Geological Circular **72-2**

Cretaceous Paleogeography: Implications of Endemic Ammonite Faunas

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CONTENTS

ILLUSTRATIONS

TABLES

CRETACEOUS PALEOGEOGRAPHY: IMPLICATIONS OF ENDEMIC AMMONITE FAUNAS

KEITH YOUNG[1]

ABSTRACT

Endemic ammonite faunas evolved from cosmopolitan faunas in a series of successive episodes over about 35 million years of the Cretaceous of the Gulf Coast of the United States. During basin—basin-margin tectonic adjustments the Cretaceous barrier reef was inundated or circumvented so that a cosmopolitan fauna entered the back-reef area. Gradual isolation of the fauna behind the barrier produced endemism. With the next basin adjustment the endemic fauna became extinct, and a new cosmopolitan fauna migrated into the back-reef area, likewise evolving into an endemic fauna in its turn. Six cosmopolitan-endemic cycles have been identified. Geological evidence suggests two or three additional cycles.

INTRODUCTION

Ammonites have long had a reputation for their cosmopolitan or world-wide representatives. In the last three decades nomenclatural refinement has made the general cosmopolitan aspect of ammonites less noticeable to the casual observer. Nevertheless, there are certain faunas that are more cosmopolitan than others. Some faunas were cosmopolitan because they were oceanopelagic. Other faunas were cosmopolitan because larval stages were oceanopelagic or because migration pathways were open for neritopelagic animals. Endemic faunas, in contrast to cosmopolitan faunas, are faunas restricted to a particular area. Although there are many causes for endemism, the endemic faunas in the present discussion are thought to have evolved (1) because of isolation by barriers to migration, (2) as adaptation to a unique environment behind the barriers, or (3) some faunas are thought to have been under the pressures of both adaptation to unique environment and isolation.

The Comanche Series (Cretaceous) of Texas (table 1) contains alternating cosmopolitan and endemic ammonite faunas. Endemism is partial, or almost complete, depending on the degree of isolation. The writer's evidence deals almost entirely with ammonites. The nomenclature and distribution of other mollusc groups indicate similar phenomena, but the relationships of Texas Cretaceous Bivalvia and Gastropoda to extra-Texas forms are not sufficiently documented to permit definite conclusions.

Ammonites show a definite alternation of cosmopolitan and endemic faunas in the Comanchean; the Gulfian faunas were almost entirely cosmopolitan until early in the Maestrichtian, when an endemic *Sphenodiscus* fauna evolved.

PALEOGEOGRAPHIC SETTING

To develop fully, a strictly endemic fauna must be evolving in an isolated environment. Otherwise, at least parts of the fauna will spread to other parts of the world, and cosmopolitan elements will enter the supposedly isolated environment. The geography of the Comanchean Gulf of Mexico (fig. 1) provided just such an isolating mechanism that functioned episodically.

The Comanchean rocks that underlie most of the Gulf Coastal Plain of the United States and Mexico were deposited on a broad shelf; in Texas this was up to 300 miles wide. Deposition on the shelf was dominated by carbonate sediments. The outer margin of the shelf consisted of clay-free carbonate deposits with rudist banks, algal masses, and other reef growths that represent a barrier reef complex (fig. 1), extending from southern Florida across the present southeast Gulf of Mexico into Louisiana and across Texas roughly underlying the present Miocene outcrop (Sandidge, 1961, pp. 13-14; Winter, 1961; Tucker, 1962). At the Rio Grande the shelf margin extended south toward Monterrey in the Albian (Bishop, 1970; Böse and Cavins, 1928, pp. 86-87); during the Aptian a westward trend is indicated by Smith (1970). Various, more spec-

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TABLE 1. *Correlation of Comanchean sections for areas from which formations are mentioned in the text.*

CENTRAL TEXAS		SOUTH TEXAS SUBSURFACE		NORTH TEXAS OUTCROP	BIG BEND, TEXAS	SIERRA DE PICACHOS, NUEVO LEON, MEXICO
Buda		Buda		Grayson	Buda	Cuesta del Crura
Del Rio		Del Rio			Del Rio	
Georgetown		Pryor		Main Street	Santa Elena	
				Pawpaw		
		Salmon Peak		Weno		
				Denton		
				Fort Worth		
				Duck Creek	Sue Peaks	
Edwards	Person	McKnight		Kiamichi		Sombrerotillo
	Kainer	West Nueces		Goodland	Del Carmen	Tamaulipas
Walnut				Walnut	Telephone Canyon	
Glen --- *Corbula* bed Rose		Glen Rose		Paluxy		
				Glen Rose	Glen Rose	
Hensel				Basal sands		
Absent		Bexar	Pearsall			La Peña
Cow Creek		Cow Creek				
Hammett		Hammett				
Sycamore		Sligo Hosston				Cupido
						Taraises

tacular reef complexes branch off on various tectonic features and confuse the configuration, tend to conceal the main shelf margin trend in northern Mexico, and have resulted in a variety of reef and shelf margin trends and interpretations for both Texas and northern Mexico (Bishop, 1970, fig. 12; Smith, 1970; Fisher and Rodda, 1967, fig. 1; Hendricks and Wilson, 1967, fig. 4). None of these are entirely wrong, but most fail to identify the southward-trending Albian shelf margin because of the more dominant reef complex trends branching off in other directions between San Antonio, Texas, and Monterrey, Mexico. Böse and Cavins (1928, pp. 86-87) had correctly interpreted this Albian shelf trend some forty years ago, and stated that it lay in the valley occupied by the National Railroad from Nuevo Laredo to Monterrey, between the Sierra Gomas, etc., on the west and the Sierra de Lampazos, etc., on the east. In identifying the trend Böse and Cavins did not identify it as a shelf margin but did recognize the change in depth of water from shallower on the west to deeper on the

