec. 9, T. 42 N., R. 25 W., Calhoun West 7$^1/_2$′ Quadrangle, Henry County, Missouri; Carroll strip pit.

Locality MID–15 (Miller and Owen, 1939): Sec. 15, T. 43 N., R. 28 W., Quick City 7$^1/_2$′ Quadrangle, Henry County, Missouri; Gooch strip pit.

Locality MID–16 (Miller and Owen, 1939): Sec. 19, T. 42 N., R. 25 W., Calhoun West 7$^1/_2$′ Quadrangle, Henry County, Missouri; George Howell strip pit.

Locality MID–17 (Miller and Owen, 1939): SENW T. 49 N., R. 25 W., Higginsville 7$^1/_2$′ Quadrangle, Lafayette County, Missouri; roadcut, 3 mi (5 km) southeast of Higginsville, Missouri.

Locality MID–18 (Miller and Owen, 1939): Leeton 7$^1/_2$′ Quadrangle, Johnson County, Missouri; 1.75 mi (2.8 km) southeast of Leeton, Missouri.

Locality MID–19 (Miller and Owen, 1939): SWSE sec. 36, T. 53 N., R. 23 W., Carrollton East 7$^1/_2$′ Quadrangle, Carroll County, Missouri; shale exposure.

Locality KSD–02 (Miller and Owen, 1939): NW sec. 11, T. 26 S., R. 25 E., Fort Scott 7$^1/_2$′ Quadrangle, Bourbon County, Kansas; 3 mi (5 km) south and 3 mi (5 km) west of Eve, Missouri.

Locality MID–20: NESE sec. 18, T. 52 N., R. 13 E., Renick 7$^1/_2$′ Quadrangle, Randolph County, Missouri; cutbank on Perche Creek.

Locality MID–21 (Miller and Owen, 1939): NW sec. 10, T. 35 N., R. 33 W., Deerfield 7$^1/_2$′ Quadrangle, Vernon County, Missouri; coal strip mine.

Locality OKD–88 (Unklesbay, 1962): Sec. 23, T. 24 N., R. 16 E., Winganon 7$^1/_2$′ Quadrangle, Rogers County, Oklahoma; strip coal mine.

Locality OKD–89 (Unklesbay, 1962): Sec. 24, T. 24 N., R. 16 E., Winganon 7$^1/_2$′ Quadrangle, Rogers County, Oklahoma; strip coal mine.

Locality OKD–90 (Unklesbay, 1962): Sec. 25, T. 24 N., R. 16 E., Winganon 7$^1/_2$′ Quadrangle, Rogers County, Oklahoma; strip coal mine.

Locality OKD–91 (Unklesbay, 1962): Sec. 36, T. 24 N., R. 16 E., Winganon 7$^1/_2$′ Quadrangle, Rogers County, Oklahoma; strip coal mine.

Locality OKD–92 (Unklesbay, 1962): Sec. 3, T. 23 N., R. 17 E., Bushyhead 7$^1/_2$′ Quadrangle, Rogers County, Oklahoma; strip coal mine.

Little Osage Shale Member (Fort Scott Limestone) (horizon NMC D9)

Locality KSD–01: SE sec. 12, T. 30 S., R. 22 E., Grindstone Creek 7$^1/_2$′ Quadrangle, Crawford County, Kansas; quarry.

Anna Shale Member (Oologah Formation in Oklahoma; Pawnee Formation in Iowa) (horizon NMC D11)

Locality OKD–09: SESW sec. 34, T. 19 N., R. 14 E., Broken Arrow 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; roadcut on Broken Arrow Expressway.

Locality IOD–07 (University of Iowa Locality): SENW sec. 17, T. 69 N., R. 18 W., Mystic 7$^1/_2$′ Quadrangle, Appanoose County, Iowa; Ludwig strip mine.

Lake Neosho Shale Member (Altamont Formation) (horizon NMC D12)

Locality OKD–06: SESESE sec. 18, T. 19 N., R. 14 E., Broken Arrow 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; cutbank.

Locality OKD–05: Center of NENE sec. 32, T. 19 N., R. 14 E., Broken Arrow 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; shale in vacant lot.

Locality OKD–29: SENENW sec. 30, T. 20 N., R. 14 E., Mingo 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; shale for water main.

Lenapah Limestone (horizon NMC D13)

Locality OKD–93 (Unklesbay, 1962): NESE sec. 30, T. 28 N., R. 16 E., Elliott 7$^1/_2$′ Quadrangle, Nowata County, Oklahoma; 2 mi (3 km) north of Lenapah, Oklahoma. This locality is the type section for the formation.

Nuyaka Creek shale bed (Holdenville Formation in Oklahoma; Holdenville Shale in Missouri) (horizon NMC D14)

Locality OKD–02: SE sec. 31, T. 22 N., R. 14 E., Collinsville 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; strip coal mine.

Locality MID–01: West half of NWSW sec. 21, T. 43 N., R. 31 W., Austin 7$^1/_2$′ Quadrangle, Cass County, Missouri; dredge channel in South Grand River.

1.4. Ardmore Basin (fig. 3)

Frensley Limestone Member (Lake Murray Formation, Dornick Hills Group) (horizon NMC OKARD D1)

Locality OKARD D3 (Unklesbay, 1962): NWSE sec. 32, T. 5 S., R. 2 E., Lake Murray 7$^1/_2$′ Quadrangle, Carter County, Oklahoma; hillside exposure.

Devil's Kitchen Member (Deese Group) (horizon NMC OKARD D2)

Locality OKARD D1: SWSWSE sec. 31, T. 3 S., R. 4 E., Mannsville 7$^1/_2$′ Quadrangle, Johnston County, Oklahoma; streambank cut.

Buckhorn Asphalt Member (Deese Group) (horizon NMC OKARD D3)

Locality OKARD D2: NE sec. 26, T. 1 S., R. 3 E., Sulfur South 7$^1/_2$′ Quadrangle, Murray County, Oklahoma; limestone quarry.

2. Missourian of the northern midcontinent

2.1. Oklahoma "basinal" section (fig. 4)

Coffeyville Formation, basal Tacket shale bed (horizon NMC M1)

*Locality OKM–39: SENWNW sec. 30, T. 9 N., R. 9 E., Wewoka East 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure adjacent to Long George Creek.

*Locality OKM–15: Center west line of SENW sec. 25, T. 6 N., R. 7 E., Sasakwa 7$^1/_2$′ Quadrangle, Seminole County, Oklahoma; hillside exposure.

*Locality OKM–12: North line of sec. 3, T. 12 N., R. 10 E., Okfuskee 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; abandoned road exposure.

Locality OKM–16: Center west line NWSENW sec. 25, T. 6 N., R. 7 E., Sasakwa 7$^1/_2$′ Quadrangle, Seminole County, Oklahoma; hillside exposure.

Coffeyville Formation, lower Tacket shale bed (Mound City Shale Member, Hertha Limestone of Kansas) (horizon NMC M2)

*Locality OKM–13: Center west line SWSW sec. 31, T. 12 N., R. 10 E., Okema 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; roadcut on OK–27.

*Locality OKM–14: East half of sec. 22, T. 19 N., R. 12 E., Sapulpa North 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside cut.

*Locality OKM–22: Center of SW sec. 21, T. 15 N., R. 11 E., Kiefer Southwest 7$^1/_2$′ Quadrangle, Okmulgee County, Oklahoma; cutbank in Tiger Creek.

*Locality OKM–40: Center south line of NW sec. 26, T. 19 N., R. 12 E., Sapulpa North 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside exposure.

*Locality OKM–27: NWNWSW sec. 36, T. 19 N., R. 12 E., Jenks 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside exposure.

*Locality OKM–28: Center of NW sec. 11, T. 18 N., R. 12 E., Sapulpa North 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; roadcut.

*Locality OKM–25: Center north line of sec. 12, T. 25 N., R. 14 E., Oglesby 7$^1/_2$′ Quadrangle, Nowata County, Oklahoma; cutbank.

*Locality OKM–59: SENE sec. 5, T. 23 N., R. 14 E., Bartlesville Southeast 7$^1/_2$′ Quadrangle, Washington County, Oklahoma; cutbank along Buck Creek.

*Locality OKM–60: NENE sec. 15, T. 27 N., R. 15 E., Delaware 7$^1/_2$′ Quadrangle, Nowata County, Oklahoma; cutbank along California Creek.

Locality OKM–62 (Kansas Locality 2266): Center of west half of sec. 20, T. 7 N., R. 8 E., Holdenville 7$^1/_2$′ Quadrangle, Hughes County, Oklahoma; hillside exposure.

Locality OKM–63 (Unklesbay, 1962): Sec. 36, T. 12 N., R. 9 E., Okemah 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; hillside exposure. This locality is adjacent to Locality OKM–13.

Locality OKM–64 [Station 3085 (Tanner, 1956)]: Center of sec. 26, T. 6 N., R. 7 E., Sasakwa 7$^1/_2$′ Quadrangle, Seminole County, Oklahoma; hillside exposure.

Coffeyville Formation, upper Tacket shale bed (= Hushpuckney shale member, Swope Limestone of Kansas) (horizon NMC M3)

*Locality OKM–37: NENENW sec. 29, T. 13 N., R. 10 E., Mason 7$^1/_2$′ Quadrangle, Okfuskee County, Oklahoma; hillside exposure.

*Locality OKM–36: Center of SW sec. 21, T. 15 N., R. 11 E., Kiefer Southwest 7$^1/_2$′ Quadrangle, Okmulgee County, Oklahoma; cutbank in Tiger Creek.

Locality OKM–55: Center north line of sec. 12, T. 25 N., R. 14 E., Oglesby 7$^1/_2$′ Quadrangle, Nowata County, Oklahoma; cutbank.

*Locality OKM–56: Center of NW sec. 11, T. 18 N., R. 12 E., Sapulpa North 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; roadcut on US–75.

*Locality OKM–58: NWNWSW sec. 36, T. 19 N., R. 12 E., Jenks 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside exposure.

*Locality OKM–61: Center south line of sec. 14 , T. 29 N., R. 16 E., Elliott 7$^1/_2$′ Quadrangle, Nowata County, Oklahoma; railroad cut.

Stark Shale Member (Hogshooter Formation of northern Oklahoma; Francis Formation of central Oklahoma) (horizon NMC M4)

*Locality OKM–41: Center north line of NWSE sec. 31, T. 26 N., R. 14 E., Oglesby 7$^1/_2$′ Quadrangle, Washington County, Oklahoma; cutbank exposure.

*Locality OKM–30: Center of NWNE sec. 33, T. 15 N., R. 10 E., Newby 7$^1/_2$′ Quadrangle, Creek County, Oklahoma; hillside exposure.

Locality OKM–43: SENWSW sec. 5, T. 5 N., R. 7 E., Sasakwa 7$^1/_2$′ Quadrangle, Seminole County, Oklahoma; cutbank of Clear Creek.

