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Abstract

Updated age assignments and new collections of molluscan fossils from lower Cenomanian through upper Campanian strata in Texas permit a much refined biostratigraphic correlation with the rocks of New Mexico and the Western Interior. Generic names of many Late Cretaceous ammonites and inoceramid bivalves from Texas are updated to permit this correlation.

Strata correlated in the west-to-east transect include the lower Cenomanian Beartooth Quartzite and Sarten Sandstone of southwest New Mexico, and the Eagle Mountains Formation, Del Rio Clay, Buda Limestone, and basal beds of the Chispa Summit, Ojinaga, and Boquillas Formations of the Texas–Mexico border area. Middle Cenomanian strata are lacking in southwestern New Mexico but are present in the lower parts of the Chispa Summit and Boquillas Formations in southwest Texas. Upper Cenomanian and lower Turonian rocks are present at many localities in New Mexico and Texas in the Mancos Shale and Chispa Summit, Ojinaga, and Boquillas Formations. Middle Turonian and younger rocks seem to be entirely nonmarine in southwestern New Mexico, but they are marine in the Rio Grande area in the Chispa Summit, Ojinaga, and Boquillas Formations. The upper part of the Chispa Summit and Boquillas contain late Turonian fossils. Rocks of Coniacian and Santonian age are present high in the Chispa Summit, Ojinaga, and Boquillas Formations, and in the lower part of the Austin. The San Carlos, Aguja, Pen, and Austin Formations contain fossils of Campanian age.

Fossils representing at least 38 Upper Cretaceous ammonite zones are present along the transect. Collections made in recent years in southwestern New Mexico and at Sierra de Cristo Rey just west of downtown El Paso, Texas, have been well treated and do not need revision. Taxonomic names and zonations published in the pre-1970 literature on the Rio Grande area of Texas have been updated. New fossil collections from the Big Bend National Park, Texas, allow for a much refined correlation in the central part of the transect in Texas.

Middle Turonian–Campanian zonation in southwest Texas is based mainly on ammonites of the Family Collignoniceratidae, as opposed to the scaphitid and baculitid ammonites that are especially abundant farther north in the Western Interior.

Introduction

The purposes of this report are (1) to correlate Upper Cretaceous strata along a west-to-east transect from Virden, New Mexico, to Del Rio, Texas (Fig. 1), using ammonites and inoceramid bivalves, and (2) to provide a provisional faunal zonation for this area that links it with the better known zonation for the Western Interior (Fig. 2). Late Cretaceous ammonite faunas from southwest New Mexico have been treated recently by us (Cobban et al. 1989) and will only be reviewed herein. Many published faunal lists and age assignments for lower Cenomanian to upper Campanian strata in Texas are updated herein. W. J. Kennedy and others have updated parts of the late Keith Young's (1963) monumental work on Coniacian through Campanian ammonites of Texas and the Gulf Coast. They have also revised some of the pre-Coniacian ammonites published in the important papers from the 1960s of J. D. Powell and associates.

New records of Cretaceous molluscan fossils from Big Bend National Park, Texas, have been provided by Roger and Dee Ann Cooper (Lamar University, Beaumont, Texas, and the University of Texas at Austin, respectively), James and Margaret Stevens (Terlingua, Texas), and T. M. Lehman (Texas Tech University, Lubbock, Texas), who are remapping parts of the park. Farther eastward in Terrell, Val Verde, and Kinney Counties, collections made by Val F. Freeman (USGS retired) and the late J. A. Sharps (USGS) are listed.

This paper is arranged stratigraphically from lower Cenomanian to upper Campanian. Fossil data from each stage or substage are then discussed geographically, with emphasis on the Texas part of the transect. Strata in the Texas part are located in Trans–Pecos Texas and parts of Val Verde and Kinney Counties. Fossil collections from the west end of the transect from Virden, New Mexico, to Chispa Summit, Texas, tend to be clustered closely around the locality markers because the Upper Cretaceous outcrops in those areas are isolated remnants. Collections from the east end of the transect, especially from Big Bend National Park to Del Rio, Texas, are widely scattered around the locality markers because of the more extensive outcrops of Upper Cretaceous rocks in those areas.

Cenomanian Stage

Lower Cenomanian

Rocks of early Cenomanian age in Trans-Pecos Texas and the adjoining part of Chihuahua and Coahuila, Mexico, consist of the following sequence, from oldest to youngest: Del Rio Clay (or Formation), Buda Limestone, and basal parts of the Boquillas, Chispa Summit, and Ojinaga Formations. Regarding the last three names, Powell (1965, p. 511) noted that "These formations intertongue; they are lateral equivalents of each other. The separate names indicate lithologic variations, that is, depositional features due to the relative proximity of the Coahuila platform (Kellum et al. 1936), and to the Diablo platform (Cohee et al. 1961)."

Two ammonite zones can be recognized in the Del Rio Clay, a lower one of *Graysonites adkinsi* Young 1958, and an upper one of *G. wacoensis* (Böse 1928). The Buda Limestone contains *Neophlycticeras* (*Neophlycticeras*) *texanum* (Shattuck 1903) in the lower part and *N. (Budaiceras) hyatti* (Shattuck 1903) in the upper part. Kennedy et al. (1990) reported the occurrence of the latter species in the European zone of *Mantelliceras dixoni* of late early Cenomanian age in Haute Normandie, France. The basal parts of the Boquillas, Chispa Summit, and Ojinaga Formations contain an *Acompsoceras inconstans* (Schlüter) fauna (Fig. 2).

Young (1959, p. 79, 1960, p. 42) noted two zones in rocks of Del Rio age, a lower one of *Graysonites adkinsi* Young 1958, and an upper one of *G. lozoi* Young 1958. *Graysonites lozoi* is now considered a junior synonym of *G. wacoensis* (Böse 1928) (Kennedy; *in* Kennedy et al. 2005). In Trans-Pecos Texas, *G. adkinsi* has been found at the base of the Del Rio Clay in Pecos County, and *G. wacoensis* has been found in the upper part of the Del Rio in Val Verde County as well as in the Del Rio area in Kinney County.

Other ammonites from the Del Rio Clay in Trans-Pecos Texas are scarce. The basal part of the Del Rio Clay in Val Verde County yielded the holotype of *Mariella brazoensis pecoensis* Clark 1965. Clark also recorded *M. brazoensis brazoensis* from the Del Rio as far west as the Quitman Mountains in Hudspeth County.

The Buda Limestone in Trans-Pecos Texas usually consists of a lower thick- and thin-bedded limestone, a softer middle nodular limestone, and an upper thick-bedded limestone (Maxwell et al. 1967; Freeman 1968). *Neophlycticeras* (*Neophlycticeras*) *texanum* (Shattuck 1903) is fairly abundant in the lowest limestone member, and *N. (Budaiceras) hyatti* (Shattuck 1903) is common in the middle and upper members. The two subgenera can be told apart easily because *Neophlycticeras* has siphonal tubercles matched by the flank ribs, whereas *Budaiceras* has more siphonal tubercles than flank ribs. Wright and Kennedy (1994, p. 550) noted the close resemblance of

Neophlycticeras and *Budaiceras* and stated that the latter "could well be treated as no more than a subgenus of *Neophlycticeras*," which is how we treat them in this paper.

In addition to *N.* (*B.*) *hyatti* and *N.* (*N.*) *texanum* (recorded as *Faraudiella texana*), Young (1979) reported *Budaiceras elegantior* (Lasswitz 1904), *B. alticarinatum* n. sp., *Faraudiella franciscoensis* (Kellum and Mintz 1962), *F. roemeri* (Lasswitz 1904), *F. barachoensis* n. sp., *F. archerae* n. sp., *Mariella wysogorskii*, and *Sharpeiceras tlahualilense* (Kellum and Mintz 1962) from the Buda Limestone of Trans-Pecos Texas.

Budaiceras has been reported from the basal part of the Maness Shale of northeastern Texas (Lozo 1951, p. 81). The Maness, known only in the subsurface, overlies the Buda Limestone and disconformably underlies the Woodbine Formation (Bailey et al. 1945). A few fragments of ammonites from the Del Rio and Buda Formations at Sierra de Cristo Rey may represent *Neophlycticeras,* but none can be assigned to a species.

Mantelliceras Hyatt 1903, an important guide to the lower Cenomanian of Europe, has been reported from Coahuila, Trans-Pecos Texas, and southwestern New Mexico. From the Buda Limestone of northern Coahuila, Böse (1928) described a specimen that he assigned to *M. mantelli* (d'Orbigny 1850) as well as another specimen he described as the new form *M. laticlavium* Sharpe var. *mexicanum*. The latter was considered later as *Sharpeiceras mexicanum* (Böse) by Matsumoto (1969, p. 259). Farther south in Coahuila, Kellum and Mintz (1962) described two specimens as new species of *Mantelliceras*, *M. charlestoni* and *M. portalesi*, from the Buda equivalent in the middle of the Indidura Formation. Both specimens are now regarded as probably *M. dixoni* by Wright and Kennedy (1984, p. 124). Adkins (1931) described the new species *M. budaense* from the top of the Buda Limestone of Travis County east of Trans-Pecos Texas. The species was considered a synonym of *M. cantianum* Spath 1926 by Young and Powell (1978) and Young (1979). Wright and Kennedy (1984, p. 120) noted that *M. budaense* is a coarsely ribbed derivative of *M. couloni* (d'Orbigny 1850). Cobban and Kennedy (1989, p. 135) reported the presence of *Mantelliceras* sp. at the top of the Buda Limestone in Hudspeth County, Texas, and Hancock et al. (1994, p. 463) noted *M. lymense* (Spath 1926) from Brewster County. *Mantelliceras* sp. also occurs at the top of the Sarten Sandstone in the Cookes Range in Luna County in southwestern New Mexico (Cobban 1987a).

The calcareous Boquillas, Chispa Summit, and Ojinaga Formations overlie the Buda Limestone in Trans-Pecos Texas. The Boquillas, Boquillas Flags of Freeman (1968), and Chispa Summit are chiefly thin-bedded limestone and shale deposited on the Diablo platform, whereas the much thicker, silty Ojinaga was deposited as a basin facies in the Chihuahua trough (Powell 1965). Young (1958) described a new fauna of silicified ammonites from near the base of the Boquillas in Jeff Davis County in Trans-Pecos Texas. He considered the fauna to represent a new zone (*Puchellia brundrettei*) at the top of the lower Cenomanian. Young and Powell (1978) more correctly placed the species *brundrettei* in the genus *Forbesiceras*. Hook and Cobban (1983, p. 51) recorded five species of ammonites in the *F. brundrettei* Zone at Gold Hill in northernmost Jeff Davis County, and Kennedy and Cobban (1993) further updated the fauna from six localities, which now consists of the following ammonites: *Moremanoceras elgini* (Young 1958), *Acompsoceras* sp., *Forbesiceras brundrettei* (Young 1958), *Borissiakoceras* sp., *Ostlingoceras (Ostlingoceras) brandi* (Young 1958), *Mariella* (*Mariella*) *davidense* (Young 1958), *Mariella* (*M.*) cf. *cenomanensis* (Schlüter 1876), and *Hypoturrilites youngi* (Clark 1965).

The most abundant fossil in the *Forbesiceras brundrettei* Zone is the small species described by Young (1958) as *Desmoceras* (*Pseudouhligella*) *elgini*, but now placed in *Moremanoceras* (Kennedy et al. 1988a). Most specimens are a centimeter or less in diameter and probably represent either juvenile individuals or inner whorls of larger specimens. Powell (1965) considered them as a guide to a *Pseudouhligella elgini* Zone at the base of the Chispa Summit Formation in Jeff Davis County, Texas. The fauna has been found as far east as Brackettville in central Kinney County (Kennedy and Cobban 1993).

Powell (1963a) described a small, but mostly new, ammonite fauna from a thin bed of limestone in the lower 23 m (75 ft) of the Ojinaga Formation in the foothills of the Quitman Mountains in Hudspeth County, Texas. The fauna was described as *Euhystrichoceras adkinsi* n. sp., *Pseudacompsoceras bifurcatum* n. sp., and *Desmoceras* (*Pseudouhligella*) *elgini* Young, and assigned to the early Cenomanian. Additional collections from Powell's locality were made by Hook and Cobban in 1973 and by W. J. Kennedy and J. M. Hancock in 1979. These new and larger collections were made from a petroliferous, sandy limestone bed 9.2 m (30 ft) above the base of the Ojinaga Formation. The fauna consists of *Moremanoceras bravoense* (Cobban and Kennedy 1989) (= *Desmoceras elgini* Young *of* Powell 1963a), *Euhystrichoceras adkinsi* (Powell 1963a), *Ojinagiceras ojinagaense* Cobban and Kennedy 1989, *Stoliczkaia* (*Lamnayella*) *chancellori* Wright and Kennedy 1984, *Acompsoceras inconstans* (Schlüter 1871) (= *Pseudoacompsoceras bifurcatum* Powell 1963a), *Hypoturrilites* cf. *gravesianus* (d'Orbigny 1842), and *Inoceramus* aff. *I. arvanus* Stephenson 1953. Daugherty and Powell (1963) also noted the presence of this fauna at the base of the Boquillas Formation in northern Coahuila, Mexico, just east of Big Bend National Park (see also Young 1969, p. 100).

The *Acompsoceras inconstans* Zone is also known farther southeastward at the base of the Chispa Summit Formation at its type locality in Jeff Davis County, Texas (Kennedy et al. 1989). Here a sandstone bed occupying depressions in the top of the Buda Limestone yielded part of a large ammonite that appears to be *A. inconstans*. Two specimens that may be *A. renevieri* (Sharpe 1857) were found nearby slightly higher in the Chispa Summit. Daugherty and Powell (1963, p. 2060) noted the presence of this fauna at the base of the Boquillas Formation in the Pico Etereo area of northern Coahuila, just east of Big Bend National Park. (See also Young 1969, table 1).

In summary, the early Cenomanian ammonite sequence in Trans-Pecos Texas, from youngest to oldest, is as follows:

Forbesiceras brundrettei (Young)
Acompsoceras inconstans (Schlüter)
Neophlycticeras (B.) hyatti (Shattuck)
Neophlycticeras (N.) texanum (Shattuck)
Graysonites wacoensis (Böse)
Graysonites adkinsi Young

Graysonites adkinsi was suggested as a guide to the base of the Cenomanian Stage at the First International Symposium on Cretaceous Stage Boundaries in Copenhagen in 1984 (Birkelund et al. 1984, p. 11), but no further action was taken. The age of this ammonite is probably equivalent to the early part of the *Mantelliceras mantelli* Zone of England and France (Hancock et al. 1994, table 1).

Both the zones of *Acompsoceras inconstans* and *Forbesiceras brundrettei* are correlated to the *Mantelliceras dixoni* Zone at the top of the lower Cenomanian of Europe (Cobban and Kennedy 1989, p. 135; Hancock et al. 1994, table 1). The American zones are known only from Trans-Pecos Texas and northern Coahuila, Mexico.