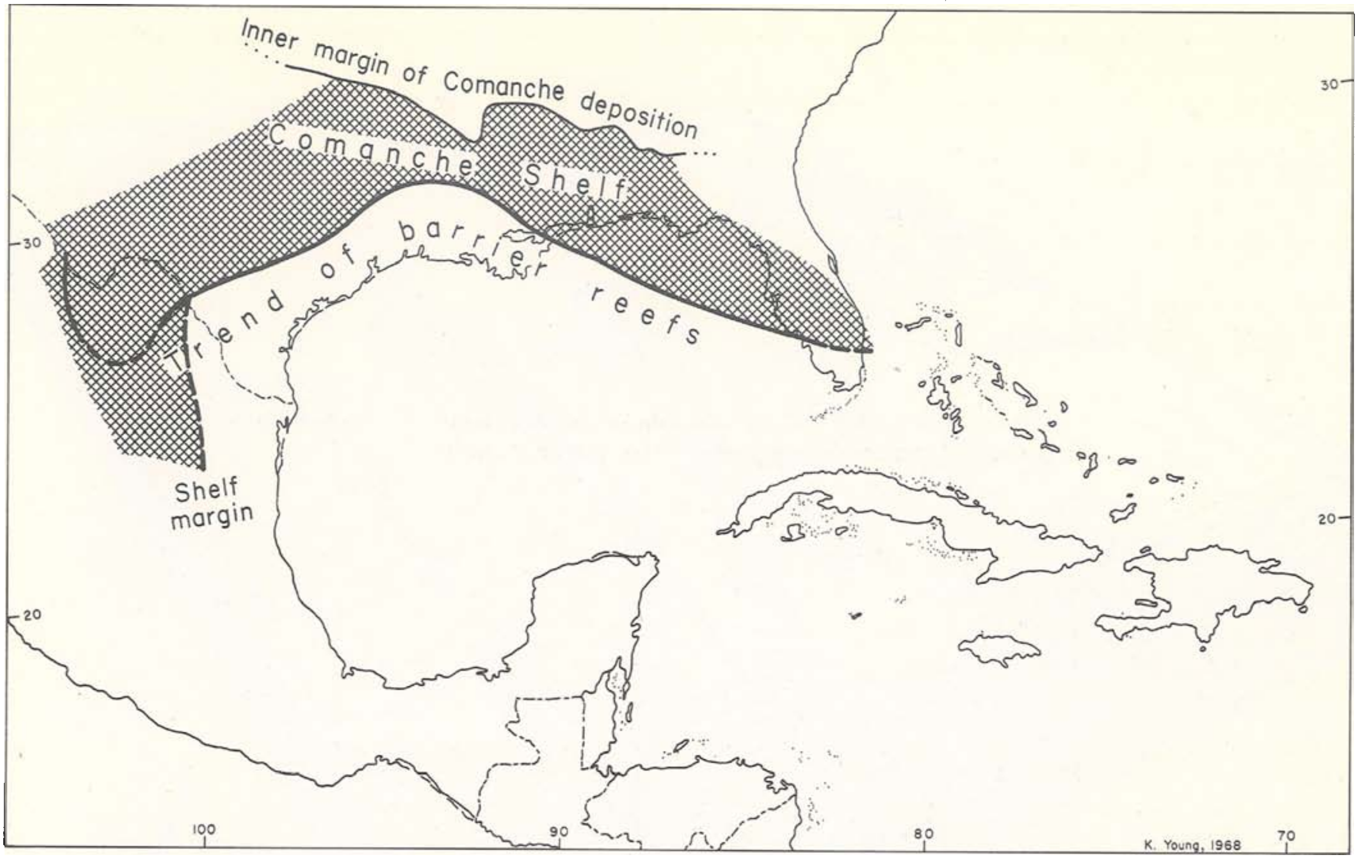

FIG. 1. The Comanche Shelf behind the barrier reef. Modified from Rose (1972).

east. That the shelf edge trend south of Laredo may have had a different configuration during the Aptian will not be argued, and it may be that the Albian shelf margin of Böse and Cavins represents a shallowing Tamaulipas ridge with deeper water deposits again farther west.

Although that part of the barrier overlying the Middle Trinity, in Texas, was first designated the Stuart City trend by Winter (1961, p. 17) (figs. 2 and 3), later interpretations show many barriers (fig. 4) not always superimposed (Hendricks and Wilson, 1967, p. 5). Although not always superimposed, at many times a barrier was sufficiently continuous across the entire Gulf Coast of Texas and northern Mexico to prevent the entrance of cosmopolitan ammonite species into the back-reef area. Perhaps it should be emphasized that a single invasion may not be sufficient to provide a viable breeding population. Continuous interrelationships and communication with contemporary descendents of ancestral populations may sometimes be necessary to produce viable populations.