Locality OKM–38: Center west line of NWNWNW sec. 9, T. 5 N., R. 7 E., Sasakwa 7$^1/_2$′ Quadrangle, Seminole County, Oklahoma; cutbank in Clear Creek.

Lower Nellie Bly Formation (= New Harmony shale bed) (horizon NMC M5)

*Locality OKM–44: Center of NW sec. 6, T. 19 N., R. 12 E., Sand Springs 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside exposure.

*Locality OKM–45: Center of northern half of NWNW sec. 16, T. 19 N., R. 12 E., Sand Springs 7$^1/_2$′ Quadrangle, Tulsa County, Oklahoma; hillside exposure.

*Locality OKM–46: Center east line of NENESE sec. 25, T. 21 N., R. 11 E., Avant Southeast 7$^1/_2$′ Quadrangle, Osage County, Oklahoma; hillside exposure.

*Locality OKM–35: Center east line of SWNWSE sec. 16, T. 24 N., R. 13 E., Ramona 7½′ Quadrangle, Washington County, Oklahoma; gulley due east of US–75.

*Locality OKM–11: NE sec. 17, T. 19 N., R. 11 E., Wekiwa 7½′ Quadrangle, Tulsa County, Oklahoma; road-metal quarry.

*Locality OKM–18: NE sec. 17, T. 19 N., R. 11 E., Wekiwa 7½′ Quadrangle, Tulsa County, Oklahoma; hillside exposure 600 ft (180 m) northwest of Locality OKM–11.

*Locality OKM–19: SENW sec. 21, T. 19 N., R. 11 E., Lake Sahoma 7½′ Quadrangle, Tulsa County, Oklahoma; limestone quarry.

Locality OKM–65 (Kansas Locality 2168): Sec. 1, T. 19 N., R. 11 W., Sand Springs 7½′ Quadrangle, Tulsa County, Oklahoma; brick pit.

Quivira Shale Member (Dewey Formation) (horizon NMC M6)

Locality OKM–09: NESE sec. 11, T. 19 N., R. 10 E., Wekiwa 7½′ Quadrangle, Tulsa County, Oklahoma; roadcut. This locality is the famous Miller and Cline (1934) locality listed by them as 6.5 mi (10 km) west of Sand Springs in the Nellie Bly Formation. Actually, this locality lies between the lower Dewey, which has thinned to 6 in. (15 cm), and the upper Dewey.

*Locality OKM–10: Center of sec. 36, T. 20 N., R. 10 E., Wekiwa 7½′ Quadrangle, Osage County, Oklahoma; excavation for trash dump.

*Locality OKM–48: Center south line of SESWNW sec. 30, T. 12 N., R. 9 E., Boley 7½′ Quadrangle, Okfuskee County, Oklahoma; abandoned railroad cut.

*Locality OKM–49: Center east line of SENW sec. 12, T. 21 N., R. 11 E., Avant Southeast 7½′ Quadrangle, Osage County, Oklahoma; hillside exposure.

Locality OKM–66 [Station 225 (Morgan, 1924)]: Fifteen-hundred feet (460 m) east and 700 ft (210 m) north of the southwest corner of sec. 7, T. 6 N., R. 7 E., Tate Mountain 7½′ Quadrangle, Seminole County, Oklahoma; hillside exposure. This locality is mapped as the Belle City Limestone by both Morgan (1924) and Tanner (1956). We correlate the Belle City with the Dewey, based on stratigraphic position and identical conodont faunas.

Muncie Creek Shale Member (Iola Formation) (horizon NMC M7)

*Locality OKM–50: Center south line of NWSWSW sec. 12, T. 21 N., R. 11 E., Avant Southeast 7½′ Quadrangle, Osage County, Oklahoma; hillside exposure.

*Locality OKM–05: Center north line of SE sec. 24, T. 22 N., R. 11 E., Avant Southeast 7½′ Quadrangle, Osage County, Oklahoma; roadcut on OK–20.

*Locality OKM–06: Center north line of NWNW sec. 25, T. 19 N., R. 10 E., Lake Sahoma 7½′ Quadrangle, Tulsa County, Oklahoma; roadcut on 41st Street West.

*Locality OKM–07: SWSE sec. 9, T. 19 N., R. 10 E., Wekiwa 7½′ Quadrangle, Tulsa County, Oklahoma; powerline excavation.

*Locality OKM–08: South half of sec. 10, T. 19 N., R. 10 E., Wekiwa 7½′ Quadrangle, Tulsa County, Oklahoma; railroad cut.

*Locality OKM–23: NWNW sec. 9, T. 23 N., R. 12 E., Avant 7½′ Quadrangle, Osage County, Oklahoma; spillway for Candy Creek reservoir.

*Locality OKM–47: SENENW sec. 19, T. 29 N., R. 14 E., Wann 7½′ Quadrangle, Nowata County, Oklahoma; hillside exposure.

Locality OKM–67 (Kansas Locality 3216): SW sec. 31, T. 22 N., R. 12 E., Avant Southeast 7½′ Quadrangle, Osage County, Oklahoma; hillside exposure.

Locality OKM–68 (Kansas Locality 2297): Southern point between secs. 16 and 17, T. 22 N., R. 12 E., Avant 7½′ Quadrangle, Osage County, Oklahoma; hillside exposure.

Lower Wann Formation (= Quindaro shale bed) (horizon NMC M8)

Locality OKM–01: Center east line of NENE sec. 12, T. 24 N., R. 12 E., Ramona 7½′ Quadrangle, Washington County, Oklahoma; roadcut.

Locality OKM–04: NENESE sec. 25, T. 24 N., R. 12 E., Ramona 7½′ Quadrangle, Washington County, Oklahoma; roadcut.

Locality OKM–21: SE sec. 23, T. 26 N., R. 12 E., Bartlesville South 7½′ Quadrangle, Washington County, Oklahoma; hillside excavation.

Locality OKM–24: Center north line of NW sec. 3, T. 21 N., R. 11 E., Avant Southeast 7½′ Quadrangle, Osage County, Oklahoma; roadcut and spillway cut for Lake Skiatook.

Upper Wann Formation (= Hickory Creek shale bed) (horizon NMC M9)

Locality OKM–26: Center west line of SWSWSW sec. 23, T. 29 N., R. 13 E., Copan 7½′ Quadrangle, Washington County, Oklahoma; pond dam.

Locality OKM–03: SE sec. 9, T. 28 N., R. 14 E., Wann 7½′ Quadrangle, Washington County, Oklahoma; hillside exposure.

Lower Barnsdall Formation (= Eudora shale bed) (horizon NMC M10)

Locality OKM–02: Center east line of sec. 9, T. 28 N., R. 13 E., Copan 7½′ Quadrangle, Washington County, Oklahoma; roadcut on US–75.

Locality OKM–17: Center of SW sec. 13, T. 27 N., R. 12 E., Bartlesville North 7½′ Quadrangle, Washington County, Oklahoma; hillside exposure.

Locality OKM–20: Center east line of sec. 15, T. 28 N., R. 13 E., Copan $7^1/_2'$ Quadrangle, Washington County, Oklahoma; road ditch.

Locality OKM–69: North half of sec. 21, T. 22 N., R. 10 E., Avant Southwest $7^1/_2'$ Quadrangle, Osage County, Oklahoma; hillside exposures.

2.2. Kansas, Nebraska, Missouri, and Iowa (fig. 4)

Exline Limestone Member, unnamed formation (horizon NMC M1)

Locality KSM–04: Center north half of sec. 34, T. 25 S., R. 22 E., Uniontown $7^1/_2'$ Quadrangle, Bourbon County, Kansas; roadcut on K–3.

Lower Tacket shale bed–Mound City Shale Member (Hertha Limestone) (horizon NMC M2)

Locality KSM–05: NENWNW sec. 12, T. 25 S., R. 22 E., Xenia $7^1/_2'$ Quadrangle, Bourbon County, Kansas; roadcut on East-West Road.

Locality KSM–06: Center north line of sec. 7, T. 25 S., R. 23 E., Xenia $7^1/_2'$ Quadrangle, Bourbon County, Kansas; roadcut.

Locality KSM–07: Center of section, also NENE sec. 7, T. 32 S., R. 18 E., Parson's West $7^1/_2'$ Quadrangle, Labette County, Kansas; hillside exposure in Tacket Mound type section.

Locality KSM–08: Center of SWSE sec. 7, T. 32 S., R. 18 E., Parson's West $7^1/_2'$ Quadrangle, Labette County, Kansas; stream cutbank exposure.

Locality KSM–09: Just south of center north line of NE sec. 31, T. 24 S., R. 23 E., Xenia $7^1/_2'$ Quadrangle, Bourbon County, Kansas; hillside exposure.

Upper Tacket shale bed–Hushpuckney Shale Member and Bethany Falls Limestone Member (Swope Limestone) (horizon NMC M3)

Locality KSM–10: NENE sec. 7, T. 32 S., R. 18 E., Parson's West $7^1/_2'$ Quadrangle, Labette County, Kansas; hillside exposure in Tackett Mound type section for Tacket Formation.

Locality KSM–11: North half of NE sec. 24, T. 21 E., R. 25 S., Moran Southeast $7^1/_2'$ Quadrangle, Bourbon County, Kansas; quarry adjacent to Schubert Creek.

Stark Shale Member–Winterset Limestone Member (Dennis Formation) (horizon NMC M4)

Locality NEBM–1: SWSESW sec. 20, T. 13 N., R. 13 E., Plattsmouth $7^1/_2'$ Quadrangle, Sarpy County, Nebraska; shale exposure in quarry.

Locality NEBM–2: SENESW sec. 32, T. 14 N., R. 13 E., Omaha South $7^1/_2'$ Quadrangle, Sarpy County, Nebraska; shale exposure.

Locality MIM–01: NWNESE sec. 1, T. 47 N., R. 32 W., Lees Summit $7^1/_2'$ Quadrangle, Jackson County, Missouri; hillside excavation.

Drum Limestone Member (Cherryvale Formation) (horizon NMC M5)

Locality KSM–12: North half of sec. 5, T. 33 S., R. 16 E., Independence $7^1/_2'$ Quadrangle, Montgomery County, Kansas; quarry of Atlas Cement plant.

Locality KSM–13: NESW sec. 5, T. 33 S., R. 16 E., Independence $7^1/_2'$ Quadrangle, Montgomery County, Kansas; roadcut.

Locality KSM–14: NW sec. 13, T. 32 S., R. 16 E., Cherryvale $7^1/_2'$ Quadrangle, Montgomery County, Kansas; railroad cut.

Locality KSM–20 (Kansas Locality 5238): Unable to ascertain legal description, Cherryvale $7^1/_2'$ Quadrangle, Montgomery County, Kansas; drum at Cherryvale, Kansas.