There appears to be a gap or two in the Trans-Pecos Texas sequence. Freeman (1968, p. K9) noted that the Buda Limestone rested disconformably on the Del Rio Clay in the area of the Terrell arch in eastern Terrell County and western Val Verde County, Texas, and that the base of the Buda is a conglomerate containing clasts of the Del Rio (see also Lonsdale et al. 1955, p. 32). Maxwell et al. (1967, p. 53) observed that the Buda rested directly on the Albian Georgetown Limestone on the Terrell arch. A hiatus within the Buda is possible. In the northern part of south-central Texas, where the Buda is two-fold, the top of the lower part is marked by a bored surface, and some truncation of the lower part is reported (Martin 1967). The bases of the Boquillas, Ojinaga, and Chispa Summit Formations rest sharply and disconformably on the Buda Limestone (Maxwell et al. 1967, fig. 32).

Middle Cenomanian

Strata of middle Cenomanian age in the Western Interior of the United States contain the following sequence of acanthoceratid ammonites (updated from Cobban 1984, fig. 2) from youngest to oldest:

Plesiacanthoceras wyomingense (Reagan)
Acanthoceras amphibolum Morrow
Acanthoceras bellense Adkins
Plesiacanthoceras muldoonense (Cobban and Scott)
Acanthoceras granerosense Cobban and Scott
Conlinoceras tarrantense (Adkins)

Kennedy et al. (1989) reported the *Acanthoceras bellense* Zone at Chispa Summit in Jeff

Davis County, Texas. A thin bed of limestone 15 ft (4.6 m) above the base of the Chispa Summit Formation contains *Acanthoceras bellense* (Adkins 1928), *Paraconlinoceras leonense* (Adkins 1928), *Acompsoceras* sp., *Cunningtoniceras johnsonanum* (Stephenson 1955), *Tarrantoceras* sp., *Turrilites acutus* (Passy 1832), *Inoceramus* aff. *arvanus* Stephenson 1953, and *Ostrea beloiti* Logan 1899. The oyster *Ostrea beloiti* is known from the lower Cenomanian zone of *Forbesiceras brundrettei* through the middle Cenomanian zone of *Acanthoceras amphibolum* in Trans-Pecos Texas (Cobban and Hook 1980; Hook and Cobban 1983; Kennedy et al. 1989).

The zone of *Acanthoceras amphibolum* has been recorded from Trans-Pecos Texas. The best record is from a calcarenitic limestone at the base of the Boquillas Formation at Sierra de Cristo Rey in Doña Ana County, New Mexico, just west of El Paso, Texas, where the Boquillas rests disconformably on the Buda Limestone (Lovejoy 1976). Here, the following molluscan fauna was collected (updated from Kennedy et al. 1988a; Cobban and Kennedy 1994): *Pseudocenoceras largilliertianum* (d'Orbigny 1840), *Acanthoceras amphibolum* Morrow 1935, *Moremanoceras straini* (Kennedy et al. 1988a), *Desmoceras* (*Pseudouhligella*) sp., *Cunningtoniceras* cf. *johnsonanum* (Stephenson 1955), *Paracompsoceras landisi* (Cobban 1972), *Tarrantoceras sellardsi* (Adkins 1928), *Anisoceras* cf. *plicatile* (Sowerby 1819), *Turrilites* (*Turrilites*) *acutus* (Passy 1832), *Ostrea beloiti* Logan 1899, and *Inoceramus arvanus* Stephenson 1953.

The *Acanthoceras amphibolum* Zone is present 6–12 ft (2–4 m) above the base of the Boquillas Formation at Gold Hill in Jeff Davis County, Texas (Fig. 1). There the lower Cenomanian fauna of *Forbesiceras brundrettei* is at the base of the formation. Molluscan fossils of the *A. amphibolum* Zone (Hook and Cobban 1983) include *Hamites simplex* (d'Orbigny 1842), *Acanthoceras* sp., *Pseudocalycoceras* cf. *P. harpex* (Stoliczka 1865), *Inoceramus arvanus* Stephenson, *I. rutherfordi* (Warren 1930), and *Ostrea beloiti* Logan. At Gold Hill, a lower zone of *Inoceramus arvanus* and an upper zone of *I. rutherfordi* are present in the ammonite zone of *A. amphibolum* (Hook and Cobban 1983, p. 51, fig. 27). The ammonite zones of *Conlinoceras tarrantense*, *Acanthoceras granerosense*, *Plesiacanthoceras muldoonense*, and *P. wyomingense* have not been recognized in Trans-Pecos Texas, in southern New Mexico, nor in Coahuila.

Upper Cenomanian

The following ammonite zonation for rocks of late Cenomanian age is recommended for southwestern New Mexico from youngest to oldest:

Neocardioceras juddii (Barrois and de Guerne)
Burroceras clydense Cobban, Hook, and Kennedy
Euomphaloceras septemseriatum (Cragin)
Vascoceras diartianum (d'Orbigny)
Metoicoceras mosbyense Cobban
Calycoceras canitaurinum (Haas)

The gap at the top of the Cenomanian in New Mexico (Fig. 2) represents the *Nigericeras scotti* Zone that is missing in southwestern New Mexico owing to an erosional interval. This zone has not been recorded in Trans-Pecos Texas.

Calycoceras canitaurinum (Haas 1949) was chosen as the zonal name because of its wide distribution in the Western Interior. The zone of *Calycoceras canitaurinum* is well developed in the Cookes Range in Luna County, New Mexico, where Cobban et al. (1989) described the following ammonites from the basal part of the flag member of the Mancos Shale:

Borissiakoceras sp.
Moremanoceras costatum Cobban, Hook, and Kennedy
Cunningtoniceras arizonense Kirkland and Cobban
Calycoceras (*Proeucalycoceras*) *canitaurinum* (Haas)
Tarrantoceras cf. *sellardsi* (Adkins)
Tarrantoceras sp.
Metoicoceras praecox Haas
Metoicoceras frontierense Cobban
Hamites cf. *simplex* (d'Orbigny)
Hamites cimarronensis (Kauffman and Powell)
Hamites? sp.
Turrilites sp.
Turrilicone indet.
Neostlingoceras kottlowskii Cobban and Hook
Neostlingoceras bayardense Cobban, Hook, and Kennedy

This is the largest and most diverse ammonite fauna of the *C. canitaurinum* Zone known from North America. A new species, *Moremanoceras montanaense* Kennedy and Cobban 1990a, was also found in the equivalent part of the Mancos Shale farther west at Virden.

In Trans-Pecos Texas *Calycoceras canitaurinum* was found in a thin bed of limestone 55 ft (16.8 m) above the base of the Chispa Summit Formation at Chispa Summit (Kennedy et al. 1989, p. 45). At Gold Hill in Jeff Davis County, Hook and Cobban (1983, pp. 51, 52) recorded *Calycoceras* cf. *canitaurinum* in a thin bed of limestone 20 ft (6 m) above the base of the Boquillas Formation.

Metoicoceras mosbyense Cobban 1953a was selected as the main guide to an upper Cenomanian zone owing to its wide distribution in the Western Interior from northern Montana to southwest New Mexico. The zone is best developed and most diverse in the flag member of the Mancos Shale in the area from the Cookes Range northwestward to the Virden area in southwest New Mexico, where the following ammonites have been described and illustrated (Cobban et al. 1989):

Moremanoceras scotti (Moreman)
Moremanoceras sp. nov.
Placenticeras sp.
Forbesiceras sp.
Cunningtoniceras novimexicanum Cobban, Hook, and Kennedy
Cunningtoniceras cookense Cobban, Hook, and Kennedy
Calycoceras (*Calycoceras*) *inflatum* Cobban, Hook, and Kennedy
Calycoceras (*Proeucalycoceras*) *guerangeri* (Spath)
Calycoceras (*Proeucalycoceras*) sp. nov.
Calycoceras (*Proeucalycoceras*) sp.
Eucalycoceras pentagonum (Jukes-Browne)
Euomphaloceras euomphalum (Sharpe)
Euomphaloceras merewetheri Cobban, Hook, and Kennedy
Metoicoceras mosbyense Cobban
Metoicoceras frontierense Cobban
Nannometoicoceras cf. *acceleratum* (Hyatt)
Vascoceras diartianum (d'Orbigny)
Hamites cf. *simplex* d'Orbigny
Hamites salebrosus Cobban, Hook, and Kennedy
Metaptychoceras hidalgoense Cobban, Hook, and Kennedy
Neostlingoceras procerum Cobban, Hook, and Kennedy
Neostlingoceras virdenense Cobban, Hook, and Kennedy

There are no records of *Metoicoceras mosbyense* in Trans-Pecos Texas or in the adjoining part of Mexico. Strata of that age may be present in the upper 35 ft (11 m) of the flag member of the Boquillas at Gold Hill in Jeff Davis County that has not yielded diagnostic fossils (Hook and Cobban 1983). Likewise, the 56 ft (17 m) "barren interval" of the Chispa Summit Formation at Chispa Summit (Kennedy et al. 1989, fig. 2) might contain rocks of *mosbyense* age. The presence of *Inoceramus ginterensis* Pergament in Big Bend National Park suggests the zone of *Metoicoceras mosbyense*.

The straight ammonite *Sciponoceras gracile* (Shumard 1860) is an excellent guide fossil to the upper one-half of the upper Cenomanian. It is especially abundant in the lower part of its range, where it is associated with the large and diverse molluscan fauna long known as the *Euomphaloceras septemseriatum* Zone. Calcareous concretions in the Bridge Creek Limestone Member of the Mancos Shale in the Cookes Range and Big Burro Mountains of southwest New Mexico yielded the following ammonites of the zone (Cobban et al. 1989):

Moremanoceras scotti (Moreman)
Placenticeras (*Karamaites*) *cumminsi* Cragin
Calycoceras (*Calycoceras*) *naviculare* (Mantell)
Pseudocalycoceras angolaense (Spath)
Sumitomoceras bentonianum (Cragin)
Sumitomoceras conlini Wright and Kennedy
Euomphaloceras septemseriatum (Cragin)
Metoicoceras geslinianum (d'Orbigny)
Vascoceras diartianum (d'Orbigny)
Allocrioceras annulatum (Shumard)
Neostlingoceras apiculatum Cobban, Hook, and Kennedy
Sciponoceras gracile (Shumard)
Worthoceras vermiculus (Shumard)

Metoicoceras geslinianum has been applied to a Cenomanian zone in Europe at least for

the last 25 yrs (Wright and Kennedy 1981), and *Euomphaloceras septemseriatum* has been applied to a subzone in the *Sciponoceras gracile* Zone in the Western Interior (Cobban 1984). *Sciponoceras gracile* is no longer used as a zonal index species. Cobban et al. (1989, p. 63) showed that *S. gracile* ranged from the *E. septemseriatum* subzone through the *Neocardioceras juddii* Zone. Therefore, *Euomphaloceras septemseriatum* is now used as the zonal index species (Fig. 2).

In contrast to the large ammonite fauna of southwestern New Mexico, records of the *Euomphaloceras septemseriatum* Zone are sparse farther southeastward in Trans-Pecos Texas and in the adjacent part of Mexico. The first record from that part of Texas is probably that of Adkins (1931, p. 67, pl. 11, figs. 7, 9) who briefly described a small ammonite as *Kanabiceras septemseriatum* (Cragin) from Chispa Summit, but in a footnote, he referred the genus to *Neocardioceras* Spath 1926. Powell (1963a) figured Adkins' specimen and reassigned it to *Kanabiceras*. That genus was considered later as a synonym of *Euomphaloceras* by Wright and Kennedy (1981, p. 54). Adkins (1931) also figured ammonites as *Scaphites* sp. aff. *S. africanus* Pervinquiere and *Allocrioceras* n. sp. aff. *ellipticum* Mantell from the Chispa Summit Formation. These specimens were reillustrated by Kennedy et al. (1989, text fig. 10) and assigned to *Worthoceras vermiculus* (Shumard) and *Allocrioceras annulatum* (Shumard). In the Chispa Summit Formation at Chispa Summit, Powell (1965, p. 517) noted a "Zone of *Kanabiceras septemseriatum*" containing the guide fossil and the species *Watinoceras* sp. cf. *W. coloradoense* (Henderson) and *Metoicoceras* sp.

From chalky limestone beds 120–126 ft (36.5–38.5 m) above the base of the Chispa Summit Formation at Chispa Summit, Kennedy et al. (1989, p. 45) reported the following ammonites:

Moremanoceras scotti (Moreman)
Calycoceras (*C.*) *naviculare* (Mantell)
Euomphaloceras septemseriatum (Cragin)
Pseudocalycoceras angolaense (Spath)
Metoicoceras geslinianum (d'Orbigny)
Borissiakoceras reesidei Morrow
Sciponoceras gracile (Shumard)
Worthoceras vermiculus (Shumard)

Strata of this age are present near the Del Rio end of the transect. Freeman (1968) recognized the following four lithologic units of his calcareous Boquillas Flags unit in his geologic investigation of parts of Brewster, Terrell, and Val Verde Counties: (1) a basal pinch and swell unit, (2) a flagstone unit, (3) a ledgy limestone unit, and (4) a laminated unit. Ammonites from the lower part of his ledgy unit (approximately 110 ft or 33.5 m above the base of Boquillas) include *Metoicoceras geslinianum* (d'Orbigny), *Pseudocalycoceras angolaense* (Spath), and *Tarrantoceras* (*Sumitomoceras*) *conlini* Kennedy, all restricted to the zone of *Euomphaloceras septemseriatum*.

The zone of *E. septemseriatum* is present in Coahuila, Mexico, where Jones (1938) described as a new species *Metoicoceras bosei* from the Indidura Formation. His holotype, the only figured specimen, appears to be a microconch of *M. geslinianum*. Likewise, the fragment from the Davis Mountains in Jeff Davis County illustrated by Young (1959) as *Metoicoceras* sp. cf. *bosei* appears to be a microconch of *M. geslinianum*. Wright and Kennedy (1981) regarded *M. bosei* as a synonym of *M. geslinianum* as well as the specimen figured as *M.* aff. *whitei* Hyatt from Mexico by Böse (1920).

Ammonites from the Mancos Shale just above the zone of *Sciponoceras gracile* in the Big Burro Mountains in Grant County, New Mexico, were assigned to the new zone of *Burroceras clydense* by Cobban et al. (1989) who described and illustrated the following species:

Placenticeras (Karamaites) cumminsi Cragin
Burroceras clydense Cobban, Hook, and Kennedy
Paraburroceras minutum Cobban, Hook, and Kennedy
Vascoceras cf. *gamai* Choffat
Vascoceras sp. A
Vascoceras sp. B
Vascoceras barcoicense exile Cobban, Hook, and Kennedy
Microdiphasoceras novimexicanum Cobban, Hook, and Kennedy
Hamites pygmaeus Cobban, Hook, and Kennedy
Sciponoceras gracile (Shumard)
Worthoceras vermiculus (Shumard)

This fauna has not been found elsewhere along the Virden–Del Rio transect.

The youngest Cenomanian ammonite fauna known from the Virden–Del Rio transect lies in the *Neocardioceras juddii* Zone. The zonal guide fossil, described as *Ammonites juddii* by Barrois and de Guerne (1878) from France, is widely distributed in Europe at the top of the Cenomanian and designated the *Neocardioceras juddii* Zone (Wright and Kennedy 1981). This zone was first applied in the Western Interior by Hook and Cobban (1981).

