Diversity and Distribution of Late Cretaceous Ammonites, Western Interior, United States

W.A. Cobban

United States Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center, Denver, Colorado 80225 U.S.A.

Cobban, W.A., 1993, Diversity and distribution of Late Cretaceous ammonites, Western Interior, United States, **in** *Caldwell, W.G.E. and Kauffman, E.G., eds., Evolution of the Western Interior Basin: Geological Association of Canada, Special Paper 39, p. 435-451.*

Abstract

During times when the Western Interior Sea was transgressive, waters of more normal salinity brought many genera of ammonites into the Western Interior from the Gulf coastal region. These migrations of ammonites peaked in the middle late Cenomanian when 19 genera were present during the time of Metoicoceras mosbyense. *Lesser peaks occurred in the early middle Turonian (10-15 genera), in the Coniacian and Santonian (9 genera each), and in the late Campanian and early Maastrichtian (9 genera each). Two genera,* Dunveganoceras *(Cenomanian) and* Hoploscaphites *(Campanian and Maastrichtian), however, may be migrants from the north.*

Important ammonite lineages were established in the Cenomanian by descendants of Acanthoceras bellense *Adkins,* Calycoceras leonense *(Adkins),* Metoicoceras praecox *Haas, and* Moremanoceras elgini *(Young).* Collignoniceras *and* Prionocyclus *formed an important lineage in the Turonian.* Placenticeras, Baculites, *and* Scaphites *each developed into endemic stocks by middle Turonian time.* Placenticeras *and* Baculites *flourished until the early Maastrichtian, but the endemic* Scaphites *were replaced by new stocks of scaphites in the early Campanian. During the middle Campanian, a new stock of scaphites (*Hoploscaphites*) replaced the local stocks and persisted until the Western Interior Sea retreated in middle Maastrichtian time.*

Résumé

Pendant la transgression de la mer Intérieure de l'Ouest, des eaux de salinité plus normale ont permis à plusieurs genres d'ammonites d'envahir le bassin Intérieur de l'Ouest, à partir des eaux de la région côtière du Gulf. L'apogée de ces migrations a eu lieu au milieu du Cénomanien supérieur, alors que 19 genres ont été dénombrés à l'époque de Metoicoceras mosbyense. *Des pousées migratoires moins importantes se sont produites au début du Turonien moyen (10-15 genres), au Coniacien et au Santonien (9 genres chacun) ainsi qu'à la fin du Campanien et au début Maastrichtien (9 genres chacun). Cependant, deux genres auraient pu venir du nord* Dunveganoceras *(Cénomanien) et* Hoploscaphites *(Campanien et Maastrichtien).*

*D'importantes lignées d'ammonites se sont constituées au Cénomanien par al descendance d'*Acanthoceras bellense *Adkins, de* Calycoceras leonense *(Adkins), de* Metoicoceras praecox *Haas, et de* Moremanoceras elgini *(Young). Les genres* Collignoniceras *et* Prionocyclus *ont constitué une lignée importante au Turonien. Au niveau du Turonien moyen environ, les genres* Placenticeras, Baculites, *et* Scaphites *se sont développés en des stocks endémiques. Les genres* Placenticeras *et* Baculites *ont prospéré jusqu'au début de Maastrichtien, mais au début du Campanien, de nouveaux stocks de scaphites ont succédé aux* Scaphites *endémiques. Durant le Campanien moyen, un nouveau stock de scaphites* (Hoploscaphites) *a remplacé les stocks locaux et a subsisté jusqu'à ce que la mer Intérieure de l'Ouest se retire au Maastrichtien moyen.*

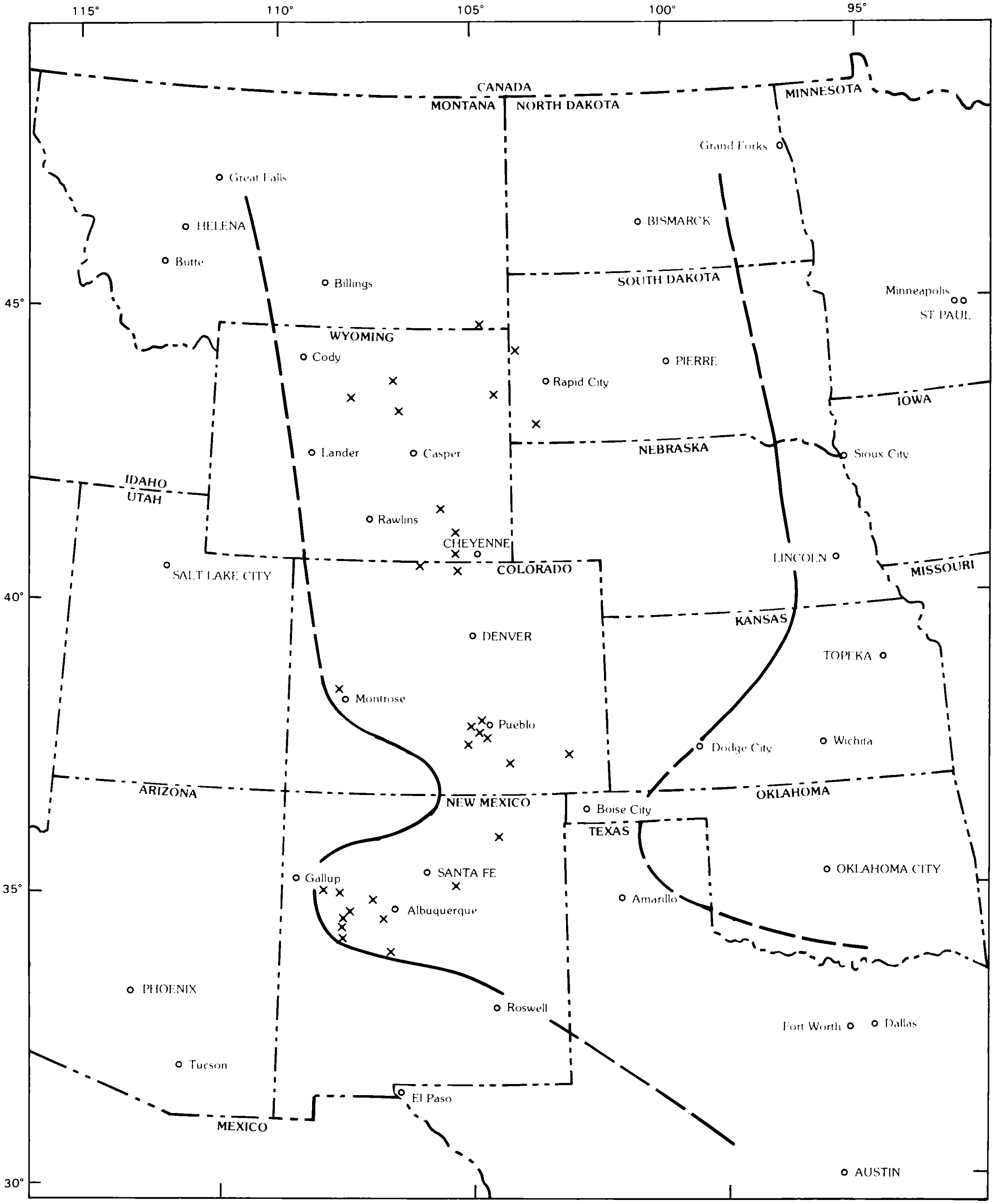

Figure 1. *Possible configuration of the Western Interior Seaway during the early part of the middle Cenomanian (Zone of* Conlinoceras tarrantense*). Solid lines indicate probable shorelines; dashed lines indicate possible shorelines. Localities where ammonites were found are indicated by* **X.**

THE EARLY LATE CRETACEOUS SEAWAY

The Late Cretaceous Sea had already transgressed into the Western Interior Basin of the United States by the middle Cenomanian before the known arrival of any ammonites. Rocks deposited in this pre-ammonite seaway consist chiefly of dark noncalcareous shale with minor amounts of siltstone, sandstone and bentonite in the eastern part of the region, and of interbedded sandstone and shale with thick beds of bentonite in the western part. These Cenomanian rocks include the lower two-thirds or more of the Graneros Shale of New Mexico, Colorado, Kansas and Nebraska; the lower two-thirds or more of the Belle Fourche Shale of the Black Hills area of eastern Wyoming, western South Dakota and southeastern Montana; the lower part of the Belle Fourche Member of the Frontier Formation of central Wyoming; and probably part of the Belle Fourche Shale of central Montana. Important investigations of the stratigraphy and foraminiferal content of the Graneros and Belle Fourche Shales by Eicher (1965, 1967) and more recently by Eicher and Diner (1985) revealed that this sea transgressed southward from Canada. The time represented by these pre-ammonite beds may be equivalent to that of three neogastroplitid ammonite zones recognized far to the north in the Peace River area of British Columbia, where Warren and Stelck (1958) described the following early Cenomanian zones, from oldest to youngest, *Neogastroplites septimus, Irenicoceras bahani*, and *Beattonoceras beattonense.*

The oldest, widely distributed ammonites of Late Cretaceous age in the Western Interior of the United States are found in the middle Cenomanian Thatcher Limestone Member of the Graneros Shale in eastern Colorado, northeastern New Mexico and southeastern Wyoming, and in equivalent rocks in west-central New Mexico, western Colorado, central and eastern Wyoming, western South Dakota and southeastern Montana. The known ammonite fauna consists of *Desmoceras* sp., *Conlinoceras tarrantense* (Adkins), *C. gilberti* Cobban and Scott, *Calycoceras leonense* (Adkins), *Borissiakoceras compressum* Cobban, *Johnsonites sulcatus* Cobban, and *Turrilites acutus* Passy. A direct tie with the Cenomanian Lewisville Member of the Woodbine Formation of north Texas is revealed by the presence there of *Conlinoceras tarrantense (Metacalycoceras? tarrantense* of Adkins, 1928), *Johnsonites sulcatus (Euhoplites?* sp. of Stephenson, 1952), and *Turrilites dearingi* Stephenson (1952). The distribution of Thatcher ammonites in the Western Interior region is shown in Figure 1. The presence of these ammonites in the Western Interior was probably due to the northward flow from the Gulf area of warmer and more normal salinity waters into the Western Interior Seaway.

The Thatcher Limestone Member consists of a bed of yellowish-orange-weathering, hard, dense, ferruginous, concretionary limestone that is usually less than 0.5 m thick (Cobban and Scott, 1972, p. 10-12, figs. 4-7). Equivalent rocks also tend to be thin and more or less ferruginous, and weather to various shades of orange or brown.

At the time of Thatcher deposition, the Western Interior Seaway was probably less than 900 km wide (Fig. 1). In the western parts of New Mexico and Colorado, the western shoreline was sinuous. A conspicuous embayment in west-central New Mexico has been named the Seboyeta Bay (Hook *et al.*, 1980, p. 44, fig. 3; Cobban and Hook, 1984, fig. 2). Here, brown-weathering limey siltstone beds and silty limestone concretions in the upper part of the Cenomanian Oak Canyon Member of the Dakota Sandstone contain a diverse molluscan fauna of at least 30 genera of bivalves, 10 genera of gastropods and 5 genera of ammonites (Cobban, 1977, table 2). In western Colorado, a sparse Thatcher fauna is present in thin beds of sandstone near the top of the Dakota Sandstone. Farther north in north-central Wyoming, dark-brown-weathering, ferruginous, sandy limestone concretions in the Belle Fourche Member of the Frontier Formation contain abundant *Borissiakoceras compressum* and *Inoceramus eulessanus* Stephenson and a few *Conlinoceras tarrantense* and *Johnsonites sulcatus,* but other fossils are scarce (Merewether, 1980, p. 18, localities D9805, D9850).