COSMOPOLITAN-ENDEMIC CYCLES OF THE COMANCHEAN

TRINITY FAUNAS

The Trinity rocks were deposited in a variety of shallow marine to near-shore terrestrial environments. Many of these environments, even the shallow marine, were not hospitable to animals adapted to marine waters of normal salinity. Consequently, the record of marine faunas is often incomplete. Although all known ammonites from the Hosston (Lower Trinity) are cosmopolitan, no ammonites are known from the Sligo Formation or its back-reef equivalents. These formations occur only in the subsurface, all of the ammonites available are those brought up from cores for oil tests, and faunal documentation is incomplete. If the sediments behind the Sligo barrier reefs (Hendricks and Wilson, 1967, p. 5) are like sediments in similar paleogeographic positions during

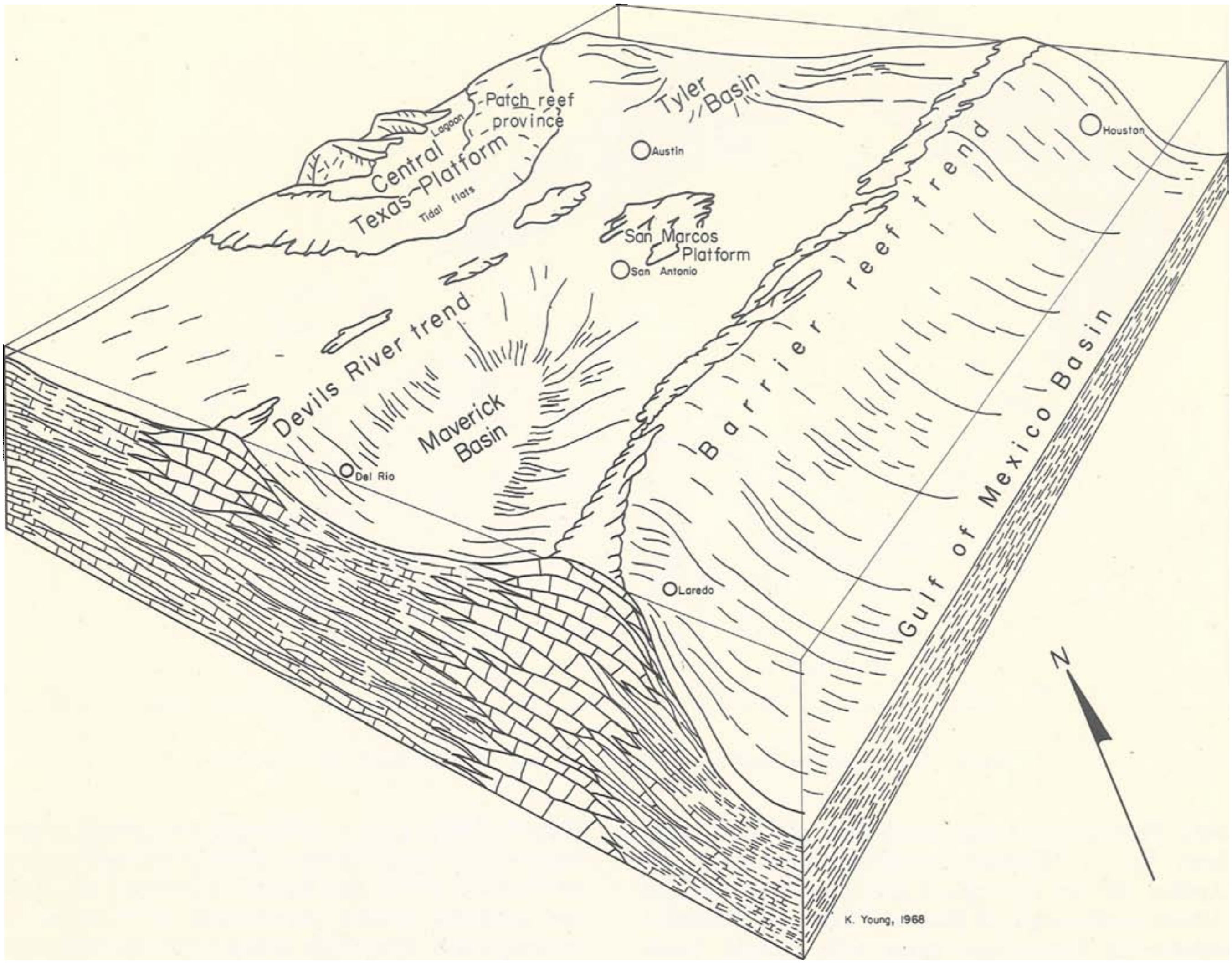

FIG. 2. Block diagram illustrating the back-reef topography for a part of Texas during the Middle Albian.

the early Cretaceous, endemic faunas probably evolved behind these barriers but have not been collected (fig. 4 and table 2).