Ammonites of the *Neocardioceras juddii* Zone attain their greatest variety at the top of the Bridge Creek Limestone Member of the Mancos Shale in the Cookes Range and in the equivalent shale member farther west in southwestern New Mexico, where the following species were described and illustrated (Cobban et al. 1989):

Placenticeras (*Karamaites*) *cumminsi* Cragin
Neocardioceras juddii (Barrois and de Guerne)
Neocardioceras woodwardi Cobban, Hook, and Kennedy
Ammonite indet. (gen. nov.?)
Watinoceras odonnelli Cobban, Hook, and Kennedy
Euomphaloceras costatum Cobban, Hook, and Kennedy
Euomphaloceras sp.
Burroceras irregulare Cobban, Hook, and Kennedy
Burroceras transitorium Cobban, Hook, and Kennedy
Pseudaspidoceras pseudonodosoides (Choffat)
Vascoceras cf. *gamai* Choffat
Vascoceras silvanense Choffat
Vascoceras sp. B
Vascoceras barcoicense exile Cobban, Hook, and Kennedy
Vascoceras hartti (Hyatt)
Fagesia catinus (Mantell)
Rubroceras alatum Cobban, Hook, and Kennedy
Rubroceras burroense Cobban, Hook, and Kennedy
Rubroceras rotundum Cobban, Hook, and Kennedy
Hamites cf. *simplex* d'Orbigny
Anisoceras coloradoense Cobban, Hook, and Kennedy
Sciponoceras gracile (Shumard)
Worthoceras sp. nov.

An ammonite described as *Microsulcatoceras* sp.? by Kennedy and Cobban (1990a) from this zone in Hidalgo County, New Mexico, can be added to this list.

In Trans-Pecos Texas, the *N. juddii* fauna was described and illustrated by Kennedy et al. (1989) from a bed of limestone approximately 40 ft (12 m) above the base of the Chispa Summit Formation at Chispa Summit. The fauna includes several species not recorded from the Cookes Range:

Thomelites robustus Kennedy, Cobban, Hancock, and Hook
Neocardioceras juddii (Barrois and de Guerne)
Pseudaspidoceras pseudonodosoides (Choffat)
Nigericeras gadeni (Chudeau)
Thomelites kaulabicus (Kler)
Thomelites sp.
Thomelites sp.?
Vascoceras (V.) *silvanense* Choffat
Vascoceras (V.) *cauvini* Chudeau

Turonian Stage

Lower Turonian

The lower Turonian ammonite zonation in the Western Interior has been based mainly on the Bridge Creek Member of the Greenhorn Limestone in the Pueblo area of south-central Colorado, where the following sequence has been determined:

Mammites nodosoides (Schlüter)
Vascoceras birchbyi Cobban and Scott
Pseudaspidoceras flexuosum Powell
Watinoceras devonense Wright and Kennedy

Watinoceras devonense, at the base of the sequence, was described first by Wright and Kennedy (1981) from the base of the Middle Chalk of England. The species occurs in the Pueblo area in a bed of limestone 14.5 ft (4.4 m) above the base of the Bridge Creek Member (Cobban and Scott 1973, p. 23, bed 86). This bed has been selected as the Global Boundary Stratotype Point for the base of the Turonian Stage (Kennedy et al. 2000, 2005). *Vascoceras birchbyi* Cobban and Scott is abundant and restricted near Pueblo to a bed of limestone 19.8 ft (6 m) above the base of the Bridge Creek Member that contains the most diverse ammonite fauna (eight species) of the member in Colorado. *Mammites nodosoides* was

described as *Ammonites nodosoides* by Schlüter (1871) from the lower Turonian of Czechoslovakia. The species is widely distributed in Europe, Africa, South America, Mexico, and United States. In the Pueblo area, the species is present from 22 to 32 ft (7–10 m) above the base of the Bridge Creek Member.

The *Watinoceras devonense* Zone has not been recorded along the Virden–Del Rio transect, and the *Vascoceras birchbyi* Zone is poorly known only from the Mancos Shale above the Bridge Creek Limestone Member in the Cookes Range and areas farther west. Cobban et al. (1989) list the following ammonites from the *V. birchbyi* Zone in the Little Burro Mountains and Fort Bayard area:

Watinoceras sp.
Nigericeras cf. *scotti* Cobban
Vascoceras birchbyi Cobban and Scott
Vascoceras sp.
Fagesia catinus (Mantell)
Fagesia sp.
Neoptychites cephalotus (Courtiller)
Thomasites adkinsi (Kummel and Decker)

In the Mancos Shale below the *V. birchbyi* Zone in the Cookes Range are the following ammonites assigned to a *Pseudaspidoceras flexuosum* Zone (Cobban et al. 1989):

Watinoceras sp.
Quitmaniceras reaseri Powell
Pseudaspidoceras flexuosum Powell
Vascoceras sp.
Fagesia catinus (Mantell)

Pseudaspidoceras flexuosum was described by Powell (1963a) from the Ojinaga Formation in Chihuahua, Mexico, and given zonal rank by him in 1965. A single well-preserved adult specimen of *P. flexuosum* was found in the *Vascoceras birchbyi* bed in the Greenhorn Limestone near Pueblo. The specimen, described as *Ampakabites collignoni* Cobban and Scott 1973, was later determined as *P. flexuosum* by Kennedy et al. (1987, p. 34). The specimen could be interpreted as being from the top of the range of *P. flexuosum*. The species is widely distributed in the southern part of the Western Interior, Trans-Pecos Texas, and northern Mexico, and even as far away as Japan, where the species marks the basal Turonian zone (Matsumoto et al. 1991, table 2; Hirano et al. 1992, table 2).

The holotype of *P. flexuosum* came from a bed of crystalline limestone 990 ft (302 m) above the base of the Ojinaga Formation about a mile south of the Kelsey Crossing on the Rio Grande in northeastern Chihuahua, Mexico (Powell 1961, fig. 1). A large and diverse ammonite fauna is present in the bed of limestone on both sides of the international border as well as farther east in Coahuila. Powell (1963a) described 11 species in eight genera. Some ammonites of this fauna (*P. flexuosum* Zone) had been described earlier by Böse (1920) from Coahuila. The fauna in Coahuila was further investigated by Chancellor et al. (1977) and Chancellor (1982) and in Chihuahua and Trans-Pecos Texas (Hudspeth County) by Kennedy et al. (1987). Their revision of Powell's identifications is as follows:

Powell (1963a)	Chancellor (1982) and Kennedy et al. (1987)
Mammites nodosoides (Schlüter)	*Mammites powelli* Kennedy, Wright, and Hancock
Pseudaspidoceras flexuosum Powell	*Pseudaspidoceras flexuosum* Powell
Acanthoceras calvertense Powell	*Kamerunoceras calvertense* (Powell)
Acanthoceras sp.	*Kamerunoceras calvertense* (Powell)
Fagesia haarmanni Böse	*Fagesia catinus* (Mantell)
Pachyvascoceras compressum Reyment	*Vascoceras proprium* (Reyment)
Vascoceras globosum Reyment	*Vascoceras proprium* (Reyment)
Allocrioceras sp.	*Allocrioceras larvatum* (Conrad)
Quitmaniceras reaseri Powell	*Quitmaniceras reaseri* Powell
Quitmaniceras brandi Powell	*Quitmaniceras reaseri* Powell

Kennedy et al. (1987) figured the following additional ammonites of the *P. flexuosum* Zone:

Neoptychites sp.
Wrightoceras munieri (Pervinquiere)
Thomasites adkinsi (Kummel and Decker)
Allocrioceras dentonense Moreman
Sciponoceras sp.
Worthoceras cf. *vermiculus* (Shumard)

Thomasites adkinsi was described as *Hoplitoides adkinsi* by Kummel and Decker (1954) from Loma el Macho, Coahuila. A new genus and species, *Rhamphidoceras saxatilis* Kennedy and Cobban 1990b from the Chispa Summit Formation in Hudspeth County, Texas, is the 14th ammonite genus known from the *P. flexuosum* Zone.

The *Mammites nodosoides* Zone of latest early Turonian age is poorly represented along the Virden–Del Rio transect. In the western part of the transect, the zone is present in the uppermost marine sandstone bed in the sandstone and shale member of the Mancos Shale in the Cookes Range, where the following ammonites were described (Cobban et al. 1989):

Watinoceras sp.
Mammites nodosoides (Schlüter)
Infabricaticeras lunaense Cobban, Hook, and Kennedy
Thomasites? sp.

In Trans-Pecos Texas, *M. nodosoides* has been recorded from 79 to 116 ft (24–35 m) above the base of the Boquillas Limestone at Gold Hill in Jeff Davis County, Texas, where the following species were found (Hook and Cobban 1983):

Mammites nodosoides (Schlüter)
Morrowites depressus (Powell)
Kamerunoceras turoniense (d'Orbigny)
Hoplitoides sp.
Fagesia? sp.

The holotype of *Morrowites depressus* (*Mammites*? *depressus* Powell 1963b, p. 1228) is a weathered specimen from the Ojinaga Formation at Cannonball Hill in northern Chihuahua a mile southwest of the international boundary. In a later paper, Powell (1967) described additional material from the Boquillas Formation at Gold Hill in Jeff Davis County, where he assigned the species to the middle Turonian. Collections from the Greenhorn Limestone near Pueblo, Colorado (Cobban 1985, fig. 1), reveal that *M. depressus* has a short range that straddles the lower–middle Turonian boundary. The following well-preserved and varied ammonite fauna of latest *nodosoides* age that includes *M. depressus* was described from the Mancos Shale from the Fence Lake area of west-central New Mexico about 140 mi (225 km) north of Virden (Cobban and Hook 1983).

Tragodesmoceras socorroense Cobban and Hook
Placenticeras cumminsi Cragin
Mammites nodosoides (Schlüter)
Morrowites subdepressus Cobban and Hook
M. depressus (Powell)
Kamerunoceras turoniense (d'Orbigny)
Neoptychites cephalotus (Courtiller)
Fagesia superstes (Kossmat)
Cibolaites molenaari Cobban and Hook

Cibolaites molenaari seems to be the immediate ancestor of the middle Turonian *Collignoniceras woollgari* (Mantell).

Wright and Kennedy (1981) described the subspecies *Watinoceras coloradoense praecursor* from the Middle Chalk of England and recognized the zones of *W. coloradoense* and *Mammites nodosoides* in the lower part of the Turonian. *Watinoceras coloradoense coloradoense* (Henderson 1908) has not been recognized in England, and the slightly older *W. devonense* Wright and Kennedy 1981 has been applied to a zone in Europe and in the Western Interior (Hancock et al. 1994, table 3). These authors replaced *Vascoceras birchbyi* by *W. coloradoense* as a lower Turonian zone in the Western Interior sequence because the latter "has a similar range and a much wider geographical distribution" (p. 457). In the present report, *V. birchbyi* is retained as the zonal index (Fig. 2).

Gale (1996, p. 181) reviewed the Turonian ammonite zonation of southern England, introduced the new zone of *Fagesia catinus* (Mantell 1822) between the zones of *W. devonense* and *M. nodosoides*, and noted that the *F. catinus* Zone was about equivalent to the zones of *Pseudaspidoceras flexuosum* and *Vascoceras birchbyi* of the Western Interior. *Fagesia catinus* occurs in the latter two zones, and the species is especially abundant in the zone of *P. flexuosum* in Trans-Pecos Texas and adjoining part of Mexico. These two zones are closely related timewise and have several ammonite species in common. Perhaps *F. catinus* could be treated in North America as a zone with *P. flexuosum* and *V. birchbyi* as subzones.

Middle Turonian

Before 1979 Turonian rocks in the Western Interior were not divided into lower, middle, and upper parts. At that time, a middle Turonian substage was recognized in the United States that is divisible into two ammonite zones, a lower *Collignoniceras woollgari* Zone and an upper *Prionocyclus hyatti* Zone (Kauffman et al. 1978, p. 23. 16). The *woollgari* Zone was subdivided into a lower *woollgari woollgari* Subzone and an upper *woollgari regulare* Subzone by Cobban and Hook (1979, fig. 1). A zone of *Prionocyclus percarinatus* was recognized later between the *woollgari* and *hyatti* Zones, and the *hyatti* Zone was divided into *Hoplitoides sandovalensis* and *Coilopoceras springeri* Subzones (Cobban and Hook 1983, fig. 1). The poorly defined *P. percarinatus* (Hall and Meek 1856) was replaced later (Merewether et al. 1998, fig. 2) by the much better defined *Collignoniceras praecox* (Haas 1946). Another change in the middle Turonian zonation in the paper by Merewether et al. (1998, fig. 2) is a shift in the middle–upper Turonian boundary upward to the base of the *Scaphites whitfieldi* Zone based on work in progress at that time on Turonian and Coniacian inoceramid faunas by Ireneusz Walaszczyk (Institute of Geology, University of Warsaw, Poland). He found that *Inoceramus costellatus* Woods 1912 of most authors, and long regarded as the main guide to the base of the upper Turonian of Europe, is the same species as *I. perplexus* Whitfield (1877, 1880), a common species restricted to the *Scaphites whitfieldi* Zone in the middle of the upper Turonian of the Western Interior (for discussion, see Walaszczyk and Cobban 2000, p. 34). The middle Turonian ammonite zonation in the Western Interior now consists of the following sequence modified from Cobban (1984, fig. 2).

Zone	Subzone
Scaphites ferronensis	
Scaphites warreni	
Prionocyclus macombi	*Coilopoceras inflatum* *Coilopoceras colleti*
Prionocyclus hyatti	*Coilopoceras springeri* *Hoplitoides sandovalensis*
Collignoniceras praecox	
Collignoniceras woollgari	*Collignoniceras woollgari regulare* *Collignoniceras woollgari woollgari*

Collignoniceras woollgari (Mantell 1822) has long been accepted informally by authors as a guide to the base of the middle Turonian; however, more recently, bed 120, a limestone high in the Bridge Creek Member of the Greenhorn Limestone near Pueblo, Colorado, containing the first occurrence of *C. woollgari* was suggested, but not accepted, as the base of the middle Turonian substage (Kennedy et al. 2000, fig. 5).

The western shoreline during the time of *Collignoniceras woollgari* was east of the Virden–Cookes Range area in southwestern New Mexico (Cobban et al. 1994, fig. 5), so that rocks of this age in that area are nonmarine. The species does occur, however, in Trans-Pecos Texas, in the upper part of the Chispa Summit Formation near Chispa Summit (Kennedy et al. 1989), where *C. woollgari regulare* (Haas 1946) occurs with *Tragodesmoceras socorroense* Cobban and Hook, *Romaniceras (Yubariceras) ornatissimum* (Stoliczka), and *Spathites coahuilaensis* (Jones). The last species is known also from Coahuila and Chihuahua, where the species was described under several names by Jones (1938), Kummel and Decker (1954), and Kennedy et al. (1980) (see Cobban 1988a, p. 8; Kennedy et al. 1989, p. 77). There is also a record of *C. woollgari* from the Big Bend National Park (Bell 1994), and the species has been found as far east as south-central Kinney County, Texas (USGS locality D2464).