In the central part of the seaway, ferruginous concretions that locally grade into ferruginous, concretionary limestone were deposited in a fairly narrow belt that extended from northeastern New Mexico northward to just beyond the Black Hills in the southeastern corner of Montana. *Conlinoceras gilberti* is locally abundant (Cobban and Scott, 1972, fig. 7), and *Borissiakoceras compressum* and *Inoceramus eulessanus* are fairly common, but other molluscan fossils are usually scarce. *Turrilites* has not been found north of southeastern Colorado.

The eastern shoreline of the Thatcher seaway is poorly known. In southeastern Colorado, the farthest east locality of Thatcher fossils is USGS Mesozoic locality D7265 (in sec. 26, T. 25 S., R. 49 W., Bent County), about 75 km west of the Kansas boundary (Fig. 1, southeasternmost locality in Colorado). Here *Conlinoceras gilberti* occurs in orange-weathering, ferruginous concretions. Farther east, in southwest Kansas, the Thatcher Limestone Member seems to be absent, and Thatcher time may be represented in sandy beds in the basal part of the Graneros Shale or possibly in the upper part of the Dakota Sandstone.

In central Kansas, limestone beds from the lower half of the Graneros Shale and from the upper part of the Dakota Sandstone include many species found in the Woodbine Formation of north Texas. Fossils from the upper part of the Dakota are like those from the Lewisville Member of the Woodbine (Hattin, 1967), whereas those from the lower part of the Graneros are more like fossils from the Templeton Member of the Woodbine (Hattin, 1965). Inasmuch as the Thatcher ammonite fauna is more like that of the Lewisville, the upper part of the Dakota in central Kansas is probably of Thatcher age. Hattin (1967, p. 582) observed that this part of the Dakota was deposited in marginal marine environments. Hattin's Dakota localities follow a northeast-southwest trend across north-central Kansas, and it seems logical to assume that the Thatcher shoreline lay along this belt or slightly east of it. Farther north in eastern Nebraska, the Thatcher shoreline probably trended north-south and passed somewhere west of present-day Sioux City, Iowa (Fig. 1). At Riverside on the northwest side of Sioux City, silty concretions in the basal part of the Graneros Shale contain (*Dunveganoceras pondi* Haas of early late Cenomanian age (Cobban, 1983, p. 12 and illustrations). Rocks of Thatcher age, if present, should lie much lower in the non-marine Dakota Formation (Merewether, 1983, fig. 7).

CENOMANIAN AMMONITE STOCKS AND MIGRATIONS

For the purposes of this report, 12 ammonite zones are recognized for middle to late Cenomanian time in the Western Interior of the United States (Fig. 2). Some of these zones can only be recognized in small geographic areas (*e.g.*, Zone of *Acanthoceras bell-*

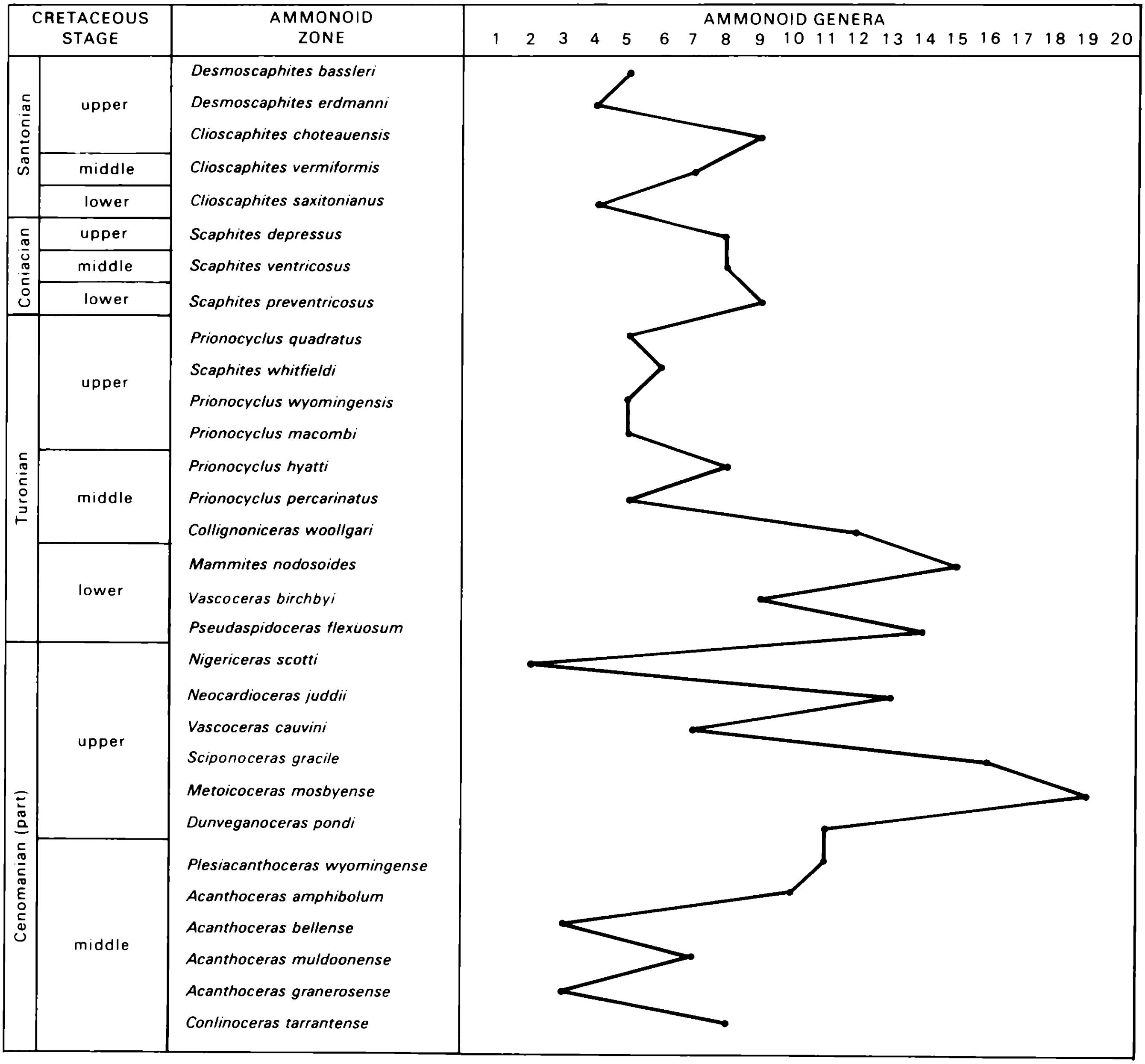

Figure 2. *Western Interior ammonoid zones and number of ammonoid genera for the middle Cenomanian through late Santonian. (Note: Since the preparation of this report,* Burroceras clydense *has been used in place of* Vascoceras cauvini *as an upper Cenomanian Zone.)*

ense), but they have to be considered in the development and migration of the ammonoid stocks. Some zones (*e.g.*, Zone of *Metoicoceras mosbyense*) are applied in a very broad sense and probably will be subdivided in future work.

A few genera are also used in a very broad sense. Among these is *Acanthoceras*, which includes both horned species (*e.g., A. muldoonense* Cobban and Scott and *A. amphibolum* Morrow) and more normal forms (*e.g., A. granerosense* Cobban and Scott). Inner whorls of some *A. amphibolum* are like those of *Cunningtoniceras*, whereas outer whorls are like those of *Plesiacanthoceras*. Until the American acanthoceratid ammonites are more thoroughly investigated, the original generic assignments are followed here. *Calycoceras*, likewise, is used in a very broad sense, and at least two distinct stocks are present.

Ammonites of the Thatcher Limestone Member of the Graneros Shale and equivalent rocks in the Western Interior consist of the following genera: *Calycoceras, Conlinoceras, Acanthoceras, Cunningtoniceras, Borissiakoceras, Johnsonites, Turrilites* and *Anisoceras*. Immediately following the deposition of the Thatcher Member and equivalent rocks, ammonite diversity greatly declined, and only *Acanthoceras, Turrilites* and *Hamites* are known from the Zone of *Acanthoceras granerosense* Cobban and Scott. These few ammonites of southern origin have been found only in the Graneros Shale of southeastern Colorado and in the Belle Fourche Member of the Frontier Formation of north-central Wyoming. A little higher in these rocks, in the Zone of *Acanthoceras muldoonense* Cobban and Scott, the diversity of genera increases to seven, which includes most of the genera known from the Thatcher Limestone Member with the addition of the heteromorph *Idiohamites*. None of these ammonites is known north of north-central Wyoming.

Southwest of the Black Hills in eastern Wyoming, a local assemblage of middle Cenomanian ammonites a little younger than *Acanthoceras muldoonense* is present in the upper part of the Belle Fourche Shale. The assemblage consists of *Acanthoceras bellense* Adkins, *Calycoceras leonense* (Adkins), and sparse *Borissiakoceras*. *Acanthoceras bellense*, which was originally described from the basal part of the Eagle Ford Group of Texas, is either a migrant from eastern Texas into the Western Interior or possibly a descendant of *A. granerosense*. The association of abundant *Calycoceras leonense*, a species absent in the underlying Zone of *A. muldoonense*, favours a new migration presumably from Texas.

Higher in the Graneros and Belle Fourche Shales, diversity in ammonites increases greatly (Fig. 2), probably reflecting a more favorable environment and a more expanded seaway (Fig. 3) than that of Thatcher time. Ten genera are known in the Zone of *Acanthoceras amphibolum* Morrow. Morrow's species, which is a direct descendant of *A. bellense*, is widely distributed from Trans-Pecos Texas northward into south-central Montana and from western Colorado to central Kansas. Diversity decreases northward (Fig. 3), and only *A. amphibolum* and *Borissiakoceras* are known from Montana, whereas in New Mexico, *A. amphibolum* is associated with *Cunningtoniceras, Borissiakocereas, Tarrantoceras* (a direct descendant of *Calycoceras leonense), Anisoceras, Desmoceras (Pseudouhligella), Moremanoceras, Plesiacanthoceras* and *Paracompsoceras*, the last four new to the Western Interior. *Plesiacanthoceras* is a split from the *A. amphibolum* lineage, *Moremanoceras* represents the continuation of a lineage that first appeared in the lower Cenomanian of Trans-Pecos Texas, and *Desmoceras (Pseudouhligella)* and *Paracompsoceras* are migrants presumably from Texas.

At the close of Graneros and Belle Fourche deposition, at the end of middle Cenomanian time, the seaway continued to be inhabited by many kinds of ammonites with a decided northward shift in diversity to the area of the present Black Hills, where at least 11 genera are present in the Zone of *Plesiacanthoceras wyomingense* (Reagan). Some are descendants of species in the underlying Zone of *Acanthoceras amphibolum*, such as *Plesiacanthoceras, Moremanoceras, Borissiakoceras* and *Anisoceras*, but others are new to the seaway (*Eucalycoceras, Scaphites* and several undescribed genera). *Plesiacanthoceras wyomingense* is the most widespread of the species, and specimens have been found as far north as the Peace River area of Alberta, where they were described as *Acanthoceras athabascense* Warren and Stelck (1955).

At the beginning of late Cenomanian time, the Western Interior Seaway continued to expand and carbonate deposition became prevalent as the warmer and more normal salinity waters from the Gulf area moved northward. *Dunveganoceras* developed out of *Plesiacanthoceras*, and the Zone of *D. pondi* in the basal part of the Cenomanian and Turonian Greenhorn Limestone and equivalent rocks contains at least 11 genera of ammonites. *Tarrantoceras, Eucalycoceras, Moremanoceras, Hamites* and *Idiohamites* continue up from the underlying Zone of *Plesiacanthoceras wyomingense*, but *Dunveganoceras, Neocardioceras, Metoicoceras, Metengonoceras* and *Neostlingoceras* are new. This assemblage is best developed from the Black Hills westward across much of Wyoming. Fossils that represent this zone have not been recorded from Canada.