Locality KSM–21 (Sayre, 1930): SWSW sec. 22, T. 11 S., R. 24 E., Shawnee $7^1/_2'$ Quadrangle, Wyandotte County, Kansas. Sayre (1930) places this locality 1 mi (1.6 km) south of Turner, Kansas. However, after reviewing the geology of the area and the position of the Union-Pacific railroad, we believe that the actual locality must have been 1 mi (1.6 km) southeast of Turner.

Locality KSM–22 (Sayre, 1930): Unable to ascertain legal description, Cherryvale $7^1/_2'$ Quadrangle, Montgomery County, Kansas. Sayre (1930) places this locality at station 40 in Cherryvale.

Locality KSM–23 (Sayre, 1930): Unable to ascertain legal description, Wyandotte County, Kansas; oolitic member of the Drum Limestone at Kansas City.

Quivira Shale Member (Dewey Limestone) (horizon NMC M6)

Locality KSM–15: SWSWSE sec. 7, T. 23 S., R. 21 E., Kincaid $7^1/_2'$ Quadrangle, Allen County, Kansas; cutbank of Small Creek.

Locality KSM–16: North of SE sec. 29, T. 23 S., R. 21 E., Blue Mound $7^1/_2'$ Quadrangle, Allen County, Kansas; just west of road.

Muncie Creek Shale Member (Iola Formation) (horizon NMC M7)

Locality MIM–02 [Locality 013OE (Ellison, 1941)]: Sec. 8, T. 49 N., R. 33 W., Kansas City $7^1/_2'$ Quadrangle, Jackson County, Missouri; roadcut on Main Street in Kansas City.

Frisbie Limestone Member–Argentine Limestone Member (Wyandotte Formation in Missouri; Wyandotte Limestone in Kansas) (horizon NMC M8)

Locality MIM–03 (Kansas Locality 6549): Unable to ascertain legal description, Kansas City $7^1/_2'$ Quadrangle, Jackson County, Missouri; Kansas City, Missouri.

Locality MIM–04 (Kansas Locality 5427): South half of sec. 18, T. 49 N., R. 33 W., Kansas City 7½′ Quadrangle, Jackson County, Missouri; quarry at 33d Street and Roanoake.

Locality KSM–24 (Kansas Locality): NW sec. 30, T. 10 S., R. 25 E., Parkville 7½′ Quadrangle, Wyandotte County, Kansas; Boynes quarry on Quindaro Creek.

Hickory Creek Shale Member–Spring Hill Limestone Member (Plattsburg Limestone) (horizon NMC M9)

Locality KSM–25 (Kansas Locality): Center of sec. 33, T. 27 S., R. 17 E., Vilas 7½′ Quadrangle, Wilson County, Kansas; railroad cut.

Eudora Shale Member (Stanton Limestone of Kansas) and Kiewitz Shale Member (Stanton Formation of Nebraska) (horizon NMC M10)

Locality KSM–01: SWSW sec. 31, T. 33 S., R. 15 E., Tyro 7½′ Quadrangle, Montgomery County, Kansas; roadcut.

Locality KSM–02: NE sec. 36, T. 33 S., R. 14 E., Bolton 7½′ Quadrangle, Montgomery County, Kansas; roadcut.

Locality KSM–03: SENWSWSE sec. 30, T. 34 S., R. 15 E., Tyro 7½′ Quadrangle, Montgomery County, Kansas; quarry.

Locality KSM–17: NW sec. 6, T. 34 S., R. 15 E., Tyro 7½′ Quadrangle, Montgomery County, Kansas; hillside exposure.

Locality KSM–18: SW sec. 35, T. 33 S., R. 14 E., Bolton 7½′ Quadrangle, Montgomery County, Kansas; shale exposure.

Locality KSM–19: NWNENE sec. 5, T. 33 S., R. 15 E., Bolton 7½′ Quadrangle, Montgomery County, Kansas; hillside exposure.

Locality NEBM–3: NENE sec. 14, T. 12 N., R. 11 E., Springfield 7½′ Quadrangle, Cass County, Nebraska; quarry.

3. Virgilian of the northern midcontinent

3.1. Northern shelf (Kansas, Missouri, Nebraska, and Iowa) (fig. 5)

South Bend Limestone Member (Stanton Limestone) (horizon NMC V0)

Locality KSV–08 (Roger K. Pabian, personal communication, 1985): Southern half of sec. 5, T. 34 S., R. 14 E., Caney 7½′ Quadrangle, Montgomery County, Kansas; railroad cut.

Shale above South Bend Limestone Member = Weston Shale Member (Stranger Formation) (horizon NMC V1)

Locality KSV–07: NWSESW sec. 10, T. 35 S., R. 13 E., Caney 7½′ Quadrangle, Chautauqua County, Kansas; roadcut.

Locality KSV–25: Center west half of NW sec. 6, T. 35 S., R. 14 E., Caney 7½′ Quadrangle, Chautauqua County, Kansas; hillside exposure.

Locality KSV–26: Southwest corner of NESE sec. 8, T. 34 S., R. 14 E., Caney 7½′ Quadrangle, Chautauqua County, Kansas; hillside exposure.

Iatan Limestone Member (Stranger Formation) (horizon NMC V2)

Miller and Furnish (1940c) reported *Schistoceras* from an unspecified locality, presumably from either Kansas or Missouri. We have not been able to verify this report.

Haskell Limestone Member and basal Robbins Shale Member (Lawrence Formation) (horizon NMC V3)

Locality KSV–09 (Kansas Locality 7033): Probably sec. 14, T. 14 S., R. 20 E., Baldwin City 7½′ Quadrangle, Douglas County, Kansas; 1 mi (1.6 km) east of Vinland, Kansas.

Locality KSV–10 (Kansas Locality 50272): Probably in sec. 34, 35, or 36, T. 15 S., R. 19 E., probably Ottawa North 7½′ Quadrangle, Douglas County, Kansas; 5 mi (8 km) north of Ottawa.

Locality KSV–11 (Kansas Locality 4894): Sec. 12, T. 14 S., R. 20 E., Baldwin City 7½′ Quadrangle, Johnson County, Kansas; 3 mi (5 km) east of Vinland, Kansas.

*Locality KSV–05: SWNENE sec. 14, T. 35 S., R. 12 E., Peru 7½′ Quadrangle, Chautauqua County, Kansas; road ditch.

*Locality KSV–06: Center of sec. 22, T. 34 S., R. 12 E., Peru 7½′ Quadrangle, Chautauqua County, Kansas; roadcut.

Heebner Shale Member and Leavenworth Limestone Member (Oread Limestone) (horizon NMC V4)

Locality KSV–12 (Kansas Locality): Center of sec. 27, T. 14 S., R. 20 E., Baldwin City 7½′ Quadrangle, Douglas County, Kansas; limestone exposure.

Queen Hill Shale Member (Lecompton Limestone) (horizon NMC V5)

Locality NEBV–2: SE sec. 17, T. 10 N., R. 14 E., McPaul 7½′ Quadrangle, Cass County, Nebraska; shale exposure in quarry.

Locality KSV–02: Center of southern half of NW sec. 3, T. 33 S., R. 10 E., Elgin Northeast 7½′ Quadrangle, Chautauqua County, Kansas; spillway for Middle Caney Creek reservoir.

Locality KSV–03: Center east line of SESW sec. 8, T. 33 S., R. 11 E., Sedan 7½′ Quadrangle, Chautauqua County, Kansas; 4.5 mi (7.2 km) northwest of Sedan, Kansas; hillside exposure.

Larsh-Burroak Shale Member and Rock Bluff Limestone Member (Deer Creek Formation) (horizon NMC V6)

Locality NEBV–3: SWNE sec. 3, T. 10 N., R. 11 E., Weeping Water 7$^1/_2$′ Quadrangle, Cass County, Nebraska; quarry.

Locality NEBV–12: SESW sec. 20, T. 10 N., R. 13 E., Nehawka 7$^1/_2$′ Quadrangle, Cass County, Nebraska; limestone exposure.

Topeka Limestone

Verville (1958) reports ammonoids from the Topeka Limestone in Elk County, Kansas. However, the specimens were not reposited and have not been verified.

Aarde Shale Member (Howard Limestone) (horizon NMC V8)

Locality KSV–13 (Kansas Locality 7189): East half of sec. 8, T. 15 S., R. 16 E., Carbondale 7$^1/_2$′ Quadrangle, Osage County, Kansas; limestone and shale exposure.

Locality KSV–14 (Kansas Locality 10042): Center north half of sec. 6, T. 15 S., R. 16 E., Carbondale 7$^1/_2$′ Quadrangle, Osage County, Kansas; limestone and shale exposure.

Locality NEBV–1: NWNWNE sec. 23, T. 1 N., R. 12 E., Dubois 7$^1/_2$′ Quadrangle, Pawnee County, Nebraska; hillside exposure.

Meek (1876) exposures in Osage, Kansas: No precise locality given.

Smith (1927) exposures near Howard, Kansas: No precise locality given.

Cedar Vale Shale Member (Scranton Formation) (horizon NMC V9)

Locality NEBV–4: SESE sec. 3, T. 2 N., R. 12 E., Table Rock 7$^1/_2$′ Quadrangle, Pawnee County, Nebraska; hillside exposure.

Locality MIV–01 [Elias (1938) Locality]: Center north line of SW sec. 32, T. 65 N., R. 37 W., Burlington Junction 7$^1/_2$′ Quadrangle, Nodaway County, Missouri; probably the strip pit 3 mi (5 km) south and 2 mi (3 km) west of Burlington Junction, Missouri.

Harveyville Shale Member (Emporia Formation) (horizon NMC V10)

Locality NEBV–5: NWSESE sec. 17, T. 1 N., R. 12 E., Dubois 7$^1/_2$′ Quadrangle, Pawnee County, Nebraska; shale exposure.

Locality NEBV–6: NW sec. 33, T. 2 N., R. 13 E., Humbolt Southwest 7$^1/_2$′ Quadrangle, Richardson County, Nebraska; shale exposure.

Locality NEBV–7: NW sec. 3, T. 1 N., R. 13 E., Humbolt Southwest 7$^1/_2$′ Quadrangle, Richardson County, Nebraska; shale exposure.

Willard Shale (horizon NMC V11)

Locality NEBV–8: NWSESE sec. 17, T. 1 N., R. 12 E., Dubois 7$^1/_2$′ Quadrangle, Pawnee County, Nebraska; shale exposure.

Locality NEBV–9: NW sec. 33, T. 2 N., R. 13 E., Humbolt 7$^1/_2$′ Quadrangle, Richardson County, Nebraska; shale exposure.

Locality NEBV–10: NW sec. 8, T. 1 N., R. 13 E., Humbolt 7$^1/_2$′ Quadrangle, Richardson County, Nebraska; shale exposure.