At Gold Hill, Jeff Davis County, Texas, *C. woollgari woollgari* (Mantell) occurs approximately 144 ft (44 m) above the base of the Boquillas Limestone (Hook and Cobban 1983) associated with *Spathites rioensis* Powell and *Neoptychites* sp. *Collignoniceras woollgari* has been described also as *Prionotropis woollgari* (Mantell) var. *mexicana* Böse 1928 from near Villa Acuña, Coahuila, across the Rio Grande from Del Rio, and Powell (1963b) noted its occurrence in the Ojinaga Formation at Cannonball Hill, Chihuahua. Other ammonites from the *C. woollgari woollgari* Subzone at Cannonball Hill were reported by Kennedy and Cobban (1988) as follows: *Morrowites depressus* (Powell), *Morrowites* sp., *Spathites* (*S.*) *rioensis* (Powell), *Neoptychites cephalotus* (Courtiller), *Kamerunoceras isovokyense* (Collignon), *Hoplitoides ingens* (von Koenen), and *Baculites yokoyamai* Tokunaga and Shimizu. Kennedy and Cobban (1988) also noted the presence of *Hoplitoides* cf. *gibbulosus* (von Koenen) in the *C. woollgari* Zone in Chihuahua.

The zone of *Collignoniceras praecox* has not been reported from the area of the Virden–Del Rio transect, but the slightly younger *Prionocyclus hyatti* Zone is known from Trans-Pecos, Texas. At Chispa Summit, *P. hyatti* (Stanton) occurs in septarian limestone concretions in the upper part of the Chispa Summit Formation approximately 130–165 ft (40–50 m) above concretions that contain *C. woollgari regulare* (Kennedy et al. 1989, fig. 3; Powell 1965, fig. 4). Other ammonites from the *hyatti* concretions include *Romaniceras* (*R.*) *mexicanum* Jones, *Spathites puercoensis* (Herrick and Johnson), *Coilopoceras springeri* Hyatt, and *Scaphites carlilensis* Morrow. A most interesting and unusual bed of limestone containing *C. woollgari woollgari* occurs in the upper part of the Boquillas Limestone at Gold Hill (Hook and Cobban 1983, bed 20, p. 49). The bed, approximately 6 inches (15 cm) thick, contains well-preserved specimens of *P. hyatti* and phosphatic pebbles and cobbles made from worn fragments of *C. woollgari* and other ammonites of *woollgari* age. For a discussion on other hiatus concretions in Trans-Pecos Texas, and the adjoining part of Chihuahua, see Kennedy et al. (1977), and for the shoreline during *hyatti* time, see Cobban et al. (1994, fig. 6).

The *Prionotropis eaglensis* Adkins 1928 (p. 250) from the base of the Eagle Mountains in Hudspeth County, Texas, is a *Prionocyclus hyatti* as noted by Powell (1963b, p. 1220). *Prionocyclus hyatti* also occurs in northeastern Chihuahua (Powell 1965, fig. 6). Kennedy and Cobban (1988) described the following new additions to the *hyatti* fauna from Chihuahua: *Puzosia* (*P.*) *serratocarinata* Kennedy and Cobban, *Romaniceras* (*Yubariceras*) *kanei* Jones, and *Romaniceras* (*R.*) *reymenti* (Collignon).

Cooper et al. (2008, p. 28, fig. 35) report *P. hyatti* and *Inoceramus howelli* White from a thin bed of limestone in the Ernst Member of the Boquillas Formation in the southern part of Big Bend National Park.

Rocks of the age of the *Prionocyclus macombi* and *P. wyomingensis* Zones are probably nonmarine west of El Paso, and records of these zones farther southeast are sparse. Hook and Cobban (1983) reported the presence of the small bivalve *Nicaisolopha lugubris* (Conrad) in the upper part of the shale and limestone member of the Boquillas Limestone at Gold Hill in Jeff Davis County, Texas. That fossil is common in the zones of *P. macombi* and *P. wyomingense* in the Juana Lopez Member of the Mancos Shale in northern New Mexico. Kennedy et al. (1989, fig. 3) listed the following species from a bed of limestone high in the Chispa Summit Formation at Chispa Summit and assigned them to the *Scaphites warreni* Subzone of the *P. wyomingensis* Zone: *P. wyomingensis* Meek, *Hourcquia* cf. *mirabilis* Collignon, *Coilopoceras inflatum* Cobban and Hook, *Baculites yokoyamai* Tokunaga and Shimizu, and *Inoceramus dimidius* White. For further information on the occurrence of *Hourcquia* at Chispa Summit, see Kennedy et al. (1988b, p. 92).

Upper Turonian

Records of late Turonian fossils are few along the Virden–Del Rio transect and confined to Trans-Pecos Texas. Kennedy et al. (1989, fig. 3) reported *Inoceramus perplexus* from a bed of limestone high in the Chispa Summit Formation at Chispa Summit approximately 2 m (6.5 ft) above a bed containing *I. dimidius* of middle Turonian age. They also reported *I. perplexus* and *Prionocyclus novimexicanus* (Marcou) approximately 22 m (72 ft) above the *I. dimidius* bed. This last occurrence indicates the *Prionocyclus novimexicanus* Zone.

Young (1963) described *Prionocycloceras adkinsae* as a new species from the upper part of the Chispa Summit Formation near Chispa Summit, and also noted its presence in Presidio County. His illustrated specimens are herein interpreted as the robust form of *Prionocyclus wyomingensis* Meek (compare to Kennedy et al. 2001, fig. 85).

As noted earlier in the treatment of the upper Cenomanian, Freeman (1961, 1968) subdivided his Boquillas Flags into four informal lithologic units in Val Verde and Terrell Counties, Texas. The uppermost unit, "laminated unit," contains *Inoceramus* cf. *dimidius* White 10 ft (3 m) above the base, which suggests a high position in the middle Turonian (Freeman 1961, table 1). Near the top of the unit, Freeman listed *I.* cf. *perplexus* Whitfield and *Prionocyclus* sp., which suggests a low position in the upper Turonian. Chalky limestone overlying the Boquillas was referred to the Austin Chalk by Freeman, who listed *Prionocyclus reesidei* Sidwell 1932 and *Inoceramus* cf. *incertus* Jimbo in the lower 35 ft (10 m). The *P. reesidei* is now considered a junior synonym of *P. germari* Reuss 1845 (Kennedy et al. 2001, p. 127), and the inoceramid is now assigned to *Mytiloides*. Freeman (unpublished) also collected *P. germari* and *Eubostrychoceras matsumotoi* Cobban 1987b approximately 25 ft (7.7 m) above the base of the Austin Chalk in Val Verde County. The helicoid ammonite *Eubostrychoceras* was known previously from the D-Cross Tongue of the Mancos Shale in Doña Ana County, New Mexico, near Davis Well, approximately 60 mi (100 km) north of El Paso, where it was associated with *P. germari* and *M. incertus*. The "*Bostrychoceras*" noted by Powell (1967, p. 318) from a higher level than *Morrowites depressus* in Jeff Davis County, Texas, is probably *E. matsumotoi*.

Turonian–Coniacian boundary

At the Second International Symposium on Cretaceous Stage Boundaries, Brussels, Belgium, 1995, the first occurrence of the inoceramid bivalve *Cremnoceramus rotundatus* (*of* Tröger 1967, *non* Fiege 1930) was recommended as marking the Turonian–Coniacian boundary. Soon after that, Walaszczyk (*in* Walaszczyk and Cobban 2000) determined that the species was a junior synonym of *Inoceramus erectus* Meek 1877, a species now placed in *Cremnoceramus*, and so *C. deformis erectus* now marks the boundary. Walaszczyk and Cobban (2000) treated *C. erectus* as a chronologic subspecies of *C. deformis* (Meek 1871). The inoceramid zonation for the upper Turonian–lower Coniacian of the Western Interior modified from Walaszczyk and Cobban (2000, table 1) is as follows.

Substage	Inoceramid zone
lower Coniacian	*Cremnoceramus crassus crassus*
	Cremnoceramus crassus inconstans
	Cremnoceramus deformis dobrogensis
	Cremnoceramus deformis erectus
upper Turonian	*Cremnoceramus waltersdorfensis*
	Mytiloides incertus
	Inoceramus perplexus

Rocks of early Coniacian age are probably nonmarine west of El Paso (Young 1983, fig. 14), and the ammonite record is poor in the marine rocks of that age in Trans-Pecos Texas southeast of El Paso. The inoceramid record, however, is much better and more useful.

A conspicuous ledge-forming unit a few feet thick consisting of flaggy limestone with shale partings is present approximately 330 ft (100 m) above the base of the Ernst Member of the Boquillas Formation in the Big Bend area of Texas (Maxwell et al. 1967) The unit is characterized by the uncoiled planispiral ammonite *Allocrioceras hazzardi* Young (1963), and the unit is "commonly termed the '*Crioceras*' ledge or '*Crioceras*' zone" (Young 1963, p. 45). Young assigned a late Turonian age to *A. hazzardi*. A few fragments of *Allocrioceras* from Wyoming, Colorado, and Utah, associated with early Coniacian molluscan fossils, were assigned to *A. hazzardi* by Kennedy and Cobban (1991a). A small collection made by V. L. Freeman (unpublished, USGS Mesozoic locality D2874) from the *A. hazzardi* bed at Del Norte Gap in the Big Bend area of Texas consists of the following molluscan species: *Cremnoceramus deformis erectus*, *Didymotis variabilis* Gerhardt, and *Forresteria* sp. J. D. Powell collected *Scaphites semicostatus* Roemer 1852 (Kennedy et al. 2004) from the *Allocrioceras* ledge in the Pico Etereo area in northern Chihuahua (USGS locality D14397). The scaphite was collected also by Freeman from the Austin Chalk 52 ft (16 m) above a bed containing the upper Turonian *Prionocyclus* at USGS locality D2457 in southwestern Terrell County. Roemer's species seems to be the same as the European *S. kieslingswaldensis* Langenhan and Grundey 1891 that straddles the Turonian–Coniacian boundary (Kaplan et al. 1987). Roemer's species occurs also in the *Allocrioceras* ledge in the Big Bend National Park, where large collections (Cooper et al. 2008) reveal that the species is dimorphic.

Lower Coniacian

Kennedy and Cobban (1991a) recognized three interval range zones of the ammonite *Forresteria* and part of a fourth in the lower Coniacian rocks of the central and southern part of the Western Interior, and Walaszczyk and Cobban (2000) recognized four inoceramid interval zones in the lower Coniacian.

Ammonite zone	Inoceramid zone
Forresteria alluaudi	*Cremnoceramus crassus crassus*
Forresteria hobsoni	*Cremnoceramus crassus inconstans*
Forresteria brancoi	*Cremnoceramus deformis dobrogensis*
Forresteria peruana (part)	*Cremnoceramus deformis erectus*

Forresteria peruana represents the upper part of its range, inasmuch as the species straddles the Turonian–Coniacian boundary. The ranges of *F. brancoi* and *F. hobson* overlap as do the ranges of *Cremnoceramus dobrogensis* and *C. crassus inconstans*.

Young (1963, p. 18) divided the Coniacian of Texas and the Gulf Coast into lower and upper substages with the following three zones of ammonites.

Substage	Ammonite zone
upper Coniacian	*Prionocycloceras gabrielense*
lower Coniacian	*Peroniceras westphalicum*
	Peroniceras haasi

The holotype of *Peroniceras haasi* Young (1963, p. 72) came from the Austin Chalk of east-central Texas, but Young recorded the species farther southwest in Uvalde and Kinney Counties. Young did not recognize a middle Coniacian, but the species *P. westphalicum* (von Strombeck 1859) is confined to that substage according to Kennedy (1984, p. 74).

Prionocycloceras gabrielense Young (1963, p. 69–71) is a problematic species as noted by Young, who assigned it to the upper Coniacian. Matsumoto (1965a, p. 41) considered it a *Protexanites* also of late Coniacian age as did Kennedy and Cobban (1991a, p. 53). Smith (1981, p. 21) reported the species (identified by Young) from 10 ft (3 m) above the base of the Atco Formation of the Austin Group at Pinto Creek and Sycamore Creek southwest of Del Rio in Kinney County associated with a late Turonian inoceramid (*Mytiloides* sp. identified by E. G. Kauffman). The ammonite at hand (USGS D14557) from Pinto Creek seems better assigned to *Prionocyclus quadratus* Cobban 1953b of late Turonian age. Smith (1981, p. 21) collected the middle Coniacian ammonite *Peroniceras westphalicum* 65 ft (19.8 m) above the base of the Austin at Pinto Creek and the late Coniacian inoceramids identified by E. G. Kauffman as "*Inoceramus stantoni* Sokolow" at 68 ft (20.7 m) and "*Inoceramus* sp. aff. *I.* (*Magadiceramus*) *subquadratus* Schlüter" at 143–147 ft (43.6–44.8 m) above the base.

An early Coniacian fauna has been described recently from the "Austin Group" at the El Rosario quarry in northwestern Coahuila approximately 100 km (62 mi) southeast of Big Bend National Park (Stinnesbeck et al. 2005). Two zones were recognized: a lower one of *Cremnoceramus deformis erectus* and an upper one of *C. crassus inconstans*. The following molluscan fossils were listed from the lower zone:

Cremnoceramus deformis erectus (Meek)
Forresteria (*F.*) *brancoi* (Solger)
Peroniceras (*P.*) *tridorsatum* (Schlüter)
Scaphites (*S.*) *frontierensis* Cobban
Scaphites (*S.*) *uintensis* Cobban
Scaphites (*S.*) *sagensis* Cobban
Scaphites (*S.*) cf. *preventricosus* Cobban

The following molluscan fossils were listed from the upper zone:

Cremnoceramus crassus inconstans (Woods)
Peroniceras cf. *P.* (*P.*) *dravidicum* (Kossmat)
Gandryceras mite (von Hauer)
Scaphites cf. *S.* (*S.*) *preventricosus* Cobban

In addition, *Baculites yokoyamai* Tokunaga and Shimizu and *Neocrioceras* sp. were noted but not assigned to a zone.

Young and Woodruff (1985) treated the stratigraphy and paleontology of the Austin Chalk in its type area in central Texas,

where they termed it the "Austin Division" made up of seven formations. *Peroniceras haasi* and *P. westphalicum* were assigned to the middle Coniacian and *Prionocycloceras gabrielense* to the upper Coniacian. Klinger and Kennedy (1984, p. 169) noted the close resemblance of *P. haasi* to the middle Coniacian *P. subtricarinatum* (d'Orbigny) and considered it as possibly d'Orbigny's species. Böse (1928, p. 268) figured a specimen as *Peroniceras* aff. *subtricarinatum* from near Ojinaga in northeast Chihuahua. Klinger and Kennedy (1984, p. 157) consider it a *Peroniceras* (*P.*) *subtricarinatum*. The small specimen (USGS D14456), mentioned by Smith (1981, p. 21) from 143 ft (43.6 m) above the base of the Austin approximately 20 mi (37 km) southeast of Del Rio, identified by Young as *Protexanites*? sp. indet. and by one of us (W. A. Cobban) as questionable juvenile whorls of *Peroniceras haasi*, closely resembles in size and ornament the small specimen assigned to *Peroniceras* (*Zuluiceras*) *bajuvaricum* (Redtenbacher) by Kennedy and Cobban (1991a, pl. 6, fig. 8) of middle Coniacian age and is probably that species. Smith (1981, p. 22), however, would place this part of the Austin in the lower Santonian on the basis of planktonic Foraminifera.

Two fragments of *Peroniceras* cf. *dravidicum* Kossmat were collected by Val Freeman and Cobban from the uppermost beds of the Boquillas Formation in Lozier Canyon in southwestern Terrell County, Texas. These fragments (USGS D2451) may be of early Coniacian age. Freeman and Cobban also collected a specimen (USGS D14510) of *Cremnoceramus crassus crassus* (Petrascheck) of late early Coniacian age in Lozier Canyon about 100 ft (30 m) above the base of the Austin.