Slightly higher in rocks of Late Cenomanian age, Late Cretaceous ammonite diversity reached its peak in the Hartland Shale Member of the Greenhorn Limestone and equivalent rocks. Nineteen genera occur in the Zone of *Metoicoceras mosbyense* Cobban. Genera known from older rocks are *Moremanoceras, Dunveganoceras, Calycoceras, Eucalycoceras, Cunningtoniceras, Metoicoceras, Neocardioceras, Borissiakoceras, Metengonoceras, Neostlingoceras* and *Hamites*. New genera are *Forbesiceras,*

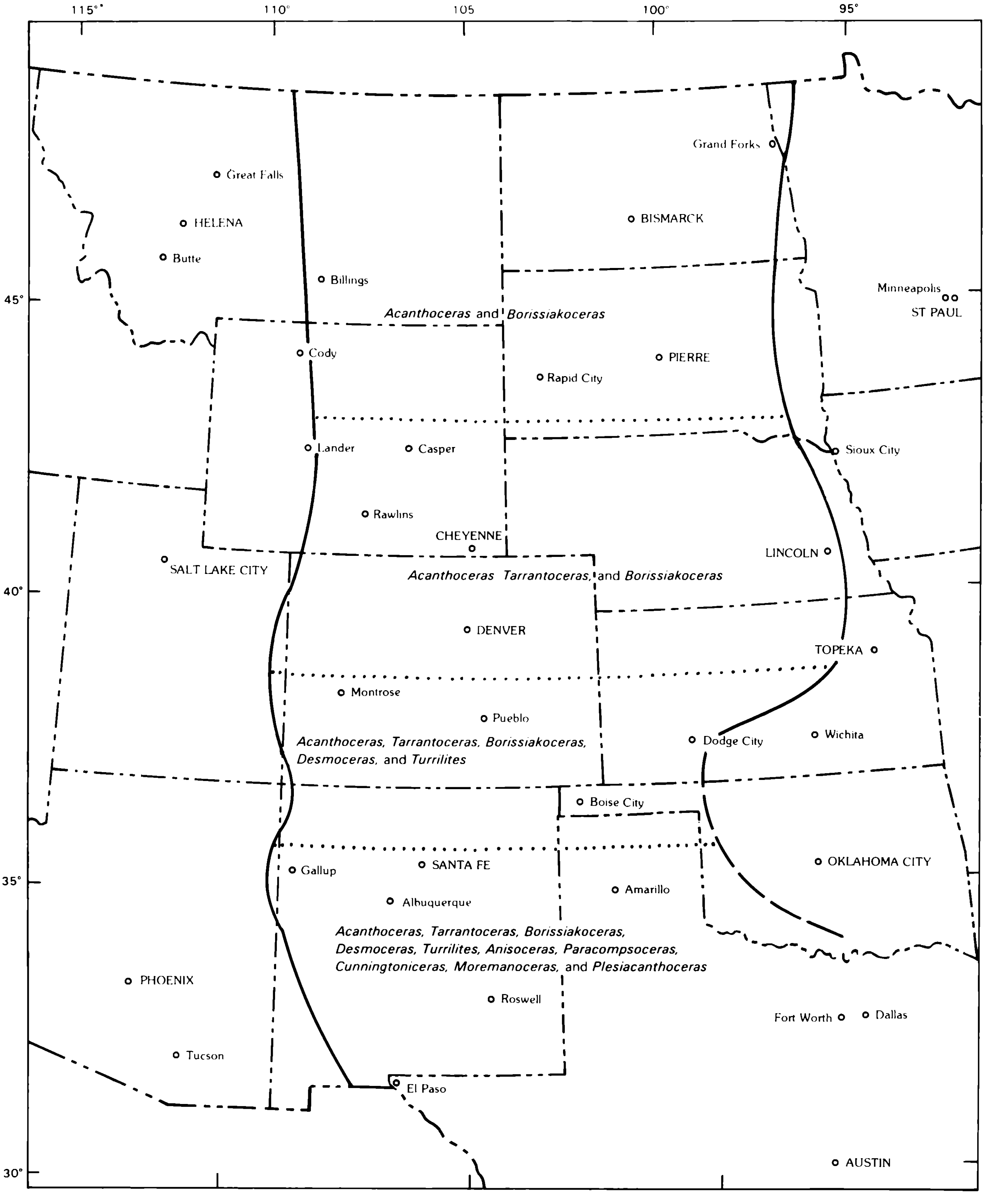

Figure 3. *Probable position of Western Interior Seaway during the later part of the middle Cenomanian (Zone of* Acanthoceras amphibolum*). Northward decrease in number of ammonoid genera is shown by broad, generalized geographic belts of genera separated by dotted lines.*

Lewesiceras, Vascoceras, Euomphaloceras, a new genus, and the heteromorphs *Metaptychoceras, Sciponoceras* and *Carthaginites*. Most of the new genera are present only in the southern part of the region. *Dunveganoceras*, however, is absent in the southern part but abundant in Wyoming and Montana. The species of *Dunveganoceras* are quite different from the older *D. pondi* and probably represent migrants from Canada, where the genus is conspicuous (Warren and Stelck, 1940, 1955). In Montana, diversity in the Zone of *Metoicoceras mosbyense* is very low. Although specimens of *Metoicoceras* and *Dunveganoceras* are abundant, only one specimen each of *Neocardioceras* and *Sciponoceras* is present in the Montana collections of the United States Geological Survey.

The Zone of *Sciponoceras gracile*, which lies immediately above the Zone of *Metoicoceras mosbyense*, also contains a varied ammonoid fauna. Of the 16 known genera, half are new to the Western Interior and include *Placenticeras (Karamaites), Euomphaloceras, Pseudocalycoceras, Sumitomoceras*, a small new genus, and the heteromorphs *Allocrioceras, Puebloites* and *Worthoceras*. Most of these genera are present in the Cenomanian Britton Formation of Texas and probably came from there.

Following the Zone of *Sciponoceras gracile*, ammonite diversity greatly decreased in the Western Interior, and most genera were restricted to present southwestern New Mexico, where the Zone of *Burroceras clydense* (Cobban, Hook and Kennedy) contains *Placenticeras (Karamaites), Kamerunoceras, Vascoceras, Paravascoceras, Sciponoceras* and two undescribed genera.

Near the close of late Cenomanian time, diversity increased and 12 genera are present in the Zone of *Neocardioceras juddii* (Barrois and Guerne). In southwestern New Mexico, where all 12 genera are present, the zone contains *Placenticeras (Karamaites), Nigericeras, Pseudaspidoceras, Neocardioceras, Vascoceras, Paravascoceras, Thomelites?, Thomasites, Worthoceras, Sciponoceras, Anisoceras* and *Hamites*. Outside southwestern New Mexico, fewer genera are present, and most localities have only *Neocardioceras* and perhaps a few specimens of *Kamerunoceras* or *Sciponoceras*. *Nigericeras* is locally abundant in southeastern Colorado. *Neocardioceras* and *Kamerunoceras* are present as far north as northwestern Montana. At the end of Cenomanian time, a marked decrease in ammonoid genera occurred throughout the Western Interior.

In summary, many genera of ammonites migrated from the Gulf coastal region into the Western Interior Seaway during the middle and late Cenomanian when warmer and near-normal salinity conditions occurred periodically. Some genera, which became adapted to the cooler and less saline water of the Western Interior Seaway, formed important lineages. Among these are the lineage of *Acanthoceras-Plesiacanthoceras-Dunveganoceras* and *Calycoceras (Gentoniceras)-Tarrantoceras* as well as species lineages of *Moremanoceras, Cunningtoniceras, Metoicoceras, Neocardioceras* and *Calycoceras* of the *canitaurinum-naviculare* group.

TURONIAN AMMONOID STOCKS AND MIGRATIONS

Ten Turonian ammonoid zones are recognized in this report (Fig. 2). These are mostly the same as those of an earlier report (Cobban, 1984, fig. 2). A Zone of *Pseudaspidoceras flexuosum* at the base of the sequence is applied in a broad sense; it will be subdivided in a forthcoming work by W.J. Kennedy and me.

The Zone of *Pseudaspidoceras flexuosum* Powell is poorly fossiliferous in most of the Western Interior, whereas in Trans-Pecos Texas, a rich fauna of ammonites is present (Powell, 1963; Kennedy *et al.*, 1987). *Kamerunoceras, Pseudaspidoceras, Thomasites, Vascoceras, Sciponoceras* and *Worthoceras* continue up from the Cenomanian *Neocardioceras juddii* Zone, and the new genera *Quitmaniceras, Mammites, Fagesia* and *Neoptychites* appear. *Allocrioceras* and *Scaphites* are also present. *Thomasites, Vascoceras, Fagesia, Neoptychites* and *Pseudaspidoceras* are typical Tethyan fossils. *Fagesia, Pseudaspidoceras* and *Quitmaniceras* are found together in southwestern New Mexico. Reeside (1923) described an interesting fauna of this age from limestone concretions in the Greenhorn Member of the Cody Shale at one small outcrop in south-central Montana that included ammonites assigned by him to *Vascoceras, Pseudotissotia* and *Helicoceras*. These ammonites would now be assigned to *Fagesia, Quitmaniceras* and *Allocrioceras*. *Pseudaspidoceras* and *Scaphites* have since been found at this locality. Ammonites of this age have not been found north of this locality.

The early Turonian Zone of *Vascoceras birchbyi* Cobban and Scott is probably just a little younger than that of *Pseudaspidoceras flexuosum*. The zone is best developed in the Pueblo area in southeastern Colorado, where it contains *Kamerunoceras, Pseudaspidoceras, Watinoceras, Vascoceras, Fagesia, Neoptychites* and *Puebloites*. A new genus, *Bassites* Cobban (1987a), is present in Kansas. *Vascoceras birchbyi* is widely distributed in New Mexico, Colorado and Kansas.

Fossils of latest early Turonian age are included in the Zone of *Mammites nodosoides* (Schlüter). In Colorado, New Mexico and Trans-Pecos Texas, this zone has a varied fauna of 15 ammonite genera. *Watinoceras, Kamerunoceras, Fagesia, Neoptychites* and *Puebloites* continue up into this zone. *Placenticeras, Mammites, Paravascoceras* and *Lewesiceras* reappear, and *Tragodesmoceras, Morrowites, Cibolaites, Hoplitoides* and *Choffaticeras* are new to the Western Interior. *Hoplitoides, Vascoceras* and *Choffaticeras* are Tethyan genera. *Baculites*, which descended from *Sciponoceras*, is abundant. Most of these genera are found in Trans-Pecos Texas, New Mexico and southern Colorado. A few of the genera are present in the Greenhorn Limestone in the Black Hills area, but only *Watinoceras* is known farther north in Canada.

In the lower part of the middle Turonian, the Zone of *Collignoniceras woollgari* (Mantell) contains a dozen genera of ammonites. *Collignoniceras* may be a descendant of *Cibolaites* from the underlying zone. *Spathites*, a Tethyan genus, is new to the Western Interior. *Binneyites* was derived from *Borissiakoceras*, and all the rest of the genera (*Placenticeras, Tragodesmoceras, Morrowites, Watinoceras, Neoptychites, Scaphites, Baculites, Allocrioceras* and *Hoplitoides*) are known from underlying zones. Conditions were favourable for northward migration and *Collignoniceras woollgari* with accompanying *Tragodesmoceras, Scaphites* and *Baculites* have been recorded from the Manitoba escarpment in southern Manitoba (McNeil and Caldwell, 1981, p. 54). *Collignoniceras* and *Scaphites* also occur along the western side of the Canadian Western Interior Basin (Stott, 1961, 1963, 1967).