Wamego Shale Member (Zeandale Limestone) (horizon NMC V12)

Locality KSV–1: Center south line of SW sec. 1, T. 32 S., R. 8 E., Grenola 7$^1/_2$′ Quadrangle, Chautauqua County, Kansas; hillside exposure adjacent to Spring Creek.

Dover Limestone Member (Stotler Limestone) and associated shale (horizon NMC V13)

Locality KSV–15 [Locality Dover P–1 (Tasch, 1953)]: Southwest corner of SESWSW sec. 5, T. 28 S., R. 10 E., Piedmont Northeast 7$^1/_2$′ Quadrangle, Greenwood County, Kansas; shale exposure.

Locality KSV–16 [Locality Dover P–2 (Tasch, 1953)]: SESWSW sec. 5, T. 28 S., R. 10 E. [also 330 ft (100 m) west of Locality Dover P–1], Piedmont Northeast 7$^1/_2$′ Quadrangle, Greenwood County, Kansas; road ditch exposure.

Locality KSV–17 [Locality Dover P–3 (Tasch, 1953)]: West line of NWNWNW sec. 8, T. 28 S., R. 10 E., Piedmont Northeast 7$^1/_2$′ Quadrangle, Greenwood County, Kansas; road ditch.

Locality KSV–18 (Kansas Locality 7076): Unable to ascertain legal description, Piedmont Northeast 7$^1/_2$′ Quadrangle, Greenwood County, Kansas; east of Piedmont, Kansas.

Locality KSV–19 (Kansas Locality): Probably sec. 5, T. 28 S., R. 10 E., Piedmont Northeast 7$^1/_2$′ Quadrangle, Greenwood County, Kansas; 1 mi (1.6 km) north and 1.5 mi (2.4 km) east of Piedmont, Kansas.

Dry Shale Member and Grandhaven Limestone Member (Stotler Limestone of Kansas; Stotler Formation of Nebraska) (horizon NMC V14)

Locality KSV–20 [Locality Dry E–1 (Tasch, 1953)]: Probably sec. 10, T. 19 S., R. 11 E., Emporia 7$^1/_2$′ Quadrangle, Lyon County, Kansas; shale exposure in park south of Emporia golf course.

Locality KSV–21 (Kansas Locality): At northern end of Emporia, Kansas, Emporia 7$^1/_2$′ Quadrangle, Lyon County, Kansas; shale exposure.

Locality KSV–22 (Kansas Locality): SESW sec. 8, T. 19 S., R. 11 E., Emporia 7$^1/_2$′ Quadrangle, Lyon County, Kansas; roadcut.

Locality NEBV–11: SESWNE sec. 18, T. 1 N., R. 13 E., Humbolt 7$^1/_2$′ Quadrangle, Richardson County, Nebraska; shale exposure.

Jim Creek Limestone Member (Root Formation) (horizon NMC V15)

Locality KSV–23 [USGS Locality 13832 (Mudge and Yochelson, 1963)]: NWNE sec. 7, T. 22 S., R. 11 E., Madison $7^{1}/_{2}'$ Quadrangle, Greenwood County, Kansas; roadside ditch.

Brownville Limestone Member (Wood Siding Formation) (horizon NMC V16)

Locality KSV–24 (Kansas Locality): Probably sec. 20, T. 16 S., R. 12 E., Admire $7^{1}/_{2}'$ Quadrangle, Lyon County, Kansas; 0.5 mi (0.08 km) north of Admire, Kansas.

3.2. Oklahoma (fig. 6)

Vamoosa Formation (Robbins shale bed) (horizon NMC V3)

Locality OKV–09: NWSW sec. 2, T. 26 N., R. 10 E., Herd $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

Vamoosa Formation (Heebner shale bed) (horizon NMC V4)

Locality OKV–02: NWNE sec. 32, T. 24 N., R. 9 E., Wynona $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

Locality OKV–03: SW sec. 18, T. 21 N., R. 8 E., Cleveland $7^{1}/_{2}'$ Quadrangle, Pawnee County, Oklahoma; large shale quarry used as trash dump.

*Locality OKV–04: Center of NWSE sec. 9, T. 25 N., R. 9 E., Pawhuska $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

Locality OKV–14: SE sec. 11, T. 25 N., R. 9 E., Pawhuska $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

Pawhuska Formation (Lecompton Limestone Member and Queen Hill Shale Member) (horizon NMC V5)

Locality OKV–10: Center east line of NENESW sec. 3, T. 22 N., R. 8 E., Hominy $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; quarry.

Locality OKV–15 (Unklesbay, 1962): Sec. 5, T. 25 N., R. 8 E., Blue Stem Lake $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

*Locality OKV–08: Center north line of NESW sec. 3, T. 22 N., R. 8 E., Hominy $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; quarry.

*Locality OKV–11: Center south line of NESE sec. 5, T. 23 N., R. 8 E., Hominy $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

*Locality OKV–12: NESWSW sec. 31, T. 25 N., R. 9 E., Happy Hollow $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

*Locality OKV–13: Northeast corner of SWSW sec. 4, T. 23 N., R. 8 E., Hominy $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

Pawhuska Formation (Deer Creek Limestone Member and Larsh-Burroak Shale Member) (horizon NMC V6)

*Locality OKV–05: SWNWNW sec. 12, T. 25 N., R. 8 E., Blue Stem Lake $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; quarry.

*Locality OKV–06: SESWSE sec. 2, T. 25 N., R. 8 E., Blue Stem Lake $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; quarry.

*Locality OKV–07: Center of northern half of NENE sec. 35, T. 26 N., R. 8 E., Blue Stem Lake $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; oil well location.

Wabaunsee Group [Howard Limestone and shale above Bird Creek Limestone (= Aarde shale)] (horizon NMC V8)

Unklesbay (1962) Locality: NW sec. 18, T. 25 N., R. 8 E., Blue Stem Lake $7^{1}/_{2}'$ Quadrangle, Osage County, Oklahoma; hillside exposure.

4. Desmoinesian of the southern midcontinent

We have verified all the following localities. The locality coordinates are given in the UTM grid system. An asterisk indicates a locality in which ammonoids are reported for the first time.

4.1. North-central Texas (fig. 8)

Dickerson Shale (horizon SMC D1)

Locality TXD–01 (Bureau of Economic Geology, 110–T–3): 14SNM^{5}9524^{36}0040, Dennis $7^{1}/_{2}'$ Quadrangle, Hood County, Texas; shale in cutbank.

Grindstone Creek Formation (above Santo Limestone Member) (horizon SMC D3)

*Locality TXD–02: 14SNM^{5}9400^{36}2400, Garner $7^{1}/_{2}'$ Quadrangle, Parker County, Texas; shale in hillside.

Mingus Shale Member (between horizons SMC D3 and SMC D4)

*Locality TXD–03: 14SNM^{5}6837^{36}1182, Lone Camp $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; spillway cut.

Lowermost East Mountain Shale (horizon SMC D4)

Locality TXD–04: 14SNM^{5}7588^{36}2440, Mineral Wells West $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; hillside exposure at base of Barber's Mountain.

*Locality TXD–05 (Bureau of Economic Geology, 181–T–2): 14SNM^{5}8872^{36}3040, Mineral Wells East $7^{1}/_{2}'$ Quadrangle, Parker County, Texas; active clay pit.

East Mountain Shale (just below Hog Mountain Sandstone Member) (horizon SMC D5)

*Locality TXD–06: 14SNM^{5}8755^{36}3150, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure on outlier in Fort Wolters.

East Mountain Shale (just above Hog Mountain Sandstone Member) (horizon SMC D6)

Locality TXD–07 (Bureau of Economic Geology, 181–T–9): 14SNM^{5}8336^{36}3094, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure at the base of East Mountain.

East Mountain Shale (just above unnamed sandstone) (horizon SMC D7)

Locality TXD–08 (Bureau of Economic Geology, 181–T–9): 14SNM^{5}8341^{36}3096, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure (black shale bed).

*Locality TXD–09: 14SNM^{5}7659^{36}2931, Mineral Wells West 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure (west of unimproved road).

The following Desmoinesian localities have not been confirmed.

Grindstone Creek Formation (undifferentiated)

Bureau of Economic Geology, 72–T–1: Shale slope near outlier on east side of prominent escarpment, 6 mi (10 km) south of Thurber and 3.3 mi (5.3 km) west of the Thurber–Stephenville road, on west side of a branch of Barton Creek and 720 ft (220 m) southwest of a wire fence. Presented by Plummer and Scott (1937) as Millsap Lake Formation.

Bureau of Economic Geology, 72–T–4: Sandy shale on south forks of Patillo–Morgan Hill Road, 6 mi (10 km) west of Patillo. Presented by Plummer and Scott (1937) as Millsap Lake Formation.

Bureau of Economic Geology, 181–T–89: Shale on north side of new highway, 3.3 mi (5.3 km) by road southeast of Santo and approximately 0.5 mi (0.8 km) east of the junction of the state highway and the Santo-Patillo road. Presented by Plummer and Scott (1938) as Millsap Lake Formation.

Grindstone Creek Formation (shale below Santo Limestone Member) (horizon TX D2)

Kansas Locality 166: Two miles (4 km) west of Santo. Presented as Mingus Shale Member.

East Mountain Shale (black shale bed?) (horizon TX D1)

Bureau of Economic Geology, 181–T–70: Shale exposure on east side of road along south-facing escarpment, 3.5 mi (5.6 km) northwest of Mineral Wells, west side of sec. 50, T & P Railroad survey. Presented by Plummer and Scott (1937) as Mineral Wells Formation.

4.2. North-central Texas and Colorado River valley (fig. 9)

Undifferentiated Strawn Group (horizon SMC KC D1)

Locality TXD–10: 14RMJ^{4}472^{33}865, Yates 7$^1/_2$′ Quadrangle, Kimble County, Texas; limestone exposure at bluff of Llano River.

Undifferentiated Strawn Group (horizon SMC KC D2)

Locality TXD–11 (Bureau of Economic Geology, University of Texas, 134–T–5): 14RMJ^{4}4804^{33}8704, Yates 7$^1/_2$′ Quadrangle, Kimble County, Texas; shale exposure at base of hill.

Locality TXD–12 (Bureau of Economic Geology, University of Texas, 134-T-1): 14RMJ^{4}5033^{33}8864, London 7$^1/_2$′ Quadrangle, Kimble County, Texas; exposure at top of Llano River bluff.

5. Missourian of the southern midcontinent: north-central Texas (fig. 10)

Bath Bend limestone and shale bed (East Mountain Shale) (horizon SMC M1)

Locality TXM–26 (Bureau of Economic Geology, 181–T–9): 14SNM^{5}8394^{36}3039, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; shale bluff on East Mountain.

Locality TXM–27 (Bureau of Economic Geology, 181–T–59): 14SNM^{5}7640^{36}2902, Mineral Wells West 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; roadcut on US–180.