Keith Young noted the following early Coniacian species in an unpublished manuscript on the Coniacian–lower Campanian ammonites of Trans-Pecos Texas:

Forresteria alluaudi (Boule, Lemoine, and Thevenin)
Forresteria cf. *peruana* (Brüggen)
Allocrioceras hazzardi Young
Baculites cf. *yokoyamai* Tokunaga and Shimizu
Yezoites aff. *cobbani* (Collignon)

Middle Coniacian

As noted earlier, Young and Woodruff (1985) recognized *Peroniceras westphalicum* as a zonal fossil of the middle Coniacian. The species, first described as *Ammonites westphalicus* by von Strombeck (1859) from Germany, is widely distributed in western Europe, southern Africa, Madagascar, Texas, and sparsely in New Mexico and Wyoming. Freeman and Cobban found it in Lozier Canyon in southeast Terrell County approximately 125 ft (38 m) above the base of the Austin. Other middle Coniacian ammonites from southwest Texas and adjoining parts of Mexico include *P. subtricarinatum* (d'Orbigny), recorded by Böse (1928, p. 268) from near Ojinaga of the Rio Grande border area, and *P. tridorsatum* (Schlüter), identified as *P. moureti* de Grossouvre by Young (1963; see Klinger and Kennedy 1984, p. 189).

Records of middle Coniacian inoceramid bivalves seem to be missing along the transect. This is odd because the common middle Coniacian genus *Volviceramus* is known from many localities north of the transect and usually from carbonate rocks like those in southwest Texas.

Upper Coniacian

Young (1963) described his new species *Prionocycloceras hazzardi* and *Paratexanites sellardsi* from his upper Coniacian *Prionocycloceras gabrielensis* Zone. Both species are assigned to *Protexanites* (Matsumoto 1965a, p. 41). Young recorded the species from Brewster County, Texas. The heteromorph ammonite *Phlycticrioceras* sp. cf. *douvillei* (Grossouvre) was also recorded from Trans-Pecos Texas (Young 1963, p. 45), and Clark (1963) recorded *P. douvillei* from Brewster County. That species is considered a junior synonym of *Hamites trinodosus* Geinitz 1850 now placed in *Phlycticrioceras* and known from Europe, Mexico, and the United States (Kennedy and Cobban 1991a, p. 57). Another upper Coniacian ammonite from southwest Texas noted by Young (1963, pp. 120, 124) is *Texasia dentatocarinata* (Roemer) from Kinney County and from the Study Butte area of Brewster County. Wolleben (1967) described as *Placenticeras colquitti*, a new species that he assigned to the upper Coniacian part of the Ojinaga Formation.

Young (1963, p. 69) described a few small fragments of an ammonite as the new species *Prionocycloceras adkinsae* from the upper part of the Chispa Summit Formation near Chispa Summit; and Wolleben (1967, p. 1152) recorded it from the Ojinaga Formation associated with *Placenticeras colquitti*. The specimens illustrated by Young and Wolleben suggest assignment to the late Coniacian *Protexanites*.

Santonian zonation

Young (1963) divided the Santonian of Texas and the Gulf Coast into a lower Santonian consisting of three zones of *Texanites* and an upper Santonian consisting of a single *Texanites* Zone as follows.

Substage	Ammonite zone
upper Santonian	*Texanites shiloensis*
lower Santonian	*Texanites texanus gallicus* *Texanites texanus texanus* *Texanites stangeri densicostus*

The Santonian zonation was followed by Young (1982) in his great summary of the Cretaceous rocks of central Texas, but a little later Young and Woodruff (1985, figs. 1, 2) replaced *T. shiloensis* with *Bevahites bevahensis* Collignon. *Bostrychoceras braithwaitei* Young (1969, p. 44), a heteromorph ammonite, was noted with Santonian fossils in Jeff Davis County but not assigned to a zone.

There is no international agreement about the substages and ammonite zonation of the Santonian (Lamolda and Hancock 1996). Most authors recognize lower and upper substages. A threefold subdivision based on scaphitid ammonites in the central and northern parts of the Western Interior was recommended by Scott and Cobban (1964, table 3). As revised slightly by Cobban (1994, fig. 2), it is shown in Figure 2 and below.

Substage	Ammonite zone
upper Santonian	*Desmoscaphites bassleri* *Desmoscaphites erdmanni* *Clioscaphites choteauensis*
middle Santonian	*Clioscaphites vermiformis*
lower Santonian	*Clioscaphites saxitonianus*

We apply a threefold division for the Santonian in Trans-Pecos Texas but use Young's updated texanid species (Fig. 2).

Substage	Ammonite zone
upper Santonian	*Plesiotexanites shiloensis* *Texanites texanus gallicus*
middle Santonian	*Texanites texanus texanus*
lower Santonian	*Plesiotexanites stangeri densicostus*

Santonian Stage

Lower Santonian

Texanites stangeri (Baily) *densicostus* (Spath), the guide fossil to the oldest ammonite zone of the lower Santonian, was recorded by Young (1963, p. 88) from the inoceramid zone of *Cladoceramus undulatoplicatus* in Brewster County. A single ammonite found as float below the *Cladoceramus undulatoplicatus* Zone in Brewster County, Texas, was described as the new genus and species *Defordiceras hazzardi* by Young (1963, p. 118). Wright (1996, p. 198) believed it to be a pathologic specimen.

Young (1963, p. 88) reported *T. stangeri densicostus* from near the top of the Fizzle Flat Lentil of the Terlingua Formation of Moon (1953) in Brewster County. He also described his species *Prionocycloceras adkinsae* from the Chispa Summit Formation near Chispa Summit, and Wolleben (1967, p. 1152) recorded it from the Ojinaga.

Middle Santonian

Ammonites from the middle Santonian zone of *Texanites texanus texanus* are uncommon and yield that species near Del Rio as well as the holotype of *Texanites texanites twiningi* Young from Brewster County (Young

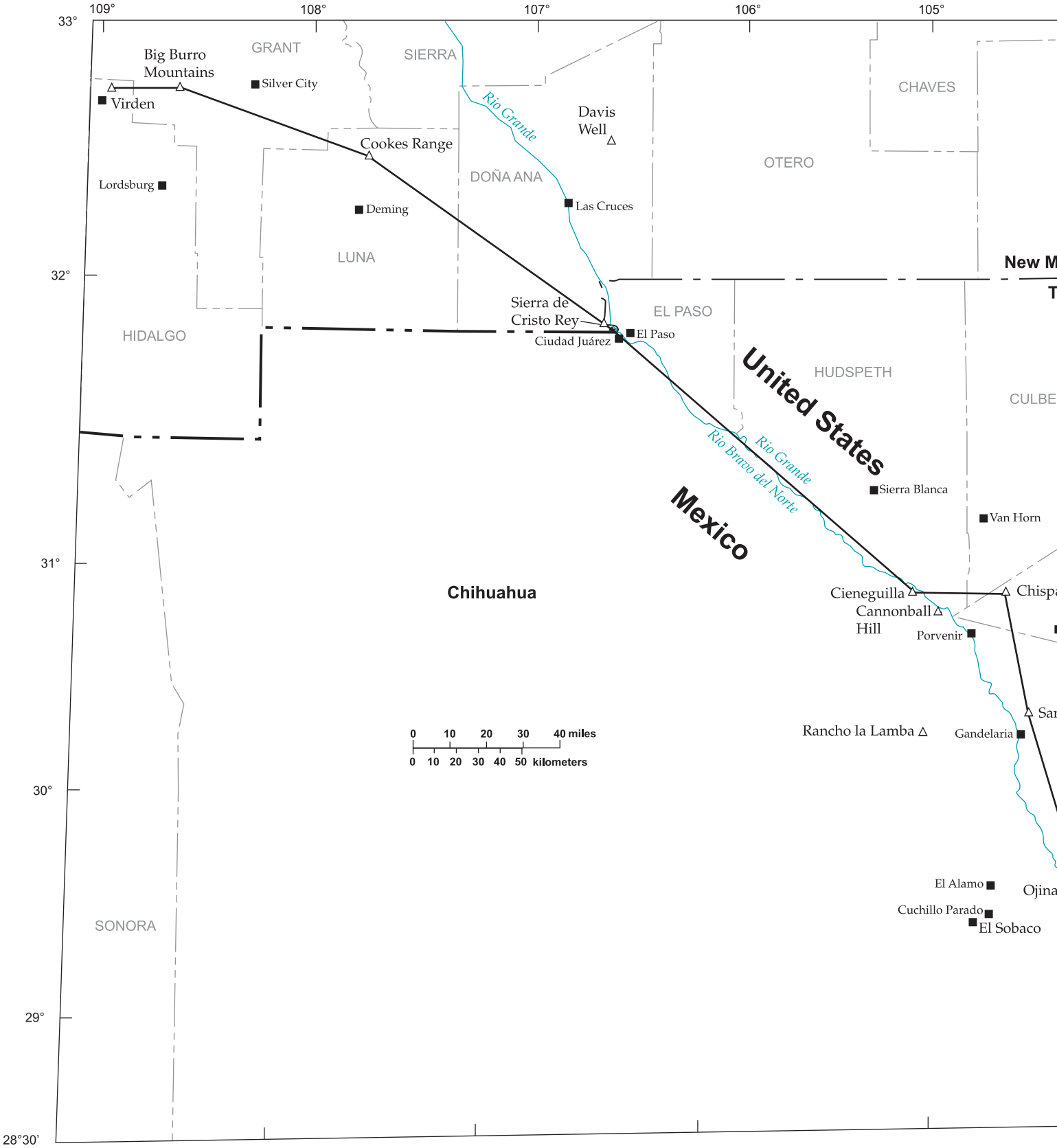
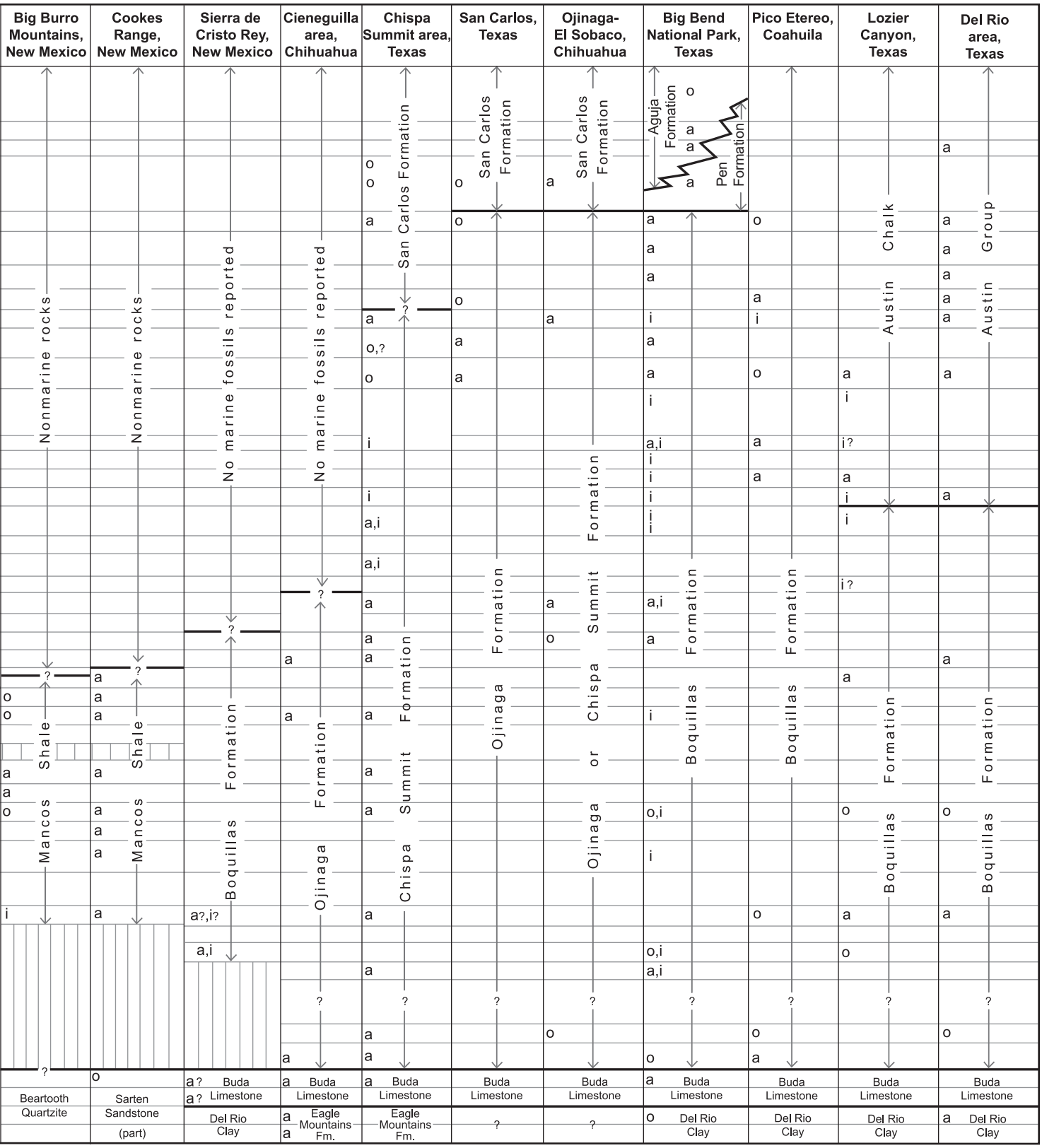


FIGURE 1— Map showing the line of transect from Virden, New Mexico, southward to El Paso, Texas, and then down the Rio Grande area to Del Rio, Texas.