Higher in the middle Turonian of the Western Interior, there is an abrupt change from calcareous to non-calcareous rocks and a corresponding abrupt decrease in ammonoid genera probably due to a return to cooler waters less favorable for ammonites. The Zone of *Prionocyclus percarinatus* (Hall and Meek) contains only five known genera (*Prionocyclus, Collignoniceras, Scaphites, Pteroscaphites* and *Placenticeras*). This zone is best developed from the Black Hills eastward to western Minnesota.

At the close of the middle Turonian, during the time of *Prionocyclus hyatti* (Stanton), diversity in ammonoid genera increased to eight genera with half of them largely confined to New Mexico and Trans-Pecos Texas. *Prionocyclus, Placenticeras* and *Scaphites* are widely distributed from south-central New Mexico to the Canadian border, whereas *Spathites, Romaniceras, Herrickiceras* and *Coilopoceras* (a derivative of *Hoplitoides*) have not been found north of the southernmost part of Colorado. *Romaniceras*, a descendant of *Kamerunoceras*, is abundant in Trans-Pecos Texas and southward into Chihuahua, Mexico. *Binneyites* occurs sparsely in the Black Hills area. *Prionocylus hyatti* has been recorded from the eastern side of the Canadian Western Interior Basin (Jeletzky, 1971, p. 52).

The beginning of late Turonian time (Zone of *Prionocyclus macombi* Meek) marked a reduction in ammonoid genera to five, and none of the three later Turonian zones has more than six genera. Species of *Prionocyclus* and *Scaphites* became endemic, and all four zones have them. The Tethyan genus *Coilopoceras* is present in the lower two zones (*Prionocyclus macombi* and *P. wyomingensis*) and then disappeared from the Western Interior. *Coilopoceras* is fairly abundant in New Mexico, Trans-Pecos Texas, and Chihuahua, Mexico. An occasional specimen has been found in the southernmost part of Colorado, and a single specimen was discovered in southeastern Wyoming. *Hourcquia*, a rare genus first described from Madagascar and later from Japan and Venezuela, occurs sparsely in the Zone of *Prionocyclus macombi* in New Mexico and Trans-Pecos Texas. Other genera in this zone are *Placenticeras, Prionocyclus, Coilopoceras* and *Scaphites*. The next younger zone (*Prionocyclus wyomingensis* Meek) has *Prionocyclus, Reesidites, Coilopoceras, Scaphites* and *Baculites*. *Reesidites* is a rare migrant that presumably came up from Mexico. *Baculites* reappeared after being absent from the Western Interior since early middle Turonian time (Zone of *Collignoniceras woollgari*). *Baculites* and *Reesidites* are also present in the Zone of *Scaphites whitfieldi* along with the endemic lineages of *Prionocyclus, Placenticeras, Pteroscaphites* and *Scaphites*. The uppermost of the late Turonian zones (*Prionocyclus quadratus*) has *Scaphites, Baculites, Placenticeras, Prionocyclus* and *Eubostrychoceras*. The last (Cobban, 1987b), a worldwide heteromorph genus only known in the Western Interior from this zone, is a migrant from the south that traveled as far north as the Black Hills. *Scaphites corvensis* is the common scaphite in this zone. Birkelund (1965) recorded a *Scaphites* cf. *corvensis* from West Greenland.

In summary, the Turonian was characterized at first by diverse Tethyan migrants (*e.g., Vascoceras, Fagesia, Neoptychites*) and later by genera (*e.g., Scaphites, Baculites, Prionocyclus*) that adapted to the water of the Western Interior Seaway with occasional migrants (*e.g., Romaniceras, Spathities, Coilopoceras, Hourcquia*) from the Gulf coastal region. *Baculites*, which descended from *Sciponoceras* of late Cenomanian age, became well established in the Western Interior in the later part of the early Turonian and the early part of the middle Turonian, but the genus disappeared from the seaway during the later part of the middle Turonian. *Baculites* reappeared in the seaway in the later part of the late Turonian and then gave rise to an endemic lineage that flourished until the early Maastrichtian. *Scaphites* became well adapted to the northwestern (Montana) part of the seaway during the Early Turonian and then gave rise to a lineage of species that persisted in much of the seaway through the rest of the Turonian, Coniacian and Santonian (Cobban, 1951). *Collignoniceras* and *Prionocyclus* are important genera that formed lineages of species that were widely distributed in the seaway during the middle and late Turonian. *Prionocyclus* descended from *Collignoniceras*, which probably had its origin in *Cibolaites* of latest early Turonian age. Other conspicuous lineages include species of the early Turonian *Watinoceras* that originated from *Neocardioceras* of latest Cenomanian age and species of *Binneyites* that descended from *Borissiakoceras* in the middle Turonian (Cobban, 1961). *Placenticeras (Placenticeras)*, which descended from *P. (Karamaites)* in the late early Turonian, became adapted to the cooler and less saline Western Interior waters and formed a succession of endemic species that flourished in the seaway during the rest of the Turonian, Coniacian, Santonian and Campanian.

CONIACIAN AMMONITE STOCKS AND MIGRATIONS

Coniacian time was marked by deposition of limestone and chalky shale over much of the central and eastern parts of the seaway. Ammonites are scarce in these deposits, but they are abundant in the equivalent non-calcareous shale and sandstone farther west.

In this report, three zones of ammonites are recognized (Fig. 2). The oldest zone, that of *Scaphites preventricosus* Cobban, contains nine genera of ammonites. Genera that continued up from the Turonian are *Placenticeras, Binneyites, Scaphites, Pteroscaphites* and *Baculites. Anisoceras* and *Idiohamites* reappeared, but are rare. *Forresteria* and *Bostrychoceras* were new to the seaway. *Forresteria* is known from New Mexico, Colorado and Wyoming, but it is absent in the large collections of ammonites from Montana. *Scaphites preventricosus*, on the other hand, is abundant in Montana and northward into the western part of the Western Interior of Canada (Stott, 1961, 1963, 1967; Irish, 1965; Jeletzky, 1968).

Eight genera are known from the middle Coniacian Zone of *Scaphites ventricosus* Meek and Hayden. The endemic lineages of *Placenticeras, Scaphites* and *Baculites* continued, and there are occasional specimens of *Bostrychoceras* and *Allocrioceras. Peroniceras, Gauthiericeras* and *Neocrioceras* were new to the Western Interior. *Peroniceras* is abundant in the lower part of the Coniacian to Campanian Austin Group of Texas, and the Western Interior specimens are migrants from that area. *Peroniceras* is rare in Montana, and there are no records from farther north although *S. ventricosus* is recorded from Canada (Stott, 1961, 1963, 1967; Irish, 1965) and West Greenland (Birkelund, 1965).

Eight genera are also known from the late Coniacian Zone of *Scaphites depressus* Reeside. Endemic lineages include *Placenticeras, Binneyites, Scaphites* and *Baculites. Neocrioceras* is present locally. *Protexanites* and *Phlycticrioceras* were migrants presumably from south or east Texas, and the heteromorph *Pseudobaculites* appeared abruptly and then disappeared until early Maastrichtian time. Most of these genera have been found as far north as central Montana, but only *Scaphites* and *Baculites* have been recorded from the Rocky Mountain Foothills of western Alberta and eastern British Columbia (Stott, 1961, 1963, 1967). Far to the north, in the Canadian Arctic Archipelago, Jeletzky (1971, p. 59) recorded *Scaphites depressus* along with other fossils that he assigned to the Santonian. The Zone of *S. depressus* could be assigned to the Santonian (*e.g.*, Obradovich and Cobban, 1975) on the basis of the presence of *Inoceramus (Cladoceramus) undulatoplicatus* Roemer. This widely distributed bivalve has been recommended as a guide to rocks of Santonian age (Birkelund *et al.*, 1984). However, this species occurs high in the Zone of *S. depressus* (Scott and Cobban, 1964, table 3), and the presence of the ammonites usually recorded in North America as *Protexanites shoshonensis* (Meek) and *Phlycticrioceras oregonense* Reeside, associated with typical *S. depressus* in Wyoming (Reeside, 1927), give the zone a distinct Coniacian aspect. Kennedy (1984) has shown that *Protexanites shoshonensis* is a junior synonym of *P. bourgeoisi* (d'Orbigny) and that *Phlycticrioceras oregonense* is a junior synonym of *P. trinodosus* (Geinitz), species originally described from the upper Coniacian of Europe.

SANTONIAN AMMONOID STOCKS AND MIGRATIONS

Five zones are assigned to the Santonian in this report (Fig. 2). The upper two contain the free-swimming crinoids, *Uintacrinus* and *Marsupites*, which, historically, have been long considered as guide fossils to rocks of Santonian age (Birkelund *et al.*, 1984).

Clioscaphites saxitonianus (McLearn), the oldest zone, has only *Clioscaphites, Placenticeras, Texanites* and *Baculites. Clioscaphites* is a direct descendant of *Scaphites*, and the species of *Placenticeras* and *Baculites* are in the endemic lineages of those genera. *Texanites*, new to the Western Interior, was a migrant from Texas or Mexico where the genus is common. In this zone, *Texanites* is not known north of southern Colorado. *Clioscaphites* and *Baculites* range into Canada, where they occur on both the eastern (McNeil and Caldwell, 1981) and western (McLearn, 1929; Stott, 1963, 1967) sides of the seaway. A subspecies of *C. saxitonianus (C. s. septentrionalis)* has been described from West Greenland (Birkelund, 1965).

Seven genera are present in the Zone of *Clioscaphites vermiformis* (Meek and Hayden). Endemic species of the genera *Placenticeras, Clioscaphites, Pteroscaphites, Baculites* and *Binneyites* occur; all are found as far north as northwestern Montana, and *Clioscaphites* and *Baculites* have been found along the western side of the seaway in Canada (Stott, 1963, 1967; Irish, 1965). *Baculites codyensis* Reeside, which is abundant in this zone, has been found in West Greenland (Birkelund, 1965). *Texanites* is a rare genus in this zone in the southern part of the Western Interior of the United States. The heteromorph *Glyptoxoceras* appeared for the first time, in the southern part of the region. Ammonites are scarce in the chalky deposits of the eastern part of the seaway, but *C. vermiformis* has been recorded from Kansas (Miller, 1968; Hattin, 1982).

A varied ammonoid assemblage is present in the overlying Zone of *Clioscaphites choteauensis* Cobban. *Texanites, Reginaites, Clioscaphites, Scaphites,* *Desmoscaphites, Pteroscaphites* and *Baculites* occur together at one locality in northeastern New Mexico (Scott *et al.*, 1986). *Placenticeras* is known from other areas, especially in New Mexico, and an ammonite recorded by Miller (1970) as *Submortoniceras* is known from Kansas (Miller, 1970). *Clioscaphites choteauensis* is widely distributed in a variety of rocks. Specimens have been found in chalk in Kansas (Miller, 1968, 1970; Hattin, 1982), in calcareous shale in Colorado (Scott and Cobban, 1964), and in non-calcareous shale and sandstone in Montana. The species, along with *Baculites*, also occurs in Canada along the western side of the seaway (Stott, 1963, 1967). The *Scaphites* in this zone is a small form from a different lineage than that of the endemic Turonian through Santonian line of *Scaphites*. The new *Scaphites* belongs to the group of *S. leei* Reeside-*S. hippocrepis* (DeKay) (Cobban, 1969) which may have a European origin. *Desmoscaphites* is a derivative of *Clioscaphites*.

In the next Zone of *Desmoscaphites erdmanni* Cobban, the only ammonite genera known are *Desmoscaphites, Scaphites, Haresiceras (Mancosiceras)* and *Baculites*. All are derivatives of species in the underlying zone. *Haresiceras* may be the last of the original stock of scaphites in the Western Interior.