*Locality TXM–28 (Bureau of Economic Geology, 181–T–74): 14SNM^{5}6724^{36}2134, Lone Camp 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure.

*Locality TXM–29 (Bureau of Economic Geology, 181–T–84): 14SNM^{5}8238^{36}3006, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; hillside exposure on West Mountain.

*Locality TXM–30: 14SNM^{5}8322^{36}3154, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; roadcut on Northeast 16th Street.

*Locality TXM–31: 14SNM^{5}8586^{36}3278, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; roadcut on west side of TX–1821.

Dog Bend Limestone Member and associated shale (lower Salesville Shale) (horizon SMC M2)

*Locality TXM–24: 14SNM^{5}6734^{36}2161, Lone Camp 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; roadcut on east side of TX–4.

*Locality TXM–25 (Bureau of Economic Geology, 181–T–74): 14SNM^{5}8586^{36}3348, Mineral Wells East 7$^1/_2$′ Quadrangle, Palo Pinto County, Texas; roadcut on east side of TX–1821.

Upper Salesville Shale (horizon SMC M3)

*Locality TXM–11: 14SNM^{5}7867^{36}3156, Mineral Wells West $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on west side of TX–337.

*Locality TXM–12 (Bureau of Economic Geology, 181–T–10): 14SNM^{5}8194^{36}3425, Mineral Wells East $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on both sides of TX–3027.

Palo Pinto Formation and uppermost Keechi Creek Shale (horizon SMC M4)

*Locality TXM–13 (Bureau of Economic Geology, 181–T–77): 14SNM^{5}6922^{36}2632, Palo Pinto $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; type section; roadcut on US–180.

Locality TXM–33 (Bureau of Economic Geology, 181–T–72): 14SNM^{5}7956^{36}3972, Graford East $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; type section; hillside exposure.

*Locality TXM–36 (Bureau of Economic Geology, 181–T–86): 14SNM^{5}8185^{36}4257, Whitt $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; type section; roadcut on secondary road.

*Locality TXM–47: 14SNM^{5}8013^{36}4026, Graford East $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; hillside exposure.

Upper Posideon Formation (CPP_3) (horizon SMC M5)

Locality TXM–08 [Martin's Lake Locality (Bureau of Economic Geology, 248–T–4)]: 14SPM^{6}1552^{36}7302, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; roadcut on west side of TX–2133. Presented as Graford Formation by Plummer and Scott (1937).

*Locality TXM–21: 14SNM^{5}4269^{35}9558, Bear Mountain $7^{1}/_{2}'$ Quadrangle, Eastland County, Texas; hillside exposure.

Lower Wolf Mountain Shale Member (Lake Bridgeport Shale) (Graford Formation) (horizon SMC M7)

*Locality TXM–01: 14SPM^{6}0510^{36}6954, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; hillside excavation.

*Locality TXM–02: 14SPM^{6}0512^{36}6956, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; roadcut.

*Locality TXM–03: 14SPM^{6}0511^{36}6960, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; hillside exposure.

*Locality TXM–04: 14SPM^{6}0524^{36}7030, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; roadcut on north side of US–380.

*Locality TXM–05: 14SPM^{6}0820^{36}7370, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; lakeside exposure.

Locality TXM–06 (Bureau of Economic Geology, 248–T–6): 14SPM^{6}1582^{36}7580, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; abandoned clay pit.

*Locality TXM–07: 14SPM^{6}1404^{36}7538, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; active clay pit.

Locality TXM–09 (Bureau of Economic Geology, 181–T–29): 14SNM^{5}6440^{36}3179, Palo Pinto $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; hillside exposure on southeast end of Kyle Mountain.

*Locality TXM–10 (Bureau of Economic Geology, 181–T–27): 14SNM^{5}6188^{36}3474, Palo Pinto $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; hillside exposure on southeast end of Shutin Mountain.

*Locality TXM–42: 14SPM^{6}0756^{36}7142, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; hillside exposure.

*Locality TXM–43: 14SPM^{6}0520^{36}6938, Bridgeport West $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; lakeside exposure.

Upper Winchell Limestone Member and associated shale (horizon SMC M7)

*Locality TXM–46: 14RML^{4}9976^{35}2234, Lake Brownwood $7^{1}/_{2}'$ Quadrangle, Brown County, Texas; spillway cut.

Lower Placid Shale Member (Brad Formation) (horizon SMC M8)

*Locality TXM–14: 14SNM^{5}4936^{36}3805, Costello Island $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on Park Road 36.

Locality TXM–15: 14SNM^{5}4924^{36}3800, Costello Island $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on Park Road 36.

*Locality TXM–16: 14SNM^{5}4917^{36}3794, Costello Island $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on Park Road 36.

*Locality TXM–17: 14SNM^{5}5052^{36}3896, Costello Island $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; roadcut on Park Road 36.

*Locality TXM–19: 14SNM^{5}5722^{36}4826, Costello Island $7^{1}/_{2}'$ Quadrangle, Palo Pinto County, Texas; hillside exposure.

The following localities have not been confirmed.

Bath Bend limestone and shale (uppermost East Mountain Shale) (horizon SMC M1)

Bureau of Economic Geology, 181–T–66: Shale exposure on south side of Mineral Wells–Palo Pinto highway, 2 mi (4 km) west of Mineral Wells. Presented by Plummer and Scott (1937) as Mineral Wells Formation.

Lower Wolf Mountain Shale Member (Lake Bridgeport Shale) (Graford Formation) (horizon SMC M6)

Bureau of Economic Geology, 181–T–24: Shale exposure along small branch near foot of escarpment, north of Dalton Fortune Bend School, 2.1 mi (3.4 km) southwest of

Dalton, 0.4 mi (0.6 km) northwest of road, and 2.1 mi (3.4 km) west-northwest of Brazos River bridge on Palo Pinto–Graford Road. Presented by Plummer and Scott (1937) as Graford Formation.

Bureau of Economic Geology, 181–T–60: Exposure on side of small hill, 100 ft (30 m) below Merriman limestone (= Winchell Limestone of modern usage), 3.5 mi (5.6 km) west-southwest of Graford and 2.25 mi (3.6 km) north-northeast of Dalton. Presented by Plummer and Scott (1937) as Graford Formation.

Bureau of Economic Geology, 181–T–94: In Dalton pasture, 1 mi (1.6 km) west of Dalton ranch house. Presented by Plummer and Scott (1937) as Graford Formation. Just above Wiles Limestone Member.

Bureau of Economic Geology, 248–T–1: Shale exposure along valley side on east side of Lake Bridgeport on Waggoner Ranch, west side of rock hill, 4 mi (6 km) west-southwest of Bridgeport, approximately 300 ft (90 m) southwest of the road fork. Presented by Plummer and Scott (1937) as Graford Formation.

Bureau of Economic Geology, 248–T–26: Shales near Berkshire switch on Rock Island Railroad, 6 mi (10 km) west-southwest of Bridgeport, in east edge of D. B. Munroe block. Presented by Plummer and Scott (1937) as Graford Formation.

Kansas Locality 5090: Three miles (5 km) northwest of Graford (presented as Graford Formation).

Kansas Locality 166: Four miles (6 km) south of Brownwood on Brady Road. Horizon is uncertain but probably is from the Adams Branch–Cedarton interval.

Upper Winchell Limestone Member (= Merriman limestone) (Graford Formation) and associated shale (horizon SMC M7)

Kansas Locality 45: One-half mile (0.8 km) south of Ranger. Probably shale associated with the Merriman limestone (= upper Winchell limestone and shale).

6. Virgilian of the southern midcontinent: north-central Texas) (fig. 11)

Colony Creek Shale Member (Caddo Creek Formation) (horizon SMC V1)

*Locality TXV–46: 14RML^{4}9692^{35}2272, Lake Brownwood $7^{1}/_{2}'$ Quadrangle, Brown County, Texas; hillside exposure.

*Locality TXV–47: 14RML^{4}9779^{35}2472, Lake Brownwood $7^{1}/_{2}'$ Quadrangle, Brown County, Texas; hillside exposure.

*Locality TXV–48: 14RML^{4}9769^{35}2358, Lake Brownwood $7^{1}/_{2}'$ Quadrangle, Brown County, Texas; hillside exposure.

*Locality TXV–49: 14RML^{4}9574^{35}2166, Lake Brownwood $7^{1}/_{2}'$ Quadrangle, Brown County, Texas; excavation for boat dock.

*Locality TXV–50: 14SNM^{5}4362^{36}2305, Caddo Northeast $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; roadcut on both sides of US–180.

Locality TXV–52: 14SPM^{6}0304^{36}1600, Crafton $7^{1}/_{2}'$ Quadrangle, Wise County, Texas; hillside exposure.

*Locality TXV–76 (Bureau of Economic Geology, 248–T–8): 14SNM^{5}8684^{36}7212, Jacksboro Northeast $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; roadcut on US–380 and adjacent hillside.

Finis Shale Member (Graham Formation) (horizon SMC V2)

Locality TXV–28: 14SNM^{5}5017^{36}5550, Ross Mountain $7^{1}/_{2}'$ Quadrangle, Young County, Texas; roadcut on unimproved road.

*Locality TXV–29 (Bureau of Economic Geology, 251–T–2): 14SNM^{5}2793^{36}0588, Lacasa $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; pond dam exposure. Presented as Graham undifferentiated by Plummer and Scott (1937).

*Locality TXV–30: 14SNM^{5}3409^{36}1950, Caddo $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; pond dam exposure adjacent to US–180.

*Locality TXV–31: 14SNM^{5}3083^{36}1340, Caddo $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; pond dam exposure.

Locality TXV–32: 14SNM^{5}2285^{36}2045, Caddo $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; pond dam exposure.

Locality TXV–33 (Bureau of Economic Geology, 214–T–28): 14SNM^{5}3271^{36}2196, Caddo $7^{1}/_{2}'$ Quadrangle, Stephens County, Texas; cutbank exposure. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937) and as Wayland Shale Member by Miller and Downs (1950).

*Locality TXV–34 (Bureau of Economic Geology, 214–T–27): 14SNM^{5}8306^{36}8105, Cundiff $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; hillside exposure. Presented as Graham Formation, undifferentiated.

*Locality TXV–35: 14SNM^{5}8328^{36}8164, Cundiff $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; wireline exposure.

Locality TXV–36: 14SNM^{5}8395^{36}8231, Cundiff $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; hillside exposure adjacent to TX–24.

Locality TXV–37 (Bureau of Economic Geology, 19–T–22): 14SNM^{5}8176^{36}7131, Jacksboro Northeast $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; railroad cut. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–38 (Bureau of Economic Geology, 119–T–8): 14SNM^{5}8219^{36}6938, Jacksboro Northeast $7^{1}/_{2}'$ Quadrangle, Jack County, Texas; roadcut on US–81. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–39: 14SNM^{5}7955^{36}7546, Jacksboro $7^{1}/_{2}'$

Quadrangle, Jack County, Texas; roadcut on unimproved road.