104°
103°
102°
101°
100°
EDDY
LEA
lexico
exas
LOVING
WINKLER
RSON
WARD
CRANE
UPTON
REEVES
Pecos
River
Kent
San Martine
Gold Hill
JEFF DAVIS
a Summit
PECOS
CROCKETT
Valentine
Fort Davis
Alpine
Marfa
TERRELL
n Carlos
Sanderson
Lozier Canyon
PRESIDIO
BREWSTER
VAL VERDE
EDWARDS
Comstock
Dos
Canyon
Presidio
Grapevine Hills
Study
Butte
Rio Grande
Rio Bravo del Norte
Del Rio
KINNEY
Brackettville
Terlingua
Chisos Pen
Pico Etereo
La Linda
Lajitas
Ernst
Coahuila
Big Bend
National Park
Boquillas
Jiménez
MAVERICK
El Remolina
Eagle Pass

Stages and substages		Western Interior ammonite range zones	Age Ma	Western Interior inoceramid range zones	Provisional ammonite zonation southwest New Mexico and Trans-Pecos Texas	Virden, New Mexico
Campanian (part)	Upper (part)	*Baculites asperiformis*		*Cataceramus subcompressus*	*Hoplitoplacenticeras* spp.	Nonmarine rocks
		Baculites maclearni		*Cordiceramus azerbaydjanensis*		
		Baculites obtusus	80.58 ± 0.55			
	Lower	*Baculites* sp. (weak flank ribs)				
		Baculites sp. (smooth)		*Cataceramus balticus*	*Menabites (Delawarella) sabinalensis*	
		Scaphites hippocrepis III			*Menabites (Delawarella) delawarensis*	
		Scaphites hippocrepis II	81.86 ± 0.36			
		Scaphites hippocrepis I				
		Scaphites leei III		*Sphenoceramus lundbreckensis*	*Submortoniceras tequesquitense*	
Santonian	Upper	*Desmoscaphites bassleri*	84.30 ± 0.34		*Plesiotexanites shiloensis*	
		Desmoscaphites erdmanni				
		Clioscaphites choteauensis		*Cordiceramus bueltenensis*	*Texanites texanus gallicus*	
	Middle	*Clioscaphites vermiformis*			*Texanites texanus texanus*	
	Lower	*Clioscaphites saxitonianus*		*Cladoceramus undulatoplicatus*	*Plesiotexanites stangeri densicostus*	
Coniacian	Upper	*Scaphites depressus*	87.14 ± 0.39	*Magadiceramus crenelatus*	*Protexanites* spp.	
				Magadiceramus subquadratus		
	Middle	*Scaphites ventricosus*		*Volviceramus involutus*	*Peroniceras westphalicum*	
				Volviceramus koeneni		
	Lower	*Scaphites preventricosus*	88.55 ± 0.59	*Cremnoceramus crassus crassus*	*Forresteria alluaudi*	
				Cremnoceramus crassus inconstans		
				Cremnoceramus deformis dobrogensis		
				Cremnoceramus deformis erectus	*Allocrioceras hazzardi*	
Turonian	Upper	*Scaphites mariasensis*		*Cremnoceramus waltersdorfensis*	*Forresteria peruana*	
		Prionocyclus germari		*Mytiloides incertus*	*Prionocyclus germari*	
		Scaphites nigricollensis			*Prionocyclus quadratus*	
		Scaphites whitfieldi		*Inoceramus perplexus*	*Prionocyclus novimexicanus*	
	Middle	*Scaphites ferronensis*		*Inoceramus dimidius*	*Prionocyclus wyomingensis*	
		Scaphites warreni				
		Prionocyclus macombi	90.21 ± 0.54	*Inoceramus* aff. *dimidius*	*Prionocyclus macombi*	
		Prionocyclus hyatti	92.46 ± 0.58	*Inoceramus howelli*	*Prionocyclus hyatti*	
		Collignoniceras praecox		*Inoceramus* n.sp.	?	
		Collignoniceras woollgari		*Mytiloides hercynicus*	*Collignoniceras woollgari regulare*	
				Mytiloides subhercynicus	*Collignoniceras woollgari woollgari*	
	Lower	*Mammites nodosoides*		*Mytiloides mytiloides*	*Mammites nodosoides*	?
		Vascoceras birchbyi	93.48 ± 0.58	*Mytiloides puebloensis*	*Vascoceras birchbyi*	
		Pseudaspidoceras flexuosum	93.19 ± 0.42		*Pseudaspidoceras flexuosum*	
		Watinoceras devonense			?	Shale
Cenomanian	Upper	*Nigericeras scotti*		*Mytiloides hattini*		
		Neocardioceras juddii	93.32 ± 0.38 93.82 ± 0.30	*Inoceramus pictus*	*Neocardioceras juddii*	o
		Burroceras clydense			*Burroceras clydense*	Mancos
		Euomphaloceras septemseriatum	93.68 ± 0.50		*Euomphaloceras septemseriatum*	o
		Vascoceras diartianum	93.99 ± 0.72		*Vascoceras diartianum*	
		Dunveganoceras conditum		*Inoceramus ginterensis*	*Metoicoceras mosbyense*	a
		Dunveganoceras albertense				
		Dunveganoceras problematicum			?	
		Dunveganoceras pondi	94.71 ± 0.49	*Inoceramus prefragilis stephensoni*	*Calycoceras (Proeucalycoceras) canitaurinum*	
	Middle	*Plesiacanthoceras wyomingense*			?	
		Acanthoceras amphibolum	94.96 ± 0.50	*Inoceramus rutherfordi*	*Acanthoceras amphibolum*	
		Acanthoceras bellense		*Inoceramus arvanus*	*Acanthoceras bellense*	
		Plesiacanthoceras muldoonense		*Inoceramus eulessanus*		
		Acanthoceras granerosense		?		
		Conlinoceras tarrantense	95.73 ± 0.61	*Inoceramus prefragilis prefragilis*		
	Lower	*Neogastroplites* spp.		Inoceramids present	*Forbesiceras brundrettei*	
					Acompsoceras inconstans	
					Neophlycticeras (Budaiceras) hyatti	
					Neophlycticeras (Neophlycticeras) texanum	
					Graysonites wacoensis	
					Graysonites adkinsi	

FIGURE 2— Upper Cretaceous molluscan record at 12 key localities along a transect from Virden in southwest New Mexico southeastward more than 500 mi (800 km) to the Del Rio area in southern Texas. Western Interior ammonite and inoceramid zones and radiometric ages are modified from Cobban et al. (2006). Scaphitid and baculitid ammonites are especially abundant in the central and northern part of the Western Interior of the United States, and the upper middle Turonian through Campanian zonation is based on



them. These ammonites are scarce in the southern part of the Western Interior into Trans-Pecos Texas, where collignonicerid ammonites are dominant. Age diagnostic fossils collected at each locality are indicated by the following letters: **a** = zonal index ammonite species; **o** = ammonite species confined to that zone, but not the index species; **i** = zonal index inoceramid species; and **?** = poorly preserved fossil or tentative identification. Vertical lines indicate hiatuses.

1963, pp. 81, 82). The holotype and only specimen known from southwest Texas of *Muniericeras*? *twiningi* Young from Brewster County may be from this zone. A collection (USGS 1467) from the San Carlos Formation of Presidio County made by T. W. Vaughan (1900, p. 79) contains *Clioscaphites vermiformis* (Meek and Hayden), the zonal index fossil for the middle Santonian of the Western Interior (Fig. 2).

Upper Santonian

Young (1963) recognized only a *Texanites shiloensis* Zone for the upper Santonian and recorded that species from southwest Texas in Kinney and Presidio Counties and Coahuila, Mexico. Young noted *Texasia dentatocarinata* (Römer) from Kinney County and from the Study Butte area in Brewster County. *Bevahites bevahensis* Collignon and the holotype of *Reginaites durhami* were also found in Kinney County. The holotype of *Pseudoschloenbachia wilsoni* Young came from Presidio County. Regarding the latter species, a collection (USGS 1467) from the San Carlos Formation of Presidio County made by T. W. Vaughan (1900, p. 79) contains *P. wilsoni* and *Clioscaphites vermiformis* (Meek and Hayden). Lot 1467 includes a lengthy list of molluscan species and may represent several stratigraphic levels inasmuch as *P. wilsoni* is upper Santonian according to Young, and *C. vermiformis* is a zonal index fossil for the middle Santonian of the middle and northern part of the Western Interior.

Pseudoschloenbachia mexicana was described by Renz (1936) as *Schloenbachia bertrandi* de Grossouvre var. *mexicana* from near Jiménez in northern Coahuila. Young (1963, p. 121) raised the variety to a species of *Pseudoschloenbachia*, designated one of Renz's specimens as the holotype (lectotype), and considered it as a late Santonian species. Among the fossils of the USGS at the Denver Federal Center is a small collection of ammonites (USGS 14678) that includes *P. mexicana* from 8 mi (13 km) south of Ojinaga, Chihuahua. The species is present also in the J. P. Conlin collection from near Study Butte in Brewster County (USGS D14555). Renz (1936, p. 3) described also the new species *Pachydiscus* (*Parapachydiscus*) *jimenezi* as a Santonian form from the Jiménez area, but Young (1963, p. 59) assigned it to *Eupachydiscus* and to the lower Campanian. Another new species, described by Renz (1936, p. 57) as *Mortoniceras densinodosum* from the Jiménez area and assigned to the Santonian, was later considered a *Menabites* by Young (1963, p. 108), who placed it in the lower Campanian *Submortoniceras tequesquitense* Zone. The slender, densely ribbed whorls of an ammonite identified as *Puzosia* (*Parapuzosia*) *corberica* de Grossouvre by Renz (1936, p. 5) from the Jiménez area and assigned to the Santonian was found by Young (1963, p. 52) to be the inner whorls of the huge ammonite *Parapuzosia bosei* Scott and Moore 1928 of early Campanian age. The holotype is from the Austin Group southeast of Del Rio on the American side of the Rio Grande not far from Jiménez, Mexico.

Maxwell et al. (1967, pp. 77–78) recorded a "dwarf fauna" of small bivalves, gastropods, and ammonites near the middle of the approximately 213-m-thick (700-ft-thick) Pen Formation near Study Butte in Brewster County. A collection by W. S. Adkins at the Texas Memorial Museum in Austin was examined by W. J. Kennedy and illustrated by Kennedy and Cobban (1991b), who referred to the fossils as the *Boehmoceras* fauna. Three specimens collected by L. W. Stephenson in 1948 from the Study Butte area were also illustrated by Kennedy and Cobban (1991b, locality 26335). The ammonites from the Study Butte area, as now known, consist of the following species:

Pseudoschloenbachia mexicana (Renz)
Reginaites subtilis Kennedy and Cobban
Glyptoxoceras spp.
Scaphites leei Reeside, form I
Baculites capensis Woods
Boehmoceras arculus (Morton)

The age is late Santonian, *Texanites shiloensis* Zone of Young. *Scaphites leei* form I occurs in the late Santonian *Desmoscaphites erdmanni* Zone of the Western Interior region (Cobban 1969, p. 14). Young (1969, table 2) later considered *T. shiloensis* and *B. bevahensis* as early Campanian in age.

Texanites stangeri densicostus was assigned to the subgenus *Plesiotexanites* by Matsumoto (1970, p. 285) and to the full genus *Plesiotexanites* by Klinger and Kennedy (1980, p. 67). *Texanites texanus texanus* and *T. texanus gallicus* as well as *T. texanus twiningi* Young were grouped by Klinger and Kennedy (1980, p. 162) as *T. texanus* s.l. *Texanites shiloensis* was assigned to the subgenus *Plesiotexanites* by Klinger and Kennedy (1980, p. 65).

The only ammonite from southwest Texas from the lower upper Santonian *Texanites texanus gallicus* Zone recorded by Young (1963, p. 82) is *Texanites texanus twiningi* from Brewster County, a species that begins in the upper part of the underlying *T. texanus texanus* Zone.

Campanian Stage

Lower Campanian

In his 1963 treatment of the Austin Chalk, Young divided the Campanian into lower and upper parts. Three ammonite zones were defined for the lower Campanian and one for the upper Campanian. The three zones of the lower Campanian are shown below.

Substage	Ammonite zone
lower Campanian	*Delawarella sabinalensis*
	Delawarella delawarensis
	Submortoniceras tequesquitense

Young (1963, p. 29) listed 23 species of ammonites from the zone of *Submortoniceras tequesquitense* of which 10 were known from southwest Texas. The holotype of the zonal fossil came from Tequesquite Creek in Kinney County, and the holotype of *S. uddeni* Young came from Brewster County. Another specimen assigned to *S. chicoense* (Trask) by Young (1963, p. 106) came from the Study Butte area in Brewster County. Another Texanitinae, *Bevahites costatus* Collignon subsp. *coahuilaensis* was described by Young (1963, p. 96) from the Jiménez area, Coahuila, and *Australiella pattoni* Young was recorded from the Davis Mountains area, Jeff Davis County.

The holotype of *Pseudoschloenbachia chispaensis* Adkins (1929, p. 210) was said to be from the San Carlos Formation of Presidio County, but Wolleben (1967) reported it from the older Ojinaga Formation, and C. L. Metz (pers. comm. 1992) collected several specimens from the uppermost concretion unit in the Ojinaga in the Gettysburg Peak quadrangle in Presidio County.

Eupachydiscus sp. was recorded by Young (1963, pp. 60–61) from Tequesquite Creek in Kinney County, and from northern Coahuila. Robust species of *Placenticeras*, often assigned to *Stantonoceras* Johnson 1903, are abundant in the upper part of the Ojinaga Formation in Presidio County. Wolleben (1967) placed them all in *P. syrtale* (Morton) with the subspecies *syrtale*, *adkinsi*, and *rooneyi*. Young (1963) had earlier recognized the placenticeratids from the San Carlos area as *Stantonoceras guadalupae* (Roemer), *S. sancarlosense* (Hyatt), and *S. pseudosyrtale* (Hyatt). Other ammonites from the *Submortoniceras tequesquitense* Zone from southwest Texas reported by Wolleben include *Texanites lonsdalei* Young and *Glyptoxoceras ellisoni* Young.

The late J. P. Conlin (1908–1972) purchased a collection of ammonites from Presidio County labeled "San Carlos shale facies." In the collection was a specimen of *Neogauthiericeras zafimahovai* Collignon, a species noted by Kennedy and Cobban (1990c) and assigned to the *S. tequesquitense* Zone. The Conlin collection includes several good specimens of *S. tequesquitense* from the Porvenir area of Presidio County.

Young (1963, p. 28) recorded 21 species of ammonites from the lower Campanian zone of *Menabites* (*Delawarella*) *delawarensis* in the Gulf Coast area of which 11 occur in southwest Texas including the zonal fossil. Kennedy et al. (1997, p. 3) noted that *D. delawarensis* has a very long vertical range into the *Delawarella sabinalensis* Zone of Young, and recommended that the two zones could be combined into a single zone of *Baculites taylorensis* Adkins. *Delawarella* is now considered a subgenus of *Menabites* Collignon (1948; see Wright 1996, p. 197). *Menabites* (*Delawarella*) *delawarensis* (Morton) occurs in the Pen Formation in Big Bend National Park (Maxwell et al. 1967, pp. 75, 78) and in the San Carlos Formation in Presidio County (Young 1963, p. 112). Young recorded *Submortoniceras vanuxemi* (Morton) from the *M. delawarensis* Zone of Brewster County. This species is now placed in *Menabites* (Cobban and Kennedy 1991, p. 2). The holotype of *Submortoniceras*

sancarlosense Young 1963 is from the upper part of the San Carlos Formation of Presidio County, and the holotype of *S. maricalense* Young is from Brewster County in Big Bend National Park. *Submortoniceras candelariae*, another species described by Young from the *M. delawarensis* Zone, came from Brewster County. It is also present in the J. P. Conlin collections from the Porvenir area of Presidio County. The species is better assigned to *Texanites* (*Plesiotexanites*) according to Matsumoto (1970, p. 279) and Klinger and Kennedy (1980, p. 65).

Two huge ammonites, *Parapuzosia bosei* and *P. americana*, were described by Scott and Moore (1928) from the Austin Group southeast of Del Rio. They were assigned to the Santonian, but Young (1963, p. 52) placed them in the *M. delawarensis* Zone. He also figured a specimen of *P*. sp. aff. *P. bradyi* Miller and Youngquist (1946) from the lower Campanian of Jeff Davis County.

Renz (1936) described the new species *Pachydiscus* (*Parapachydiscus*) *jimenezi* from the Jiménez area of northern Coahuila and assigned it to the Santonian. Young (1963, p. 59) placed it in *Eupachydiscus* and assigned it to the *M. delawarensis* Zone. He also described *Eupachydiscus* sp. from Kinney County and Coahuila.