With the beginning of the Middle Trinity (Lozo and Stricklin, 1956), the Pearsall Formation of many subsurface workers, there appears for the first time at the outcrop in the Hammett Shale an Aptian cosmopolitan ammonite fauna containing *Cheloniceras*, *Procheloniceras*, *Eodouvilleiceras*, *Burckhardtites*, and several species of *Dufrenoyia*. The equivalent beds in the La Peña Formation of Tamaulipas, Mexico, contain an even more generically diverse fauna. As the Hammett Formation changes to the Cow Creek Limestone, the cosmopolitan forms disappear, and the ammonite fauna of the Cow Creek Limestone consists almost entirely of the endemic species *Dufrenoyia justinae* (Hill, 1893) [= *D. texana* (Burckhardt) = *D. roemeri* (Cragin)]. Collection failure does not seem to be involved since only a half dozen ammonite specimens are known from the Cow Creek Limestone, except for the many, many specimens of *D. justinae*. Although most authors do not indicate a barrier for any part of the Pearsall (= Middle Trinity) (Winter, 1961, fig. 3; Tucker, 1962; Hendricks and Wilson, 1967, p. 5), some condition, perhaps a peculiar environment, prevented the normal entrance of more cosmopolitan

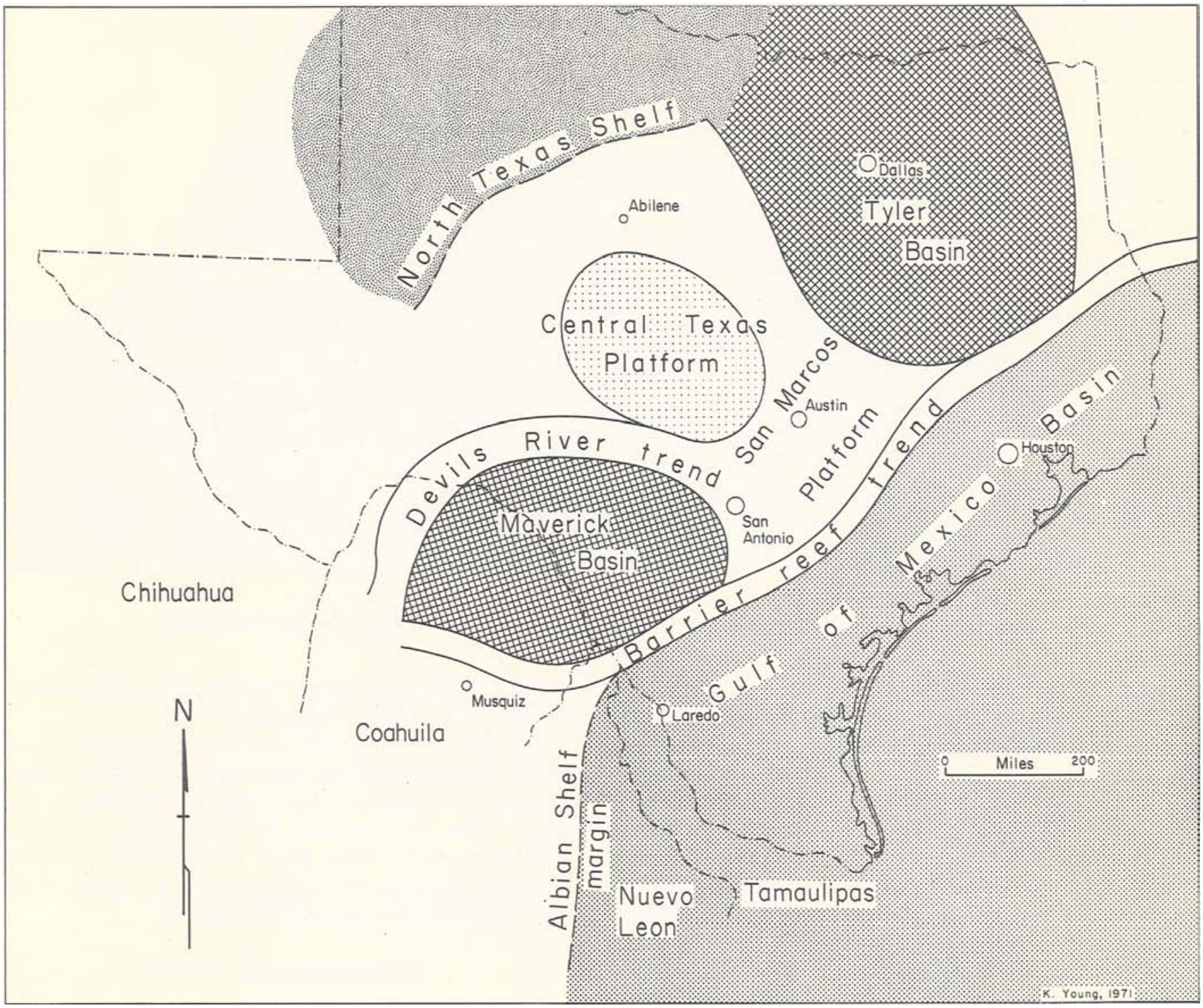

FIG. 3. Paleogeographic features of Texas during much of the Comanchean.

ammonite species behind the trend of the barrier during Cow Creek deposition and resulted in the extremely low diversity of ammonites in the Cow Creek Limestone.