*Locality TXV–40: 14SNM^{5}8306^{36}7469, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–41: 14SNM^{5}8333^{36}7496, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–42: 14SNM^{5}8309^{36}7415, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–43: 14SNM^{5}8126^{36}7276, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; roadcut on US–380.

*Locality TXV–44: 14SNM^{5}8331^{36}7344, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; roadcut on US–380.

Locality TXV–45 (Bureau of Economic Geology, 119–T–20): 14SNM^{5}9467^{36}8758, Crafton 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure; adjacent to unimproved road. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–54: 14SNM^{5}8336^{36}7320, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–55: 14SNM^{5}8370^{36}7282, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–56: 14SNM^{5}8334^{36}7234, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; well pad exposure.

*Locality TXV–67 [USGS Locality 7367 (Lee et al., 1938)]: 14SNM^{5}4510^{36}5252, Graham 7$^{1}/_{2}$′ Quadrangle, Young County, Texas; hillside roadcut.

*Locality TXV–68: 14SNM^{5}5576^{36}6017, Ross Mountain 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–70: 14SNM^{5}6822^{36}6482, Long Hollow 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; well pad exposure.

*Locality TXV–73: 14SNM^{5}8006^{36}7787, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; spillway cut for Lake Jacksboro.

*Locality TXV–74: 14SNM^{5}7364^{36}6625, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–80: 14SNM^{5}5620^{36}5700, Ross Mountain 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–93: 14SNM^{5}6631^{36}6407, Long Hollow 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; well pad exposure.

*Locality TXV–116 (Boston, 1988): 14SNM-^{5}8329^{36}7755, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–117 (Boston, 1988): 14SNM^{5}8219-^{36}7648, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–118 (Boston, 1988): 14SNM^{5}8653-^{36}7719, Jacksboro Northeast 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–119 (Boston, 1988): 14SNM^{5}7917-^{36}7153, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; pond dam.

*Locality TXV–120 (Boston, 1988): 14SNM^{5}8019-^{36}6826, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

*Locality TXV–121 (Boston, 1988): 14SNM^{5}7919-^{36}6914, Jacksboro 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; hillside exposure.

Necessity Shale Member = Bluff Creek Shale Member (Graham Formation) (horizon SMC V3)

*Locality TXV–66: 14SNM^{5}7110^{36}8050, Johnson Lake 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; roadcut on unimproved road.

*Locality TXV–64: 14RML^{4}9412^{35}2886, Byrd's 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; pond dam adjacent to TX–2559.

*Locality TXV–63: 14RML^{4}9107^{35}2134, Lake Brownwood 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; hillside exposure adjacent to TX–279.

*Locality TXV–62: 14RML^{4}9095^{35}2155, Lake Brownwood 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; roadcut on TX–279.

*Locality TXV–27: 14RML^{4}9415^{35}2672, Byrd's 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; pond dam adjacent to TX–2559.

*Locality TXV–26: 14RML^{4}9422^{35}2562, Lake Brownwood 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; pond dam adjacent to TX–2559.

*Locality TXV–25: 14SNM^{5}7041^{36}7931, Johnson Lake 7$^{1}/_{2}$′ Quadrangle, Jack County, Texas; pond dam adjacent to US–281.

*Locality TXV–24: 14RML^{4}9496^{35}2494, Lake Brownwood 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; roadcut on Park Road 15.

*Locality TXV–23: 14RMK^{4}8179^{34}9826, Trickim 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; pond dam adjacent to TX–586.

*Locality TXV–22: 14RMK^{4}8186^{34}9652, Trickim 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; pond dam adjacent to TX–586.

*Locality TXV–21: 14RMK^{4}7517^{34}8665, pond dam at 14RMK^{4}7534^{34}8634, and pond dam at 14RMK^{4}7494^{34}8648, Speck Mountain 7$^{1}/_{2}$′ Quadrangle, Coleman County, Texas; pond dam and hillside exposures.

Locality TXV–20 (Bureau of Economic Geology, 25–T–42; USGS Locality 15098): 14RML^{4}9465^{35}2529, Lake Brownwood 7$^{1}/_{2}$′ Quadrangle, Brown County, Texas; hillside exposure. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937) and as Wayland Shale Member by Miller and Downs (1950).

Locality TXV–19 (Bureau of Economic Geology, 25–T–3): 14RML^{4}9451^{35}2586, Lake Brownwood 7^{1}/2′ Quadrangle, Brown County, Texas; hillside exposure. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Locality TXV–18 (Bureau of Economic Geology, 42–T–22): 14RMK^{4}7076^{34}7707, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposures. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–16 [USGS Locality 7369; Lee et al. (1938)]: 14RMK^{4}7498^{34}8358, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposure next to dam.

Locality TXV–15 (Bureau of Economic Geology, no number assigned; USGS Locality 7368): 14SNM-^{5}3382^{36}5298, South Bend 7^{1}/2′ Quadrangle, Young County, Texas; hillside exposures near base of Bass Mountain. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937) and as Wayland Shale Member by Miller and Downs (1950).

Locality TXV–14 (Bureau of Economic Geology, 251–T–4): 14SNM^{5}3031^{36}5094, Ivan North 7^{1}/2′ Quadrangle, Young County, Texas; hillside exposures near base of hill. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Shale above lower Gunsight Limestone Member (Graham Formation) (between horizons SMC V3 and V4)

Locality TXV–101: 14SNL^{5}1098^{35}9582, Harpersville 7^{1}/2′ Quadrangle, Eastland County, Texas; hillside exposure adjacent to roadcut on US–183.

Wayland Shale Member (Graham Formation) (horizon SMC V4)

*Locality TXV–65: 14SNM^{5}1700^{36}0636, Wayland 7^{1}/2′ Quadrangle, Stephens County, Texas; hillside exposure adjacent to TX–1852.

*Locality TXV–61: 14SNM^{5}3631^{36}6167, Graham 7^{1}/2′ Quadrangle, Young County, Texas; shallow gullies adjacent to TX–67.

*Locality TXV–60: 14SNM^{5}3614^{36}6255, Graham 7^{1}/2′ Quadrangle, Young County, Texas; roadcut on TX–209.

*Locality TXV–59: 14SNM^{5}3653^{36}6224, Graham 7^{1}/2′ Quadrangle, Young County, Texas; hillside exposures due east of TX–67.

Locality TXV–58 (Bureau of Economic Geology, 42–T–27): 14RMK^{4}6800^{34}7734, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposures. Presented as Graham Formation, undifferentiated by Plummer and Scott (1937).

Locality TXV–57 (Bureau of Economic Geology, 251–T–7): 14SNM^{5}3736^{36}6138, Graham 7^{1}/2′ Quadrangle, Young County, Texas; hillside exposures. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Locality TXV–17 (Bureau of Economic Geology, 42–T–22): 14RMK^{4}6852^{34}7769, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposure on Round Mountain. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Locality TXV–13: 14SNL^{5}1258^{35}9865, Wayland 7^{1}/2′ Quadrangle, Stephens County, Texas; hillside exposure. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–12: 14SNL^{5}1336^{35}9810, Wayland 7^{1}/2′ Quadrangle, Stephens County, Texas; hillside exposures.

*Locality TXV–11: 14SNM^{5}6844^{36}8010, Lynn Creek 7^{1}/2′ Quadrangle, Jack County, Texas; pond dam and hillside exposures adjacent to US–281.

Locality TXV–10 (Bureau of Economic Geology, 119–T–23): 14SNM^{5}6917^{36}7974 for roadcut and 14SNM-^{5}6900^{36}7967 for hillside, Lynn Creek 7^{1}/2′ Quadrangle, Jack County, Texas; roadcut and adjacent hillside exposures on US–281. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–09: 14SNM^{5}3760^{36}6396, Graham 7^{1}/2′ Quadrangle, Young County, Texas; roadcut.

Locality TXV–08 (Bureau of Economic Geology, 251–T–3): 14SNM^{5}3727^{36}6372, Graham 7^{1}/2′ Quadrangle, Young County, Texas; hillside exposure. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

*Locality TXV–07: 14RMK^{4}7474^{34}8798, Speck Mountain 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposures.

*Locality TXV–06: 14RMK^{4}7448^{34}8777, Speck Mountain 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposure.

Locality TXV–05 (Bureau of Economic Geology, 42–T–32): 14RMK^{4}6763^{34}7812, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposure at southeast end of Park's Mountain. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Locality TXV–03 (Bureau of Economic Geology, 153–T–10): 14RMK^{4}6646^{34}7267, Whon 7^{1}/2′ Quadrangle, Coleman County, Texas; hillside exposure north of TX–765. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Blach Ranch Limestone Member and associated shale (Thrifty Formation) (horizon SMC V5)

*Locality TXV–109: 14SNM^{5}7239^{36}9270, Johnson Lake 7^{1}/2′ Quadrangle, Jack County, Texas; hillside exposures.

*Locality TXV–02: 14SNM^{5}7465^{36}9236, Johnson Lake 7^{1}/2′ Quadrangle, Jack County, Texas; hillside exposures.

*Locality TXV–01: 14RML^{4}8717^{35}2722, Burkett 7^{1}/2′ Quadrangle, Brown County, Texas; pond dam and hillside exposures.

The following localities have not been confirmed.

Ranger Limestone and Placid Shale Member (Brad Formation) (between horizons SMC M7 and V1)

Kansas Locality (no number): Two miles (3 km) southeast of Pickwick, Texas, on Brazos River.

?Home Creek Limestone Member (Caddo Creek Formation) (between horizons SMC V1 and V2)

Kansas Locality 5641: Six miles (10 km) north of Brad, Texas.

Finis Shale Member (Graham Formation) (horizon SMC V2)

Unnumbered locality: Riley and Ramsey ranches, 3 mi (5 km) east of Jacksboro. Presented as Finis Shale by Miller and Downs (1950) as one locality. Recent work indicates that the Riley Ranch localities are equivalent to our localities TXV–40, TXV–41, and TXV–42, whereas the Ramsey Ranch localities are our localities TXV–54, TXV–55, and TXV–56.

Unnumbered locality: Four and one-half miles (7.2 km) southwest of Jacksboro, Texas. Presented as Finis Shale by Miller and Downs (1950). The exact locality is in doubt; however, this locality is near or equivalent to our locality TXV–74.

Unnumbered locality: Four and one-half miles (7.2 km) southwest of Jacksboro, Texas. Presented as Finis Shale by Miller and Downs (1950). The exact locality is in doubt.

Unnumbered locality: Four miles (6 km) east-northeast of Jacksboro, Texas. Presented as Finis Shale by Miller and Downs (1950). The exact locality is in doubt; however, our locality TXV–116 is probably near or equivalent to this locality .