After completing a thesis on the San Carlos beds of Presidio County, C. L. Metz (Blinn College, Bryan, Texas) donated some ammonites to the USGS. Among them were several specimens of *Baculites vaalsensis* Kennedy and Jagt 1995, a species described from Belgium from the Vaals Formation that contains *Scaphites hippocrepis* III of early, but not earliest, Campanian age. Kennedy and Jagt also noted the occurrence of the baculitid in New Jersey and in the Western Interior.

J. P. Conlin obtained a specimen from the "San Carlos shale facies" of the Porvenir area in western Presidio County that appears to be *Ishikericeras* Matsumoto (1965b, p. 236). The specimen is missing from the Conlin collection, but there is a good plaster cast of it (Conlin 14932). Conlin assigned the specimen to the "*Submortoniceras candelariae* Zone."

The zonal species of *Delawarella sabinalensis* was described by Young (1963, p. 112), who mentioned the occurrence of a specimen from "the Terlingua formation on Tornillo Creek, Big Bend National Park, Trans-Pecos Texas." *Delawarella sabinalensis* is the only ammonite recorded by Young from this zone in southwest Texas. This species is now assigned to the genus *Menabites*, subgenus *Delawarella*.

Upper Campanian

Adkins (1933, p. 474) noted the European upper Campanian zone of *Hoplitoplacenticeras vari* (Schlüter) in the basal Aguja Formation in the Big Bend area. The zone overlies a zone of "*Mortoniceras* aff. *delawarense*." Young (1963, p. 28) recognized for the Gulf Coast area a basal late Campanian zone of *Hoplitoplacenticeras marroti* (Coquand 1859). This species in Europe occurs in the basal upper Campanian zone of *H. vari* (Schlüter), which is overlain by the upper Campanian zone of *Trachyscaphites spiniger* (Schlüter) (for example, Kaplan et al. 2005). Young (1963) illustrated several fragments of *H. marroti* from the Anacacho Limestone from south-central Texas, but none from southwest Texas. Kennedy and Cobban (2001) recorded a single fragment from the Anacacho of Medina County, Texas, and described the new species *H. minor* from the Wolfe City Sand that underlies the Pecan Gap Chalk (Anacacho equivalent) of northeastern Texas (Cobban and Kennedy 1993), where it is associated with *Trachyscaphites spiniger*. Assuming that one or more of these species of *Hoplitoplacenticeras* will be found in Trans-Pecos Texas, Young's zone is herein treated as *Hoplitoplacenticeras* spp. (Fig. 2).

Adkins (1933, p. 475) recorded the presence of an ammonite resembling *Libycoceras* Hyatt southeast of Terlingua, Texas. The specimen is probably *Manambolites ricensis* Young (1963, p. 127), an early Campanian species inasmuch as Adkins (p. 508) noted the occurrence of "*Libycoceras*(?) n. sp." along with "*Mortoniceras* cfr. *delawarense*" and other ammonites in the Aguja Formation.

Localities

Formations and stratigraphic positions of diagnostic fossils are shown in Figure 2. At the west end of the transect near Virden, New Mexico, strata of late Cenomanian age rest unconformably on Precambrian rocks, and eastward from Virden to the Cookes Range, the middle Cenomanian and younger ammonite and inoceramid records are missing because the rocks are nonmarine. This middle Cenomanian hiatus may extend through Trans-Pecos Texas to or beyond the Del Rio area. A minor hiatus may exist at the top of the upper Cenomanian, where records of the *Nigericeras scotti* Zone are lacking.

Strata above the Mancos Shale in southwestern New Mexico are nonmarine and not treated in this report. In the area from Sierra de Cristo Rey to Chispa Summit, records of marine fossils above the Boquillas, Ojinaga, and Chispa Summit Formations are lacking. Farther southeastward from the Chispa Summit area to the Del Rio area, marine fossils as young as late Campanian are known.

Virden

The shaly marine Cenomanian–Turonian strata of southwestern New Mexico have long been termed the Colorado Formation. Molenaar (1983, p. 213 and fig. 4) pointed out that these strata represent a tongue of the Mancos Shale, and that Mancos Shale should be applied (see also Lucas and Estep 1998, pp. 51–53). In the area from Virden eastward to the Cookes Range, much of the Mancos Shale consists of the following lithologic units: (1) a basal ledge-forming flaggy member of siltstone, sandstone, and shale, (2) a shale member, (3) a limestone and calcareous shale member containing fossiliferous concretions, and (4) an upper shaly unit that grades upward into sandstone. These units have been termed the flag member, lower shale member, Bridge Creek Limestone Member, and upper sandstone and shale member (Cobban et al. 1989, fig. 3).

Graphic sections for the sequence of the Virden area are shown by Cobban et al. (1989, fig. 15), Lucas and Estep (1998, fig. 16), and Lucas et al. (2000, fig. 3). There, the flag member yielded *Metoicoceras mosbyense* from limestone concretions, 10–15 ft (3–5 m) above the base, and the lower shale member had *M. frontierense*, *Eucalycoceras pentagonum*, *Moremanoceras scotti*, *Euomphaloceras merewetheri*, and the heteromorph ammonites *Hamites* cf. *simplex*, *H. salebrosus*, *Metaptychoceras hidalgoense*, *Neostlingoceras procerum*, and *N. virdenense* (Cobban et al. 1989, p. 16). The last species has been recorded from the upper Cenomanian *Calycoceras guerangeri* Zone of England (Wright and Kennedy 1996, p. 330). *Metoicoceras geslinianum* occurs in the Bridge Creek Member in the Virden area. *Euomphaloceras costatum* and *Pseudaspidoceras pseudonodosoides* occur high in the Bridge Creek Member. Ammonites were not found in the upper sandstone and shale member, but the presence there of *Mytiloides puebloensis* indicates an early Turonian age (Walaszczyk and Cobban 2000).

Big Burro Mountains

The lithology and fossil sequence in the Big Burro Mountains is treated by Cobban et al. (1989, pp. 15, 16). The flag unit of the Mancos has a basal conglomerate of chert and quartzite pebbles that rests disconformably on the Beartooth Quartzite. Ammonites collected from calcareous concretions 11–16 ft (3–5 m) above the base consist of *Moremanoceras* sp., *Tarrantoceras* sp., and *Hamites* sp., which suggest the upper Cenomanian zone of *Calycoceras canitaurinum* as does the *Inoceramus prefragilis stephensoni*? collected from near the base of the flags (D11014). The lower shale unit is thin and concealed, but above it is a 15-ft-thick (4.6-m-thick) sandy, calcareous coral thicket (*Archohelia dartoni* Wells) that contains *Metoicoceras geslinianum* and other fossils of the upper Cenomanian *Euomphaloceras septemseriatum* Zone. Four feet above the coral thicket is a 5-ft-thick (1.5-m-thick) shale unit that contains limestone concretions with *Burroceras clydense* overlain by limestone concretions with *Neocardioceras juddii* and *Pseudaspidoceras pseudonodosoides*. The highest of the last concretions represent a hardground with corroded ammonites that mark the end of Cenomanian deposition. Resting sharply on the hiatus concretions is silty shale containing an occasional *Quitmaniceras reaseri* Powell of the lower Turonian zone of *Pseudaspidoceras flexuosum*. The presence of *Mytiloides puebloensis* still higher in the section suggests the lower Turonian zone of *Vascoceras birchbyi*.

Cookes Range

At one locality in the Cookes Range (Cobban 1987a, fig. 1, locality D10104), several specimens of the early Cenomanian ammonite *Mantelliceras* (probably *M. budaense* Adkins) were found in sandy, nodular limestone at the top of the Sarten Sandstone, which suggest an age equivalent to the upper part of the Buda Limestone of Trans-Pecos Texas. The collection, which is considerable, includes a specimen identified as *Turrilites* aff. *T. costatus* Lamarck (Cobban 1987a, p. 3) that is now assigned definitely to *T. costatus* (Hook and Cobban 2007).

Much of the Mancos Shale in the Cookes Range area is very fossiliferous. The flag member has a large fauna of the lowermost upper Cenomanian zone of *Calycoceras canitaurinum* with the ammonite genera *Borissiakoceras*, *Moremanoceras*, *Cunningtoniceras*, *Calycoceras*, *Tarrantoceras*, *Metoicoceras*, *Hamites*, *Turrilites*, and *Neostlingoceras*. The lower shale member and the basal part of the Bridge Creek Limestone Member contain *Vascoceras diartianum*, *Metoicoceras mosbyense*, and the genera *Moremanoceras*, *Placenticeras*, *Forbesiceras*, *Cunningtoniceras*, *Calycoceras*, *Eucalycoceras*, *Euomphaloceras*, *Nannometoicoceras*, *Hamites*, *Metaptychoceras*, and *Neostlingoceras*. *Calycoceras* (*Proeucalycoceras*) *guerangeri*, guide to the European basal upper Cenomanian *C. guerangeri* Zone, was found in the upper part of the lower shale member.

The upper part of the Bridge Creek Member contains *Euomphaloceras septemseriatum*, *Metoicoceras geslinianum*, *Sciponoceras gracile*, and the genera *Moremanoceras*, *Placenticeras*, *Calycoceras*, *Pseudocalycoceras*, *Sumitomoceras*, *Vascoceras*, *Allocrioceras*, *Neostlingoceras*, and *Worthoceras*. Calcareous hiatus concretions at the top of the Bridge Creek Member contain *Neocardioceras juddii*, *Pseudaspidoceras pseudonodosoides*, and *Anisoceras coloradoense* of the upper Cenomanian *N. juddii* Zone.

The lower part of the upper shale member has yielded *Pseudaspidoceras flexuosum*, *Fagesia catinus*, and *Watinoceras* sp. of early Turonian age. The lower part of the sandstone and shale member contains *F. catinus*, *Vascoceras birchbyi*, and *Neoptychites cephalotus*. *Mammites nodosoides*, of latest early Turonian age, was found higher in the member.

Sierra de Cristo Rey

Strain (1968) applied the name Boquillas Formation to marine Upper Cretaceous beds resting on the Buda Limestone at Sierra de Cristo Rey (Cerro de Cristo Rey, Cerro de Muleros) west of El Paso, Texas, but later (1976) he suggested that the names Ojinaga or Chispa Summit could be just as well applied. We are following Lovejoy (1976), who mapped the beds as Boquillas at Sierra de Cristo Rey. We examined only the lower part of the Boquillas, which has a fossiliferous calcarenitic limestone at the base. The molluscan fauna that represents the middle Cenomanian *Acanthoceras amphibolum* Zone is listed in the first part of the present report. Bits of a large ammonite that has alternate primary and secondary ribs (USGS D14390) were collected approximately 100 ft (30 m) above the base, and could be from *Calycoceras canitaurinum*. Associated fragments of *Inoceramus* resemble *I. prefragilis stephensoni* of early late Cenomanian age.

Cieneguilla area

Upper Cretaceous strata and fossil content in the Cieneguilla area, which borders the Rio Grande in Chihuahua, Mexico, and Hudspeth County, Texas were treated by Powell (1961, 1963a, b, 1965), Reaser (1970, 1974), Jones and Reaser (1970), Kennedy and Cobban (1988), Kennedy et al. (1989), and Cobban and Kennedy (1989). The stratigraphic sequence consists of the Eagle Mountains Formation and Buda Limestone of early Cenomanian age and the Del Rio Clay equivalent, which contains the *Graysonites* fauna including abundant foraminifera (*Cribratina texana*). The Buda Limestone, threefold and nearly 850 ft (259 m) thick, contains the *Neophlycticeras* (*Budaiceras*) fauna.

The Ojinaga Formation is at least 2,000 ft thick (610 m) and consists of a lower flaggy unit 75 ft (23 m) thick, a much thicker middle shale unit 1,380 ft (420 m), and an upper sandy unit 1,010 ft (308 m) (Kennedy et al. 1987, fig. 1). A fauna characterized by the early Cenomanian *Acompsoceras inconstans* Zone is present in the flaggy unit 30 ft (9 m) above the base. (See early part of the present report for an updated list of fossils.) Fossils have not been recorded from the lower one-half of the thick middle shale unit. Powell (1963a) described an early Turonian fauna that contained *Pseudaspidoceras flexuosum* from a limestone bed 990 ft (302 m) above the base of the Ojinaga. This fauna was revised by Chancellor (1982) and Kennedy et al. (1987), and updated names are given in the early part of the present report. A total of 12 genera of ammonites is now known from the *P. flexuosum* Zone of Trans-Pecos Texas. The lower part of the upper sandy unit is of early middle Turonian age. Concretions at the base of the unit contain *Collignoniceras woollgari* (Mantell), identified by Powell (1963b) as *Selwynoceras mexicanum* (Böse) from Powell's Cannonball Hill locality. For other ammonites from that locality, see the early part of the present report. The middle Turonian *Prionocyclus hyatti* Zone was not observed in the Cieneguilla area, but Powell (1965, p. 519) noted the occurrence of *P. hyatti* in the Cuchillo Parado area approximately 100 mi (160 km) south of Cieneguilla, and Kennedy and Cobban (1988) figured specimens from that area.

Chispa Summit area

The thick shale of the Ojinaga Formation was deposited in the Chihuahua trough along the Chihuahua–Texas border area, whereas the equivalent Chispa Summit Formation was deposited to the northeast as a shelf facies on the Diablo platform (Powell 1965, fig. 2; Lehman 1986, fig. 7; Kennedy et al. 1989, fig. 1). Graphic sections of the Chispa Summit Formation were presented by those authors.

At its type locality, the Chispa Summit Formation rests disconformably on the Buda Limestone and contains the early Cenomanian *Acompsoceras inconstans* and *Forbesiceras brundrettei* faunas in the basal beds. A collection 15 ft (4.6 m) above the base contains *Acanthoceras bellense* and other fossils of that middle Cenomanian zone. *Calycoceras canitaurinum* is present 59 ft (18 m) above the base. The next 60 ft (18.5 m) of calcareous shale did not yield fossils. Limestone beds in a calcareous shale unit 120–125 ft (36.5–38.5 m) above the base contain *Metoicoceras geslinianum*, *Euomphaloceras septemseriatum*, *Sciponoceras gracile*, and other ammonites of the upper Cenomanian *E. septemseriatum* Zone. *Pseudocalycoceras angolaense* was recorded from Chispa Summit 128 ft (39 m) above the base (Cobban 1988b, p. 14). Approximately a meter above the *E. septemseriatum* Zone is a soft bed of limestone that contains *Neocardioceras juddii* and other ammonites whose top surfaces are corroded indicating a hiatus just as in ammonites at the top of the *N. juddii* Zone in southwest New Mexico. Above the *N. juddii* Zone is 26 ft (8 m) of calcareous shale lacking molluscan fossils that probably contains the Cenomanian–Turonian boundary. A bed of concretionary limestone above this barren unit contains *Pseudaspidoceras flexuosum*, *Mammites powelli*, *Vascoceras proprium*, and *Neoptychites* cf. *cephalotus*. Limestone beds and concretions a little above the *flexuosum* bed contain *Mammites nodosoides*, *Morrowites depressus*, and other ammonites of the uppermost lower Turonian *Mammites nodosoides* Zone. (See Hancock et al. 1994, pp. 469–470.)

