A Correlation of the Upper Albian to Basal Coniacian Sequences of Northwest Europe, Texas and the United States Western Interior

---

J.M. Hancock
Department of Geology, Imperial College, Prince Consort Road, London SW7 2BP England

W.J. Kennedy
Geological Collections, University Museum, Parks Road, Oxford OX1 3PW England

W.A. Cobban
United States Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center,
Denver, Colorado 80225 USA

Hancock, J.M., Kennedy, W.J. and Cobban, W.A., 1993, A correlation of the upper Albian to basal Coniacian sequences of northwest Europe, Texas and the United States Western Interior, **in** *Caldwell, W.G.E. and Kauffman, E.G., eds., Evolution of the Western Interior Basin: Geological Association of Canada, Special Paper 39, p. 453-476.*

Abstract

From the base of the middle Cenomanian to the top of the Turonian, there are 27 zonal units recognizable in the Western Interior of the United States. These are correlated with 13 units in northwest Europe. There is a nearly complete succession in trans-Pecos Texas through the upper Albian to the upper part of the Turonian, but in central and northeast Texas there are major gaps.

Twelve zones in the upper Albian-lower Cenomanian of central and northeast Texas can be correlated only approximately, and with difficulty, with nine zones or subzones in northwest Europe.

The closest ammonite connections between North America and Europe were during the late Cenomanian. In contrast, during the earliest Cenomanian, there were very few elements in common between the two continents.

Résumé

Du base du Cénomanien moyen au sommet du Turonien il y a 27 unités zonales ou sous-zonales qu'ont peut reconnaître dans l'intérieur ouest des États-Unis. Ces unités correspondent à 13 unités en nord-ouest Europe. Il y a une succession presque entière de l'Albien supérieur à Turonien haut au delà le fleuve Pecos en Texas, mais il y a des lacunes grandes au milieu et nord-est de Texas.

Douze zones dans l'Albien supérieur-Cénomanien inférieur du milieu et nord-est de Texas ne peuvent être corrélatif qu'approxitivement, et avec difficulté, à neuf zones ou sous-zones en nord-ouest de l'Europe.

Les rapports les plus étroits exprimés par les ammonites entre l'Amerique du Nord et l'Europe étaient pendant le Cénomanien avancé. Par contraste, pendant le Cénomanien le plus ancien il y était très peu d'éléments constitutifs en communs entres les deux continents.

GENERAL PROBLEMS FOR THE CORRELATION

It is an accident in the history of science that the first biostratigraphical studies were in Europe. The stage names used for the Cretaceous System are all derived from localities in Switzerland, France and the Netherlands. Today, the international standards in stratigraphy are based on the most widely traceable isochronous markers (Birkelund *et al.*, 1984; Bassett, 1985). Inasmuch as the fundamental international unit — the stage — is a package of zones, the correlation at zonal level between continents is a pre-requisite to find which markers are most easily traced over wide areas.

There have been remarkably few general attempts to correlate Cretaceous sediments between North America and Europe, other than the assignment of American strata to European stages (*e.g.*, Stephenson *et al.*, 1942; Cobban and Reeside, 1952). Jeletzky (1968) tried to make a correlation at zonal level, but he was hampered by the lack of modern work on the ammonite succession in western Europe; he used zonal schemes introduced by Spath (*e.g.*, 1926) that are now known to be very misleading. Similar problems plagued the detailed correlation attempted by Young (1972) for the Albian to lower Cenomanian between Texas and Europe. Kennedy (1985, 1986) published correlation tables between the two continents, but limitations of space prevented discussion, and, in fact, some of these correlations are modified here.

The scarcity of such attempts at correlation for the Middle to Upper Cretaceous, and for the Albian to Turonian stages in particular, arise from distinct problems.

1. In the far north of the United States and in the Canadian arm of the Western Interior Seaway, a boreal realm was present that contained an ammonite fauna, characterized by gastroplitids, so peculiar that it was almost totally isolated ecologically during the Albian and Cenomanian. During the late Cenomanian and early Turonian, the Canadian-northern United States faunas were more cosmopolitan, but provincialism returned during the mid-Turonian, and late Turonian correlations again became difficult.

2. In southern Texas and Mexico, the ammonite faunas are dominantly Tethyan at most levels. Some of these ammonites straggled into Europe during the late Albian, but, by and large, northwest European ammonites during the late Albian to late Turonian were boreal with few Tethyan invaders, although there is a sufficient sprinkling of cosmopolitan forms to allow the correlations shown in our tables.

3. American endemic ammonites, *e.g., Prionocyclus*, often evolved very fast compared with cosmopolitan genera; this may well be a general feature of endemic faunas. It allows a fine zonation where the endemic ammonites are found, but these numerous zones are then especially difficult to correlate with schemes erected outside the endemic centre.

4. Even cosmopolitan genera gave rise to local offshoots in the United States. This is exemplified by *Acanthoceras* and *Calycoceras* in the middle and upper Cenomanian. One of the advances in our work has been to correlate their horizons with the European succession — having first sorted out the mid-Cenomanian to Turonian successions in Texas.

5. The zonal successions compiled for Europe have been a mixture of partial range-zones, total range-zones and assemblage-zones. The imperfections of this hodge-podge are made worse by the difficulty of using a single family of ammonites to define or name these zones. Ideally, the Cenomanian-Turonian zonation would have been based on the acanthoceratids, for much of their phylogeny is now fairly well known and, geographically, they are a widespread family. In practice, even within the acanthoceratid zonation for part of the Cenomanian Wright *et al.* (1984), it has to be recognized that the change from the Zone of *Mantelliceras dixoni* to the Zone of *Acanthoceras rhotomagense* above is abrupt.

6. American authors have generally been more explicit. From Cobban and Reeside (1952) onward, index species have been used to name total-range-zones or total-range-subzones, *e.g.*, Cobban and Scott (1972), Cobban and Merewether (1983), Cobban and Hook (1979), Hook and Cobban (1979, 1983) and Cobban (1984). When these have been based on a defined phylogenetic series, as in the *Neogastroplites* zones in the Albian-Cenomanian, or the *Hoplitoides-Coilopoceras* lineage in the Turonian, they have been easy to understand, but many of the American zones have also been based on indices that are phylogenetically isolated, *e.g.*, the Zone of *Calycoceras canitaurinum*. Only a geologist with field experience of both regions, or a partnership between geologists from both continents, has a reasonable chance of making reliable correlations.

7. There are unequal concentrations of ammonites between the two continents. They are scarce in the lower Cenomanian of the southern part of the Western Interior of the United States, but not close to the Gulf Coast. They are scarce in much of the Turonian of England except near the base of the stage in Devon and the lower part of *Subprionocyclus neptuni* Zone in the southeast, but are common in the lower Turonian of the Iberian peninsula. Even where ammonites are both relatively frequent and there are many species in common, as in the *Sciponoceras gracile* and *Metoicoceras geslinianum* zones in the upper part of the Cenomanian, many more specimens can be collected in a short time in the United States than in northwest Europe.

Differences in the preservation of the ammonites can also present problems, but these are primarily for the taxonomy rather than for correlation.

8. Parallel evolution in the two continents has not

proved a problem. *Acanthoceras bellense* Adkins in Texas is superficially similar to *Acanthoceras rhotomagense* (Brongniart) in Europe and is the same age (see discussion at the end of note 22). *Romaniceras mexicanum* Jones in New Mexico and Texas seems to differ slightly from *Romaniceras deverianum* (d'Orbigny), (Kennedy and Cobban, 1988), but they both mark the same zone.

THE NORTHWEST EUROPEAN STANDARDS

The Base of the Lower Cenomanian

In southern England, northwest France, western Germany and Switzerland, the base of the Cenomanian is marked by the assemblage Subzone of *Neostlingoceras carcitanense*. The very few species in this assemblage that may also occur in North America are too long-ranging to be of help, *e.g., Hypoturrilites tuberculatus* (Bosc) probably occurs in the Zone of *Budaiceras hyatti*. (See discussion under note 11).

The Base of the Middle Cenomanian

This is marked in northwest Europe by the appearance of *Acanthoceras* and *Cunningtoniceras. Turrilites costatus* Lamarck appears a little below this, but possibly above the highest English *Mantelliceras.*

The Western Interior Zone of *Conlinoceras tarrantense* contains *Cunningtoniceras inerme* (Pervinquière) and *Turrilites* aff. *costatus*. It happens to be the lowest level with ammonites in the Cenomanian of Colorado, but correlates easily with the *T. costatus* Subzone at the base of the middle Cenomanian in Europe.

The Base of the Upper Cenomanian

In Europe, the base of the upper Cenomanian is placed where *Acanthoceras* has disappeared and the acanthoceratid fauna has become dominated by *Calycoceras*. Many of these *Calycoceras*, notably *C. (Proeucalycoceras)* and *Calycoceras* s.s., have a rounded and inflated whorl section as in *C. guerangeri* (Spath) and *C. naviculare* (Mantell). Limited subdivision of the upper Cenomanian based on *Calycoceras* spp. has been made in southern England and northwest France. Thomel (1972) has proposed three zones and six subzones for the upper Cenomanian in Provence; we have not been able to confirm these.

Calycoceras s.s. and closely allied subgenera are rarer in North America than in Europe, but the base of the Zone of *Calycoceras canitaurinum* also marks a level immediately above the highest analogue of *Acanthoceras* in the *Plesiacanthoceras wyomingense* Zone. *C. (Proeucalycoceras) canitaurinum* (Haas) is a rather variable species including a number of forms which are bituberculate flat-ventered in middle growth. The typical form loses its inner ventro-lateral tubercles and develops flat sides and a flat venter at a diameter of about 30 mm.

Metoicoceras appears earlier in the United States than in Europe, but, even in the United States, it was previously thought to be limited to the upper Cenomanian. In fact, northeast Texas *Metoicoceras latoventer* Stephenson occurs in the *P. wyomingense* Zone in the lower part of the Templeton Member of the Woodbine Formation (see note 20).

True *Pseudocalycoceras* in Europe is not known below the upper Cenomanian, but it may occur at a lower level in Israel, where *P. haugi* (Pervinquière) has been recorded as *Protacanthoceras judaicum* (Taubenhaus) from the "Calcaires à *Acanthoceras*" by Avnimelech and Shoresh (1962). In the United States, there are probably no *Pseudocalycoceras* below the *gracile* zone: the record from the *Plesiacanthoceras wyomingense* Zone in Kansas (Hattin, 1975, pl. 4, fig. E) is a misidentification.

The Base of the Lower Turonian

The base of the lower Turonian is taken here at the base of the Zone of *Watinoceras devonense*, which may correspond with the appearance of the earliest *Mytiloides, M. sackensis* (Keller). This definition agrees with the usage in England, where the base of the stage has been placed at the appearance of *Watinoceras* (*e.g.*, Hancock *et al.*, 1977; Wright and Kennedy, 1981). With the recognition that *Watinoceras praecursor* Wright and Kennedy is a distinct species, and that the earliest *Watinoceras* in England is *W. devonense* Wright and Kennedy, we have discontinued the use of a European Zone of *W. coloradoense* (Cobban, 1988a; Kennedy and Cobban, 1991). The succession is more easily disentangled in Colorado than in northwest Europe, where the succession is often complicated by condensation.

In the recent past, we have used the base of the Zone of *Pseudaspidoceras flexuosum* as the standard, which coincides with the base of the Zone of *Mytiloides columbianus; M. columbianus* (Heinz) = *M. opalensis* auct non Böse (Cobban in Kennedy *et al.*, 1987). In the expanded succession on the Rock Canyon anticline, west of Pueblo, Colorado, this is one zone higher than *W. devonense*. For a discussion of other possible definitions of the base of the stage, see Birkelund *et al.* (1984) and Hancock (1984).

The Base of the Middle Turonian

In Touraine in France, a sequence of mid-Turonian zones based on species of *Romaniceras* was worked out by de Grossouvre (1901); the present zones are little more than nomenclatorial modifications of these. *Kamerunoceras turoniense* (d'Orbigny) is the ancestor of *Romaniceras kallesi* Zazvorka and the two species occur together briefly in the St. Cyr en Bourg Fossil Bed near Saumur. Similarly, there are individuals that are intermediate between *R. kallesi* and *R. ornatissimum* (Stoliczka) in the upper part of the Tuffeau Blanc according to Amédro and Badillet (in Robaszynski *et al.*, 1982).

Specialists in France (Robaszynski *et al.*, 1982, fig. 7) and in England (Kennedy, 1984a, table 2) have

Table I

Correlation of the upper Albian and lower Cenomanian.

British Columbia [1, 2]	Montana - Wyoming			Trans - Pecos Texas [3]	Travis County, central Texas [4]	north - east Texas	southern England and northern France	
Beattonoceras beattonense	(no ammonites)	CENOMANIAN	LOWER	Forbesiceras brundrettei [12]	? [13]	▥	Mantelliceras dixoni	
Ireniceras bahani								
Neogastroplites septimus				Acompsoceras inconstans [11]	▥	▥		
Neogastroplites maclearni	Neogastroplites maclearni			Budaiceras hyatti [10]	Budaiceras hyatti [10]	Budaiceras hyatti [10]	Mantelliceras saxbii	Mantelliceras mantelli
	Neogastroplites americanus							
Neogastroplites americanus	Neogastroplites muelleri				(no diagnostic ammonites)	Graysonites lozoi [9]	Neostlingoceras carcitanense	
Neogastroplites cornutus [7]	Neogastroplites cornutus			Graysonites adkinsi	Graysonites adkinsi [8]	Graysonites adkinsi [8]		
Neogastroplites haasi	Neogastroplites haasi	ALBIAN	UPPER	Mariella brazoensis	Mariella brazoensis	Mariella brazoensis	Stoliczkaia dispar	Mortoniceras (Durnovarites) perinflatum
				Mortoniceras sp.	Drakeoceras drakei	Drakeoceras drakei [6]		
					Mortoniceras wintoni	Mortoniceras wintoni [6]		Mortoniceras rostratum
				Drakeoceras cf. lasswitzi	Drakeoceras lasswitzi	Drakeoceras lasswitzi	Mortoniceras inflatum	Callihoplites auritus
				(Mortoniceras equidistans)	Mortoniceras equidistans	Mortoniceras equidistans		Hysteroceras varicosum
				Eopachydiscus marcianus	Eopachydiscus marcianus	Eopacydiscus marcianus		
(no ammonites)				Craginites serratescens		Craginites serratescens		Hysteroceras orbignyi
				(no ammonites)	Adkinsites bravoensis	Adkinsites bravoensis		Dipoloceras cristatum
Stelckiceras liardense				Manuaniceras supani [5]	(no ammonites)	Manuaniceras powelli [5]		
						Manuaniceras carbonarium		

Legend

- - - - - - - - stratigraphical position uncertain or not yet defined

〰〰〰〰 definite paleontological or sedimentological evidence for a break in the succession

———— - - -| uncertain correlation from division on left to successions to the right of the vertical line

▥ probably no sediments of this age

placed the base of the middle Turonian at a coincident base of the zones of *Kamerunoceras turoniense* and *Collignoniceras woollgari*. The only known English specimen of *K. turoniense* came from an unknown locality and horizon (Wright and Kennedy, 1981). In Touraine, Amédro and Badillet have a number of *K. turoniense* and *C. woollgari* from below the St. Cyr en Bourg Fossil Bed (where they are common together), but their own records show that *K. turoniense* extends some 3 m below *C. woollgari* (Robaszynski *et al.*, 1982, fig. 5). Our own collecting in central Tunisia shows that *K. turoniense* there has a considerable overlap with the range of *Mammites nodosoides*.