The youngest of the Santonian zones, *Desmoscaphites bassleri* Reeside, has the genera *Placenti-*

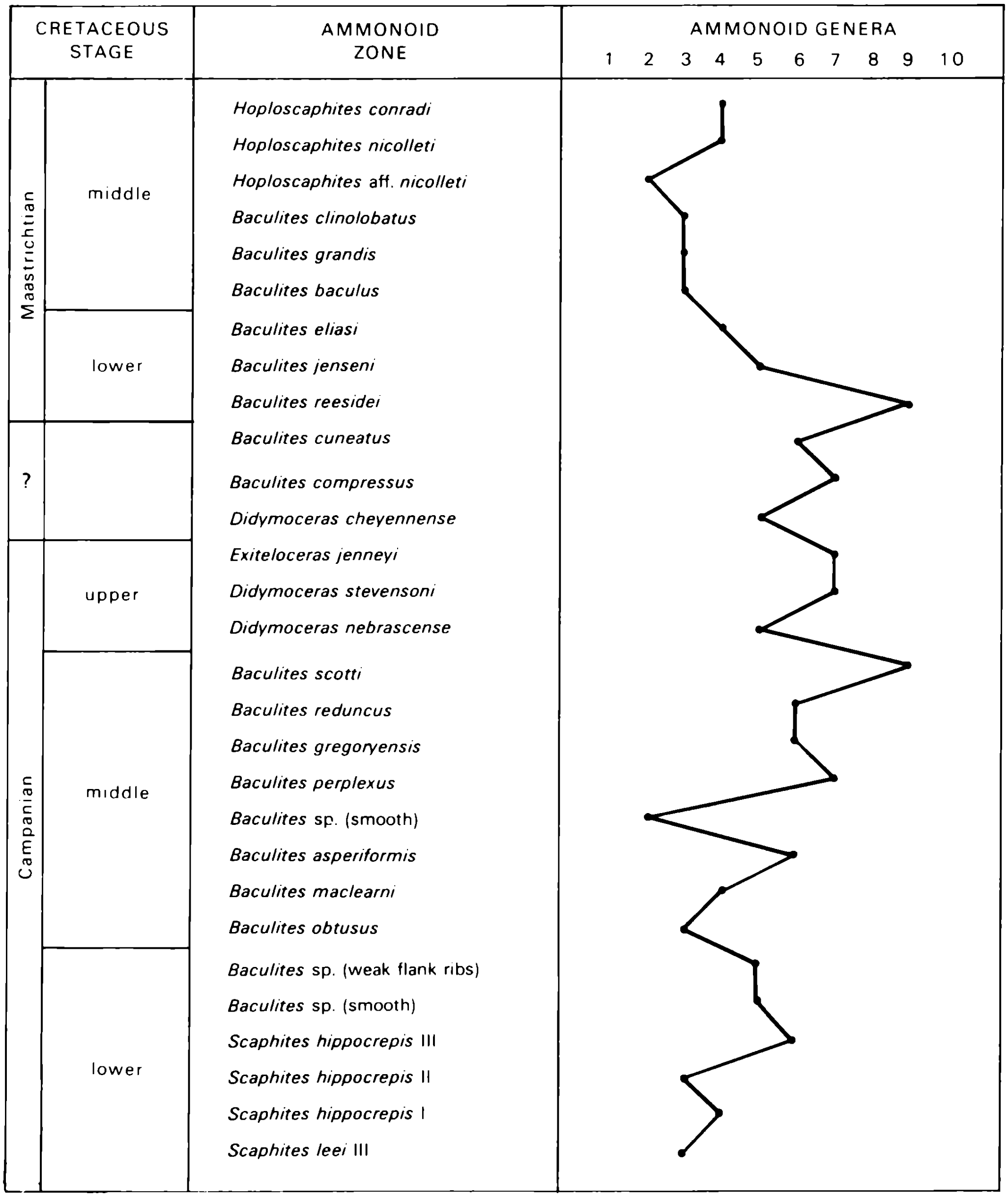

Figure 4. *Western Interior ammonoid zones and number of ammonoid genera for the Campanian and Maastrichtian.*

ceras, Desmoscaphites, Scaphites, Haresiceras (Mancosiceras) and *Baculites*. Species of these genera are all endemic and represent continuations of stocks well established in the Western Interior.

In summary, only 12 genera of ammonites are known from the Western Interior Seaway during the Santonian. Seven of these (*Placenticeras, Binneyites, Baculites*, and the scaphites *Clioscaphites, Pteroscaphites, Desmoscaphites* and *Haresiceras*) represent well-established endemic stocks. During the earlier half of the Santonian, a few migrants (*Texanites, Reginaites, Submortoniceras* and *Glyptoxoceras*) from the Gulf coastal region appeared briefly in the southern part of the seaway. A new stock of scaphites (*leei-hippocrepis* group) entered the seaway from the south and became adapted to local conditions as far north as the Canadian border.

CAMPANIAN AMMONOID STOCKS AND MIGRATIONS

Seventeen ammonoid zones are assigned to the Campanian in this report (Fig. 4). Overlying these are several zones that are either Campanian or Maastrichtian. These zones are shown with a query in Fig. 4. Paleontologists and stratigraphers have long known that the stratotypes of the Campanian and Maastrichtian in northwestern Europe are very incomplete and that a considerable time gap separates them (well shown by Sissingh, 1978, fig. 3). The widely distributed planktonic foraminiferal Zone of *Globotruncanita calcarata* (Cushman), although not found in northwestern Europe, is now well accepted by micropaleontologists as defining the top of the Campanian (Marks, 1984). *Globotruncanita calcarata* has not been found in the Western Interior, but it is known in the Gulf and Atlantic coastal regions and in southern Europe, northern Africa and elsewhere (for map showing distribution of *G. calcarata*, see Masters, 1977). The presence of *G. calcarata* at the top of the Marshalltown Formation in New Jersey and Delaware (Olsson, 1964; Petters, 1976) is of special interest inasmuch as several ammonites from formations in those states occur also in the Western Interior. Float specimens from Marshalltown collected along the Chesapeake and Delaware Canal include *Didymoceras stevensoni* (Whitfield) and *Exiteloceras jenneyi* (Whitfield). The overlying Mount Laurel Sand, along the Chesapeake and Delaware Canal, contains fragments of *Didymoceras cheyennense* (Meek and Hayden) as well as fragments of *Anaklinoceras reflexum* Stephenson, a species confined to the Zone of *Baculites compressus* Say. The Mount Laurel has been dated as early Maastrichtian using planktonic foraminifera (Olsson, 1964), ostracodes (Brouwers and Hazel, 1978), dinoflagellates and acritarchs (May, 1980), pollen (Christopher, 1980), and barnacles (Zullo, 1987). Bivalves and gastropods in the Mount Laurel Sand belong to the Zone of *Exogyra cancellata* Stephenson which is generally accepted as early Maastrichtian in age (Sohl and Christopher, 1983). However, work in Israel suggests that rocks of Mount Laurel age may be late Campanian. Lewy (1986) has equated the *G. calcarata* Zone with rocks in Israel that contain *Axonoceras reflexum*. Even the basal part of the Navesink Formation, which overlies the Mount Laurel, may be of latest Campanian age according to the investigations of Błaszkiewicz (1980), who described an ammonite fauna from Poland that is very closely related to that found in the basal Navesink. Błaszkiewicz's fauna (Zone of *Nostoceras pozaryskii* at the top of the Polish Campanian) includes *Belemnella langei* Jeletzky, a species that characterizes the uppermost zone of the Campanian of the standard northern European belemnoid sequence. Until an international agreement is reached concerning the placement of the Campanian-Maastrichtian boundary, the several ammonite zones of the Western Interior that seem to be of Mount Laurel-basal Navesink age are treated together, but not definitely assigned to either the Campanian or the Maastrichtian.

The oldest zone assigned to the Campanian in this report is that of *Scaphites leei* Reeside III, which is named for the youngest of three chronologic subspecies of *S. leei* (Cobban, 1969). Species of *Scaphites, Haresiceras (Haresiceras)* and *Baculites* are the only ammonites known, and all are endemic.

The latest of the three chronologic subspecies *Scaphites leei* gave rise to the oldest of three chronologic subspecies of *S. hippocrepis* (DeKay), which have been designated, from oldest to youngest, I, II and III (Cobban, 1969). Four ammonoid genera are known in the Zone of *S. hippocrepis* I. *Scaphites, Baculites* and *Haresiceras* continue lineages from the underlying zone. *Parapuzosia*, a gigantic ammonite (Miller and Youngquist, 1946), was a migrant from Texas that became well adapted to the area extending from north-central Wyoming to central Montana.

The next zone, that of *Scaphites hippocrepis* (DeKay) II, is well known in Colorado, Wyoming and Montana. Only representatives of the three endemic lineages of *Scaphites, Baculites* and *Haresiceras* have been found. The specimen illustrated as *S. hippocrepis* from Saskatchewan by Jeletzky (1970, pl. 27, fig. 6) may be *S. hippocrepis* II.

Ammonites of the Zone of *Scaphites hippocrepis* (DeKay) III are more varied owing to a northward migration from the Texas-Chihuahua region. The lineages of *Placenticeras, Scaphites, Haresiceras (Haresiceras)* and *Baculites* continued. The loosely coiled heteromorph *Glyptoxoceras* reappeared and migrated as far north as south-central Montana. *Submortoniceras*, a common genus in the Austin Group of Texas, migrated into the southern part of the Western Interior as far north as central eastern Utah. This northward migration is evident in southern Canada, where *S. hippocrepis* has been reported from Saskatchewan and *Haresiceras natronense* Reeside, a species restricted to the Zone of *S. hippocrepis* III, has been identified from Manitoba

(Jeletzky, 1970, 1971) and southeastern Manitoba (Williams and Baadsgaard, 1975). During this time, *Haresiceras* may have migrated across the Hudson Bay region to West Greenland, where Birkelund (1965, p. 138) recorded some poorly preserved specimens.

A zone characterized by dominantly smooth-flanked baculites lies just above the Zone of *Scaphites hippocrepis* III. Although baculites are abundant, other kinds of ammonites are scarce. A few specimens that represent a small descendant of *S. hippocrepis* are locally present, and the *S. hippocrepis* lineage then became extinct higher in this zone. An entirely new stock of small, compressed scaphites abruptly appeared in the central part of the seaway. These scaphites show some resemblance to the Indian *Indoscaphites* and are herein referred to as *"Indoscaphites"*. Their geographic origin is unknown. Other ammonites in this zone include *Placenticeras* and an occasional *Submortoniceras*. The zone of smooth baculites is best developed in central and north-central Wyoming and in south-central Montana. The late J.R. Gill and the author found these smooth baculites farther north in east-central Montana (Gill *et al.*, 1972, p. 97) and also in southeastern Alberta and southern Manitoba.

A zone of *Baculites* that has weakly ribbed flanks succeeds the zone of smooth-flanked forms. The endemic lineages of *Baculites* and *Placenticeras* continue through the zone. *"Indoscaphites"* persisted for a while in Wyoming and then disappeared from the Western Interior. New to the region is the genus *Trachyscaphites* Cobban and Scott (1964) which may have had its origin in the European *Scaphites gibbus* Schlüter (1872) of latest early Campanian age (Schmid and Ernst, 1975, fig. 2). *Trachyscaphites* probably migrated from Europe to Texas and then into the Western Interior as far north as the Black Hills during the time of the zone of weakly ribbed baculites. The baculites, however, had migrated farther north into southern Saskatchewan (North and Caldwall, 1975, p. 325).

Only *Baculites, Trachyscaphites* and *Placenticeras* are known from the Zone of *Baculites obtusus* Meek. In the Western Interior of the United States, *B. obtusus* is widely distributed from northern New Mexico (Cobban *et al.*, 1974) to east-central Montana (Gill *et al.*, 1972). The species has been recorded farther north in Alberta (Landes, 1940), Saskatchewan (Price and Ball, 1973; North and Caldwell, 1975) and West Greenland (Birkelund, 1965).