In the Needle Peak area approximately 2 km southwest of Chispa Summit, a flaggy sandstone unit lies at an undetermined distance above the *M. nodosoides* Zone. The middle Turonian ammonite *Collignoniceras woollgari woollgari* was found 105 ft (32 m) below the flaggy sandstone, and *C. woollgari regulare* was found 39 ft (12 m) below. Limestone concretions 65–98 ft (20–30 m) above the flaggy sandstone contain *Prionocyclus hyatti*, abundant *Coilopoceras springeri*, and other ammonites of the middle Turonian *P. hyatti* Zone. A barren shaly unit, possibly 150 ft (45 m) thick separates the *hyatti* beds from calcarenite and calcarenitic concretions with *Scaphites warreni* and *Prionocyclus wyomingensis* of late middle Turonian age. A thin bed of sandstone slightly higher has *Inoceramus perplexus* of earliest late Turonian age, and a concretionary limestone still higher yielded the middle late Turonian *Mytiloides incertus*. At another locality in the Chispa Summit area, the early Coniacian *Cremnoceramus deformis erectus* and *Forresteria* sp. were collected. The J. P. Conlin collection (see pp. 85 and 86) from the San Carlos shale facies near Porvenir, Presidio County, 15 mi (27 km) southwest of Chispa Summit, contains several good specimens of the lower Campanian zonal index species, *Submortoniceras tequesquitense*, as well as

ammonites restricted to the overlying *Menabites (Delawarella) delawarensis* Zone.

San Carlos

Vaughan (1900, p. 81) gave the name San Carlos Formation to the fossiliferous sandstone and shale with some coal exposed at the former San Carlos store and San Carlos Coal Company's coal mine in northwestern Presidio County, Texas. He included shaly rocks now assigned to the Ojinaga Formation. A generalized graphic section by Wolleben (1967, fig. 2E-F) shows the restricted San Carlos Formation to consist of lower and upper sandstone members separated by a shaly member and to lie in the lower Campanian zone of *Menabites* (*Delawarella*) *delawarensis* as well as in the upper part of the underlying *Submortoniceras tequesquitense* Zone. Fossils reported by Wolleben (1967, fig. 3) from the San Carlos included *Placenticeras syrtale rooneyi*, *Submortoniceras vanuxemi*, *Menabites belli*, *Delawarella delawarensis*, *Pseudoschloenbachia* cf. *mexicana*, and the oyster *Exogyra ponderosa upatoiensis*. C. L. Metz, who did a Ph.D. dissertation on the San Carlos area (pers. comm. 1995), noted that carbonate concretions were abundant in the lower part of the middle shale member of the San Carlos and that they contain *Baculites vaalsensis* Kennedy and Jagt 1995. Wolleben (1967, figs. 2, 3) reported the following fossils from concretions in the upper part of the Ojinaga Formation: *Glyptoxoceras ellisoni*, *Placenticeras syrtale adkinsi*, *Texanites* aff. *omeraensis*, *Submortoniceras candelariae*, *Pseudoschloenbachia chispaensis*, and *Exogyra ponderosa upatoiensis*. His *Placenticeras colquitti* is said to come from Young's upper Coniacian *Prionocycloceras gabrielensis* Zone. Vaughan (1900, p. 75) listed many bivalves, gastropods, and cephalopods collected by him and T. W. Stanton in 1895 from "1 mi south of store, San Carlos." The collection (USGS 1467), however, is a mixture of San Carlos and Ojinaga species because it includes a specimen of the early Campanian *Menabites* (*Delawarella*) *delawarensis* and a specimen of the middle Santonian *Clioscaphites vermiformis*.

Ojinaga–El Sobaco

Wolleben (1967, fig. 2; 1968, fig. 2) measured a section of Ojinaga Formation 4,577 ft (1,395 m) thick overlain conformably by 424 ft (129 m) of San Carlos Formation in the Ojinaga area. He placed the latter in the early Campanian *Delawarella delawarensis* Zone, and noted the presence of the lower Santonian *Texanites stangeri densicostus* 1,800 ft (548 m) above the base of the Ojinaga.

Powell (1965, p. 519, fig. 6) applied the name Chispa Summit Formation in the Cuchilla Parado area and recorded the following ammonites above the base of the Ojinaga: *Pseudouhligella elgini* [*Moremanoceras bravoense*] at 10–35 ft (3–10.6 m), mantelliceratines at 300 ft (91 m), a *Spathites chispaensis* fauna at 1,600 ft (488 m) [*Collignoniceras woollgari regulare* Zone], *Prionocyclus hyatti* approximately 2,130 ft (650 m), and *Coilopoceras* higher.

Big Bend National Park

The authors have not carried out field work in the Big Bend National Park, and the following account is based mainly on collections made by Maxwell et al. (1967), Cooper et al. (2008), and Keith Young (University of Texas, Austin).

Maxwell et al. (1967) and Maxwell and Dietrich (1972) recognized the following Upper Cretaceous sequence of strata in the Big Bend National Park: Aguja Formation, Pen Formation, Boquillas Formation (San Vicente Member, Ernst Member), Buda Limestone, and Del Rio Clay.

Those authors noted the presence of *Stoliczkaia* sp. in the Del Rio and *Budaiceras* spp. in the Buda. They noted also the presence of "small desmoceratid ammonites"(*Moremanoceras*) near the base of the Boquillas. They recognized a widely distributed, prominent, ledge-forming unit of limestone and shale known as the "*Allocrioceras* beds" or "*Crioceras* ledge" for the many *A. hazzardi* Young (1963, p. 44). Maxwell et al. (1967) placed this unit in the upper part of their Boquillas Formation. Cooper et al. (2008) have found for mapping purposes that the *Allocrioceras* bed is better considered as the top of the Ernst Member.

The following discussion of fossils from the Ernst Member of the Boquillas Formation is based on Cooper et al. (2008, pp. 24–33, fig. 35). Careful collecting in the lower 16 inches (40 cm) of the Ernst Member in Big Bend National Park has revealed the presence of *Moremanoceras bravoense* Cobban and Kennedy and *Euhystrichoceras adkinsi* (Powell) of the early Cenomanian *Acompsoceras inconstans* Zone. *Inoceramus arvanus* Stephenson collected from approximately 10 ft (3 m) above the Buda may represent the middle Cenomanian *Acanthoceras bellense* Zone. The large coiled ammonite 12 ft (3.6 m) above the contact with the Buda tentatively identified as *Calycoceras* sp. (Cooper et al. 2008, p. 26) is quite likely a large *A. bellense* Adkins.

Approximately 7 ft (2 m) above *I. arvanus*, a collection of *Ostrea beloiti* Logan, *Tarrantoceras sellardsi* (Adkins), and *Turrilites acutus* Passy indicates the middle Cenomanian *Acanthoceras amphibolum* Zone. This assemblage is followed by *Inoceramus ginterensis* Pergament probably from the upper Cenomanian *Metoicoceras mosbyense* Zone; a little higher *Inoceramus pictus* Sowerby and *Pseudocalycoceras angolaense* indicate the upper Cenomanian *Euomphaloceras septemseriatum* Zone; and higher still, the inoceramids *Mytiloides puebloensis* Walaszczyk and Cobban and *M. goppelnensis* (Badillet and Sornay) are probably from the lower Turonian *Pseudaspidoceras flexuosum* Zone. These middle Cenomanian–lower Turonian zones have not been recorded previously in Big Bend National Park.

A white limestone near the middle of the Ernst Member has yielded the middle Turonian fossils *Collignoniceras woollgari* (Mantell)? as float, *Prionocyclus hyatti*, and *Inoceramus howelli* White, both in situ. High in the Ernst Member, the Coopers have collected the upper Turonian inoceramids *Inoceramus perplexus* Whitfield, *I. dakotensis* Walaszczyk and Cobban, *Mytiloides incertus* (Jimbo), *M. scupini* (Heinz), and *Cremnoceramus waltersdorfensis* (Andert). The *Allocrioceras hazzardi* beds at the top of the Ernst contain the important lower Coniacian inoceramid *Cremnoceramus deformis erectus* (Meek).

Maxwell et al. (1967, pp. 53, 64) reported the ammonites *Sciponoceras* cf. *gracilis* and *Scaphites* from the *Allocrioceras hazzardi* beds. Collections made by the Coopers show that the specimens of *Sciponoceras* are poorly preserved *Baculites* (possibly *B. yokoyamai* Tokunaga and Shimizu) and that the scaphite is *Scaphites semicostatus* Roemer (1852, p. 35; Kennedy et al. 2004, p. 442).

James and Margaret Stevens, Terlingua, Texas, are investigating the San Vicente Member of the Boquillas Formation and the overlying Pen Formation. Many collections of fossils made by them and identified by Keith Young reveal almost all of the Coniacian–lower Campanian ammonite zones recognized by Young (1963). Among the key lower Coniacian to lower Santonian fossils shown by Cooper et al. (2008, table 2) from the San Vicente Member are (in ascending stratigraphic order): *Cremnoceramus deformis erectus* (Meek), *C. crassus crassus* (Petrascheck), *Protexanites bourgeoisianus* (d'Orbigny), and *Cladoceramus undulatoplicatus* (Roemer).

J. D. Powell collected and donated to the U.S. Geological Survey a phragmocone of the scaphitid *Trachyscaphites spiniger* (Schlüter) that came from just outside Big Bend National Park. The specimen (USGS D14461), associated with a worn *Pachydiscus* aff. *P. paulsoni* Young, came from the "Aguja Formation" near the Study Butte road entrance to Big Bend National Park. In terms of the Western Interior sequence of ammonites, *T. spiniger* lies in the upper part of the *Baculites obtusus–B. asperiformis* Zones of Campanian age (*Hoplitoplacenticeras* spp. Zone of present report).

Lehman (1985, fig. 2; 1986, fig. 1) showed the relationship of the Ojinaga, Boquillas, San Carlos, Pen, and Aguja Formations in the Big Bend area. He also showed that the Pen Formation interfingered with the overlying Aguja Formation and that both units rise in age eastward. In a more recent paper, Lehman and Tomlinson (2004, fig. 1) show details of the interfingering and that a westward-thinning marine unit, informally called the McKinney Springs tongue of the Pen Formation, is present near the middle of the Aguja. The McKinney Springs tongue rests on a marine sandstone referred to informally by Lehman and Tomlinson as the Rattlesnake Mountain sandstone member of the Aguja Formation. Fossils collected from this sandstone include *Pachydiscus paulsoni*

(Young), *Baculites maclearni* Landes, and *Hoplitoplacenticeras* cf. *plasticum* (Paulcke).

Pico Etereo

Fossils from the Pico Etereo fluorite district in northern Coahuila, just east of the Big Bend area, were listed by Daugherty and Powell (1963) and Powell (1965). *Euhystrichoceras adkinsi* and *Moremanoceras elgini* at the base of the Boquillas indicate the lower Cenomanian zone of *Forbesiceras brundrettei*. The presence of an undescribed species of the ammonite *Tragodesmoceroides* 75 ft (23 m) above the base of the Boquillas suggests the basal upper Cenomanian zone of *Calycoceras canitaurinum*. The basal Coniacian *Allocrioceras hazzardi* ledge was recorded 282 ft (86 m) above the base of the Boquillas. Limestone of Austin age overlying the Boquillas yielded the middle Coniacian *Gauthiericeras* sp. 40 ft (12 m) above the base, *Cladoceramus undulatoplicatus* and *Texanites texanus* at the lower-middle Santonian boundary 101 ft (31 m) above the base, and the lower Campanian *Bevahites bevahensis* near the top.

Lozier Canyon

Lozier Canyon, a tributary of the Rio Grande, is located in southeast Terrell County, Texas (Sharps 1963). There, the Boquillas and lower part of the Austin are well exposed and quite fossiliferous. Hazzard (1959) referred to them as the Eagle Ford and Austin Formations and presented two graphic sections with a few invertebrate fossils identified by W. S. Adkins. Hazzard showed the Eagle Ford as a threefold formation consisting of a lower shaly member, a thinner middle member of interbedded limestone and calcareous clay, and an upper shaly member. Freeman (1968, pp. 11–18) referred to the formation as the Boquillas Flags and recognized a fourfold division consisting of a basal pinch and swell unit, a flagstone unit, a ledgy unit, and a laminated unit. The pinch and swell unit yielded flattened fragments of *Tarrantoceras sellardsi* that suggest the middle Cenomanian *Acanthoceras amphibolum* Zone, and one large but badly corroded ammonite that appears to be the late Cenomanian *Calycoceras* (*Proeucalycoceras*) *canitaurinum*. Ammonites were not found in the overlying flagstone unit, but the basal part of the ledgy unit (Hazzard's interbedded limestone and clay unit) contains the middle late Cenomanian *Euomphaloceras septemseriatum* fauna mentioned earlier in the present report. A specimen of *Tarrantoceras* (*Sumitomoceras*) *conlini* from this fauna was illustrated by Kennedy (1988, pl. 6, figs. 16, 17). *Mammites* was found near the top of the unit.

Freeman's laminated unit contains *Inoceramus* cf. *dimidius* in the lower half, which suggests a very late middle Turonian age for this part. A late Turonian age is indicated for the upper part of the unit by the presence of *Inoceramus perplexus*, *Nicaisolopha lugubris*, and *Prionocyclus* sp. 6 ft (1.8 m) below the top (USGS D2443). The small oyster *N. lugubris* (Conrad), widely distributed in the Juana Lopez Member of the Mancos Shale in New Mexico, Utah, and Colorado, has been recorded as far south as Coahuila (Böse 1913, pl. 8).

Freeman measured the lower 113 ft (34 m) of his Austin Chalk, which rests conformably on the Boquillas (Freeman 1961, fig. 1). The late Turonian inoceramid *Mytiloides incertus* was collected in the lower 15 ft (5 m) of the Austin, and the early Coniacian *Cremnoceramus* sp. was found approximately 75 ft (23 m) above the base. A specimen of *Peroniceras* was found as float approximately 25 ft (7.6 m) higher.

Hazzard (1959) showed a zone of *Coilopoceras* and *Glebosoceras* in his upper unit (Freeman's laminated unit). *Glebosoceras* is none other than an inflated form of *Coilopoceras*.

Pessagno (1969) investigated the stratigraphy and foraminiferal content of the Upper Cretaceous strata in Lozier Canyon, where he divided the Boquillas Formation into a lower Rock Pens Member of calcareous siltstone, mudstone, and flaggy limestone and an upper Langtry Member of marlstone, marl, and chalky limestone. In the Rio Grande area of Terrell, Val Verde, and Kinney Counties, Pessagno applied the name Austin Chalk, in which he recognized the Atco, Dessau, Burditt, and Big House Members from other areas in Texas.

Del Rio area

The Boquillas Formation and Austin Group crop out in Kinney County southeast of Del Rio. Pessagno (1969) noted outcrops at Sycamore Creek, Cow Creek, Pinto Creek, and Tequesquite Creek and that *Texanites* [*Plesiotexanites*] aff. *T. stangeri densicostus* was found at the last locality. Reeside (1932, pl. 4) illustrated a fragment of the Santonian ammonite *Texasia dentatocarinata* (Roemer) from the Austin at Cow Creek, and Young (1963, p. 120) recorded the species from Tequesquite Creek. Young also recorded *Plesiotexanites shiloensis*, *Reginaites durhami*, *Bevahites bevahensis*, and *Submortoniceras tequesquitense* from Tequesquite Creek and *Texanites texanus* from Cow Creek. The holotype of *Parapuzosia bosei* Scott and Moore came from Tequesquite Creek.

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