Consequently, we suggest that the base of the middle Turonian be defined by the appearance of *Collignoniceras woollgari*, which is below the Zone of *R. kallesi*. This definition is easily applied in Texas and the Western Interior because *Collignoniceras* is widespread.

The Base of the Upper Turonian

French and German scientists place the base of the upper Turonian at the base of the Zone of *Romaniceras deverianum* (*e.g.*, Wiedmann, 1979; Amédro and Badillet in Robaszynski *et al.*, 1982). For reasons discussed in detail in note 21, we prefer to use the base of the Zone of *Subprionocyclus neptuni*, which equates with the base of the Zone of *Prionocyclus macombi* in the United States.

THE WESTERN INTERIOR AND TEXAS STANDARDS

The zonation of the Albian-Cenomanian in British Columbia is taken from Warren and Stelck (1969); that in Montana-Wyoming, from Reeside and Cobban (1960), with modifications by Cobban and Kennedy (1989a). The upper Albian and lower Cenomanian zonation in Texas is derived from Young (1967b, 1972) and Young and Powell (1978).

The ammonite zones of the middle Cenomanian to the top of the Turonian in the Western Interior of the United States were described by Cobban (1984); these zones are used here with minor modifications.

The *Conlinoceras tarrantense* Zone was formerly called the *C. gilberti* Zone by Cobban and Scott (1972) who also recognized the *Acanthoceras granerosense* and *A. muldoonense* zones. The *A. bellense* Zone in the Western Interior corresponds to the gap in the zonal record of Cobban and Scott (1972, p. 30).

We now know that *Acanthoceras alvaradoense* Moreman is a synonym of *A. amphibolum* Morrow and these two former subzones are recombined; there is another subzone recognizable between the zones of *A. amphibolum* and *Plesiacanthoceras wyomingense* (Subzone of *A. amphibolum fallense*), but we have not needed to use it here (Cobban, 1987a).

The Zone of *Calycoceras canitaurinum* has also been called the Zone of *Dunveganoceras pondi*, but *D. pondi* is primarily a species of Wyoming and is not known south of Colorado. In some parts of the Western Interior, this zone is divisible into an upper part characterized by *Metoicoceras praecox* Haas and a lower part with an inflated *Metoicoceras* cf. *M. latoventer* Stephenson described from the Templeton Member in northeast Texas.

The Zone of *Metoicoceras mosbyense* has also been called the Zone of *Dunveganoceras albertense* (Warren and Stelck, 1940; Cobban, 1953). In northeast Wyoming, the *M. mosbyense* Zone is probably divisible into three, from bottom to top: *D. problematicum, D. albertense* and *D. conditum* (Cobban, 1988b).

We no longer recognize a separate Subzone of *Vascoceras diartianum*, but it is still true that *Euomphaloceras septemseriatum* first appears above the base of the Zone of *Sciponoceras gracile*.

Berthou *et al.* (1985) have pointed out that *Vascoceras cauvini* Chudeau is probably a synonym of *V. barcoicense* Choffat. This species also ranges up into the Zone of *Neocardioceras juddii.* Therefore, the *V. cauvini* Zone has been renamed the Zone of *Burroceras clydense*, based on the succession in the Big Burro Mountains in southwest New Mexico (Cobban *et al.*, 1989).

The Zone of *Nigericeras scotti* is inserted in the Western Interior column to show its vertical position, which, being below the *W. devonense* Zone, places it within the Cenomanian. To date, the *N. scotti* Zone has not been recognized outside southeastern Colorado, and northeastern and southwestern New Mexico (Cobban and Hook, 1979). The *N. scotti* Zone seems to represent a minimum of ammonite diversity and abundance in the Western Interior succession.

In the excellent section on the Rock Canyon anticline west of Pueblo, Colorado, the appearance of the inoceramid *Mytiloides columbianus* (Heinz), which is one of the possible standards for the base of the Turonian, is in Bed 90, accompanied by *Vascoceras proprium* (Reyment), previously recorded as *V. angermanni* (Böse) (Chancellor, 1982; Cobban, 1985b).

Vascoceras birchbyi is replaced as an index by *Watinoceras coloradoense* s.s. which has a similar range and a much wider geographical distribution. In the Pueblo section, the index species appears in bed 97, 0.46 m above bed 90, and is accompanied by *W.* aff. *devonense* Wright and Kennedy, *Pseudaspidoceras flexuosum* Powell, *Vascoceras birchbyi* Cobban and Scott, *Fagesia catinus* (Mantell), *Neoptychites cephalotus* (Courtiller) and *Puebloites spiralis* Cobban and Scott (Cobban, 1985b).

We find ourselves in some disagreement on the generic assignation of *Ammonites percarinatus* Hall and Meek and have left it here as *Prionocyclus* (?); flared ribs in juveniles and usually weak serration of the keel point to *Prionocyclus*; on the relative strengths of the inner and outer ventro-lateral tubercles, it would be a *Subprionocyclus*. The *P.* (?) *percarinatus* Zone also contains *Collignoniceras vermillionense* (Meek and Hayden) and *C. praecox* Haas.

The Zone of *Scaphites whitfieldi* is so named because the index species is common and widespread. The *Prionocyclus* in this part of the sequence is *P. novimexicanus* (Marcou).

There is, at present, no standard for the base of the Coniacian in ammonite terms in the Western Interior (see note 22).

NOTES ON THE CORRELATION TABLES

1. The Marine Connection Between Canada and the Southern United States

It has been widely agreed that the first north-south connection of the seas from Texas to Alberta was some time during the middle or late Albian; this was the Skull Creek Seaway of McGookey *et al.* (1972). It has also been thought that this connection was broken again before a general Late Cretaceous flooding (*e.g.*, McGookey *et al.*, 1972, fig. 17; Williams and Stelck, 1975, fig. 4). Detailed analyses through time have been by Jeletzky (1971) and Williams and Stelck (1975).

In the southern part of the seaway, there is definite marine Albian in Kansas, represented by the Kiowa Formation, but this dies out northward (Franks, 1975; Witze *et al.*, 1983). The scarcity of dated pre-middle Cenomanian Cretaceous surface sediments, in Utah, Arizona and most of New Mexico and Colorado, has always meant that this marine connection has had to depend upon indirect evidence. On the northern side of the seaway, the Skull Creek Shale (and its equivalent, the Thermopolis Shale) may not extend south of Wyoming.

A faunal connection very early in the late Albian might be indicated by the tethyan genus *Manuaniceras* in northeastern British Columbia (Stelck, 1975)(see note 2). The next faunal evidence is the occurrence of tethyan *Metengonoceras* in the *Neogastroplites* zones of the Mowry Shale in Wyoming and Montana. Until recently, most of these *Neogastroplites* zones were regarded as Albian, but there is now evidence that they are probably Cenomanian (see note 7). The implication is that there may have been no marine connection between Canada and the southern United States across latitudes 35°-37°N during most of the late Albian. How much connection existed during the Cenomanian is uncertain. Until recently, there were no standard lower Cenomanian ammonites known from the Western Interior, but *Mantelliceras* has now been found in the top of the Sarten Sandstone in southwest New Mexico (Cobban, 1987b). From the middle Cenomanian onward, the seaway remained open until some time in the Maastrichtian (regressions 9 and 10 of Kauffman, 1984).

2. Zonation in British Columbia

Below the *Neogastroplites* zones, there are zones based on other gastroplitinid genera. The Zone of *Gastroplites* s.s. has often been thought to contain the base of the upper Albian in the sense agreed by Birkelund *et al.* (1984), because the *Diploceras cristatum* Subzone at Folkestone in England had yielded *Gastroplites cantianus* Spath (1937). However, Jeletzky (1980) assigns the Folkestone specimen to an unrelated genus *Pseudogastroplites.* More important for correlation is the reported occurrence of *Dipoloceras* cf. *fredericksburgense* Scott (Stelck, 1958) and *Manuaniceras* cf. *supani* (Lasswitz) (Stelck, 1975) above the *Gastroplites* Zone in the Zone of *Stelckiceras liardense*; these would indicate that the *S. liardense* Zone marks the base of the upper Albian.

The succession of *Neogastroplites* zones is based on Warren and Stelck (1969). An exact position for *N. muelleri* Reeside and Cobban was not obtained and is omitted from our table.

Above the *Beattonoceras beattonense* Zone and in the Dunvegan Sandstone is found *Inoceramus rutherfordi* which, according to Warren and Stelck (1969), also occurs in the *Acanthoceras amphibolum* Zone in the United States which occurs in the upper part of the middle Cenomanian section.

3. Upper Albian in Trans-Pecos Texas

There are only scattered reports of upper Albian (and lowest Cenomanian) ammonite zones in trans-Pecos Texas and the relationships between them are poorly known. The best account is by Jones and Reaser (1970) for the Southern Quitman Mountains in Hudspeth Country, and the zonation quoted here is derived from their paper. Below the level of *Manuaniceras supani* (Lasswitz) in the lower member of the Benevides Formation, there are no other Albian ammonites of zonal value recorded by Jones and Reaser. Young (1969) said that Jones had collected ammonites of the "zone of *Manuaniceras powelli*" from the Finlay Limestone below the Benevides Formation in the southern Quitman Mountains, but Jones himself records no ammonites from the Finlay Limestone; nor does Córdoba (1969) from nearby Chihuahua. It is possible that Young's record was actually from somewhere in the 120 m of the upper member of the Benevides Formation which contains ammonites that Young spaces out over five zones in north Texas. From the upper member, Jones and Reaser record:

Drakeoceras cf. *lasswitzi* Young
Mortoniceras n. sp.
Oxytropidoceras stenzeli Young
Beudanticeras sp.
Idiohamites fremonti (Marcou)
Ophryoceras sp. (probably *Mortoniceras* s.s.)
Craginites serratescens (Cragin)

Other records of ammonites from the Benevides Formation (undivided) in Hudspeth County include: *Mortoniceras (Boesites) romeri* (Haas) (said by Young (1968) to form a zone whose components overlap with the range of *Craginites serratescens* above and the range of *Adkinsites bravoensis* below) and *M.*

(Boesites) perarmata (Haas). The west Texas-Chihuahua record of *Eopachydiscus marcianus* (Shumard) (= *E. brazoensis* auct) by Kennedy *et al.* (1983a) is from the upper part of the Benevides Formation, and we have numerous *Mortoniceras equidistans* (Cragin) from the same beds. From northeastern Chihuahua, Mexico, there are further records by Córdoba (1969) which include:

Eopachydiscus sp. *Mortoniceras equidistans* (Cragin)
Venezoliceras cf. *trinitense* Gabb
Adkinsites bravoensis (Böse)
Manuaniceras aff. *multifidum* (Steinmann)
Adkinsites diazi Young
Prohysteroceras cf. *austinense* (Römer)
Dipoloceras cf. *fredericksburgense* Scott

The presence of *D.* cf. *fredericksburgense* shows that the Benevides Formation extends down to the Subzone of *Dipoloceras cristatum* that marks the base of the upper Albian in Europe (Birkelund *et al.*, 1984; Owen, 1984, 1985). The other species of Mojsisoviczinae have not been recorded from Europe and correlation is dependent on the general style of the few examples of mortoniceratids; these would indicate the zone of *Mortoniceras inflatum*, that is the lower half of the upper Albian (Owen, 1985), but a finer correlation between trans-Pecos Texas and Europe is not possible at present. There is no evidence for any middle Albian in these assemblages.

Other upper Albian ammonites in the trans-Pecos Texas region are known from the Cerro del Cristo Rey near the junction of New Mexico, Texas and Mexico where the Muleros Formation contains: *Engonoceras serpentinum, Goodhallites burckhardti* (Böse), *Mortoniceras nodosum* (Böse), whereas the Smeltertown Formation contains: *Mortoniceras equidistans* (= *M. trinodosum* (Böse) = *Goodhallites whitei* (Böse)), *Mortoniceras nodosum* (Böse), *Adkinsites bravoensis, Eopachydiscus marcianus.*

The Zone of *Adkinsites bravoensis* is known in Brewster, Presidio, Jeff Davis, Reeves and Pecos counties (Fallon, 1981). There are also a few ammonites from the Sue Peaks Formation and the Del Rio Clay in the Big Bend area (Maxwell *et al.*, 1967).

The presence of the European Zone of *Stoliczkaia dispar* in southwest Texas is shown by the presence of *Mortoniceras equidistans* close to *M. rostratum* (J. Sowerby), in the Smeltertown Formation and probably by the *Stoliczkaia* from the Big Bend area.

4. Upper Albian Zones in Central Texas

The zones in the upper part of the Albian in central Texas, taken from Young (1967b, 1972) are listed to show the connection between trans-Pecos Texas and northeast Texas (about 1000 km apart). Below the *Eopachydiscus marcianus* Zone, the central zonation no longer fits with that in northeast Texas.

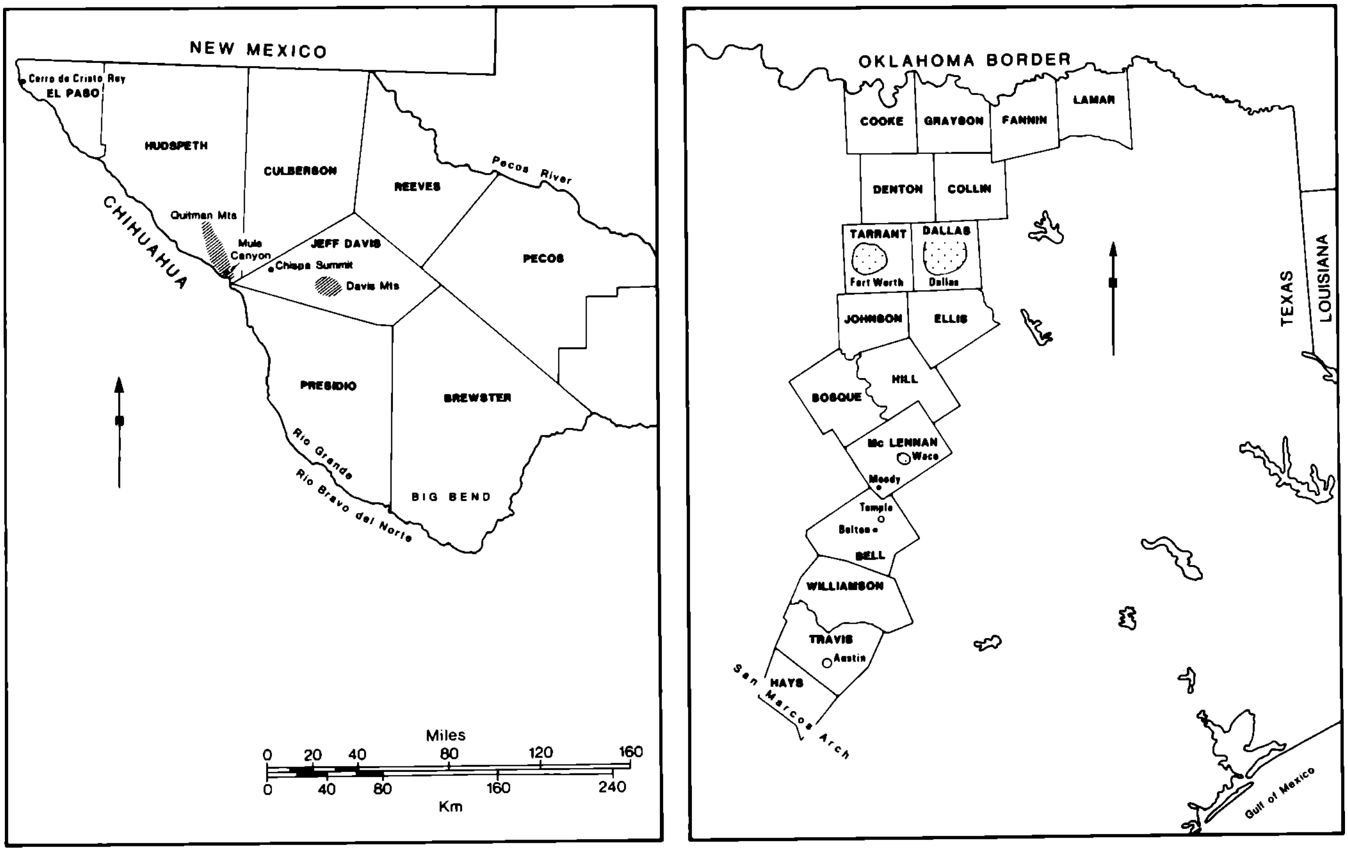

Figure 1. *Localities in Texas; names in bold upper case are counties.*

5. The Base of the Upper Albian in Texas

It is now widely agreed that the base of the upper Albian should be at the base of the Zone of *Dipoloceras cristatum* (Birkelund *et al.*, 1984; Owen, 1985). Many years ago, a few specimens (3?) of this index species were collected from the top of the Goodland Limestone, northwest of Fort Worth (Adkins, 1928). According to Young (1972), these specimens of *D. cristatum*, together with the allied species *D. fredericksburgense* Scott (also known from the *D. cristatum* Subzone at Folkestone in England), came from the Zone of *Manuaniceras powelli* in northeast Texas. Hence, we place the base of the upper Albian at the base of the *M. powelli* Zone.