The Bexar Formation, the upper terrigenous unit of the Pearsall, does not crop out; a single excellent ammonite from a core in this formation represents the *Kazanskyella* fauna of the lower Clansayes horizon (latest Aptian) of southern Arizona (Stoyanow, 1949), western New Mexico, and northern Chihuahua (Young, 1969), and further represents the introduction of the uppermost Aptian into the Texas Gulf Coast. The upper member of the La Peña Formation of northern Mexico contains a cosmopolitan fauna of this age with *Gargasiceras*, *Subgargasiceras*, *Acanthoplites*, *Parahoplites*, etc.,

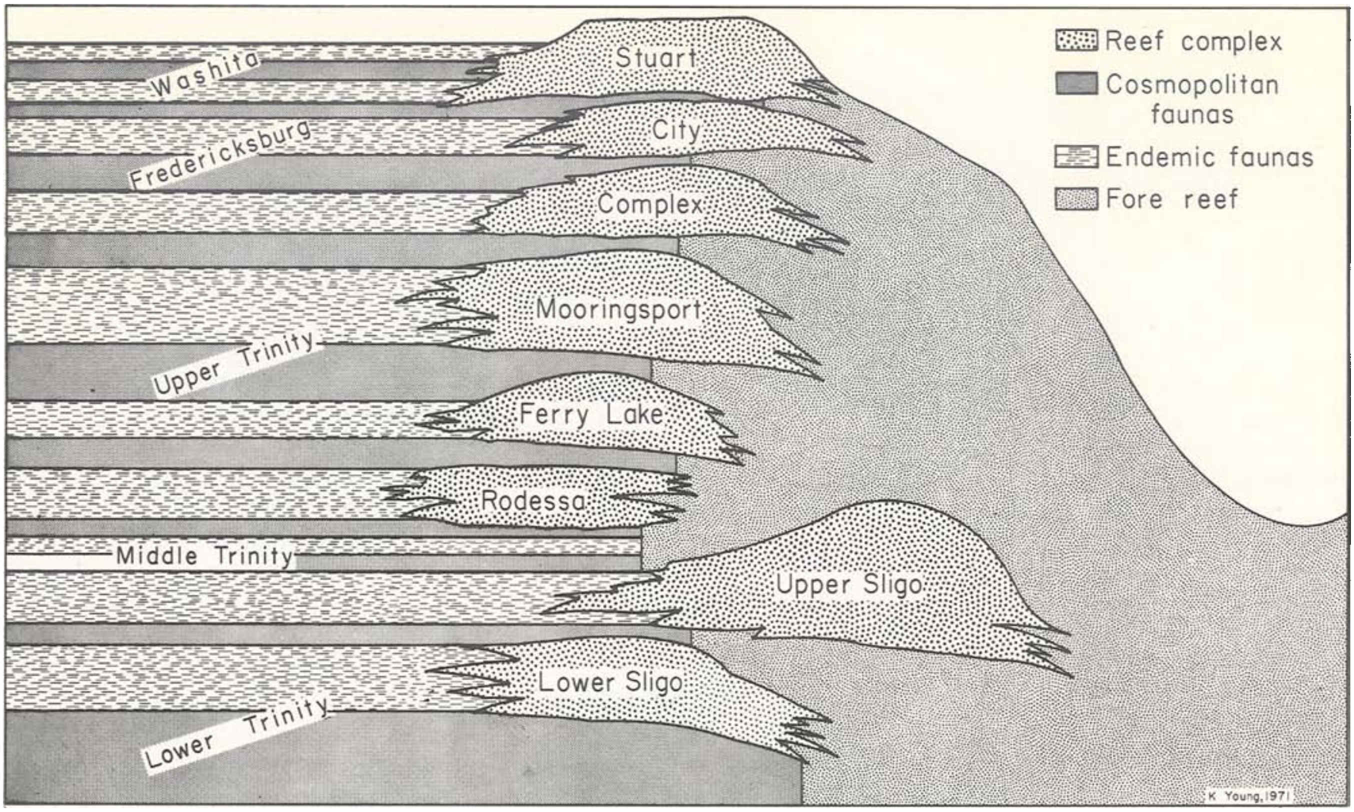

FIG. 4. Diagrammatic representation of rocks containing endemic and cosmopolitan faunas.

representing a cosmopolitan fauna.

The uppermost part of the Clansayes horizon is not represented by a cosmopolitan fauna in Texas but is represented by the *Hypacanthoplites mayfieldensis* fauna, of low species and generic diversity, from the lower part of the Glen Rose Limestone. This fauna appears to have developed behind the barrier that Hendricks and Wilson (1967) have termed the Rodessa Platform (fig. 4). The distribution of the fauna suggests that the Rodessa Platform was sufficiently extensive to bar the free entrance into the back-reef area of species not endemic to Texas and northern Mexico.

Prior to the deposition of the middle part of the Glen Rose Limestone, at a horizon approximately 80 feet below the *Corbula* bed, the barrier was again either flooded or circumvented to allow the entrance of ammonites of the *Douvilleiceras* zone, Lower Albian, including cosmopolitan species of *Douvilleiceras* and *Hypacanthoplites.* This fauna, in Central Texas, is still of low diversity but becomes more diverse to the west. This cosmopolitan zone extends to above the *Corbula* bed that marks the top of the lower part of the Glen Rose Formation of Stricklin, Smith, and Lozo (1971).

For the remainder of Glen Rose Limestone deposition no cosmopolitan ammonites are known from behind the barriers. The only ammonites in the Texas Glen Rose behind the Mooringsport barrier and the upper Glen Rose barrier are probably endemic engonocerid ammonites, as suggested by the complete absence of other genera.