Unnumbered locality: Four miles (6 km) south of Jacksboro, Texas. Presented as Finis Shale by Miller and Downs (1950). The exact locality is in doubt; however, our localities TXV–119, TXV–120, and TXV–121 are all in the vicinity.

Unnumbered locality: Six and one-half miles (10 km) east of Jacksboro, Texas. Presented as Finis Shale by Miller and Downs (1950). The exact locality is in doubt; however, our locality TXV–118 should be near or at the locality in question.

Wayland Shale Member (Graham Formation) (horizon SMC V4)

Renfro Locality 11: South-facing scarps 2 mi (3 km) west of Berwick and east of the intersection of the Berwick-Senate Road with the Berwick-Jermyn Road. Presented by Renfro (1942) as ?Necessity Shale.

Renfro Locality 16: North- and east-facing scarps on the Massey Ranch, 7.9 mi (13 km) northwest of Jacksboro, Texas, and 0.25 mi (0.4 km) east of TX–24. Presented by Renfro (1942) as ?Necessity Shale.

Renfro Locality 17: South- and northwest-facing scarps 600–900 ft (180–270 m) south of TX–199, 6.8 mi (11 km) northwest of Jacksboro, Texas. Presented by Renfro (1942) as ?Necessity Shale. The exact locality is in doubt; however, our localities TXV–10 and TXV–11 are in the immediate area of this locality.

Renfro Locality 24: South-facing scarps on the east side of Prospect Road, 5.8 mi (9.3 km) north of Jacksboro, Texas. Presented by Renfro (1942) as ?Necessity Shale.

Renfro Locality 29: West- and south-facing scarps, 0.5 mi south of a lateral road, 2 mi (3 km) east of Avis, an abandoned oil refinery, and 10 mi (16 km) north of Jacksboro on Post Oak Road. Presented by Renfro (1942) as ?Necessity Shale.

Graham Formation, undifferentiated (stratigraphic interval not determined)

Bureau of Economic Geology, 119–T–20: Shale outcrop 2 mi (3 km) southeast of Cundiff, Texas. Presented by Plummer and Scott (1937) as Caddo Creek Formation.

Bureau of Economic Geology, 25–T–27: Shale exposure near creek. Middle of sec. 25, H&TC Railroad Survey, about 3 mi (5 km) north of Bangs, Texas. Presented as Graham Formation, undifferentiated, by Plummer and Scott (1937).

Bureau of Economic Geology, 42–T–28: Shale exposure along valley of Home Creek on Sellari's Place, 2 mi (3 km) east of Rockwood, Texas. Presented as ?Thrifty Formation by Plummer and Scott (1937).

7. Missourian and Virgilian of the southern midcontinent: Marathon Uplift (fig. 13)

Limestone Member (bed H) (Gaptank Formation) (horizon SMC MAR V1)

Locality TX MAR V1: 13RFD^{6}8618^{33}6342, Glass Mountain Ranch 7^{1}/2′ Quadrangle, Brewster County, Texas; hillside exposure at base of H limestone bed.

Locality TX MAR V2: 13RFD^{6}8574^{33}6306, Glass Mountain Ranch 7^{1}/2′ Quadrangle, Brewster County, Texas; hillside exposure in thin limestone above H limestone bed.

Uddenites Shale Member (Gaptank Formation) (horizon SMC MAR V1)

Locality TX MAR V3: 13RFD^{6}7928^{33}5886 to 13RFD-^{6}7940^{33}5866, Leonard Mountain 7^{1}/2′ Quadrangle, Brewster County, Texas; saddle in hill northwest of Wolf Camp.

The following localities have not been confirmed.

Conglomerate Member (Gaptank Formation) between second and third conglomerates (horizon TX MAR M1)

USGS Localities 6691 and 7095: Two miles (3 km) southeast of Gaptank, Texas. Presented as late Desmoinesian [ammonoids were reported by King (1938, p. 77) and were identified and correlated by Girty (1938); however, no faunal list was given]. McKenzie Gordon (U.S. Geological Survey, personal communication, 1988) identified the ammonoid in USGS Locality 6691 as *Pennoceras*; however, the collection from USGS Locality 7095 could not be found.

Conglomerate Member (Gaptank Formation) between fourth and fifth conglomerates (horizon TX MAR M2)

USGS Localities 6705, 7085, and 7088 (Bureau of Economic Geology, 185–T–1): Two miles (3 km) south of Gaptank, Texas.

The relationship between the Dugout Creek beds part of the Gaptank Formation and the type area of the Gaptank is uncertain. In addition, the relative stratigraphic position of the following two localities is uncertain.

Unnamed limestone bed in dugout beds part of the Gaptank Formation (horizon TX MAR M2A)

Locality TX MAR M1 (Bureau of Economic Geology, 22–T–47): 13RFD^{6}5841^{33}3904, Beckwith Hills 7^{1}/2′ Quadrangle, Brewster County; isolated limestone block. One and three-quarter miles (2.8 km) due south of Arnold Ranch house and 4.5 mi (7.2 km) south and 15° east of Lenox station.

Unnamed shale in dugout beds part of the Gaptank Formation (unnumbered horizon)

Bureau of Economic Geology, 22–T–143: Outcrop southwest of Hargis Ranch house near railroad mile post 580, 4 mi (6 km) west of Marathon, Texas.

Appendix 3: Lithology of ammonoid-producing intervals

This appendix gives the lithology where ammonoids occur in each ammonoid-producing interval and the source of information for the generic occurrences that are used throughout this bulletin.

Desmoinesian of the northern midcontinent

Southwestern Arkoma-McAlester Basin region (fig. 2)

Shale in upper McAlester Formation (unnumbered horizon): Reported by Hendricks (1937). This interval is not reported in the text because the ammonoids reported by Hendricks could not be examined and the locality has not been verified. Hendricks reported *Gastrioceras* sp. from this interval.

Shale in middle part of the Savanna Sandstone (unnumbered horizon): Reported by Hendricks (1937). This interval is not reported in the text because the ammonoids reported by Hendricks could not be examined and the locality has not been verified. Hendricks reported *Gastrioceras listeri* and *Gastrioceras* sp. from this interval.

Shale in the upper part of the Savanna Formation (horizon NMC D1): Reported by Hendricks (1937). The locality from the southwestern part of the Arkoma-McAlester Basin does not appear in fig. 2 because the ammonoids reported by Hendricks could not be examined and the locality has not been verified. Hendricks reported *Goniatites* aff. *G. lunatus* and *Goniatites* sp. from this locality.

Shale in the lower part of the Boggy Formation (horizon NMC D2): Reported by Morgan (1924), Miller and Furnish (1958), Unklesbay (1962), and Beghtel (1962).

Shale in the middle part of the Boggy Formation (horizon NMC D3): Reported by Morgan (1924), Miller and Owen (1939), Miller and Furnish (1958), Unklesbay (1962), and Beghtel (1962).

Shale in the upper part of the Boggy Formation (horizon NMC D4): Reported by Morgan (1924), Unklesbay (1962), and Beghtel (1962).

Shale in the Thurman Sandstone (unnumbered horizon): Reported by Weaver (1954). This horizon is not included in fig. 2 because we have not been able to verify its occurrence. The locality listed by Weaver is shown on his map as Thurman Formation; however, the specimen is labeled as having been found in the Calvin Sandstone. Weaver (1954) listed *Wewokites* (juvenile gonioloboceratid in this bulletin) as occurring both in the Calvin and the Thurman.

Shale in the Stuart Shale (horizon NMC D5): New report.

Shale underlying Verdigris Limestone Member (middle Senora Formation) (horizon NMC D7): New report.

Shale in the Calvin Sandstone (horizon NMC D8): Reported by Weaver (1954).

Shale in the Wetumka Shale (horizon NMC D9): Reported by Morgan (1924), Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in the lower Wewoka Formation (horizon NMC D10): Reported by Morgan (1924), Girty (1911, 1915), Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in the middle Wewoka Formation (horizon NMC D11): Reported by Morgan (1924), Girty (1911, 1915), Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in the upper part of the Wewoka Formation (horizon NMC D11): Reported by Morgan (1924), Girty (1911, 1915), Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report. The upper Wewoka merges with the middle Wewoka in the northern part of the Arkoma-McAlester Basin, and therefore the faunas are treated as one for the purposes of this bulletin.

Shale in the lower part of the Holdenville Formation (horizon NMC D12): Reported by Morgan (1924), Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in the middle part of the Holdenville Formation (horizon NMC D13): Reported by Weaver (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in the upper part of the Holdenville Formation (horizon NMC D15): New report.

Northwestern Arkoma-McAlester Basin region (fig. 2)

Shale over Doneley Limestone Member (horizon NMC D1): New report.

Shale underlying Tiawah Limestone Member (= Stuart Shale) (horizon NMC D5): New report.

Shale overlying Tiawah Limestone Member (= Stuart Shale) (horizon NMC D5): New report.

Shale overlying Mineral coal (basal Senora Formation) (horizon NMC D6): New report.

Excello Shale Member (Senora Formation) (horizon NMC D8): New report.

Wetumka Shale (horizon NMC D9): Reported by Ries (1954) and Unklesbay (1962) and new report.

Shale in lower part of Wewoka Formation (horizon NMC D10): Reported by Unklesbay (1962) and new report.

Shale in middle part of Wewoka Formation (horizon NMC D11): Reported by Unklesbay (1962), Beghtel (1962), Furnish and Beghtel (1961), and Chatelain (1984) and new report.

Shale in middle part of Wewoka Formation (horizon NMC D11): Reported by Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report. This interval merges with the middle Wewoka in the northern part of the region. Because the two faunas are not substantially different, we consider them to represent one fauna.

Shale in lower part of Holdenville Formation (horizon NMC D12): Reported by Ries (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in middle part of Holdenville Formation (horizon NMC D13): Reported by Ries (1954), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Shale in upper part of Holdenville Formation (horizon NMC D15): New report.

Northern shelf section (fig. 2)

Lower Cherokee Shale, undifferentiated (Iowa): Reported by Furnish and Spinosa (1966), Meek and Worthen (1860), and Wiedey (1929).

Shale above Jordan coal (= Seville Formation of Missouri and Tiawah Limestone Member of Oklahoma) (horizon NMC D2): Reported by Miller and Owen (1939) and Hoare (1961).

Mecca Quarry Shale Member (horizon NMC D7): Reported by Miller and Owen (1939) and new report.

Excello Shale (horizon NMC D8): Reported by Miller and Owen (1939) and Unklesbay (1962) and new report.

Little Osage Shale Member (horizon NMC D9): New report.

Anna Shale Member (horizon NMC D10): New report.

Lake Neosho Shale Member to basal Nowata Shale (horizon NMC D12): New report.