However, Owen (1971, p. 136) equates the *Dipoloceras cristatum* Subzone with the Zone of *Manuaniceras carbonarium* below the *M. powelli* Zone. This is based on the similarity of *Oxytropidoceras cantianum* Spath (from the *D. cristatum* Subzone at Folkestone) to *Manuaniceras carbonariuim* transitional to *M. peruvianum multifidum* (Steinmann) in Texas.

6. The *Stoliczkaia dispar* Zone in Central and Northeast Texas

It is not possible at present to say where the base of the *Stoliczkaia dispar* Zone falls in the central and northeast Texas successions. According to H.G. Owen (*in litteratis*), the index species of the Zone of *Mortoniceras wintoni* (Adkins) is "a true *Mortoniceras*, closely comparable to *M. (Mortoniceras) crassissima* (Kilian) of *Callihoplites auritus* subzone age." This is based on the holotype of *M. wintoni* which came from the upper part of the Weno Member in Cooke County. According to Wilbert (1967), in Bell County, this species ranges from somewhere in the Fort Worth Limestone through the Denton and Weno Formations. In Johnson and Tarrant counties, *M. wintoni* is not known below the Weno Formation and is more common in the upper half (McGill, 1967). In the J.P. Conlin collections at Denver, there are examples of *M. wintoni* occurring with *M. (Durnovarites)* in the Weno Formation at the Diamond L Ranch in Tarrant County and the B. Bell Farm in Johnson County: *M. (Durnovarites)* is a characteristic subgenus of the Subzone of *Mortoniceras (Durnovarites) perinflatum* at the top of the Albian (= the Vraconian of French authors) (unless one believes that *Mortoniceras rostratum* (J. Sowerby) is also a *Durnovarites*). Similarly, in Travis County, Young (1957) records *M. (Durnovarites) adkinsi* Young from the upper part of his Zone of *Drakeoceras drakei*; in the lower part of the *D. drakei* Zone, he records *M. wintoni*. From these records, it looks as though the base of the *S. dispar* Zone lies somewhere in the Weno Formation in Johnson and Tarrant counties; that it probably corresponds with the base of the *D. drakei* Zone; that the *Mortoniceras rostratum* Subzone (*sensu* Owen, 1985) of Europe is thin or not separately recognizable in Texas. In the absence of clearer indicators of the *Callihoplites auritus* and *M. rostratum* subzones, this can only be approximate.

The index species *Mortoniceras equidistans* (Cragin), in the upper part of the Duck Creek Formation, is the senior synonym, of *M. kiliani* (Lasswitz) (Young, 1967a; Cobban, 1985a). Spath (1932, 1933, pl. 38, figs. 1, 2; pl. 47, fig. 1) illustrated several ammonites he called *M. kiliani* that came from the *M. rostratum* Subzone; these are actually a form with two lateral tubercles, in addition to the umbilical and ventro-lateral ones, that is now named *M. (M.) alstonensis* (Breistroffer) (Owen, 1985). *M. equidistans* with only one lateral tubercle is an earlier species whose equivalents in Europe appear as early as the *Hysteroceras varicosum* Subzone (H.G. Owen, *in litt.*).

Young (1957) recorded *Mortoniceras (Durnovarites) adkinsi* as ranging up into the lower part of the Zone of *Mariella brazoensis*, but that is in Travis County almost over the San Marcos Arch where the wholly carbonate representation of the Albian contains gaps in the record (Young, 1986b). In northeast Texas, a tongue of more argillaceous sediment, the Pawpaw Formation, comes in north of Hill County above the Weno Formation and below the Main Street Limestone. It is the lower part of the Pawpaw Formation that is the more fossiliferous (Adkins, 1920; McGill, 1967) and yields *Mortoniceras (Durnovarites) spinosum* (Pervinquière) (= *Mortoniceras worthense* Adkins, 1920, pl. 1, fig. 19) and *Stoliczkaia worthense* (Adkins) (= *Acanthoceras worthense* Adkins, 1920, pl. 1, fig. 12; examination of the type series at Austin shows that Kennedy and Hancock (1971, p. 443) were wrong to compare this species with *Mantelliceras saxbii* (Sharpe)) which together provide a good correlation with the *Mortoniceras (Durnovarites) perinflatum* Subzone in Europe.

We do not know any records of *Mariella brazoensis* from the Pawpaw Formation, in spite of the diagrammatic indications in Young (1979, figs. 3 and 4).

The overlying Main Street Limestone is more contentious. The commonest ammonite of this formation, but more common in the upper part (McGill, 1967), is *Mariella (Wintonia) brazoensis* (Shumard), a species indigenous to Texas and possibly long-ranging. K. Young (personal communication) reports that *Durnovarites* and *Drakeoceras* overlap with *M. brazoensis* in the lower part of the Main Street Limestone south of Hill County, but Young (1986a) states that there is still a considerable thickness between the highest mortoniceratid and the lowest mantelliceratid. In fact, there are mortoniceratids in the Main Street Limestone north of Hill County: in the J.P. Conlin collection from "Upper Mainstreet, Creek Bank in Meadowbrook Golf Course"; and possibly on route 114 several hundred metres west of route 377, northwest of Roanoke, Denton County (JMH, field notes). Yet Young (1979) is correct in listing *Graysonites* in the Main Street

Limestone; they were recorded as *Mantelliceras* n. spp. from the "transition zone" between the Main Street Limestone and the Grayson [Marl] Formation by Adkins (1933, p. 384-385). In the Conlin collection, there are three *Graysonites* from the "transition zone" in the Walker Branch upstream from the bridge in HaltomCity (Fort Worth), at what is now the junction of route 121 and the NE loop 820: *G. adkinsi, G. lozoi* and *G.* intermediate between *G. adkinsi* and *G. wooldridgei* Young.

We have no evidence that *Graysonites* and mortoniceratids overlap or occur together, but the gap between the two must be small.

7. Albian-Cenomanian Boundary in British Columbia to Wyoming

The *Neogastroplites* fauna is unknown outside this region (Jeletzky, 1980; Owen, 1988). The foraminifera are also largely endemic (Caldwell and North, 1984). For many years, the boundary in Canada has been taken by convention at the base of a "fish-scale marker bed", which can be traced from the Peace River area of British Columbia to the Wilson River in the Manitoba escarpment; this puts the boundary immediately beneath the Zone of *N. maclearni* (Warren and Stelck, 1969), although other authors, *e.g.*, Caldwell and North (1984), put this zone also in the Albian.

Re-examination of the *Metengonoceras* from Montana and Wyoming by Cobban and Kennedy (1989a) shows that *M. aspenanum* (Reeside and Weymouth) occurs with *Neogastroplites americanus* (Reeside and Weymouth), and *M. teigenense* Cobban and Kennedy occurs with *N. muelleri* Reeside and Cobban. *M. aspenanum* closely resembles *M. bravoense* (Böse) from the lower Cenomanian Grayson Formation (= Del Rio Clay), 7 km south of McGregor, McLennan County, Texas (*Graysonites adkinsi* or *G. lozoi* zone). Similarly, *M. teigenense* appears to be related to *M. dumbli* (Cragin) from the middle and upper Cenomanian of north Texas (and elsewhere) and to *M. acutum* Hyatt from the upper Cenomanian of north Texas. There are no known Albian species of *Metengonoceras* that resemble these Wyoming-Montana species. It is almost certain that the zones of *N. muelleri* and *N. americanus* are Cenomanian, and the Zone of *N. cornutus* may be. No *Metengonoceras* have been found in the Zone of *N. haasi.*

8. The Base of the Cenomanian Stage in Texas

Some improvement in resolution for the Albian-Cenomanian boundary in Texas is now possible beyond the discussions by Mancini (1979, 1982), Hancock (1984) and Young (1986a). The main problem has always been that the characteristic ammonites of the Zone of *Hypoturrilites schneegansi* in Tunisia and in the equivalent Subzone of *Neostlingoceras carcitanense* in France, England and Germany are absent in Texas (and elsewhere in North America). The most oft-quoted and sometimes the commonest genera close to the boundary in Texas are either rare outside Texas and northern Mexico, *e.g., Graysonites*, known from Japan, northern Spain, north Africa and Israel; or unknown with certainty elsewhere, *e.g., Mariella (Wintonia)* (= *Plesioturrilites* auct in Texas), possibly present in the upper Albian of Switzerland and the lower Cenomanian of France.

Mancini (1979) described the following interval zones in the Grayson [Marl] Formation in northeast Texas, and these were quoted by Hancock (1984):

Mariella (Wintonia) rhacioformis
Mariella (Wintonia) bosquensis
Graysonites lozoi
Graysonites adkinsi
Mariella (Wintonia) brazoensis,

but only the bottom 0.5 m of the Grayson Formation was in the *M. (W.) brazoensis* Zone, most of which was represented by the underlying Main Street Limestone.

However, Mancini's records differ from Young's (1979, figs. 3 and 4) which show the range of *Mariella brazoensis* and *Graysonites adkinsi* overlapping, with both species occurring throughout the Main Street Limestone (and even down into the Pawpaw Formation) in Grayson County and *G. adkinsi* continuing into the Grayson Formation in northeast Texas. K. Young (personal communication) has found no *G. adkinsi* below 2 m from the top of the Main Street.

Young (1958a, 1979, 1986a) has consistently recognized three zones above the *Drakeoceras drakei* Zone in the Albian and below the *Budaiceras hyatti* Zone in the Cenomanian:

Graysonites lozoi
Graysonites adkinsi (with *G. wooldridgei*
    and *G. fountaini*)
Mariella (Wintonia) brazoensis.

We venture to suggest that neither of these zonations is yet clearly established. *Graysonites*, at least as limestone moulds, is a scarce genus: in his original description, Young had only two specimens of *G. lozoi* and only about a dozen specimens of the genus. The possibility exists that each of Young's species has a longer range. In our experience, the commonest ammonite genus in much of the Main Street Limestone and in the Grayson Formation from McLennan to Denton Counties is *Mariella (Wintonia).*

The degree of confusion is shown at the section at the Waco Dam spillway, west of Waco in McLennan County. The essential descending succession as recorded by Mancini (1982) and seen by ourselves is:

Pepper Shale 1 m +	shales with ferruginous concretions and beds of siltstones; at base, an oyster-bearing sandstone with pebbles of limestone resting disconformably on unit below.
Del Rio Clay (Grayson Formation in description by Mancini)	0.5 m of nodular wackestone with many fossils as internal moulds.
some 15 m exposed	some 14 m of clays with occasional thin marlstone beds. Many fossils, the cephalopods as internal moulds of nuclei in pyrite or limonite.

The nodular wackestone at the top of the Del Rio Clay has yielded:

Mariella (Wintonia) rhacioformis Clerk - common
Mariella (Wintonia) cf. *bosquensis* (Adkins) - common
Engonoceras cf. *bravoense* Böse
Stoliczkaia (Lamnayella) sp.
Stoliczkaia sp. (= (?) *Paracalycoceras* sp., Mancini, 1982, fig. 7b)
Graysonites wooldridgei (= *Mantelliceras saxbii* of Mancini, 1982, fig. 7a)
Sharpeiceras (= *Sharpeiceras mexicanum* of Mancini, 1982, fig. 6c).

From the main mass of the Del Rio Clay, the commonest of the ammonite nuclei are the local *Mariella (Wintonia)*, but the other ammonites include:

Submantelliceras aumalense (Coquand) (= *Mantelliceras brazoense* Böse)
Submantelliceras wacoense (Böse)
Stoliczkaia (Lamnayella) juv. (= *Mantelliceras* cf. *cantianum* of Mancini, 1982, figs. 4g, 4h)

The general tenor of the assemblage from the wackestone could be interpreted as belonging to Mancini's *Mariella rhacioformis* Zone of northeast Texas which is the only one of his zones in the Grayson Formation that is said to contain *Stoliczkaia (Lamnayella)* and *Sharpeiceras*; but the lower index species *M. bosquensis* is equally common, whilst *G. wooldridgei* is said to characterize the *Graysonites adkinsi* Zone. This assemblage is certainly dated as Cenomanian by the *Sharpeiceras*, a genus unknown below the Cenomanian in northwest Europe, north and south Africa, all regions with a good ammonite succession across the Albian-Cenomanian boundary. Two valuable conclusions follow: (1) at least part of the *Graysonites adkinsi* Zone is truly Cenomanian; and (2) *Sharpeiceras* itself ranges down to the *G. adkinsi* Zone in Texas; in southern England, it appears in the *Neostlingoceras carcitanense* Subzone at the base of the Cenomanian, but ranges up to the *Mantelliceras saxbii* Subzone or higher (Wright and Kennedy, 1984).

The assemblage from the main part of the Del Rio Clay may also be Cenomanian. The *Submantelliceras* spp. show inner, as well as outer, ventrolateral tubercles. No nuclei of the Stoliczkainae-Acanthoceratidae lineage from the *Stoliczkaia dispar* Zone (top Albian) in Europe and north Africa that we have examined to date show such double tuberculation. We assign (as Mancini did) these Texan nuclei to *Submantelliceras* because re-examination of the holotype of *Mantelliceras brazoense* Böse shows that this species is a synonym of *S. aumalense* (Coquand) *sensu* Pervinquière. The holotype of *M. brazoense* (Böse, 1928, pl. 6, figs. 7, 8, 26, 27) has a slightly narrower venter (as noted by Böse himself) and much weaker inner ventro-lateral tubercles, but paratypes include individuals that are indistinguishable (compare Böse (1928, pl. 6, figs. 42-43) with Pervinquière (1910, pl. 4, figs. 16a-b)).

We have retained the name *Graysonites* in this paper, but like Matsumoto (1960) and others, we suspect that *Graysonites* is a junior synonym of *Submantelliceras* (Spath, 1923) type species *S. aumalense* (Coquand). The problem is that there are few specimens of *Graysonites* (preserved as internal moulds in limestone) that are small enough to provide a connection with the pyritic or limonitic nuclei of *Submantelliceras*. The smallest *Graysonites* illustrated by Young (1958a), the inner whorls of the holotype of *G. lozoi*, shows no ornamentation corresponding to a diameter of less than 30 mm (in pl. 27 of Young, 1958a, the magnifications of figs. 1, 2, 6, 7, 9 and 10 are incorrectly stated as twice the real sizes). Young himself has suggested that some of Böse's species of *Submantelliceras* are probably nuclei of *Graysonites*.