Baculites, Trachyscaphites and *Placenticeras* persist through the Zone of *Baculites maclearni* Landes. *Trachyscaphites* migrated as far north as central Montana, and *B. maclearni* migrated farther north into southern Alberta (Landes, 1940) and Saskatchewan (Price and Ball, 1973; North and Caldwell, 1975). An important new genus, *Hoploscaphites*, appears in this zone. The Western Interior species of the genus are closely related to the form described from Germany as *Scaphites ornatus* Roemer (1841) which seems to be an early representative of the *Hoploscaphites* stock. Scaphites of this type are unknown in the *Trachyscaphites* faunas of Texas. However, scaphites that seem assignable to *Hoploscaphites* occur with *Baculites obtusus* in West Greenland (Birkelund, 1965); thus, *Hoploscaphites* of the *ornatus*-type probably entered the Western Interior from the north. The *Scaphites* sp. recorded with *B. maclearni* by Price and Ball (1973, p. 41, 61) from a potash shaft in Saskatchewan may be of the *ornatus* stock.

Hoploscaphites of the *ornatus* type are fairly abundant in the Zone of *Baculites asperiformis* Meek. The largest collections are from Colorado, but some specimens are known from northern New Mexico and central and eastern Wyoming. Fragments of scaphites were recorded with *B. asperiformis* from a potash shaft in Saskatchewan (Price and Ball, 1973, p. 41). *Baculites asperiformis* is also present in southern Alberta (Landes, 1940). The lineages of *Trachyscaphites* and *Placenticeras* continue through this zone in the Western Interior of the United States, and two genera new to the Western Interior appear in this zone. A few specimens of *Hoplitoplacenticeras* have been found as far north as south-central Wyoming (Cobban, 1963), but the genus is fairly common in northeastern Texas. Fragments of the heteromorph ammonite *Bostrychoceras* occur with *Baculites asperiformis* in the Campanian part of the Pierre Shale in north-central Colorado (Izett *et al.*, 1971, p. A11). *Bostrychoceras* has been found at many localities in Texas (Young, 1963), and this genus, as well as *Hoplitoplacenticeras*, thus migrated northward into the Western Interior for a brief period.

A poorly known zone of smooth-flanked baculites lies above the Zone of *Baculites asperiformis. Hoploscaphites* of the *ornatus* stock occurs with the baculites.

Baculites, Hoploscaphites, Trachyscaphites and *Placenticeras* are widely distributed in the Zone of *Baculites perplexus* Cobban. *Hoploscaphites* is especially common in much of Colorado and Wyoming and along the west flank of the Black Hills uplift (Robinson *et al.*, 1964, p. 82-84). The genus seems to have split into a nodeless lineage (*H. gilli* Cobban and Jeletzky, 1965) and the main *ornatus* stock. At a few localities in Colorado and Wyoming, fragments of heteromorph ammonites (*Didymoceras*?, *Exiteloceras*?) have been found, and at one locality in east-central Wyoming, a portion of a pachydiscid ammonite was collected. *Baculites* and *Hoploscaphites*, which were now well adjusted to the Western Interior waters, are abundant in Saskatchewan (North and Caldwell, 1975; Price and Ball, 1971). *Hoploscaphites gilli* has also been recorded from Manitoba (Cobban and Jeletzky, 1965).

Six genera of ammonites are known from the Zone of *Baculites gregoryensis* Cobban. The lineages of *Baculites, Placenticeras, Trachyscaphites* and *Hoploscaphites* (nodeless and noded stocks) continued. *Baculites* and *Hoploscaphites* occur as far north as southern Saskatchewan (Cobban and Jeletzky, 1965; North and Caldwell, 1975). The heteromorph ammonites *Didymoceras* and *Anaklinoceras*, migrants from the south, became well established as far north as central South Dakota.

Six genera are also present in the Zone of *Baculites reduncus* Cobban. Stocks well adjusted to living in the Western Interior included *Baculites, Placenticeras* and *Didymoceras*. For reasons unknown, *Hoploscaphites* and *Trachyscaphites* have not been collected, although they are present in the underlying and overlying zones. New to the Western Interior are the heteromorph *Oxybeloceras* and the pachydiscid ammonites *Anapachydiscus* and *Menuites*; none has been found north of central Wyoming. The last two may be a dimorphic pair (*Anapachydiscus*, the macroconch and *Menuites*, the microconch).

Ammonoid genera increased to nine in the Zone of *Baculites scotti* Cobban. *Anapachydiscus, Menuites* and *Placenticeras* are the only normally coiled genera; the rest (*Baculites, Hoploscaphites, Trachyscaphites, Didymoceras, Exiteloceras* and *Oxybeloceras*) are heteromorphs. All occur in Colorado and Wyoming, but only *Baculites, Hoploscaphites* and *Didymoceras* have been recorded as far north as east-central Montana (Gill *et al.*, 1972). The *Trachyscaphites, Anapachydiscus* and *Menuites* stocks disappeared from the Western Interior at the end of *Baculites scotti* time.

Diversity decreased to five genera in the Zone of *Didymoceras nebrascense* (Meek and Hayden). *Baculites, Hoploscaphites* (nodeless and noded stocks), *Placenticeras* and *Didymoceras* were well established and the small heteromorph *Solenoceras* was new to the region. All except *Placenticeras* have been recorded as far north as east-central Montana (Gill *et al.*, 1972), and *D. nebrascense* has been reported farther northeastward in Montana (Jensen and Varnes, 1964). A baculite suggestive of this zone was found in the Campanian to Maastrichtian(?) Odanah Member of the Pierre Shale in southern Manitoba (McNeil and Caldwell, 1981, p. 72).

Seven genera are present in the Zone of *Didymoceras stevensoni* (Whitfield). Six (*Baculites, Hoploscaphites, Didymoceras, Oxybeloceras, Solenoceras* and *Placenticeras*) represent stocks well known in the Western Interior. A new heteromorph, *Nostoceras*, found at one locality in Colorado, is closely related to a species from southwestern Arkansas and represents migration from that area. The rest of the genera are abundant in New Mexico, Colorado and Wyoming, and most are found as far north as east-central Montana (Gill *et al.*, 1972). *Didymoceras stevensoni* has also been found in northeastern Montana (Jensen and Varnes, 1964, p. F10).

Heteromorphs continued to dominate the ammonoid fauna in the Zone of *Exiteloceras jenneyi* (Whitfield). The stocks of *Baculites, Hoploscaphites (noded and nodeless), Exiteloceras, Didymoceras* and *Solenoceras* flourished along with *Placenticeras*. A rare occurrence of *Pachydiscus* is in Colorado. *Baculites, Hoploscaphites, Exiteloceras* and *Placenticeras* have been recorded as far north as east-central Montana (Gill *et al.*, 1972), but only *Baculites* and *Placenticeras* have been recorded farther north in Saskatchewan (Caldwell, 1968, p. 71). Great intraspecific variation is displayed in the *Hoploscaphites* stock. Specimens are dominantly compressed and finely ribbed, but the variation series includes robust forms. Most have ventrolateral tubercles and a few umbilical tubercles, but an occasional specimen is nodeless.

In summary, 21 genera of ammonites are known from Campanian rocks in the Western Interior of the United States, and of these, more than two-thirds are heteromorphs. Persistent stocks of endemic heteromorphs include the baculites and scaphites which are abundant in most zones. The endemic baculites formed a single lineage in which successive species became larger with more complex sutures through most of the Campanian. These baculites attained their maximum size in the Zone of *Exiteloceras jenneyi* (Whitfield), after which they gradually become smaller with accompanying simplification of the suture. Near the end of the Campanian, these baculites had to compete with new migrants from the Gulf coastal region represented by large baculites with much simpler sutures. Several successive stocks of scaphites were present during the Campanian. The endemic lineage of scaphites (*Scaphites-Clioscaphites-Desmoscaphites-Haresiceras*) that began in the Cenomanian finally became extinct in the earliest part of the Campanian. Scaphites of the *leei-hippocrepis* group became dominant in the early Campanian and then were displaced by new migrants represented by the small "*Indoscaphites*" stock. These, in turn, were displaced by new migrants from the south represented by the large *Trachyscaphites*. Finally in the middle Campanian, *Hoploscaphites*, a migrant from the north, displaced the *Trachyscaphites* and flourished through the rest of the Campanian. Most of the other heteromorphs (*Glyptoxoceras, Bostrychoceras, Exiteloceras, Anaklinoceras* and *Nostoceras*) made only brief appearances in the Western Interior, whereas a few (*Didymoceras, Oxybeloceras* and *Solenoceras*) remained in the seaway long enough to form short lineages. Of the regularly coiled ammonites, only *Placenticeras* was conspicuous in most of the zones.

CAMPANIAN OR MAASTRICHTIAN AMMONOID STOCKS AND MIGRATIONS

Three ammonoid zones could be either Campanian or Maastrichtian (Fig. 4). The lowest is the Zone of *Didymoceras cheyennense* (Meek and Hayden). *Baculites, Hoploscaphites, Didymoceras, Oxybeloceras*, and *Placenticeras* continue through this zone. Some of the *Hoploscaphites* become larger and more coarsely ribbed, and it is possible that the holotype of the coarsely ribbed species described by Owen (1852) as *Scaphites (Ammonites?) nodosus* came from this zone. Ammonites of this zone are most numerous and best represented in the area that extends from northern New Mexico to the Black Hills. Only *Baculites* and *Placenticeras* have been found in this zone in east-central Montana (Gill *et al.*, 1972, p. 95, bed 54). The zone has not been identified in Canada (Caldwell, 1968, p. 70, 71; North and Caldwell, 1975, p. 329). At this time, a new stock of baculites, characterized by the robust, fairly simple-sutured *B. undatus* Stephenson, migrated from Texas into the Western Interior as far as northern Colorado (Cobban, 1973). This stock of baculites contrasts greatly to the forms endemic to the Western Interior that have more compressed shells and more complex sutures.

The Zone of *Baculites compressus* Say is best developed in the Western Interior of the United States in Colorado, South Dakota, and Montana. Ammonite diversity in this zone is greatest in north-central Colorado, where the genera *Baculites, Hoploscaphites, Anaklinoceras, Axonoceras, Solenoceras* and *Placenticeras* have been found (Izett *et al.*, 1971). This area in Colorado became an endemic centre in which several lineages of heteromorph ammonites developed. The baculites include both the endemic stock and the migrant *B. undatus* stock (Cobban, 1973). The heteromorph *Axonoceras*, new to the Western Interior, was a migrant from Texas. Species of this genus along with those of *Anaklinoceras* were originally described from the Maastrichtian Neylandville Marl of the Navarro Group in northern Texas (Stephenson, 1941). Few of the heteromorph genera ranged north of Colorado. *Baculites, Hoploscaphites*, and *Placenticeras* were abundant in South Dakota and Montana as well as in southern Alberta (Landes, 1940, p. 185) and Saskatchewan (Caldwell, 1968, p. 70, 71), where the northern subspecies *B. compressus robinsoni* Cobban is conspicuous. An occasional specimen of *Pachydiscus* has been found in the Bearpaw Shale of east-central Montana, and Karl Waage (personal communication, 1985) recalled seeing a specimen from Canada. The appearance of this genus was brief, and no representatives are known above this zone in the Western Interior.

The endemic stocks of *Baculites, Hoploscaphites*, and *Placenticeras* continued to thrive in great abundance during the time of *Baculites cuneatus* Cobban in the northern Great Plains region in South Dakota and Montana, as well as farther north in southwestern Saskatchewan (Forester *et al.*, 1977, fig. 2). In north-central Colorado, these genera occur along with *Didymoceras, Nostoceras, Solenoceras*, endemic baculites, and the migrant *B. undatus* stock (Cobban, 1973). *Hoploscaphites* continued to have great intraspecific variation; large, robust, coarsely ornamented forms are conspicuous.