Lenapah Limestone (horizon NMC D13): Reported by Unklesbay (1962).

Nuyaka Creek Shale Member (horizon NMC D14): Reported by Miller and Owen (1937), Miller and Furnish (1958), Unklesbay (1962), Beghtel (1962), and Chatelain (1984) and new report.

Ardmore Basin and Arbuckle Mountains (fig. 3)

Frensley Limestone Member, Lake Murray Formation (horizon NMC ARD D1): Reported by Unklesbay (1962).

Unnamed shale member underlying Devil's Kitchen Member, Deese Group (horizon NMC ARD D2): Reported by Mapes (1979) and Chatelain (1984) and this report.

Buckhorn Asphalt Member, Deese Group (horizon NMC ARD D3): Reported by Smith (1938), Miller and Furnish (1958), Unklesbay (1962), and Beghtel (1962).

Missourian of the northern midcontinent

Oklahoma (fig. 4)

Basal Tacket shale member, Coffeyville Formation (horizon NMC M1): New report.

Lower Tacket shale member, Coffeyville Formation (horizon NMC M2): Reported by Ries (1954) and Unklesbay (1962) and new report.

Upper Tacket shale member, Coffeyville Formation (horizon NMC M3): New report.

Stark Shale Member, Hogshooter Limestone (horizon NMC M4): Reported by Morgan (1924) and new report.

New Harmony shale bed, Nellie Bly Formation (horizon NMC M5): New report.

Quivira Shale Member, Dewey Limestone (horizon NMC M6): Reported by Miller and Cline (1934) and Unklesbay (1962) and new report. This also includes the famous Miller and Cline Nellie Bly ammonoid fauna.

Muncie Creek Shale Member, Iola Limestone (horizon NMC M7): New report.

Lower shale member of Wann Formation (= Quindaro shale member) (horizon NMC M8): New report.

Middle shale member of Wann Formation (= Hickory Creek Shale Member) (horizon NMC M9): New report.

Upper shale member of Wann Formation (= upper Eudora Shale Member) (horizon NMC M10): Reported by Miller and Furnish (1940c), Unklesbay (1962), Saunders (1971), and Frest et al. (1981) and new report.

Kansas, Missouri, and Nebraska (fig. 4)

Exline Limestone Member = basal Tacket shale member (horizon NMC M1): New report.

Lower Tacket shale member (horizon NMC M2): New report.

Upper Tacket shale member = Hushpuckney Shale Member and overlying Bethany Falls Limestone Member (horizon NMC M3): Reported by Shutter (personal communication, 1987) and new report.

Stark Shale Member and overlying Winterset Limestone Member (horizon NMC M4): Reported by Miller and Gurley (1896), Miller and Furnish (1940c), and Roger K. Pabian (Nebraska Geological Survey, personal communication, 1985) and new report.

Drum Limestone Member (horizon NMC M5): Reported by Sayre (1930) and Miller and Furnish (1940c) and new report.

Quivira Shale Member (horizon NMC M6): New report.

Muncie Creek Shale Member (horizon NMC M7): Reported by Miller and Furnish (1940c).

Wyandotte Limestone (horizon NMC M8): Reported by Newell (1936) and Elias (1938) and new report.

Plattsburg Limestone (horizon NMC M9): New report.

Eudora Shale Member, Stanton Limestone (horizon NMC M10): Reported by Boardman et al. (1984) and new report.

Virgilian of the northern midcontinent

Exclusive of Oklahoma (fig. 5)

South Bend Limestone Member, Stanton Limestone (horizon NMC V0): New report [courtesy of Roger K. Pabian (Nebraska Geological Survey), who found the specimens].

Unnamed dark-gray shale bed in the South Bend Limestone Member, Stanton Limestone (horizon NMC V1): New report.

Iatan Limestone Member (horizon NMC V2): Reported by Miller and Furnish (1940c).

Basal Robbins Shale Member (horizon NMC V3): Reported by Miller and Swineford (1957).

Oread Limestone (horizon NMC V4): Reported by Miller and Furnish (1940c) and Unklesbay (1962) and new report.

Queen Hill Shale Member (horizon NMC V5): Reported by Pabian (personal communication, 1987) and new report.

Deer Creek Limestone (horizon NMC V6): Reported by Pabian (personal communication, 1987) and new report.

Topeka Limestone (horizon NMC V7): Ammonoids are reported by Verville (1958) from the Topeka Limestone in Elk County, Kansas. We have not been able to examine the specimens or confirm their occurrence.

Aarde Shale Member (horizon NMC V8): Reported by Smith (1927) and Plummer and Scott (1937) and new report.

Cedar Vale Shale Member (horizon NMC V9): Reported by Elias (1938) and Frest et al. (1981).

Harveyville Shale Member (horizon NMC V10): Reported by Pabian et al. (1983) and new report. Courtesy of Roger K. Pabian (Nebraska Geological Survey).

Willard Shale (horizon NMC V11): Reported by Pabian et al. (1983) and new report. Courtesy of Roger K. Pabian (Nebraska Geological Survey).

Wamego Shale Member (horizon NMC V12): New report.

Dover Limestone and associated shale (horizon NMC V13): Reported by Tasch (1953).

Dry Shale Member and Grandhaven Limestone Member (horizon NMC V14): Reported by Tasch (1953) and new report. Courtesy of Roger K. Pabian (Nebraska Geological Survey).

Jim Creek Limestone Member (horizon NMC V15): Reported by Mudge and Yochelson (1963).

Brownville Limestone Member (horizon NMC V16): New report.

Oklahoma (fig. 6)

Vamoosa Formation (Labodie Limestone Member) = Robbins Shale Member (horizon NMC V3): New report.

Vamoosa Formation (Heebner Shale Member) (horizon NMC V4): Reported by Unklesbay (1962) and new report.

Pawhuska Formation (Lecompton Limestone Member and Queen Hill Shale Member) (horizon NMC V5): Reported by Unklesbay (1962) and new report.

Pawhuska Formation (Deer Creek Limestone Member and Larsh-Burroak Shale Member) (horizon NMC V6): New report.

Wabaunsee Group (Howard Limestone and associated shale above Bird Creek Limestone, = Aarde Shale) (horizon NMC V8): Reported by Unklesbay (1962).

Desmoinesian of the southern midcontinent

North-central Texas (fig. 8)

Dickerson Shale (horizon SMC D1): Reported by Plummer and Scott (1937, 1938).

Grindstone Creek Formation (below Santo Limestone Member) (horizon SMC D2): Reported by Plummer and Scott (1937, 1938).

Grindstone Creek Formation (above Santo Limestone Member) (horizon SMC D3): Reported by Plummer and Scott (1938) and new report.

Mingus Shale Member (between horizons SMC D3 and D4): New report.

Lowermost East Mountain Shale (horizon SMC D4): Reported by Plummer and Scott (1937) and new report.

East Mountain Shale (just below Hog Mountain Sandstone Member) (horizon SMC D5): New report.

East Mountain Shale (just above Hog Mountain Sandstone Member) (horizon SMC D6): Reported by Plummer and Scott (1937) and new report.

East Mountain Shale (black shale bed) (horizon SMC D7): Reported by Plummer and Scott (1937) and new report.

Colorado River valley, Kimble County (fig. 9)

Limestone conglomerate at base of undifferentiated Strawn Group (horizon SMC KC D1): Reported by Plummer and Scott (1937).

Shale above limestone conglomerate in middle part of undifferentiated Strawn Group (horizon SMC KC D2): Reported by Plummer and Scott (1938) and Plummer (1950) and new report.

Missourian of the southern midcontinent

North-central Texas (fig. 10)

Bath Bend limestone and shale (horizon SMC M1): Reported by Plummer and Scott (1937) and new report.

Dog Bend Limestone and associated shale (horizon SMC M2): New report.

Upper Salesville shale (horizon SMC M3): New report.

Palo Pinto Formation and uppermost Keechi Creek Formation (horizon SMC M4): Reported by Plummer and Scott (1937) and new report.

Upper Posideon shale bed (PP3) (horizon SMC M5): Reported by Plummer and Scott (1937) and new report.

Lower Wolf Mountain Shale Member (Lake Bridgeport shale) (horizon SMC M6): Reported by Plummer and Scott (1937) and new report.

Upper Winchell limestone and associated shale (horizon SMC M7): New report.

Lower Placid shale member (horizon SMC M8): New report.

Virgilian of the southern midcontinent

North-central Texas (fig. 11)

Ranger Limestone Member or uppermost Placid Shale Member (unnumbered horizon): Ammonoids are present in the University of Kansas collections from the Ranger and the Placid, but the locality information is insufficient to identify the correct horizon.

Colony Creek Shale Member (horizon SMC V1): Reported by Plummer and Scott (1937), Frest et al. (1981), Boardman and Mapes (1984b), and Mapes and Boardman (1988) and new report.

Home Creek Limestone and associated shale (unnumbered horizon): We have collected ammonoid protoconches from a shale parting in the Home Creek Limestone Member; however, they are not large enough to identify positively. In addition, the University of Kansas collections have yielded one specimen of *Emilites*, which was reported from the Home Creek Limestone Member.

Finis Shale Member (horizon SMC V2): Reported by Plummer and Scott (1937), Miller and Furnish (1940a,c), and Miller and Downs (1950) and new report.

Necessity Shale Member = Bluff Creek Shale Member (horizon SMC V3): Reported by Smith (1903), Böse (1919), and Plummer and Scott (1937) and new report.

Shale above the lower Gunsight Limestone Member (between horizons SMC V3 and V4): New report. We have collected unidentifiable ammonoid protoconches from this horizon.

Wayland Shale Member (horizon SMC V4): Reported by Smith (1903), Böse (1919), Plummer and Scott (1937), Miller and Downs (1950), and Frest et al. (1981) and new report.

Blach Ranch Limestone and associated shale (horizon SMC V5): New report.

Missourian and Virgilian ammonoids from the Marathon Uplift (fig. 13)

Conglomerate Member, Gaptank Formation (between the second and the third conglomerates) (horizon TX MAR M1): Reported by Girty (1938) and new report.

Conglomerate Member, Gaptank Formation (between the fourth and the fifth conglomerates) (horizon TX MAR M2): Reported by Plummer and Scott (1937).

Dugout creek beds, Gaptank Formation (localized limestone block) (horizon TX MAR M2A): Reported by Miller (1930) and Miller and Furnish (1940c) and new report.

Dugout creek beds, Gaptank Formation (unnamed shale bed) (unnumbered horizon): Reported by Plummer and Scott (1937).

Limestone Member (bed H) of Gaptank Formation (horizon SMC MAR V1): Reported by Smith (1929) and Miller and Furnish (1940a) and new report.

Uddenites Shale Member, Gaptank Formation (horizon SMC MAR V2): Reported by Böse (1919), Plummer and Scott (1937), and Miller and Furnish (1940a) and new report.

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