FREDERICKSBURG CYCLE

The rocks of the Fredericksburg Division represent a single cycle of endemic development. Sometime in the early Fredericksburg (Middle Albian) an *Oxytropidoceras* fauna of European affinities appeared behind the reef. The rest of the Fredericksburg is the story of the evolution of (1) species of *Oxytropidoceras*, such as *O. stenzeli* Young and *O. pandalensis* Young, that are not yet known outside of Texas and northern Mexico; (2) species of *Manuaniceras*, such as *M. moorei* Young, not yet known outside of Texas, and

TABLE 2. *Alternation of endemic and cosmopolitan zones on the Texas Comanche Shelf.*

Stage	Zone	C = Cosmpolitan E = Endemic M = Mixed	Division
LOWER CENOMANIAN	*Budaiceras hyatti*	E	WASHITA
	Graysonites	C	
	Plesioturrilites brazoensis	M	
UPPER ALBIAN	*Drakeoceras drakei*		
	Mortoniceras wintoni		
	Drakeoceras lasswitzi	C	
	Pervinquieria equidistans		
	Eopachydiscus brazoensis		
	Adkinsites bravoensis		
	Manuaniceras powelli	E	FREDERICKSBURG
MIDDLE ALBIAN	*Manuaniceras carbonarium*	M	
	Oxytropidoceras salasi	C	
	Metengonoceras hilli	E	
	Endemic engonocerids	E	UPPER TRINITY
	Ceratostreon Weatherfordense	M	
LOWER ALBIAN	*"Sonneratia" whitneyi*	E	
	Douvilleiceras "mammillatum"	C	
	Quitmanites ceratosus	E	
	Hypacanthoplites mayfieldensis		
APTIAN	*Kazanskyella trinitensis*	C	
	Dufrenoyia justinae	E	MIDDLE TRINITY
	Cheloniceras spp.	C	
NEOCOMIAN		?	LOWER TRINITY
	Leopoldia victoriensis	C	

M. powelli Young, only questionably known outside of Texas and Mexico; and (3) the development of species of *Venezoliceras* like *V. acutocarinatum* (Shumard), *V. texanum* Young, and *V. obscurum* Young, with different, but related, species in South America (Young, 1966a). Such relationships may mean no more than parallel evolution from common ancestors. Certainly the combination of above species of *Oxytropidoceras*, *Manuaniceras*, and *Venezoliceras* is endemic to Texas and northern Mexico. Rare cosmopolitan species are known, like the restricted horizon of dipolocerines in Tarrant County (Young, 1966a, pp. 55, 56), but access to the back-barrier was not continuously open and free to cosmopolitan forms.

WASHITA ENDEMIC FAUNAS

The Washita Division represents two separate cycles of endemism, one late Upper Albian and the other late Lower Cenomanian. With the beginning of the Washita two separate faunas entered the Texas area: (1) a *Manuaniceras-Adkinsites* (Young, 1966a) fauna similar to that of Madagascar (Besairie, 1936; Collignon, 1936) and (2) the *Boeseites* fauna of Angola (Haas, 1942; Young, 1968). In Texas these two faunas overlap, the *Boeseites* fauna following and mixing with the upper part of the *Adkinsites* fauna, and continuing into overlying rocks. These faunas are eventually replaced by another cosmopolitan fauna, the *Mortoniceras equidistans* fauna. This Upper Albian cosmopolitan fauna has representatives in India, Europe, Madagascar, Angola, etc. (Adkins, 1927; Spath, 1932; Haas, 1942; Stoliczka, 1861-1866; Kossmat, 1895, 1898; Young, 1968). During the course of the later Upper Albian (= Middle Washita) the genus *Drakeoceras*, unknown outside of Texas and northern Mexico, evolved, and cosmopolitan immigrants became rarer.

With the beginning of the Cenomanian (= upper Washita) the back-reef area was again flooded by species with cosmopolitan affinities, including *Plesioturrilites brazosensis* (Römer), *Graysonites* spp., *Hypophylloceras tanit* (Pervinquière), *Scaphites tenuicostus* (Pervinquière), and *Ficheuria* sp. (Young, 1966b; Pervinquière, 1907). In the later Lower Cenomanian the *Budaiceras* fauna evolved. *Budaiceras* s. s., with more ventral clavae than lateral ribs, is unknown outside of Texas and northern Mexico, and all of the species of *Faraudiella* from the Buda Limestone are unique to that formation. Ninety-nine percent of the Buda Limestone ammonites belong to the *Budaiceras* subgenera *Budaiceras* s. s. and *Faraudiella;* cosmopolitan forms include species of *Sharpeiceras* and *Mantelliceras*, but these are so scarce that correlation is difficult. The *Budaiceras* fauna is the most remarkable of all of the endemic faunas in this area and age because *Budaiceras* and *Faraudiella* are lyellicerids. Lyellicerids were extinct over the remainder of the world during the time of this flourishing endemic fauna behind the Gulf Coast barrier reef (Young, 1966b). The *Budaiceras* endemic fauna is relict behind the barrier.

Some writers have argued that bank deposition on the Stuart City trend ended with the deposition of the Georgetown Limestone and its equivalents (Tucker, 1962; Hendricks and Wilson, 1967), but the restriction of about 15 endemic and relict species of *Budaiceras* and *Faraudiella* to the back-barrier area indicates that the trend was still an effective isolating mechanism until near the end of the Lower Cenomanian. Just before the end of the Lower Cenomanian cosmopolitan faunas of many different genera again invaded the back-barrier area, and it was at this time that the barrier foundered, because cosmopolitan forms were then abundant in the Texas Cretaceous almost continuously for the next 20 million years. Lower Cenomanian fossils entered the back-reef area with the foundering of the barrier and even then occupied only the basinal areas (Maness Formation of the East Texas Embayment, the lowest part of the Ojinaga Formation of the Chihuahua Trough, and the basal Boquillas Formation along the east front of the Davis Mountains) include species of *Neopulchellia*, *Acompsoceras*, *Mantelliceras*, *Euhystrichoceras*, and *Ostlingoceras* (Powell, 1963; Young, 1958).