MAASTRICHTIAN AMMONOID STOCKS AND MIGRATIONS

During the Maastrichtian, the Western Interior Sea in Montana and Colorado was transgressive at first (Bearpaw transgression) and regressive later (Fox Hills regression) (Gill and Cobban, 1973). Upper Maastrichtian rocks in the Western Interior are entirely non-marine. Nine ammonoid zones are recognized in this report and these are arbitrarily assigned to the lower and middle Maastrichtian (Fig. 4).

The endemic centre in north-central Colorado continued through the Zone of *Baculites reesidei* Elias, where *Baculites, Hoploscaphites, Didymoceras, Nostoceras, Anaklinoceras, Exiteloceras, Solenoceras* and *Placenticeras* occur. The baculites include the endemic *B. reesidei* and representatives of the *B. undatus* stock of Texas (Cobban, 1973). A new genus, *Rhaeboceras* Meek, is present in this zone a little farther east in northern Colorado. Most of the heteromorphs were not present north of Colorado, but *Baculites reesidei, Hoploscaphites*, and *Rhaeboceras* are abundant in the Bearpaw Shale of Montana and Saskatchewan (Caldwell, 1968, p. 70, 71). Large, robust, coarsely ornamented *Hoploscaphites* are conspicuous, but smaller, slender forms are present, as well as small, densely ribbed, nodeless, compressed forms. *Placenticeras* is uncommon in the Zone of *B. reesidei* and became extinct in the Western Interior before the close of this time period.

The endemic center of heteromorphs in north-central Colorado disappeared before the time of the Zone of *Baculites jenseni* Cobban. The endemic stocks of *Baculites* and *Hoploscaphites* continued to flourish during this time from northeastern New Mexico to northeastern Montana and on into southwestern Saskatchewan (Forester *et al.*, 1977, fig. 3). *Rhaeboceras* was abundant in Montana and Saskatchewan. A gigantic baculitid, *Pseudobaculites*, originally described from the Bearpaw Shale of southwestern Saskatchewan as *Baculites natosini* Robinson (1945), appeared abruptly in this zone (*e.g.*, Gill *et al.*, 1972, p. 94). This genus, probably a migrant from the north, has been found as far south as southern Colorado. The origin of this genus is unknown; it first appears in the upper Coniacian of Colorado (Scott and Cobban, 1964, p. L11), persists through the upper Coniacian Zone of *Scaphites depressus* Reeside in Utah and Wyoming (Cobban, 1952), and then disappears from the Western Interior until the lower Maastrichtian Zone of *Baculites jenseni*. The Zone of *B. jenseni* also marks the end of large, coarsely ornamented scaphites. A few specimens of the heteromorph *Nostoceras* have been found in southern Colorado.

Diversity decreases to four genera in the Zone of *Baculites eliasi* Cobban. The endemic stocks of *B. eliasi* and *Hoploscaphites* were widely distributed from southeastern Colorado to northeastern Montana. *Baculites eliasi* also occurs in southern Saskatchewan (Jeletzky, 1970; Riccardi, 1983). The long lineage of endemic baculites, of which *B. eliasi* is the end member, finally became extinct at this time. *Pseudobaculites*, however, continues into this zone. An occasional specimen of *Nostoceras* has been found in Colorado.

Only three genera of ammonites are present in the Zone of *Baculites baculus* Meek and Hayden. This baculite represents a new migrant from the south and may be a descendant of *B. undatus*. *Baculites baculus*, along with endemic *Hoploscaphites*, occurs in the Western Interior of the United States from southern Colorado to northeastern Montana. Jeletzky (1971, p. 71) noted that the seaway during the time of *B. baculus* occupied southern Saskatchewan and eastern Alberta, and Riccardi (1983) illustrated specimens of *B. baculus* from Saskatchewan. *Ponteixites*, a small descendant of *Rhaeboceras*, lived in the seaway from southeastern Montana to southern Saskatchewan, where the genus was first described (Warren, 1934). The *Rhaeboceras-Ponteixites* stock became extinct at the end of this time.

Low generic diversity also marks the Zone of *Baculites grandis* Hall and Meek. This baculite, a descendant of *B. baculus*, is known as far north as southwestern Saskatchewan (Forester *et al.*, 1977, fig. 3). The endemic *Hoploscaphites* continued to flourish and display great intraspecific variation. One lineage developed lateral tubercles (Jeletzky, 1970, pl. 27, fig. 10) in addition to the normal umbilical and ventrolateral ones. Occasional specimens of a new oxycone, *Sphenodiscus*, appeared. This genus, a migrant from the south, is not known in this zone north of Colorado.

The three genera *Baculites, Hoploscaphites* and *Sphenodiscus* continue through the Zone of *Baculites clinolobatus* Elias. *Hoploscaphites* in this zone varies from compressed forms with only ventrolateral tubercles to stout forms with ventrolateral tubercles and several rows of lateral ones. By the time of this zone, the Western Interior Sea was regressing southeastward, and ammonites indicative of this zone have not been found north of southern North Dakota. The lineage of *Baculites baculus-grandis-clinolobatus* became extinct during this time.

Above the Zone of *Baculites clinolobatus* is a zone of undescribed scaphites that can be referred to as *Hoploscaphites* aff. *H. nicolleti* (Morton). These scaphites represent a continuation of the endemic *Hoploscaphites* stock. *Sphenodiscus* is the only known associated ammonite.

The stocks of *Hoploscaphites* and *Sphenodiscus* continue through the Zone of *Hoploscaphites nicolleti* (Morton). New migrants from the Gulf region included *Discoscaphites* and small *Baculites* of the *B. columna* Morton group. The zone is best developed in the Fox Hills of north-central South Dakota and southern North Dakota, where the scaphites show great intraspecific variation. These four genera continue on through the overlying Zone of *Hoploscaphites conradi* (Meek), which is the youngest known ammonite zone in the Western Interior.

In summary, only 14 genera of Maastrichtian ammonites are known from the Western Interior, and these show a general decrease in number in the younger rocks. Heteromorphs continued to dominate, especially the baculitid and scaphitid stocks. The endemic lineage of baculites that had persisted since the late Cenomanian finally became extinct late in the early Maastrichtian (Zone of *Baculites eliasi* Cobban), and a new stock of large baculites from the Gulf coastal region filled the vacated niche. This stock of large baculites (*baculus-grandis-clinolobatus*) became extinct in the middle Maastrichtian. Just before the close of marine deposition, a stock of smaller, mostly smooth baculites migrated from the south into the seaway as far north as southeastern South Dakota, and about the same time smaller, ornate baculites that belong to the *B. columna* Morton group found their way up to north-central South Dakota. The endemic *Hoploscaphites* was abundant and highly variable; it was joined by the migrant *Discoscaphites* near the end of marine conditions in the late middle Maastrichtian. *Sphenodiscus*, a smooth to nearly smooth oxycone, migrated into the seaway from the south during the time of *Baculites grandis* Hall and Meek and persisted to the end of marine deposition; its compressed shape suggests that it probably occupied the niche vacated by *Placenticeras*, which had become extinct during the time of *Baculites reesidei* Elias.

REFERENCES

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

Birkelund, T., 1965, Ammonites from the Upper Cretaceous of West Greenland: Meddelelser om Grönland, v. 179, 192 p.

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 33(1-2), p. 3-20.

Błaszkiewicz, A., 1980, Campanian and Maastrichtian ammonites of the middle Vistula River valley, Poland; A stratigraphic-paleontological study: Prace Instytuto Geologicznego, v. 92, 63 p.

Brouwers, E.M. and Hazel, J.E., 1978, Ostracoda and correlation of the Severn Formation (Navarroan; Maestrichtian) of Maryland: Society of Economic Paleontologists and Mineralogists, Paleontological Monograph 1, 52 p.

Caldwell, W.G.E., 1968, The Late Cretaceous Bearpaw Formation in the South Saskatchewan River valley: Saskatchewan Research Council Geology Division, Report 8, 86 p.

Christopher, R.A., 1980, Cretaceous pollen, *in* Minard, J.P., Geology of the Round Bay quadrangle, Anne Arundel County, Maryland: United States Geological Survey, Professional Paper 1109, p. 20-28.

Cobban, W.A., 1951, Scaphitoid cephalopods of the Colorado Group: United States Geological Survey, Professional Paper 239, 42 p.

Cobban, W.A., 1952, A new Upper Cretaceous ammonite genus from Wyoming and Utah: Journal of Paleontology, v. 26, p. 758-760.

Cobban, W.A., 1961, The ammonite family Binneyitidae Reeside in the Western Interior of the United States: Journal of Paleontology, v. 35, p. 737-758.

Cobban, W.A., 1963, Occurrence of the Late Cretaceous ammonite *Hoplitoplacenticeras* in Wyoming, *in* Shorter Papers in the Geological Sciences: United States Geological Survey, Professional Paper 475-C, p. C60-C62.

Cobban, W.A., 1969, The Late Cretaceous ammonites *Scaphites leei* Reeside and *Scaphites hippocrepis* (DeKay) in the Western Interior of the United States: United States Geological Survey, Professional Paper 619, 29 p.

Cobban, W.A., 1973, The Late Cretaceous ammonite *Baculites undatus* Stephenson in Colorado and New Mexico: United States Geological Survey, Journal of Research, v. 1, p. 459-465.

Cobban, W.A., 1977, Characteristic marine molluscan fossils from the Dakota Sandstone and intertongued Mancos Shale, west-central New Mexico: United States Geological Survey, Professional Paper 1009, 30 p.

Cobban, W.A., 1983, Molluscan fossil record from the northeastern part of the Upper Cretaceous seaway, Western Interior, *in* Cobban, W.A. and Merewether, E.A., Stratigraphy and Paleontology of mid-Cretaceous rocks in Minnesota and Contiguous Areas: United States Geological Survey, Professional Paper 1253-A, p. 1-23.

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

Cobban, W.A., 1987a, A new ammonite from the Upper Cretaceous of Kansas: United States Geological Survey, Bulletin 1690, p. B1-B3.

Cobban, W.A., 1987b, The Upper Cretaceous ammonite *Eubostrychoceras* Matsumoto in the Western Interior of the United States: United States Geological Survey, Bulletin 1690, p. A1-A5.

Cobban, W.A. and Hook, S.C., 1984, Mid-Cretaceous molluscan biostratigraphy and paleogeography of southwestern part of Western Interior, United States, *in* Westermann, G.E.G., ed., Jurassic-Cretaceous Biochronology and Paleogeography of North America: Geological Association of Canada, Special Paper 27, p. 257-271.

Cobban, W.A. and Jeletzky, J.A., 1965, A new scaphite from the Campanian rocks of the Western Interior of North America: Journal of Paleontology, v. 39, p. 794-801.

Cobban, W.A., Landis, E.R. and Dane, C.H., 1974, Age relations of upper part of Lewis Shale on east side of San Juan Basin, New Mexico: New Mexico Geological Society, 25th Annual Field Conference, Central-northern New Mexico, 1974, Guidebook, p. 279-282.

Cobban, W.A. and Scott, G.R., 1964, Multinodose scaphitid cephalopods from the lower part of the Pierre Shale and equivalent rocks in the conterminous United States: United States Geological Survey, Professional Paper 483-E, p. E1-E13.

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.

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

Eicher, D.L., 1967, Foraminifera from Belle Fourche Shale and equivalents, Wyoming and Montana: Journal of Paleontology, v. 41, p. 167-188.