Purely in ammonite terms, the position of the Zone of *Mariella brazoensis* is still uncertain. Young (1986a) produced arguments in favour of regarding this zone as Cenomanian, but the main representative is the Main Street Limestone, and Young extends the zone down into the Pawpaw Formation. As indicated in note 6, there are Albian mortoniceratid ammonites known from the Main Street Limestone, even north of Hill County.

9. Zones in the Grayson Formation in Northeast Texas

Mancini (1979) assigned the bulk of the Grayson Formation in northeast Texas to two zones above that of *Graysonites lozoi*: *Mariella (Wintonia) bosquensis* below and *Mariella (Wintonia) rhacioformis* above. However, we have both these species in some number from the same bed that has yielded *Graysonites wooldridgei* in the *G. adkinsi* Zone at Waco Dam spillway (see note 8).

10. The Age of the Buda Limestone

The Zone of *Budaiceras hyatti* is represented almost entirely by the Buda Limestone, which extends from northern Mexico into central Texas, but becomes discontinuous north of Bell County. In the far north of Texas, in Grayson County, it is represented by the marly Modlin Limestone within the upper part of the Grayson Formation, and the Grayson Formation above the Modlin Limestone is still part of the *B. hyatti* zone (Young, 1979, p. 6). The situation may be the same in the local development of Buda Limestone in the southern part of Denton County. In central Texas (*e.g.*, Travis County), the Buda Limestone is some 15 m thick, with a marked disconformity in the middle, and ammonites are common only in the lower part (Martin, 1967); not more than six specimens are known from the upper member (Young, 1967a). In trans-Pecos Texas, the formation expands to 105 m (Reaser, 1970).

We have been able to examine a considerable range of the ammonites from the Buda Limestone (K. Young, personal communication) and much of the assemblage has a very low Cenomanian appearance. Many of the species of *Stoliczkaia* are endemic to the region. The following look like pre-*Mantelliceras saxbii* Subzone forms: *Stoliczkaia (Stoliczkaia) crotaloides (Stoliczka), S. (S.) scotti* Breistroffer, *S. (Faraudiella) texana* (Shattuck), *S. (F.) roemeri* (Lasswitz), *S. (F.) archerae* Young, *S. (F.) franciscoensis* (Kellum and Mintz). *Hypoturrilites roemeri* (Whitney) falls within the range of variation of *H. gravesianus* (d'Orbigny), but this is a relatively long-ranging species.

The small number of specimens of *Mantelliceras* suggest that the Buda Limestone belongs to the European Subzone of *M. saxbii.* Among the specimens we have seen are: *M. saxbii* (Sharpe) (the holotype of *Acanthoceras hoplitoides* Lasswitz as indicated by Young, 1979, p. 20; and UT 45662, both from Austin); *M. lymense* (Spath) (UT 42856 from San Francisco Creek in Brewster County; and probably UT 18012 from the lower member of the Buda Limestone, Onion Creek, Travis County); *M.* aff. *cantianum* Spath (BEG 34022, the holotype of *M. budaense* Adkins, from the top of the Buda Limestone at Bear Creek, 0.8 km (0.5 mile) west of Manchaca, Travis County). A *M. saxbii* Subzone age is supported by the presence of *Sharpeiceras laticlavium* (Sharpe) which is not known above this level in England (Wright and Kennedy, 1987).

There are two different possible stratigraphic interpretations of these ammonites. The lower member, with the great variety of *Stoliczkaia* spp., could correlate with the Subzone of *Neostlingoceras carcitanense* in Europe, and the upper member, from which possibly all the *Mantelliceras* derive except one *M. lymense* (a relatively long-ranging species), equates with the *Mantelliceras saxbii* Subzone of Europe. Alternatively, the whole formation represents only one subzone, as Young (1979, p. 13) believes, in which case it belongs to the *M. saxbii* Subzone and the *Stoliczkaia* spp. represent a relict fauna.

The commonest genus, *Budaiceras*, is nearly endemic to the region; the only known example from outside Texas and northern Mexico that can actually be demonstrated by its suture line not to be a malformed *Schloenbachia*, came from the Zone of *Mantelliceras dixoni* of Haute Normandie, France (Kennedy *et al.*, 1990). This fits with the possibility that the Buda Limestone extends higher in Mexico because *M. charlestoni* Kellum and Mintz may not be *M. cantianum* (as Young has stated), and it looks like a *M. dixoni* Zone variety.

11. *Acompsoceras inconstans* Zone in West Texas

The lowest beds with ammonites in the Chispa Summit Formation at Chispa Summit (Jeff Davis County) are probably distinctly older than the *Forbesiceras brundrettei* Zone, but they also contain *Acompsoceras* cf. *inconstans* (Schlüter) (and possibly other species of *Acomposoceras*), a species which in northwest Europe is known only from the lower Cenomanian Zone of *Mantelliceras dixoni.*

Some 50 km to the west, in the southern Quitman Mountains (Hudspeth County), bed A of Powell (1963), in the basal part of the Ojinaga Formation, yields an equivalent assemblage (Cobban and Kennedy, 1989b). The Ojinaga Formation is much thicker than the Chispa Summit Formation, and the lowest ammonite assemblage occurs some 7 m above the Buda Limestone in Mule Canyon (within lower flaggy unit shown in fig. 1 of Kennedy *et al.*, 1987). In addition to numerous *Moremanoceras bravoense* Cobban and Kennedy, we have: *Acompsoceras inconstans* (= *Pseudacompsoceras bifurcatum* Powell), *Stoliczkaia (Lamnayella) chancellori* Wright and Kennedy, *Ojinagiceras ojinagaense* Cobban and Kennedy (correct generic spelling chosen here), *Hypoturrilites* sp. cf. *gravesianus* (d'Orbigny) and *Inoceramus* aff. *arvanus.* Again, this assemblage correlates with the *Mantelliceras dixoni* Zone.

12. Zone of *Forbesiceras brundrettei*

The level of the *Forbesiceras brundrettei* Zone outside trans-Pecos Texas was something of a problem until recently. The fauna was originally described from a geographically and stratigraphically isolated assemblage from the base of the Boquillas Formation in the Davis Mountains, Jeff Davis County, Texas (Young, 1958b). The Chispa Summit occurrence shows that it lies below the *Acanthoceras bellense* Zone; the co-occurrence of *Oslingoceras* sp., *Hypoturrilites youngi* Clark and *Mariella* cf. *cenonanensis* (Schlüter) show that the zone is lower Cenomanian, whilst the presence of *Acompsoceras* strongly suggests the *Mantelliceras dixoni* Zone of Europe.

Table II
Correlation of the middle and upper Cenomanian (legend as for Table I).

		Western interior of the U. S. A.	Trans - Pecos Texas 14	Travis County, central Texas	Bell and McLennan Counties, central Texas 15		Dallas County, Texas		north Texas	southern England and northern France	
TURONIAN		Watinoceras devonense	(not recognised)						?	Watinoceras devonense	
CENOMANIAN	UPPER	Nigericeras scotti	(no ammonites)								
		Neocardioceras juddii	Neocardioceras juddii							Neocardioceras juddii	
		Burroceras clydense	(no ammonites)							(not recognised)	
		Sciponoceras gracile	Sciponoceras gracile		Sciponoceras gracile ?	Lake Waco Limestone and Shales	Sciponoceras gracile 16	Britton [Shale] Formation		Metoicoceras geslinianum	
		Metoicoceras mosbyense	(no ammonites)		(no ammonites)		(no ammonites)			Calycoceras guerangeri	
		Calycoceras canitaurinum	Calycoceras canitaurinum 17						Templeton Member 18		
	MIDDLE	Plesiacanthoceras wyomingense	(no ammonites)							Acanthoceras jukes-brownei	
		Acanthoceras amphibolum		Acanthoceras amphibolum 19	Acanthoceras amphibolum		Acanthoceras amphibolum	Six Flags Limestone Mbr.	?	Turrilites acutus	Acanthoceras rhotomagense
		Acanthoceras bellense	Acanthoceras bellense 20		Acanthoceras bellense 21		?	?			
		Acanthoceras muldoonense	(no ammonites)							Turrilites costatus	
		Acanthoceras granerosense									
		Conlinoceras tarrantense					Conlinoceras tarrantense 21	Tarrant [Sandstone] Formation			

13. The Pepper Shale in Central Texas

As did Adkins and Lozo (1951), we have not found any identifiable ammonites in the Pepper Shale. However, the United States Geological Survey collection contains ammonites from an old brickpit on Cloice Branch, southwest of Waco, McLellan County (USGS 14592), that were thought to have been from the Bluebonnet or Cloice Member of the overlying Lake Waco Formation, but they are clearly a *Forbesiceras brundrettei* Zone assemblage and must have come from the Pepper Shale: *Forbesiceras brundrettei* (Young), *Moremanoceras elgini* (Young) and *Ostlingoceras brandi* Young (see also Kennedy and Cobban, 1990).

14. Trans-Pecos Texas

The top lower Cenomanian and Turonian zonal succession in trans-Pecos Texas is based on work in progress by Kennedy, Cobban, Hancock and Hook on the Chispa Summit Formation in Jeff Davis County.

15. Middle to Upper Cenomanian in Bell and McLennan Counties

The base of the Lake Waco Formation contains fish debris, granules of lignite and phosphatic pebbles resting disconformably on the Pepper Shale. Only 0.5 m above this are local lenticular developments of very fossiliferous limestone that yield the fauna of the Zone of *Acanthoceras bellense* (see note 21). Where this is absent there are alternations of limestones and shales with an *A. amphibolum* Zone fauna that rest directly on the Pepper Shale. The common ammonites in the *A. amphibolum* Zone here are *Tarrantoceras sellardsi* (Adkins) (= *T. rotatile* Stephenson) and *Moremanoceras straini* Kennedy, Cobban and Hook, with *A. amphibolum* itself less common. Both the *A. bellense* and *A. amphibolum* zones occur within the lower part of the Bluebonnet Member of the Lake Waco Formation.

The upper part of the Bluebonnet Member is a lagoonal deposit (Silver, 1963) and hence lacks ammonites. The occurrence of ammonites in the overlying Cloice and Bouldin Members is discontinuous and much of the Bouldin Flags Member may represent a saline lagoon (Young, 1986b). Our knowledge of this part of the succession is still largely dependent on the work of Adkins and Lozo (1951). They seem to have confused three different ammonite faunas in their zone 4: their Pepper Creek assemblage is from the *Acanthoceras bellense* Zone; their zone that "covers most of the Lake Waco Unit" includes elements, *e.g., "Mantelliceras" sellardsi* of the *A. amphibolum* Zone referred to above; they also list ammonites that would suggest a still higher assemblage, including their "*Calycoceras (Eucalycoceras) bentonianum*" (= *Tarrantoceras (Sumitomoceras) bentonianum* (Cragin), "*Proplacenticeras*" (= *Placenticeras cumminsi* Cragin), "*Allocriceras pariense*" (= *Allocrioceras annulatum* (Shumard)). This apparent *Sciponoceras gracile* Zone fauna extends to the top of the Lake Waco Formation in McLennan County according to Adkins and Lozo (1951, p. 136), but we ourselves have not seen any post-*Acanthoceras amphibolum* Zone Cenomanian fossils from these counties. There is then a break that includes the rest of the upper Cenomanian, the whole of the lower Turonian and most of the middle Turonian, the base of the South Bosque Marl belonging to the Zone of *Prionocyclus hyatti.*

16. The Zone of *Sciponoceras gracile* in Northeast Texas

The Zone of *Sciponoceras gracile* in Texas and the Western Interior is the equivalent of the Zone of *Metoicoceras geslinianum* in northwest Europe, although *M. geslinianum* is recorded with *Vascoceras "cauvini"* in Israel *(Lewy et al.*, 1984), a species generally considered to be characteristic of the higher *Burroceras clydense* Zone (Cobban, 1984; Cobban *et al.*, 1989). Of the whole succession under discussion in this paper, the *S. gracile* and *M. geslinianum* zones show the closest correspondence in ammonite assemblages between North America and northwest Europe. Even so, there are but seven species in common between the two continents: *Calycoceras (Calycoceras) naviculare* (Mantell), *Pseudocalycoceras angolaense* (Spath), *Euomphaloceras septemseriatum* (Cragin), *Metoicoceras geslinianum* (d'Orbigny), *Allocrioceras annulatum* (Shumard), *Sciponoceras gracile* (Shumard), *Worthoceras vermiculus* (Shumard). In addition, the rare subgenus *Tarrantoceras (Sumitomoceras)*, confined stratigraphically to this zone, is found in Texas, southern England and northern France.

Typical of the two regions, a greater number of taxa is known in Texas (18 genera, some 26 species; see Kennedy, 1988) than in northwest Europe (12 genera, 12 species in southern England from the records in Wright and Kennedy, 1981). Some of this more limited variety in England is probably a matter of the poor preservation of ammonites in the Chalk compared with the good preservation in the shale of the Britton Formation of northeast Texas.

17. Zone of *Calycoceras canitaurinum* in West Texas

Only two fragments of the index species have been found in the Chispa Summit Formation (and it is unknown east of the Pecos), but the presence of *Inoceramus prefragilis* Stephenson supports the presence of the *Calycoceras canitaurinum* Zone.

18. The Templeton Member in Northeast Texas

This, the uppermost member of the Woodbine Formation, is formed of shales and sands, some glauconitic, poorly exposed from central Denton County northward to Grayson County, eastward to eastern Lamar County in the far northeast of Texas on the Oklahoma border. Taxonomic revisions can be found in Kennedy and Cobban (1990), but we are almost completely dependent on Stephenson (1953) for our knowledge of the internal stratigraphy. An analysis of his records suggests that the following descending succession can be recognised:

(Eagle Ford Shale)

locality 167, 9 m below the summit: *Tarrantoceras cuspidum* (Stephenson), *Metengonoceras dumbli* (Cragin).

locality 154, 13.5 m below the summit: *Tarrantoceras cuspidum, Metoicoceras latoventer* Stephenson. *Metengonoceras dumbli, "Acanthoceras* sp." (Stephenson, 1953, pl. 46, figs. 5, 6). *Moremanoceras* ?, *Inoceramus prefragilis* Stephenson.

locality 201, about 7.5 to 9 m above the base: *Metoicoceras swallovii* Shumard).

locality 164, about 6 m above the base: *Plesiacanthoceras bellsanum* (Stephenson), *Metoicoceras crassicostae* Stephenson, *M. latoventer, Metengonoceras dumbli.*

(Lewisville Member of the Woodbine Formation with *Acanthoceras amphibolum*)

The top two assemblages correlate with the Zone of *Calycoceras canitaurinum: Tarrantoceras cuspidum* and *Metoicoceras* aff. *latoventer* occur in this zone in the Black Hills. The bottom assemblage probably correlates with the *Plesiacanthoceras wyomingense* Zone. The level with *Metoicoceras swallovii* is still stratigraphically slightly enigmatic between these two zones.

19. The Cenomanian Above the Buda Limestone in Travis County

The Buda Limestone is overlain disconformably by some 4.5 m of black Pepper Shale (Adkins, 1933, p. 436), of uncertain age, but, by comparison with Bell County, it must be older than the *Acanthoceras bellense* Zone, which suggests the *Forbesiceras brundrettei* Zone.

The Pepper Shale is, in turn, overlain disconformably by about 3.5 m of Lake Waco [Shales] Formation, whose upper flaggy portion yielded a range of ammonites, listed in Adkins and Lozo (1951, p. 157). We have not seen these ammonites, but the names they used are those for the assemblage from the *Acanthoceras amphibolum* Zone further north; and there is a *Tarrantoceras sellardsi* (Adkins) from these beds just north of the county border near Round Rock about 16 km north of Austin.