LOW GENERIC DIVERSITY—A KEY TO ENDEMISM

In the different endemic faunas of Texas and northern Mexico there is always a low generic diversity, if the endemic faunas are compared to the more cosmopolitan faunas. The cosmopolitan fauna of the Hammett Shale contains many genera, including *Cheloniceras*, *Procheloniceras*, *Eodouvilleiceras*, *Dufrenoyia*, *Burckhardtites*, and *Gargasiceras*, in about equal abundance. The endemic Cow Creek Limestone fauna contains only specimens of the genus *Dufrenoyia* in abundance.

Although the outcrop Glen Rose Limestone, through much of its thickness, represents environments inhospitable to animals adapted to normal oceanic salinities, including most ammonites, the cosmopolitan *Douvilleiceras* fauna contains a few more genera than any of the faunas herein identified as endemic.

Fredericksburg generic diversity was cut down before environments hospitable to ammonites reached the present outcrop. Fredericksburg endemism is the story of the evolution of three genera of ammonites—*Oxytropidoceras*, *Manuaniceras*, and *Venezoliceras*—behind the barrier.

Each of the Washita cycles begins with a large number of ammonite genera. The lower cosmopolitan hemicycle contains many genera, including *Adkinsites*, *Manuaniceras*, *Boeseites*, *Mortoniceras*, *Eopachydiscus*, *Beudanticeras*, *Idiohamites*, and *Craginites*. The endemic part of the cycle is dominated by the single genus *Drakeoceras*, but with rare occurrences of cosmopolitan species, such as *Stoliczkaia (Faraudiella)* sp. aff. *rhamnonota* (Seeley, 1865). The upper Washita cosmopolitan hemicycle contains *Graysonites*, *Plesioturrilites*, *Ficheuria*, *Adkinsia*, *Hypophylloceras*, *Worthoceras*, and *Engonoceras*, to list only a few of many genera, whereas the overlying endemic hemicycle is dominated completely by the genera *Budaiceras* and *Faraudiella*.

RELATION OF ENDEMISM TO DEPOSITIONAL CYCLES

Lozo (Lozo, 1959; Lozo and Stricklin, 1956; Stricklin, Smith, and Lozo, 1971) has emphasized that the Texas Comanchean comprises, in its type area, a series of depositional cycles. Each cycle is composed of a lower, more terrigenous facies and an upper limestone facies that Lozo has termed a depositional "couplet." The terrigenous facies usually thickens toward the source area at the expense of the limestone facies, whereas away from the source area the limestone facies may thicken by replacement of the underlying terrigenous facies. The "Division" of R. T. Hill consisted of one or more of these cycles that Hill recognized as larger cycles (Hill, 1894; Lozo and Stricklin, 1956; Lozo, 1959; Young, 1967). A close examination of the division concept of R. T. Hill reveals that cosmopolitan faunas are associated with the terrigenous part of a couplet as defined by Lozo, wherever that phase is widespread. The Hammett Shale with its diverse fauna is the terrigenous phase of the Middle Trinity; the Cow Creek Limestone, with the single, dominant genus *Dufrenoyia*, is the carbonate phase.

The more cosmopolitan *Douvilleiceras* fauna occupies a more marly or shaly part of the Glen Rose Limestone; the endemic engonocerids occupy the more limy parts. Fredericksburg deposition represents one such cycle, starting with more terrigenous deposits (Paluxy and Walnut) and ending with less terrigenous deposits (Edwards and Goodland). It is also a single cosmopolitan-endemic cycle.

The lower Washita cosmopolitan fauna appears with the terrigenous Kiamichi, Benevides, and Sue Peaks Formations (table 1). The upper Washita cosmopolitan fauna appears with the terrigenous Del Rio Shale. Their endemic counterparts are associated with Late Albian carbonate deposition and Buda Limestone deposition, respectively.

The persistent relationship of cosmopolitan faunas with more terrigenous deposits and endemism with less terrigenous deposits indicates that cosmopolitan faunas invaded the back-reef area during periods of greater terrigenous influx following basin—basin-margin tectonic adjustment. Although lower salinities in the near-shore areas may have accompanied the tectonic adjustment, cosmopolitan faunas behind the reef and accompanying the terrigenous sediments indicate general oceanic salinities. If flooding is related to tectonic adjustment of the barrier, the tectonic adjustment was local and was not related to world-wide eustatic events (table 2).

ENDEMISM AND CORRELATION

Beds containing only fossils endemic to a particular area are more difficult to correlate paleontologically than beds containing fossils that are more cosmopolitan. There are three problems faced by the biostratigrapher working in those deposits behind the Stuart City trend: (1) Many sites of deposition were either too brackish or too saline, or perhaps too isolated, to be inhabited by animals, the remains of which are normally used for correlation; (2) experience in collecting ammonites indicates that these cephalopods avoided, if at all possible, not only the reef and near-reef areas of greater hydraulic energy but also other areas where water would be rough; and (3) extreme examples of endemism prohibit direct correlation.