Eicher, D.L. and Diner, R., 1985, Foraminifera as indicators of water mass in the Cretaceous Greenhorn sea, Western Interior, *in* Pratt, L.M., Kauffman, E.G. and Zelt, F.G., eds., Fine-grained Deposits and Biofacies of the Cretaceous Western Interior Seaway: Evidence of Cyclic Sedimentary Processes: Society of Economic Paleontologists and Mineralogists, 1985 Midyear Meeting, Golden, Colorado, Field Trip Guidebook No. 4, p. 60-71.

Forester, R.W., Caldwell, W.G.E. and Oro, F.H., 1977, Oxygen and carbon isotopic study of ammonites from the Late Cretaceous Bearpaw Formation in southwestern Saskatchewan: Canadian Journal of Earth Sciences, v. 14, p. 2086-2100.

Gill, J.R. and Cobban, W.A., 1973, Stratigraphy and geologic history of the Montana Group and equivalent rocks, Montana, Wyoming, and North and South Dakota: United States Geological Survey, Professional Paper 776, 37 p.

Gill, J.R., Cobban, W.A. and Schultz, L.G., 1972, Correlation, ammonite zonation, and a reference section for the Montana Group, central Montana: Montana Geological Society, 21st Annual Field Conference, Crazy Mountains Basin, Guidebook, p. 91-97.

Hattin, D.E., 1965, Stratigraphy of the Graneros Shale (Upper Cretaceous) in central Kansas: Geological Survey of Kansas, Bulletin 178, 83 p.

Hattin, D.E., 1967, Stratigraphic and paleoecologic significance of macroinvertebrate fossils in the Dakota Formation (Upper Cretaceous) of Kansas, *in* Essays in Paleontology and Stratigraphy — R.C. Moore Commemorative Volume: University of Kansas Department of Geology, Special Publication 2, p. 570-589.

Hattin, D.E., 1982, Stratigraphy and depositional environment of Smoky Hill Chalk Member, Niobrara Chalk (Upper Cretaceous) of the type area, western Kansas: Kansas Geological Survey, Bulletin 225, 108 p.

Hook, S.C., Cobban, W.A. and Landis, E.R., 1980, Extension of the intertongued Dakota Sandstone-Mancos Shale terminology into the southern Zuni Basin: New Mexico Geology, v. 2(3), p. 42-44, 46.

Irish, E.J.W., 1965, Geology of the Rocky Mountain Foothills, Alberta: Geological Survey of Canada, Memoir 334, 241 p.

Izett, G.A., Cobban, W.A. and Gill, J.R., 1971, The Pierre Shale near Kremmling, Colorado, and its correlation to the east and the west: United States Geological Survey, Professional Paper 684-A, 19 p.

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., 1970, Cretaceous macrofauna, *in* Douglas, R.J.W., ed., Geology and Economic Minerals of Canada: Geological Survey of Canada, Economic Geology Report 1, Canada, 5th edition: p. 649-662.

Jeletzky, J.A., 1971, Marine Cretaceous biotic provinces and paleogeography of Western and Arctic Canada: Illustrated by a detailed study of ammonites: Geological Survey of Canada, Paper 70-22, 92 p.

Jensen, F.S. and Varnes, H.D., 1964, Geology of the Fort Peck area, Garfield, McCone, and Valley counties, Montana: United States Geological Survey, Professional Paper 414-F, 49 p.

Kennedy, W.J., 1984, Systematic paleontology and stratigraphic distribution of the ammonite faunas of the French Coniacian: Palaeontological Association, Special Papers in Palaeontology 31, 160 p.

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

Landes, R.W., 1940, Paleontology of the marine formations of the Montana Group, Pt. 2 *of* Geology of the southern Alberta plains: Geological Survey of Canada, Memoir 221, p. 129-217.

Lewy, Z., 1986, *Anaklinoceras reflexum* Stephenson in Israel and its stratigraphic significance: Newsletter on Stratigraphy, v. 16(1), p. 1-8.

Marks, P., 1984, Proposal for the recognition of boundaries between Cretaceous stages by means of planktonic foraminiferal biostratigraphy: Bulletin of the Geological Society of Denmark, v. 33, p. 163-169.

Masters, B.A., 1977, Mesozoic planktonic foraminifera, a worldwide review and analysis, *in* Ramsay, A.T.S., ed., Oceanic Micropalaeontology: Academic Press, London, v. 1, p. 301-731.

May, F.E., 1980, Dinoflagellate-acritarch palynology, *in* Minard, J.P., Geology of the Round Bay quadrangle, Anne Arundel County, Maryland: United States Geological Survey, Professional Paper 1109, p. 17-20.

McLearn, F.H., 1929, Cretaceous invertebrates, *in* Mesozoic paleontology of Blairmore region, Alberta: National Museum of Canada, Bulletin 58, p. 73-79.

McNeil, D.H. and Caldwell, W.G.E., 1981, ed., Cretaceous Rocks and Their Foraminifera in the Manitoba Escarpment: Geological Association of Canada, Special Paper 21, 440 p.

Merewether, E.A., 1980, Stratigraphy of mid-Cretaceous formations at drilling sites in Weston and Johnson counties, northeastern Wyoming: United States Geological Survey, Professional Paper 1186-A, 25 p.

Merewether, E.A., 1983, Lower Upper Cretaceous strata in Minnesota and adjacent areas — Time-stratigraphic correlations and structural attitudes, *in* Cobban, W.A. and Merewether, E.A., Stratigraphy and Paleontology of Mid-Cretaceous Rocks in Minnesota and Contiguous Areas: United States Geological Survey, Professional Paper 1253-B, p. 27-52.

Miller, A.K. and Youngquist, W., 1946, A giant ammonite from the Cretaceous of Montana: Journal of Paleontology, v. 20, p. 479-484.

Miller, H.W., 1968, Invertebrate fauna and environment of deposition of the Niobrara Formation (Cretaceous) of Kansas: Fort Hays Studies, new series, no. 8, 90 p.

Miller, H.W., 1970, Additions to the fauna of the Niobrara Formation of Kansas: Transactions of the Kansas Academy of Science, v. 72, p. 533-546.

North, B.R. and Caldwell, W.G.E., 1975, Foraminiferal faunas in the Cretaceous System of Saskatchewan, *in* Caldwell, W.G.E., ed., The Cretaceous System in the Western Interior of North America: Geological Association of Canada, Special Paper 13, p. 303-331.

Obradovich, J.D. and Cobban, W.A., 1975, A time-scale for the Late Cretaceous of the Western Interior 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. 31-54.

Olsson, R.K., 1964, Late Cretaceous planktonic foraminifera from New Jersey and Delaware: Micropaleontology, v. 10, p. 157-188.

Owen, D.D., 1852, Report of a geological survey of Wisconsin, Iowa, and Minnesota and incidentally of a portion of Nebraska Territory: Lippincott, Grambo and Co., Philadelphia, 638 p.

Petters, S.W., 1976, Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of New Jersey: American Association of Petroleum Geologists, Bulletin, v. 60, p. 87-107.

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

Price, L.L. and Ball, N.L., 1971, Stratigraphy of Duval Corporation Potash Shaft No. 1, Saskatoon, Saskatchewan: Geological Survey of Canada, Paper 70-71, 107 p.

Price, L.L. and Ball, N.L., 1973, Stratigraphy of Cominco Potash Shaft no. 1 Vanscoy, Saskatchewan: Geological Survey of Canada, Paper 72-11, 155 p.

Reeside, J.B., Jr., 1923, A new fauna from the Colorado Group of southern Montana: United States Geological Survey, Professional Paper 132-B, p. 25-33.

Reeside, J.B., Jr., 1927, Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyoming: United States Geological Survey, Professional Paper 105-A, p. 1-19.

Riccardi, A.C., 1983, Scaphitids from the Upper Campanian-Lower Maastrichtian Bearpaw Formation of the Western Interior of Canada: Geological Survey of Canada, Bulletin 354, 103 p.

Robinson, C.S., Mapel, W.J. and Bergendahl, M.H., 1964, Stratigraphy and structure of the northern and western flanks of the Black Hills uplift, Wyoming, Montana and South Dakota: United States Geological Survey, Professional Paper 404, 134 p.

Robinson, H.R., 1945, New baculites from the Cretaceous Bearpaw Formation of southwestern Saskatchewan: Royal Society of Canada, Transactions, v. 39(4), p. 51-54.

Roemer, F.A., 1841, Die Versteinerungen des norddeutschen Kreidegebirges: Hannover, Germany, 145 p.

Schlüter, C., 1871-72, 1876, Cephalopoden der oberen deutschen Kreide: Palaeontographica, 1871-72, v. 21, p. 1-120; 1876, v. 24, p. 121-264.

Schmid, F. and Ernst, G., 1975, Ammoniten aus dem Campan der Lehrter Westmulde und ihre stratigraphische Bedeutung. I, Teil; *Scaphites, Bostrychoceras* und *Hoplitoplacenticeras*: Bericht der Naturhistorischen Gesellschaft zu Hannover, v. 119, p. 315-359.

Scott, G.R. and Cobban, W.A., 1964, Stratigraphy of the Niobrara Formation at Pueblo, Colorado: United States Geological Survey, Professional Paper 454-L, p. L1-L30.

Scott, G.R., Cobban, W.A. and Merewether, E.A., 1986, Stratigraphy of the Upper Cretaceous Niobrara Formation in the Raton basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 115, 34 p.

Sissingh, W., 1978, Microfossil biostratigraphy and stage-stratotypes of the Cretaceous: Geologie en Mijnbouw, v. 57, p. 433-440.

Sohl, N.F. and Christopher, R.A., 1983, The Black Creek-Peedee formational contact (Upper Cretaceous) in the Cape Fear River region of North Carolina: United States Geological Survey, Professional Paper 1285, 37 p.

Stephenson, L.W., 1941, The larger invertebrate fossils of the Navarro Group of Texas: Texas University, Publication 4101, 641 p.

Stephenson, L.W., 1952, Larger Invertebrate Fossils of the Woodbine Formation (Cenomanian) of Texas: United States Geological Survey, Professional Paper 242, 211 p.

Stott, D.F., 1961, Summary account of the Cretaceous Alberta Group and equivalent rocks, Rocky Mountain Foothills, Alberta: Geological Survey of Canada, Paper 61-2, 34 p.

Stott, D.F., 1963, The Cretaceous Alberta Group and Equivalent Rocks, Rocky Mountain Foothills, Alberta: Geological Survey of Canada, Memoir 317, 306 p.

Stott, D.F., 1967, The Cretaceous Smoky Group, Rocky Mountain Foothills, Alberta and British Columbia: Geological Survey of Canada, Bulletin 132, 133 p.

Warren, P.S., 1934, Palaeontology of the Bearpaw Formation: Royal Society of Canada, Transactions, v. 28(4), p. 81-100.

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, v. 34(4), p. 143-152.

Warren, P.S. and Stelck, C.R., 1955, New Cenomanian ammonites from Alberta: Research Council of Alberta, Report No. 70, p. 63-75.

Warren, P.S. and Stelck, C.R., 1958, Lower Cenomanian Ammonoids and Pelecypoda from Peace River area, Western Canada, Part 2 *of* Lower Cenomanian faunas, Peace River area: Research Council of Alberta, Bulletin 2, p. 36-51.

Williams, G.D. and Baadsgaard, H., 1975, Potassium-argon dates and Upper Cretaceous biostratigraphy in eastern Saskatchewan, *in* Caldwell, W.G.E., ed., The Cretaceous System in the Western Interior of North America: Geological Association of Canada, Special Paper 13, p. 417-426.

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

Zullo, V.A., 1987, Scalpelloid and brachylepadomorph barnacles (Cirripedia, Thoracica) from the Upper Cretaceous Mt. Laurel Sand, Delaware: Journal of Paleontology, v. 61, p. 333-345.