20. Zone of *Acanthoceras bellense* in West Texas

We have four fragments of the index species from the Chispa Summit Formation (better specimens are known from the Davis Mountains) supported by the zonally characteristic *Paraconlinoceras leonense* (Adkins) and abundant *Ostrea beloiti.*

21. *Conlinoceras tarrantense* and *Acanthoceras bellense* Zones

These two zones are geographically isolated in Texas: the *Conlinoceras tarrantense* Zone is in the Tarrant Formation of the Eagle Ford Group in Denton and Tarrant Counties; the *Acanthoceras bellense* Zone lies in the basal part of the Bluebonnet Member of the Lake Waco Formation of the Eagle Ford Group, best known in Bird Creek (= Pepper Creek) between Belton and Temple, but probably extending northward in McLennan County (Silver, 1963). These two areas are some 180 km apart. Both contain turrilitids that correlate them with the Zone of *Acanthoceras rhotomagense* in northwest Europe; the general appearance of their ammonites is sufficiently similar for Moreman (1942) to have recorded both assemblages as coming from a single "Tarrant Formation". Yet a closer examination of the faunas reveals that there is no species in common. The lists, including revisions in Kennedy and Cobban (1990), are:

Acanthoceras bellense Zone:
  Anagaudryceras involvulum (Stoliczka)
  Puzosia sp.
  Forbesiceras cf. *chevillei* (Pictet and Renevier)
  Acanthoceras bellense Adkins - common
  Cunningtoniceras lonsdalei Adkins
  Conlinoceras sp.
  Paraconlinoceras leonense (Adkins) - outnumbers all other species together.
  Calycoceras (Newboldiceras) sp.
  Hamites cimarronensis (Kauffman and Powell)
  Sciponoceras sp.
  Turrilites acutus Passy
  transitions between *Turrilites costatus* Lamarck and *T. acutus*

Conlinoceras tarrantense Zone:
  Conlinoceras tarrantense (Adkins) - very common
  Paraconlinoceras barcusi (Jones)
  Cunningtoniceras inerme (Pervinquière)
  (= *Acanthoceras? eulessanum* Stephenson)
  Forbesiceras conlini Stephenson
  Metengonoceras dumbli (Cragin) - common
  Turrilites dearingi Stephenson - rare
  (There are also species from the Tarrant Formation in northeast Texas that may not be from the same horizon, *e.g., Johnsonites* (Stephenson, 1953, pl. 45, figs. 5, 6)

The possibility that the *Conlinoceras tarrantense* Zone of north Texas is younger than the *Acanthoceras bellense* Zone of central Texas might be suggested by:

(a) The ammonite-bearing Tarrant Formation rests on a disconformity on top of the Arlington Member (Dodge, 1969), but is transitional into the overlying Templeton Member.

(b) All four specimens of *Turrilites* from the Tarrant Formation are closely allied to *Turrilites acutus* and there are no specimens transitional to the normally older *T. costatus* that do occur in the *A. bellense* Zone.

(c) Stephenson (1953) recorded from the *C. tarrantense* Zone: *Acanthoceras hazzardi* (= *A. amphibolum*) of the overlying zone; *Inoceramus prefragilis* which is a *Plesiacanthoceras wyomingense* Zone species in north Texas and extends into the *Calycoceras canitaurinum* and *Sciponoceras gracile* zones in Kansas (Hattin, 1975).

(d) *Paraconlinoceras barcusi* (Jones) could be a derivative of *P. leonense*.

(e) The *A. bellense* fauna looks closer to its European analogues at the base of the *A. rhotomagense* Zone, *i.e.*, the *A. bellense* Zone represents the start of a genetic separation from Europe.

(f) The next ammonites above the *C. tarrantense* assemblage in northeast Texas are already in the *A. amphibolum* Zone (in the Six Flags Limestone Member of the Woodbine Formation).

Nevertheless, we believe that the *Conlinoceras tarrantense* Zone is the older and that the *Acanthoceras bellense* Zone is not only younger, but younger than the *A. muldoonense* Zone of Colorado, because:

(a) *Conlinoceras gilberti* Cobban and Scott although not conspecific with *C. tarrantense* is certainly very close taxonomically, and presumably stratigraphically.

(b) *A. bellense* occurs above *Acanthoceras muldoonense* Cobban and Scott in the Kaycee section in Wyoming. For the *C. tarrantense* and *A. bellense* zones to be even contiguous, they would both have to lie between the *A. muldoonense* and *A. amphibolum* zones (see also Cobban, 1987a).

(c) In the one area outside Texas that yields *C. tarrantense*, namely west-central New Mexico, it is accompanied by *Johnsonites sulcatus*, a species that was recorded by Stephenson (1953, as *Euhoplites* ?, pl. 45, figs. 5, 6) from Denton County at a horizon that he considered to be *C. tarrantense* Zone. *Johnsonites sulcatus* is known principally from Colorado and Wyoming in the *C. tarrantense* Zone.

(d) *Inoceramus eulessanus*, whose holotype came from Euless Member of the Woodbine Formation in north Texas below the *C. tarrantense* Zone, ranges in the Western Interior from the *C. tarrantense* to the *A. muldoonense* zones. Therefore, if the *C. tarrantense* Zone adjoins the *A. bellense* Zone, the *C. tarrantense* Zone must lie below because in the *A. bellense* Zone and upward *Inoceramus arvanus* Stephenson occurs, as in the *A. amphibolum* Zone. The type locality of *A. hazzardi* is definitely in the *A. amphibolum* Zone, not the *C. tarrantense* Zone as misleadingly suggested by Stephenson (1953). Similarly the type locality of *Inoceramus prefragilis* is so far north of the Tarrant Formation, near the Dallas-Fort Worth airport, that its biostratigraphic horizon is questionable. It seems that Stephenson's lithological boundaries become younger northeastward from the Dallas-Fort Worth area, which would be expected from the pattern of deposition.

We conclude that the *Acanthoceras bellense* Zone is higher than the *Conlinoceras tarrantense* Zone. One notes that near Dallas-Fort Worth airport, the Tarrant Formation is overlain by a phosphate nodule bed; this marks a biostratigraphic break in which lies the *A. bellense* Zone. *Paraconlinoceras barcusi* is ancestral to *P. leonense*, not *vice versa*. The two zones are almost homotaxial, representing the same transgressive surge.

In European terms, these two Texan zones and the *Conlinoceras tarrantense* to *Acanthoceras muldoonense* zones in Colorado fall into the lower part of the middle Cenomanian. Of the species in the *C. tarrantense* Zone, only *Cunningtoniceras inerme* occurs with certainty in the old world: all accurately dated specimens come from the Subzone of *Turrilites costatus*. When there were only two known specimens of *Turrilites dearingi*, we considered it to be synonymous with *T. acutus* Passy, but now that we have four specimens, we find that they all have the strong bottom row of tubercles exposed on the outer surface; with a less squat helix and smaller apical angle than European species. In 1970, we referred 1.8% of the specimens of *Acanthoceras* from the *T. costatus* and *T. acutus* subzones at Rouen in France to transitions between *A. rhotomagnese clavatum* and *A. adkinsi* Stephenson (= *C. tarrantense*) (Kennedy and Hancock, 1970, fig. 9); we now regard this as homeomorphy rather than genetic relationship.

In the *Acanthoceras bellense* Zone, the turrilitids suggest correlation with the Subzone of *Turrilites acutus* in Europe. It is true that it contains rare passage forms to *T. costatus*, but the total range of this species is from high in the lower Cenomanian, *i.e.*, below the appearance of *Acanthoceras* and *Calycoceras*, extending to low in the upper Cenomanian. *Forbesiceras chevillei* is found in the lower Cenomanian of England, but *Forbesiceras* spp. commonly have rather a long stratigraphic range. No other species of the *A. bellense* Zone of stratigraphic significance has been found in Europe. The commonest species, *Paraconlinoceras leonense*, does not even have an analogue in the old world. Juveniles of *Acanthoceras bellense* (and its variants named by previous authors: *A. pepperense* Moreman, *A. stephensoni* Adkins, *A. validum* Moreman and *A.* aff. *sherborni* Moreman, refigured by Kennedy and Cobban, 1990) are similar in general appearance to juveniles of *A. rhotomagense* (Brongniart) of Europe, but, at equivalent whorl proportions, the Texan species is more densely ribbed, all the tubercles are stronger, the ribs cross the venter, and there are separate siphonal tubercles beyond the stage where they are lost in European species. The adults are strikingly different. At present, we regard *A. bellense* as a stratigraphical analogue with nearly homeomorphic juveniles of *A. rhotomagense* rather than representing a different stratigraphical horizon.

22. The Lowest Coniacian in the Western Interior

The earliest known Coniacian ammonite horizon in the Western Interior is marked by a smooth and slender *Forresteria (Forresteria), F. peruana* (Brüggen). It occurs in the Mancos Shale in north-central and northwest New Mexico, accompanied by *Inoceramus* gr. *frechi* Flegel, an inoceramid which, in Lower Saxony in Germany, is associated with the lower *Didymotis* eco-event and also occurs for some metres above this; the *I.* aff. *frechi* Zone is regarded in Germany as lying just below the base of the Coniacian (Wood *et al.*, 1984). In the absence of scaphitids in the New Mexican assemblage, we cannot place this horizon in the *Scaphites corvensis-S. preventricosus* sequence.

The lowest previously quoted Coniacian zone in the Western Interior is that of *Scaphites preventricosus* (*e.g.*, Cobban, 1976). This contains *Forresteria (Forresteria) alluaudi* (Boule, Lemoine and Thevenin) (= *F. stantoni* Reeside, = *F. forresteri* Reeside, = *Alstadenites sevierense* Reeside, = *Harleites castellense Reeside*) which in Madagascar, Zululand and the Beausset Basin of Var in France is accompanied by *Peroniceras (Peroniceras) tridorsatum* (Schlüter) of the middle Coniacian (Klinger and Kennedy, 1984; Kennedy, 1984b). In the Western Interior, this zone contains *Inoceramus (Cremnoceramus) deformis* Meek which, in Germany, marks the third inoceramid zone up in the Coniacian (Wood *et al.*, 1984).

In France, *Forresteria (Forresteria)* is preceded by a lower Coniacian zone characterized by *Forresteria (Harleites)*, the Zone of *F. (Harleites) petrocoriensis* which is the *Barroisiceras haberfellneri* of de Grossouvre (1894) from the basal Coniacian in Aquitaine, the type region. The only common ammonite in this zone is the index-species. This older *Forresteria* species has not yet been found in the Western Interior.

23. The Lowest Coniacian in Trans-Pecos Texas

The highest fossil assemblage in the Chispa Summit Formation at USGS D11173 contains *Inoceramus (Cremnoceramus)* cf. *rotundatus* Fiege and *I. (C.) waltersdorfensis* Andert. In Lower Saxony, these inceramids are commonly regarded as marking the base of the Coniacian and occur in a narrow

Table III

Correlation of the Turonian and lower Coniacian (legend as for Table I).

		Western Interior of the U. S. A.		**Chispa Summit Trans - Pecos Texas**		**Travis County, central Texas**	
CONIACIAN		Forresteria alluaudi	Scaphites preventricosus	(inoceramid assemblage) 23		Peroniceras haasi 24	Austin Chalk
	22	Forresteria sp. 22		(no diagnostic fossils)			
TURONIAN	UPPER	Prionocyclus quadratus	Scaphites corvensis		Chispa Summit Formation		'condensed zone'
		Scaphites whitfieldi		Scaphites whitfieldi 26			
		Prionocyclus wyomingensis	Scaphites ferronensis	?			
			Scaphites warreni	Prionocyclus wyomingensis			
		Prionocyclus macombi	Coilopoceras inflatum	Coilopoceras inflatum			
	27		Coilopoceras colleti	(no fossils)		29	
	MIDDLE	Prionocyclus hyatti	Coilopoceras springeri	Coilopoceras springeri		Coilopoceras springeri	
			Hoplitoides sandovalensis	(not recognised)			
		Prionocyclus (?) percarinatus					
		Collignoniceras woollgari	C. woollgari regulare	C. woollgari regulare			
			C. woollgari woollgari	C. woollgari woollgari		? 32	
	LOWER	Mammites nodosoides		(no exposure)			
				Mammites nodosoides			
		Watinoceras coloradoense		(not recognisable)	26		
		Pseudaspidoceras flexuosum		**Pseudaspidoceras flexuosum** 26			
		Watinoceras devonense		**(not recognised)**			

band some 17 m beneath the appearance of *Micraster cortestudinarium*, the old zonal index used in Europe (Wood *et al.*, 1984). At Dover in southeast England, *I.* cf. *rotundatus* also occurs below the lowest appearance of *M. cortestudinarium*, but immediately above a *Forresteria (Harleites) petrocoriensis* (Gale and Woodroof, 1981). In inoceramid terms, this Chispa Summit assemblage is younger than the Mancos Shale horizon with the slender species *Forresteria peruana* referred to above.

24. The Base of the Austin [Chalk] Group in Central Texas

Smith (1981) included the "condensed zone " (see note 29) in the Atco Formation of the Austin Group, but the top of the "condensed zone" is itself a disconformity. The oldest known ammonites from the Austin [Chalk] Group in Travis County are the two specimens of *Peroniceras haasi* Young recorded by Young (1963), one from "the basal 15 ft", one from "the basal 20 ft". In spite of many authors' belief that there are lower Coniacian *Peroniceras* in both France and Zululand, *Peroniceras* is a middle to upper Coniacian genus (Klinger and Kennedy, 1984; Kennedy, 1984b). It is, of course, still possible that there is lower Coniacian beneath these ammonites in Travis County.

Further to the south and west from Travis County, the development of the Austin Group starts earlier. In Kinney County, the Atco [Chalk] Formation, at the base of the Austin Group, rests directly on the Boquillas Formation (Smith, 1981). Along the Rio Grande, the Atco Formation has yielded *Prionocyclus hyatti.*

25. The Base of the Austin [Chalk] Group in Northeast Texas

We have seen *Baculites* of Coniacian aspect only 1 m above the base of the Austin Group between Arlington and Dallas. From 2 m above the base at Cedar Hill Scarp, just outside Belt Line Road on the southwest side of Dallas, we have *Inoceramus (Cremnoceramus) deformis* Meek in an early form that, according to Kauffman *et al.* (1978), characterizes the upper part of the lower half of the *Scaphites preventricosus* Zone — which is already middle Coniacian (see note 22). Smith (1981) places this chalk in the nannofossil-zone of *Lucianorhabdus cayeuxii.*

26. The Turonian in the Chispa Summit Formation

The Zone of *Scaphites whitfieldi* is based on the presence of *Prionocyclus novimexicanus* (Marcou) and *Inoceramus perplexus* Whitfield.

Table III *(continued)*

Bell and McLennan Counties central Texas		Dallas County, Texas		north Texas	Touraine, France		southern England
	Austin Chalk Gp.	25	Austin Chalk Gp.				
	South Bosque [Shales] Fm.			Maribel Shale Member			Forresteria petrocoriensis
28 Prionocyclus sp.nov.					(ammonites very rare)		Subprionocyclus neptuni
(not recognised)							
Prionocyclus macombi				Bells Ss. Mbr.			
Prionocyclus hyatti		30 Prionocyclus macombi Coilopoceras springeri	Arcadia Park [Shales] Fm.	(not recognised)	Romaniceras deverianum	Collignoniceras woollgari regulare	Collignoniceras woollgari
		Hoplitoides sandovalensis					
		(not recognised)	31		Romaniceras ornatissimum		
		C. woollgari regulare 33	Kamp Ranch Lst. Mbr.				
					Romaniceras kallesi Kamerunoceras turoniense	C. woollgari woollgari	
					Mammites nodosoides		Mammites nodosoides
		Watinoceras coloradoense	Britton [Shale] Fm.		(not recognised)		(not recognised)
		Pseudaspidoceras flexuosum			(not recognised)		?
					(not recognised)		Watinoceras devonense

Prionocyclus wyomingensis and *Coilopoceras inflatum* occur together in the Chispa Summit Formation, indicating an overlap of the *Prionocyclus wyomingensis* and *P. macombi* zones.

The *Coilopoceras* graveyard of Powell (1965) belongs to the Subzone of *Coilopoceras springeri*, which also contains *Romaniceras mexicanum* Jones and *Inoceramus* cf. *cuvieri* which provide a correlation with the upper half of the *Collignoniceras woollgari* Zone in England.

Ammonites of the Subzone of *Collignoniceras woollgari regulare* occur in the hiatus bed of Kennedy *et al.* (1977) and for some metres below and above, including *C. woollgari regulare, Romaniceras ornatissimum (Stoliczka)* and *Spathites (Spathites) coahuilensis* (Jones). The occurrence of *R. ornatissimum* shows that the hiatus bed correlates with the upper part of the Tuffeau de Bourré at Bourré (Touraine) and Poncé (Sarthe) in France. This confirms that upper part of the Tuffeau de Bourré belongs to the *C. woollgari regulare* Subzone, as foreshadowed by Kennedy *et al.* (1983b). The ammonites are accompanied by *Mytiloides mytiloides* (Mantell), a species which occurs through the Western Interior in the *Mammites nodosoides* and *C. woollgari* zones, but which in northwest and central Europe is confined to the *M. nodosoides* Zone (Tröger, 1981; Mortimore, 1986). A similar anomaly is found with *Mytiloides subhercynicus* Seitz which at Chispa is found more than 10 m above the highest *C. woollgari*, which occurs in the *C. woollgari* Zone in the Western Interior, but which in central and western Europe marks a level high in the *M. nodosoides* Zone (Tröger, 1981).

Although the index species of the Zone of *Mammites nodosoides* has not been found at Chispa Summit, there are typical *M. nodosoides* Zone indices such as *Morrowites depressus* (Powell), *M. wingi* (Morrow) and *Mytiloides mytiloides* (Mantell). *Mammites nodosoides* has been recorded at Gold Hill near the northern limit of Jeff Davis County (Hook and Cobban, 1983), and is accompanied there by *Kamerunoceras turoniense* (d'Orbigny).

27. The Base of the Upper Turonian Stage

At present, there is no universally agreed-upon formal definition for subdividing the Turonian stage into lower, middle and upper sub-stages. Nevertheless, it has long been customary in both Europe and America to use such sub-stage divisions.

In Britain, the base of the upper Turonian has coincided with the base of the Zone of *Subprionocyclus neptuni*. This boundary is locally convenient because it corresponds in the Chiltern Hills to the Chalk Rock, a complex of hardgrounds that forms a mappable horizon. There are now small numbers of *Romaniceras deverianum* in England that have been collected from the Caburn Sponge Bed in Sussex (Mortimore, 1986) which lies high in the *C. woollgari* Zone. This confirms previous more generalized records of the horizon of *R. deverianum* which were from the old English mid-Turonian Zone of *Terebratulina lata (e.g.*, Gaster, 1932; Hancock *et al.*, 1977; Wright and Kennedy, 1981). This *C. woollgari* Zone assignment is reinforced by the fact that not a single *R. deverianum* is known from the thousands of ammonites collected from the *S. neptuni* Zone. The point is emphasized because, as recently as 1981, Wright and Kennedy (p. 60) did not know which collignoniceratid zone *R. deverianum* came from.

In France, following the practice of de Grossouvre, the top zone of the upper Turonian has been named the Zone of *Romaniceras deverianum*, but this was because *R. deverianum* was the youngest index ammonite that de Grossouvre could find in the type Turonian of Touraine. The top third of the stage is represented by the Tuffeau Jaune, a relatively condensed formation, some 25 m thick, with many glauconitized disconformities. The few specimens of *R. deverianum* from a recorded level came from near the base of the Tuffeau Jaune, probably from the same horizon as *Coilopoceras requienianum* (d'Orbigny). Until recently, it was also difficult in France to relate the horizons of *R. deverianum* to the *Collignoniceras-Subprionocyclus* lineage. De Grossouvre (1901, p. 336) recorded *Romaniceras deverianum* and *C. requienianum* with *Gauthiericeras bravaisi, i.e.*, with a probable *Subprionocyclus*. We have never seen *Subprionocyclus* from low in the Tuffeau Jaune, although we have two specimens from higher levels (Kennedy *et al.*, 1984, p. 44).

From the eastern side of the Paris basin, there are now three specimens of *Romaniceras deverianum* from some metres below the base of the *Subprionocyclus neptuni* Zone at Champs-Dey (Amédro *et al.*, 1982) and there are two *Collignoniceras woollgari* from the same quarry (Kennedy *et al.*, 1986), confirming English records that *R. deverianum* is a *C. woollgari* Zone species.

It was formerly thought that *Romaniceras deverianum* occurred with *Subprionocyclus neptuni* in the hill at Uchaux in southeast France (Roman and Mazeran, 1913), but the recent careful records of Devalque *et al.* (1983) show that *R. deverianum* occurs only in the Grès Jaunes à Cucullea, and there commonly, and does not range into the overlying Grès de Boncavail of the *S. neptuni* zone with a variety of *Subprionocyclus* spp. (*S. hitchinensis, S. neptuni, S. branneri, S.* cf. *normalis*). This agrees with our own field observations. In France also, *R. deverianum* occurs below the *S. neptuni* Zone, but French geologists place the *R. deverianum* horizons in a Zone of *R. deverianum* of the upper Turonian.

In the United States Western Interior, there has long been a difficulty in relating to this European zonation. *Collignoniceras* is widespread in the Western Interior and in Texas, but gave rise to *Prionocyclus*, whereas in Europe it evolved into *Sub-*

prionocyclus. Several *Prionocyclus* spp. have been considered as possible *Subprionocyclus* relatives, but these comparisons do not stand up to critical examination. Thus, *P. macombi* Meek has the same general appearance as *S. hitchinensis* (Billinghurst), but *P. macombi* shows the typical *Prionocyclus* variation in the strength of the ribs above a diameter of 7 mm; has fewer really short ribs; has more sharply defined shoulders; and in general is more evolute. Similarly, *Ammonites percarinatus* Hall and Meek was formerly assigned to *Subprionocyclus* (Cobban, 1983, p. 18), but it, too, may be a *Prionocyclus*. It might be thought that the top of the *C. woollgari* Zone was at the same level in the two continents, but we reject this view; we equate the base of the *S. neptuni* Zone of Europe with the base of the *P. macombi* Zone in the United States for the following reasons.

a. Small numbers of *Romaniceras* have been found in Texas and New Mexico. At Chispa Summit, in western Jeff Davis County, in the hiatus bed described by Kennedy *et al.* (1977), there are *R. ornatissiumum (Stoliczka)* with *Collignoniceras woollgari*, as in Touraine. About 20-30 m above this, in the "Coilopoceras graveyard" of Powell (1965), one finds *Prionocyclus hyatti* (Stanton) and *Coilopoceras springeri* Hyatt, accompanied by *Romaniceras mexicanum* Jones. This *Romaniceras* is kept specifically distinct by Kennedy and Cobban (1988), but Hancock considers it to be no more than a geographical subspecies of *R. deverianum*, some of the apparent differences arising from differences of preservation.

Romaniceras mexicanum is also known from the *Hoplitoides sandovalensis* Subzone of the *Prionocyclus hyatti* Zone in New Mexico (Cobban, 1984), while fragments of *Romaniceras* sp. are found in the higher *Coilopoceras springeri* Subzone.

This places the base of the *Subprionocyclus neptuni* Zone above the Zone of *Prionocyclus hyatti*.

b. The *Coilopoceras* in the "graveyard" at Chispa Summit belong to the species *C. springeri* Hyatt. Of the succession of coilopoceratid subzonal indices in the United States (Cobban and Hook, 1980), *C. springeri* is the species closest to the European *C. requienianum* (d'Orbigny), a species known to be associated with *R. deverianum* at Uchaux, but also ranging into the *S. neptuni* Zone (Devalque *et al.*, 1983).

Coilopoceras evolved from *Hoplitoides* in the middle of the Zone of *Prionocyclus hyatti* (Cobban and Hook, 1980). Therefore horizons with *C. requienianum* in Europe cannot be older than mid-*P. hyatti* Zone; *C. springeri* is the earliest species of *Coilopoceras*.

c. Further direct correlation is provided by *Baculites undulatus* d'Orbigny. In Europe, this is stratigraphically restricted to the *Subprionocyclus neptuni* Zone in England (Wright, 1979) and at Uchaux in France (Devalque *et al.*, 1983). In Texas and New Mexico, this baculitid occurs in the *Prionocyclus macombi* and *P. wyomingensis* zones.

d. Independent evident that the European *Collignoniceras woollgari* Zone extends up to include the *Prionocyclus hyatti* Zone is given by the presence of *Inoceramus cuvieri* in the *P. hyatti* Zone in the Western Interior and at Chispa Summit in Texas.

A few individuals of *Prionocyclus* are now known from Germany. They are *P. germari* (Reuss) from the Zone of *Subprionocyclus* aff. *normalis* (= upper half of the more generalized *S. neptuni* Zone), 3 m above the "Micraster event" and below the Rothenfelde Grünsande in Westphalia (Kaplan, 1986).

28. The Turonian in McLennan County, Texas

Although the Eagle Ford Group thins southward from about 120-145 m in Dallas County to some 60 m at Waco in McLennan County, approximately 150 km to the south-southwest, there is almost no overall change in thickness between the Arcadia Park [Shales] Formation and their lithological equivalent the South Bosque [Shales] Formation (both around 37 m). The zonal representation in the Turonian is very different.

The lower and lower middle Turonian, already condensed and incomplete in the "Kamp Ranch Limestone Member" of Norton (1965) in Dallas County, probably disappears altogether in McLennan County. Adkins and Lozo (1951) recognized that, near Moody, a break existed somewhere near the base of the South Bosque Formation, and Pessagno (1969) also found foraminiferal evidence for a non-sequence in the Lake Waco Formation, some 3-4 m below the South Bosque Formation, but the boundary is not precisely located within a 3 m sampling interval. We have *Prionocyclus* cf. *hyatti* from flaggy limestones around the base of the shales of the South Bosque Formation, while Adkins and Lozo (1951, p. 136) record ammonites about a couple of metres below this that sound like the *Sciponoceras gracile* Zone (which would fit with Pessagno's foraminiferal dating for high in the Lake Waco Formation). The highest Cenomanian and all of the Turonian up to the *Prionocyclus*(?) *percarinatus* Zone is probably missing.

Prionocyclus hyatti in the bottom 10 m of the South Bosque [Shales] Formation are accompanied by *Metaptychoceras crassum* Kennedy and *Worthoceras minor* Kennedy that also occur in the *Coilopoceras springeri* Subzone in trans-Pecos Texas. Somewhere in the middle of the Formation, there are crushed *Prionocyclus macombi* Meek. The top 7 m yield numerous *Prionocyclus bosquensis* Kennedy (possibly with affinities to both *P. wyomingensis* and *P. novimexicanus* (Marcou)) and *Inoceramus perplexus* Whitfield, indicating the *S. whitfieldi* Zone, up to 1 m beneath the Austin [Chalk] Group. Thus, the South Bosque [Shales] Formation has a more complete representation of the upper Turonian than the Arcadia Park [Shales] Formation, but the *P. quadratus* Zone still seems to be missing.

29. The *Coilopoceras springeri* Subzone in Central Texas

Resting disconformably on marls of the South Bosque Formation and overlain disconformably by chalk of the Austin [Chalk] Group, there is about 1 m of grey chalky marl in Travis County known as the "condensed zone" (Adkins, 1933; Smith, 1981). It contains dark green glauconite and phosphatic nodules and has yielded many ammonites (though many of those in museum collections contain limonite rather than glauconite grains, which may be due to weathering or they could have come from a minor condensed bed some 5 m down in the marls of the South Bosque Formation): *Coilopoceras springeri* (very common), *Prionocyclus hyatti* (moderately common), *Romaniceras (Romaniceras) mexicanum* Jones, *Puzosia (Puzosia) serratocarinata* Kennedy and Cobban, *Parapuzosia (Austiniceras)* cf. *seali* Clark, *Baculites yokoyamai* Tokunaga and Shimizu, *Scaphites carlilensis* Morrow, *Worthoceras minor* Kennedy. This assemblage indicates the *C. springeri* Subzone.

This "condensed zone" is the only known ammonite-bearing Turonian in Travis County.

30. The Turonian of Northeast Texas

The Turonian succession in northeast Texas is based on field work by two of the authors (JMH and WJK) helped by R.J. Parish, principally in Dallas County (see also Kennedy, 1988).

There is no evidence of any upper Turonian in the Dallas area other than the possible base of the *Prionocyclus macombi* Zone.

This break beneath the Austin Group decreases as one goes north from Dallas toward the border with Oklahoma. The thin sandstones at the top of the main mass of shales of the Arcadia Park Formation of the Eagle Ford Group in Dallas County expand in Grayson County into the Bells Sandstone Member whose top has yielded the upper Turonian index *Prionocyclus* cf. *wyomingensis* Meek. Overlying the Bells Sandstone Member is the Maribel Shale Member, still part of the Eagle Ford Group, of uncertain Late Turonian age (McNulty, 1966). Smith (1981) described the Ector Chalk of the Austin Group resting conformably on the Maribel Shale Member some 13 km east of Sherman in Grayson County.

31. The Arcadia Park [Shales] Formation in Northeast Texas

We have one *Prionocyclus* cf. *macombi* Meek only 1 m below the chalk of the Austin Group and *Prionocyclus hyatti* (Stanton) ranges from about 3 m below the Austin Group down to perhaps 10 m above the "Kamp Ranch Limestone Member". A thin sandstone about 4 m below the Austin Group has yielded *Nicaesilopha bellaplicata bellaplicata* (Shumard) which is evidence for the *Coilopoceras springeri* Subzone. Some 17 m beneath the Austin Group, the *P. hyatti* are accompanied by *Scaphites carlilensis* Morrow and the *Hoplitoides sandovalensis* Subzone bivalve *N.* cf. *bellaplicata novimexicana* (Kauffman). *Hoplitoides sandovalensis* Cobban and Hook itself occurs with *P. hyatti* some 10 m above the "Kamp Ranch Limestone Member".

We have not seen the bottom 10 m of the Arcadia Park [Shales] Formation and these may well contain the *Prionocyclus.* (?) *percarinatus* Zone.

32. South Bosque [Shales] Formation in Travis County, Texas

The top 5 m of shales beneath the Austin Chalk are usually referred to as the South Bosque Formation. We have found no ammonites, but an inoceramid from Oak Haven Waterfall, some 10 km north of Austin, which is *Mytiloides subhercynicus* (Seitz), is comparable to forms from the *Collignoniceras woollgari* Zone.

33. The "Kamp Ranch Limestone Member" in Northeast Texas

About two-thirds of the way up the Eagle Ford Group in Denton, Dallas and Ellis counties, there are 1-4 m of shales and silty-shales with lenses of shell-hash limestone and occasional continuous beds of limestone, together known as the "Kamp Ranch Limestone Member" (Norton, 1965). In some areas, *e.g.*, southern Denton County, the member expands to include ordinary shales which can easily be confused with the shale of Britton Formation below or shale of the Arcadia Park Formation above. Moreman (1927) recorded *Collignoniceras woollgari* through a thickness of 20 feet in eastern Denton County, but some of these were probably *Prionocyclus hyatti.* J.D. Powell collected several *C. woollgari regulare* from shales said to have been below the limestone, *i.e.*, from the Britton Formation along the Mansfield Road in southwest Dallas County.

We have been able to collect from the "Kamp Ranch Limestone Member" exposed temporarily in 1973 in southwest Dallas beside Loop 12 about 400 m south of Route 80.

"Kamp Ranch Limestone Member" shelly limestone, probably bituminous, with *Collignoniceras woollgari regulare* (Haas), *Scaphites larvaeformis* Meek and Hayden	tens of cm
Britton [Shales] Formation	
3. silty shales with much shell-hash and occasional phosphatic lumps *Placenticeras* sp., *Watinoceras* cf. *reesidei* Warren, *W. coloradoense* (Henderson), *Mammites* sp., *Metaptychoceras* sp., *Baculites yokoyamai* Tokunaga and Shimizu, *Mytiloides columbianus* Heinz.	*ca.* 2.3 m

2. brown-grey shell-hash and shale; top gradational, base sharp disconformable; *Watinoceras* cf. *reesidei, Mytiloides columbianus* 0.06-0.2 m

(sharp break)

1. buttery blue shale; ammonites of the *Sciponoceras gracile* Zone within 0.3 m of top to 6 m

We have seen no evidence of the *Collignoniceras woollgari woollgari* Subzone of the *Mammites nodosoides* Zone here or elsewhere in northeast Texas. Unit 3 contains a mixture of *Watinoceras coloradoense* and *Pseudaspidoceras flexuosum* Zone ammonites. The two species from unit 2 indicate the zone of *Pseudaspidoceras flexuosum* which rests directly on shales of the *Sciponoceras gracile* Zone. This is good evidence for the absence of the *Burroceras clydense, Neocardioceras juddii* and *Nigericeras scotti* zones in the Dallas area, and confirms the unconformity suggested by Norton (1965).

It is possible that at some other localities mentioned by Norton (1965) the equivalents of units 2 and 3 have also been included in the "Kamp Ranch Limestone Member".

ACKNOWLEDGEMENTS

We are grateful to H.G. Owen, C.W. Wright and K. Young for advice from their wide knowledge of Cretaceous ammonites. Ray Parish has given us much help in the field, both in North America and Europe. J.M.H. and W.J.K. are indebted to the Natural Environment Research Council and the Royal Society for research support over many years. This paper is a contribution to the International Geological Correlation Programme (IGCP) project on mid-Cretaceous events under the chairmanship of R.A. Reyment.

REFERENCES

Adkins, W.S., 1920, The Weno and Pawpaw Formations of the Texas Comanchean: University of Texas, Bulletin 1856, p. 3-172, pls. 1-11.

Adkins, W.S., 1928, Handbook of Texas Cretaceous Fossils: University of Texas, Bulletin 2838, 385 p., 37 pls.

Adkins, W.S., 1933 (misdated 1932), The Mesozoic systems in Texas, *in* Sellards, E.H., Adkins, W.S. and Plummer, F.B., eds., The Geology of Texas: University of Texas, Bulletin 3232, p. 239-518.

Adkins, W.S. and Lozo, F.E., 1951, Stratigraphy of the Woodbine and Eagle Ford, Waco area, Texas, *in* Lozo, F.E., ed., The Woodbine and Adjacent Strata of the Waco Area of Central Texas: Fondren Science Series, no. 4, p. 105-175.

Amédro, F., Colleté, C., de Saint-Aubin, J.P. and Robaszynski, F., 1982, Le Turonien supérieur à Romaniceras (Romaniceras) deverianum de l'Aube (France), Géologues du Bassin de Paris, Bulletin d'Information, v. 19, p. 29-37.

Avnimelech, M.A. and Shoresh, R., 1962, Les céphalopodes cénomaniens des environs de Jérusalem: Société Géologique de France Bulletin, série 7, v. 4, p. 528-535, pl. 15.

Bassett, M.G., 1985, Towards a "common language" in stratigraphy: Episodes, v. 8, p. 87-92.

Berthou, P.Y., Chancellor, G.R. and Lauverjat, J., 1985, Revision of the Cenomanian-Turonian ammonite *Vascoceras* Choffat, 1898, from Portugal: Servicos Geológicos de Portugal Comunicações, v. 71, p. 55-79.

Birkelund, T., Hancock, J.M., Hart, M.B., Rawson, P.F., Remane, J., Robaszynski, F., Schmid, F. and Surlyk, F., 1984, Cretaceous stage boundaries — Proposals: Geological Society of Denmark, Bulletin, v. 33, p. 3-10.

Böse, E., 1928, (mis-dated 1927), Cretaceous ammonites from Texas and northern Mexico: University of Texas, Bulletin 2748, p. 143-357, pls. 1-18.

Caldwell, W.G.E. and North, B.R., 1984, Cretaceous stage boundaries in the southern interior plains of Canada: Geological Society of Denmark, Bulletin, v. 33, p. 57-69.

Chancellor, G.R., 1982, Cenomanian-Turonian ammonites from Coahuila, Mexico: Geological Institutions of the University of Uppsala, Bulletin, new series, v. 9, p. 77-129.

Cobban, W.A., 1953, Cenomanian ammonite fauna from the Mosby Sandstone of central Montana: United States Geological Survey, Professional Paper 243-D, p. 45-55, pls. 6-12.

Cobban, W.A., 1976, Ammonite record from the Mancos Shale of the Castle Valley-Price-Woodside area, east-central Utah: Brigham Young University, Geology Studies, v. 22, p. 117-126.

Cobban, W.A., 1983, Molluscan fossil record from the northeastern part of the Upper Cretaceous seaway, Western Interior: United States Geological Survey, Professional Paper 1253-A, p. 1-25.

Cobban, W.A., 1984, Mid-Cretaceous ammonite zones, Western Interior, United States: Geological Society of Denmark, Bulletin, v. 33, p. 71-89.

Cobban, W.A., 1985a, The Lower Cretaceous ammonite *Schloenbachia leonensis* Conrad var. *equidistans* Cragin: United States Geological Survey, Bulletin 1641-A, 4 p.

Cobban, W.A., 1985b, Ammonite record from Bridge Creek Member of Greenhorn Limestone at Pueblo Reservoir State Recreation Area, Colorado, *in* Pratt, L.M., Kauffman, E.G. and Zelt, F.G., eds., Fine-grained Deposits and Biofacies pf the Cretaceous Western Interior Seaway: Evidence of Cyclic Sedimentary Processes: Society of Economic Paleontologists and Mineralogists, 1985 Mid-year Meeting, Golden, CO, Fieldtrip Guidebook No. 4, p. 135-138.

Cobban, W.A., 1987a, Some Middle Cenomanian (Upper Cretaceous) acanthoceratid ammonites from the Western Interior of the United States: United States Geological Survey, Professional Paper 1445, 28 p.

Cobban, W.A., 1987b, Ammonite faunas of the Sarten Sandstone (Cretaceous), Luna County, Mexico: United States Geological Survey, Bulletin 1641-B, p. B1-B15.

Cobban, W.A., 1988a, The Upper Cretaceous ammonite *Watinoceras* Warren in the Western Interior of the United States: United States Geological Survey, Bulletin 1788, 18 p.

Cobban, W.A., 1988b, Some Acanthoceratid ammonites from Upper Cenomanian (Upper Cretaceous) rocks of Wyoming: United States Geological Survey, Professional Paper 1353, 20 p.

Cobban, W.A. and Hook, S.C., 1979, *Collignoniceras woollgari woollgari* (Mantell) ammonite fauna from Upper Cretaceous of Western Interior, United States: New Mexico Bureau of Mines and Mineral Resources, Memoir 37, 51 p.

Cobban, W.A. and Hook, S.C., 1980, The Upper Cretaceous ammonite family Coilopoceratidae Hyatt in the Western Interior of the United States: United States Geological Survey, Professional Paper 1192, 28 p.

Cobban, W.A., Hook, S.C. and Kennedy, W.J., 1989, Upper Cretaceous rocks and ammonite faunas of southwestern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 45, 137 p.

Cobban, W.A. and Kennedy, W.J., 1989a, The ammonite *Metengonoceras* Hyatt, 1903, from the Mowry Shale (Cretaceous) of Montana and Wyoming: United States Geological Survey, Bulletin 1787, p. L1-L11.

Cobban, W.A. and Kennedy, W.J., 1989b, *Acompsoceras inconstans* zone, a lower Cenomanian marker horizon in Trans-Pecos Texas, U.S.A.: Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 178, p. 133-145.

Cobban, W.A. and Merewether, E.A., 1983, Stratigraphy and paleontology of the mid-Cretaceous rocks in Minnesota and contiguous areas: United States Geological Survey, Professional Paper 1253, 52 p.

Cobban W.A. and Reeside, J.B., Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States: Geological Society of America, Bulletin, v. 63, p. 1011-1044.

Cobban, W.A. and Scott, G.R., 1972, Stratigraphy and ammonite fauna of the Graneros Shale and Greenhorn Limestone near Pueblo, Colorado: United States Geological Survey, Professional Paper 645, 108 p.

Córdoba, D.A., 1969, Mesozoic stratigraphy of north-eastern Chihuahua, Mexico, *in* Córdoba,D.A., Wengerd, S.A. and Shomaker, J., eds., Guidebook of the Border Region: New Mexico Geological Society, p. 91-96.

de Grossouvre, A., 1894 (mis-dated 1893), Recherches sur la craie supérieure 2: Paléontologie - Les ammonites de la craie supérieur: Mémoires pour servir à l'explication de la carte géologique détaillée de la France, 264 p.

de Grossouvre, A., 1901, Recherches sur la craie supérieure 1: stratigraphie générale: Mémoires pour servir à l'explication de la carte géologique détaillée de la France, 1013 p.

Devalque, C., Amédro, F., Philip, J. and Robaszynski, F., 1983 (misdated 1982), État des corrélations litho et biostratigraphiques dans le Turonien supérieur des massifs d'Uchaux et de la Cèze: les zones d'ammonites et de rudistes: Muséum National d'Histoire Naturelle Mémoires (new series, Series C - Sciences de la Terre), v. 49, p. 57-69.

Dodge, C.F., 1969, Stratigraphic nomenclature of the Woodbine Formation, Tarrant County, Texas: Texas Journal of Science, v. 21, p. 43-62.

Eicher, D.L., 1965, Foraminifera and biostratigraphy of the Graneros Shale: Journal of Paleontology, v. 39, p. 875-909.

Fallon, J.H., 1981, Depositional environments, history and biostratigraphy of Upper Albian rocks, trans-Pecos Texas: Association Round Table, v. 65, p. 759.

Franks, P.C., 1975, The transgressive-regressive sequence of the Cretaceous Cheyenne, Kiowa, and Dakota Formations of Kansas, *in* Caldwell, W.G.E., ed., The Cretaceous System in the Western Interior of North America: Geological Association of Canada, Special Paper 13, p. 469-521.

Gale, A.S. and Woodroof, P.B., 1981, A Coniacian ammonite from the "Top Rock" in the Chalk of Kent: Geological Magazine, v. 118, p. 557-560.

Gaster, C.T.A., 1932, The zone of the Chalk of the Arun Gap, Sussex: Proceedings of the Geologists' Association, v. 43, p. 212-223.

Hancock, J.M., 1984, Some possible boundary-stratotypes for the base of the Cenomanian and Turonian stages: Geological Society of Denmark, Bulletin, v. 33, p. 123-128.

Hancock, J.M. Kennedy, W.J. and Wright, C.W., 1977, Towards a correlation of the Turonian sequences of Japan with those of north-west Europe: Palaeontological Society of Japan, Special Paper 21, p. 151-168.

Hattin, D.E., 1975, Stratigraphy and depositional environment of Greenhorn Limestone (Upper Cretaceous) of Kansas: Kansas Geological Survey, Bulletin 209, 128 p.

Hook, S.C. and Cobban, W.A., 1979, *Prionocyclus novimexicanus* (Marcou) - Common Upper Cretaceous guide fossil in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1977-78, p. 34-42.

Hook, S.C. and Cobban, W.A., 1983, Mid-Cretaceous molluscan sequence at Gold Hill, Jeff Davis County, Texas, with comparison to New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 185, p. 48-54.

Jeletzky, J.A., 1968, Macrofossil zones of the marine Cretaceous of the Western Interior of Canada and their correlation with the zones and stages of Europe and the Western Interior of the United States: Geological Survey of Canada, Paper 67-72, 66 p.

Jeletzky, J.A., 1971, Marine Cretaceous biotic provinces and palaeogeography of western and Arctic Canada: Illustrated by a detailed study of ammonites: Geological Survey of Canada, Paper 70-72, 92 p.

Jeletzky, J.A., 1980, New or formerly poorly known, biochronologically and paleobiogeographically important gastroplinitid and cleoniceratinid (Ammonitida) taxa from Middle Albian rocks of mid-western and Arctic Canada: Geological Survey of Canada, Paper 79-22, 63 p.

Jones, B.R. and Reaser, D.F., 1970, Geology of Southern Quitman Mountains, Hudspeth County, Texas, *in* Geology of the Southern Quitman Mountains area, trans-Pecos Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 70-12, p. 31-54.

Kaplan, U., 1986, Ammonite stratigraphy of the Turonian of NW-Germany: Newsletters in Stratigraphy, v. 17, p. 9-20.

Kauffman, E.G., 1984, Paleobiogeography and evolutionary response dynamic in the Cretaceous Western Interior seaway of North America, *in* Westerman, G.E.G., ed., Jurassic-Cretaceous Biochronology and Paleogeography of North America: Geological Assocation of Canada, Special Paper 27, p. 273-306.

Kauffman, E.G., Cobban, W.A. and Eicher, D.L., 1978, Albian through Lower Coniacian strata, biostratigraphy and principal events, Western Interior United States: Muséum d'Histoire Naturelle de Nice Annales, v. 4 (for 1976), ch. 23, 24 p.

Kennedy, W.J., 1984a, Ammonite faunas and the "standard zones" of the Cenomanian to Maastrichtian Stages in their type areas, with some proposals for the definition of the stage boundaries by ammonites: Geological Society of Denmark, Bulletin, v. 33, p. 147-161.

Kennedy, W.J., 1984b, Systematic palaeontology and stratigraphic distribution of the ammonite faunas of the French Coniacian: Special Papers in Palaeontology, no. 31, 160 p.

Kennedy, W.J., 1985, Integrated macrobiostratigraphy of the Albian to basal Santonian, *in* Reyment, R.A. and Bengston, P., compilers, Mid-Cretaceous Events: Report on results obtained 1974-83 by IGCP Project no. 58: Publications from the Paleontological Institution of the University of Uppsala, Special Volume 5, p. 91-108.

Kennedy, W.J., 1986, Ammonite biostratigraphy of the Albian to basal Santonian, *in* Reyment, R.A. and Bengston, P., eds., Events of the Mid-Cretaceous: Physics and Chemistry of the Earth, v. 16, p. 129-144.

Kennedy, W.J., 1988, Late Cenomanian and Turonian ammonite faunas from north-east and central Texas: Special Papers in Palaeontology, v. 39, 131 p.

Kennedy, W.J., Amédro, F., Badillet, G., Hancock, J.M. and Wright, C.W., 1984, Notes on Late Cenomanian and Turonian ammonites from Touraine, western France: Cretaceous Research, v. 5, p. 29-45.

Kennedy, W.J., Amédro, F. and Colleté, C., 1986, Late Cenomanian and Turonian ammonites from Ardennes, Aube and Yonne, eastern Paris Basin: Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 72, p. 193-217.

Kennedy, W.J. and Cobban, W.A., 1988, The Late Cretaceous ammonite *Romaniceras* Spath, 1923, in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 114, p. 23-24.

Kennedy, W.J. and Cobban, W.A., 1990, Cenomanian ammonite faunas from the Woodbine Formation and lower part of the Eagle Ford Group, Texas: Palaeontology, v. 33, p. 75-154.

Kennedy, W.J. and Cobban, W.A., 1991, Stratigraphy and interregional correlation of the Cenomanian-Turonian transition in the Western Interior of the United States near Pueblo, Colorado: A potential boundary stratotype for the base of the Turonian Stage: Newsletters on Stratigraphy, v. 24, p. 1-33.

Kennedy, W.J., Cobban, W.A., Hancock, J.M. and Hook, S.C., 1989, Biostratigraphy of the Chispa Summit Formation at its type locality: A Cenomanian through Turonian reference section for Trans-Pecos Texas: Geological Institutions of the University of Uppsala, Bulletin, N.S., v. 15, p. 39-119.

Kennedy, W.J. and Hancock, J.M., 1970, Ammonites of the genus *Acanthoceras* from the Cenomanian of Rouen, France: Palaeontology, v. 13, p. 462-490.

Kennedy, W.J. and Hancock, J.M., 1971, *Mantelliceras saxbii*, and the horizon of the Martimpreyi Zone in the Cenomanian of England: Palaeontology, v. 14, p. 437-454, pls. 79-82.

Kennedy, W.J., Juignet, P. and Girard, J., 1990, *Budaiceras hyatti* (Shattuck, 1903), a North American index ammonite from the Lower Cenomanian of Haute Normandie, France: Neues Jahrbuch für Geologie und Paläontologie, Monatshefte for 1990, p. 525-535.

Kennedy, W.J., Lindholm, R.C., Helmold, K.P. and Hancock, J.M., 1977, Genesis and diagenesis of hiatus- and breccia-concretions from the mid-Cretaceous of Texas and northern Mexico: Sedimentology, v. 24, p. 833-844.

Kennedy, W.J., Wright, C.W. and Chancellor, G.R., 1983a, The Cretaceous ammonite *Eopachydiscus* and the origin of the Pachydiscidae: Palaeontology, v. 26, p. 655-662.

Kennedy, W.J., Wright, C.W. and Hancock, J.M., 1983b (misdated 1982), Ammonite zonation and correlation of the uppermost Cenomanian and Turonian of southern England and the type areas of Sarthe and Touraine in France: Muséum National d'Histoire Naturelle Mémoires (new series, Series C - Sciences de la Terre), v. 49, p. 175-181.

Kennedy, W.J., Wright, C.W. and Hancock, J.M., 1987, Basal Turonian ammonites from west Texas: Palaeontology, v. 30, p. 27-74.

Klinger, H.C. and Kennedy, W.J., 1984, Cretaceous faunas from Zululand and Natal, South Africa. The ammonite subfamily Peroniceratinae Hyatt, 1900: South African Museum Annals, v. 92, p. 113-294.

Lewy, Z., Kennedy, W.J. and Chancellor, G.R., 1984, Cooccurrence of *Metoicoceras geslinianum* (d'Orbigny) and *Vascoceras cauvini* Chudeau (Cretaceous Ammonoidea) in the Southern Negev (Israel) and its stratigraphic implications: Newsletters in Stratigraphy, v. 13, p. 67-76.

McGill, D.W., 1967, Washita Formations, north Texas, correlated to Georgetown Limestone, central Texas, *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) Stratigraphy and Paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 67-8, p. 218-239.

McGookey, D.P., Haun, J.D., Hale, L.A., Goodell, H.G., McGubbin, D.G., Weimer, R.J. and Wulf, G.R., 1972, Cretaceous System, *in* Geologic Atlas of the Rocky Mountain Region: Rocky Mountain Association of Geologists, Denver, p. 190-228.

McNulty, C.L., Jr., 1966, Nomenclature of uppermost Eagle Ford Formation in northeastern Texas: American Association of Petroleum Geologists, Bulletin, v. 50, p. 375-379.

Mancini, E.A., 1979, Late Albian and Early Cenomanian Grayson ammonite biostratigraphy in north-central Texas: Journal of Paleontology, v. 53, p. 1013-1022.

Mancini, E.A., 1982, Early Cenomanian cephalopods from the Grayson Formation of north-central Texas: Cretaceous Research, v. 3, p. 241-259.

Martin, K.G., 1967, Stratigraphy of the Buda Limestone, south-central Texas, *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) Stratigraphy and Paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 67-8, p. 286-299.

Matsumoto, T., 1960, *Graysonites* (Cretaceous ammonites) from Kyushu: Faculty of Science, Kyushu University, Memoirs (series D-Geology), v. 10, p. 41-58.

Maxwell, R.A., Lonsdale, J.T., Hazzard, R.T. and Wilson, J.A., 1967, Geology of Big Bend National Park, Brewster County, Texas: University of Texas, Publication 6711, 320 p.

Moreman, W.L., 1927, Fossil zones of the Eagle Ford of north Texas: Journal of Paleontology, v. 1, p. 89-101.

Moreman, W.L., 1942, Paleontology of the Eagle Ford group of north and central Texas: Journal of Paleontology, v. 16, p. 199-220.

Mortimore, R.N., 1986, Stratigraphy of the Upper Cretaceous White Chalk of Sussex: Geologists' Association, Proceedings, v. 97, p. 97-139.

Norton, G.H., 1965, The surface geology of Dallas County, Texas, *in* The Geology of Dallas County: Dallas Geological Society, p. 40-125.

Owen, H.G., 1971, Middle Albian stratigraphy in the Anglo-Paris Basin: British Museum (Natural History) Bulletin (Geology series), Supplement 8, 164 p.

Owen, H.G., 1984, Albian Stage and Substage boundaries: Geological Society of Denmark, Bulletin, v. 33, p. 183-189.

Owen, H.G., 1985, The Albian Stage: European province chronology and ammonite zonation: Cretaceous Research, v. 5 (for 1984), p. 320-344.

Owen, H.G., 1988, Correlation of ammonite faunal provinces in the Lower Albian (mid-Cretaceous), *in* Wiedmann, J. and Kullman, J., eds., Cephalopods - Present and Past: Schweizerbart'sche, Stuttgart, p. 477-489.

Pervinquière, L., 1910, Sur quelques ammonites du Crétacé algérien: Société Géologique de France Mémoires de Paléontologie, no. 42, 86 p.

Pessagno, E.A., Jr., 1969, Upper Cretaceous stratigraphy of the western Gulf Coast area of Mexico, Texas, and Arkansas: Geological Society of America, Memoir 111, 139 p., 60 pls.

Powell, J.D., 1963, Cenomanian-Turonian (Cretaceous) ammonites from trans-Pecos Texas and northeastern Chihuahua, Mexico: Journal of Paleontology, v. 37, p. 309-322.

Powell, J.D., 1965, Late Cretaceous platform-basin facies, northern Mexico and adjacent Texas: American Association of Petroleum Geologists, Bulletin, v. 49, p. 511-525.

Reaser, D.F., 1970, Preliminary study of the Buda Limestone in foothills of the Southern Quitman Mountains, trans-Pecos Texas, *in* Geology of the Southern Quitman Mountains Area, Trans-Pecos Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 70-12, p. 76-81.

Reeside, J.B., Jr. and Cobban, W.A., 1960, Studies of the Mowry Shale (Cretaceous) and contemporary formations in the United States and Canada: United States Geological Survey, Professional Paper 355, 126 p.

Robaszynski, F., Alcaydé, G., Amédro, F., Badillet, G., Demotte, R., Foucher, J.-C., Jardiné, S., Legoux, O., Manivet, H., Monciardini, C. and Sornay, J., 1982, Le Turonien de la région-type: Saumurois et Touraine. Stratigraphie, biozonations, sédimentologie: Centres de Recherches Exploration-Production Elf-Aquitaine, Bulletin, v. 6, p. 119-225.

Roman, F. and Mazeran, P., 1913, Monographie paléontologique de la faune du Turonien du bassin d'Uchaux et de ses dépendances: Archives du Muséum d'Histoire naturelle de Lyon, v. 12, p. 1-137.

Silver, B.A., 1963, The Bluebonnet Member, Lake Waco Formation (Upper Cretaceous), central Texas - A lagoonal deposit: Baylor Geological Studies, Bulletin 4, 47 p.

Smith, C.C., 1981, Calcareous nannoplankton and stratigraphy of Late Turonian, Coniacian, and early Santonian age of the Eagle Ford and Austin Groups of Texas: United States Geological Survey, Professional Paper 1075, 98 p.

Spath, L.F., 1923, On the ammonite horizons of the Gault and contiguous deposits: Summary of Progress of the Geological Survey of Great Britain for 1922, p. 139-149.

Spath, L.F., 1926, On the zones of the Cenomanian and the uppermost Albian: Geologists' Association, Proceedings, v. 37, p. 420-432.

Spath, L.F., 1932, 1933, A monograph of the Ammonoidea of the Gault, parts 9 and 10: Palaeontographical Society, Monographs, p. 379-442.

Spath, L.F., 1937, The Canadian ammonite genus *Gastroplites* in the English Gault: Annals and Magazine of Natural History, series 10, v. 19, p. 257-260.

Stelck, C.R., 1958, Stratigraphic position of the Viking sand: Alberta Society of Petroleum Geologists, Proceedings, v. 6, p. 2-7.

Stelck, C.R., 1975, The upper Albian *Miliammina manitobensis* Zone in northeastern British Columbia, *in* Caldwell, W.G.E., ed., The Cretaceous System in the Western Interior of North America: Geological Association of Canada, Special Paper 13, p. 253-275.

Stephenson, L.W., 1953 (mis-dated 1952), Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas: United States Geological Survey, Professional Paper 242, 226 p.

Stephenson, L.W., King, P.B., Monroe, W.H. and Imlay, R.W., 1942, Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and trans-Pecos Texas: Geological Society of America, Bulletin, v. 53, p. 435-448.

Thomel, G., 1972, Les Acanthoceratidae cénomaniens des chaines subalpines méridionales: Société Géologique de France Mémoires, nouvelle série, 116, 204 p.

Tröger, K.-A., 1981, Zu problemen der biostratigraphie der Inoceramen und der untergliederung des Cenomans und Turons in mittel- und Osteuropa: Newsletters in Stratigraphy, v. 9, p. 139-156.

Warren, P.S. and Stelck, C.R., 1940, Cenomanian and Turonian faunas in the Pouce Coupe district, Alberta and British Columbia: Royal Society of Canada, Transactions, 3rd series, v. 34, p. 143-152.

Warren, P.S. and Stelck, C.R., 1969, Early *Neogastroplites* Fort St. John Group, western Canada: Canadian Petroleum Geology, Bulletin, v. 17, p. 529-547.

Wiedmann, J., 1979, Die Ammoniten der NW-deutschen, Regensburger und Ostalpinen Oberkreide im Vergleich mit den Oberkreidefaunen des westlichen Mediterrangebiets, *in* Wiedmann, J., ed., Aspekte der Kreide Europas: International Union of Geological Sciences, Series A, no. 6, p. 335-350.

Wilbert, W.P., 1967, Stratigraphy of the Georgetown Formation, central Texas, *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 67-8, p. 256-285.

Williams, G.D. and Stelck, C.R., 1975, Speculations on the Cretaceous palaeogeography of North America, *in* Caldwell, W.G.E., ed., The Cretaceous System in the Western Interior of North America: Geological Association of Canada, Special Paper 13, p. 1-20.

Witze, B.J., Ludvigson, G.A., Poppe, J.R. and Ravn, R.L., 1983, Cretaceous paleogeography along the eastern margin of the western interior seaway, Iowa, southern Minnesota, and eastern Nebraska and South Dakota, *in* Reynolds, M.W. and Dolly, E.D., eds., Mesozoic Paleogeography of the west-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, Rocky Mountain Paleogeography Symposium 2, p. 225-252.

Wood, C.J., Ernst, G. and Rasemann, G., 1984, The Turonian-Coniacian stage boundary in Lower Saxony (Germany) and adjacent area: The Salzgitter-Salder Quarry as a proposed international standard section: Geological Society of Denmark, Bulletin, v. 33, p. 225-238.

Wright, C.W., 1979, The ammonites of the English Chalk Rock (Upper Turonian): British Museum (Natural History) Bulletin, Geology Series, v. 31, p. 281-332.

Wright, C.W. and Kennedy, W.J., 1981, The Ammonoidea of the Plenus Marls and the Middle Chalk: Palaeontographical Society, Monographs, No. 560, 148 p.

Wright, C.W. and Kennedy, W.J., 1984, The Ammonoidea of the Lower Chalk, part 1: Palaeontographical Society, Monographs, No. 567, 126 p.

Wright, C.W. and Kennedy, W.J., 1987, The Ammonoidea of the Lower Chalk, part 2: Palaeontographical Society, Monographs, No. 573, p. 127-218.

Wright, C.W., Kennedy, W.J. and Hancock, J.M., 1984, Stratigraphic introduction, *in* Wright, C.W. and Kennedy, W.J., The Ammonoidea of the Lower Chalk, pt. 1: Palaeontographical Society, Monographs, No. 567, p. 1-16.

Young, K., 1957, Upper Albian (Cretaceous) Ammonoidea from Texas: Journal of Paleontology, v. 31, p. 1-33.

Young, K., 1958a, *Graysonites*, a Cretaceous ammonite in Texas: Journal of Paleontology, v. 32, p. 171-182.

Young, K., 1958b, Cenomanian (Cretacous) ammonites from trans-Pecos Texas: Journal of Paleontology, v. 32, p. 286-294.

Young, K., 1963, Upper Cretaceous ammonites from the Gulf Coast of the United States: University of Texas, Publication 6304, 373 p.

Young, K., 1967a, Comanche Series (Cretaceous), south central Texas, *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) Stratigraphy and Paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 67-8, p. 8-29.

Young, K., 1967b, Ammonite zonations, Texas Comanchean (Lower Cretaceous), *in* Hendricks, L., ed., Comanchean (Lower Cretaceous) Stratigraphy and Paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Publication 67-8, p. 65-70.

Young, K., 1968, Upper Albian (Cretaceous, *M. romeri* zone) ammonites in Texas and Mexico: Journal of Paleontology, v. 42, p. 70-80.

Young, K., 1969, Ammonite zones of northern Chihuahua, *in* Córdoba, D.A., Wengerd, S.A. and Shomaker, J., eds., New Mexico Geological Society, Guidebook of the Border Region, p. 97-101.

Young, K., 1972, Cretaceous Paleogeography: Implications of endemic ammonite faunas: Bureau of Economic Geology, Austin, Texas, Geological Circular 72-2, 13 p.

Young, K., 1979, Lower Cenomanian and Late Albian (Cretaceous) ammonites, especially Lyelliceridae, of Texas and Mexico: Texas Memorial Museum, Bulletin 26, 99 p.

Young, K., 1986a, The Albian-Cenomanian (Lower Cretaceous-Upper Cretaceous) boundary in Texas and northern Mexico: Journal of Paleontology, v. 60, p. 1212-1219.

Young, K., 1986b, Cretaceous, marine inundations of the San Marcos platform, Texas: Cretaceous Research, v. 7, p. 117-140.

Young, K. and Powell, J.D., 1978, Late Albian-Turonian correlations in Texas and Mexico: Annales du Muséum d'Histoires Naturelle de Nice, v. 4 (for 1976), ch. XXV, 36 p.