Following over twenty years of searching for ammonites in Central Texas, the writer has learned that it is almost hopeless to search for ammonites in the deposits that represent either hypersaline or brackish-water environments. Although modern cephalopods are frequently seen in brackish water, these waters do not seem to represent either their usual or preferred habitat. Many of the environments described by Nagle (1968) from the Glen Rose Formation or by Rose (1972) and Fisher and Rodda (1969) from the Edwards Group were inhospitable to ammonites and to most other oceanopelagic animals. Hence direct biostratigraphic correlations are difficult or impossible, unless the beds can be bracketed by beds of other environments containing more readily correlatable fossils.

Ammonites are almost unknown in Mesozoic reef and near-reef deposits, so unknown that one suspects that the rare find of an ammonite in a reef environment was an accident, not of the animal's own volition (Adkins, 1933; Young, 1959), such as being washed in, or being carried in and regurgitated by a predator, or fleeing, in panic, to escape a predator, or one of a number of other reasons.

Whereas reef and near-reef deposits generally contain foraminiferans, rudists, corals, or other fossils useful in zonation and correlation, the sediments representing brackish or hypersaline environments are commonly devoid of fossils that can be used for correlation. The near-shore environments of the Trinity described by Nagle (1968) or the Fredericksburg (Rose, 1972; Moore, 1961, 1964) are examples. The many intertidal and supratidal deposits are even less likely to contain pelagic marine fossils.

If one adds to the examples of inhospitable environments the phenomenon of episodic endemism, correlation problems are compounded. Although Comanchean endemic ammonite faunas were isolated behind a barrier reef, the back-reef environments may have been unique so that each endemic fauna, as it evolved, also adapted to a unique environment. Certainly, the endemic ammonites became so specialized in adapting to their environments that the tectonic adjustment, admitting the next terrigenous influx and a cosmopolitan fauna of a new cycle, completely eradicated all endemic ammonites of the preceding cycle.

Endemism of ammonites in subsurface formations, for which environmental and ammonite distribution information is scarce, cannot be critically evaluated. Starting with the Middle Trinity, the Hammett Shale contains a cosmopolitan fauna that has not yet been studied sufficiently to present exact correlations. The overlying Cow Creek Limestone part of the couplet can be correlated to northern Mexico but little farther.

Beginning with the Bexar Shale *(Kazanskyella* fauna) (table 3) there are three cycles to the top of the Glen Rose Limestone. The first limestone hemicycle following the Bexar Shale contains an endemic fauna that is difficult to correlate, except that it is above the cosmopolitan Clansayes horizon of the Bexar Shale and below the cosmopolitan *Douvilleiceras* fauna of the middle Glen Rose Limestone. Although the *Douvilleiceras* fauna is the cosmopolitan hemicycle of the lower of two more cycles in the upper Glen Rose Limestone, the depositional environments above the *Douvilleiceras quitmanense* zone on the outcrop were inhospitable to oceanopelagic animals, and the ages of the beds can only be estimated (Young, 1966a). One would expect these two cycles to represent cosmopolitan-endemic couplets in areas of proper environments, if such areas exist.

In the Fredericksburg Division the endemic *Manuaniceras powelli* zone is between the underlying *Manuaniceras carbonarium* zone, which can be correlated to South America, and the overlying cosmopolitan fauna that represents the *Pervinquieria pricei* zone. Only the chance occurrence of a few specimens of *Diploceras cristatum* and *D. fredericksburgense* in the *Manuaniceras powelli* zone in Tarrant County, Texas, tends to validate the age determined by this bracketing.

In the Washita the lower endemic hemicycle, dominated by species of the genus *Drakeoceras*, is bracketed between representatives of the *Neoharpoceras hugardianum* zone below and the "pre-*martimpreyi*" beds above. Otherwise, direct correlation to the *Paraturrilites gresslyi* and *Pervinquieria rostrata* zones would be impossible. The upper Washita endemic hemicycle is bracketed by representatives of the cosmopolitan *Mantelliceras martimpreyi* zone below and the late Lower Cenomanian *Mantelliceras costatum* zone above. Otherwise, it would be difficult to correlate the *Budaiceras hyatti* zone of the upper Washita hemicycle with the *Mantelliceras cantianum* zone.

Endemism behind the Stuart City trend has complicated correlation of parts of formations that contain environments not always hospitable to

TABLE 3. *Correlation with European zones.* The zones marked with an asterisk are correlated with the European section because they are bracketed by good correlations.

Texas Zone	European Zone	Stage
Neopulchellia brundrettei	*Mantelliceras costatum*[4]	Lower Cenomanian
*Budaiceras hyatti**	*Mantelliceras cantianum*[4]	
Graysonites lozoi	*Mantelliceras martimpreyi*[4]	
Graysonites adkinsi	"*pre-martimpreyi*"	
*Drakeoceras gabrielense**	*Pervinquieria rostrata*[2]	Upper Albian
*Mortoniceras wintoni**	*Paraturrilites gresslyi*[2]	
Drakeoceras lasswitzi[5]	*Neoharpoceras hugardianum*[2]	
Pervinquieria equidistans[5]		
	Pervinquieria pricei[2]	
Adkinsites bravoensis[5]		
*Manuaniceras powelli**	*Diploceras cristatum*[2]	
Manuaniceras carbonarium[5]	*Hoplites nitidus*[2]	Middle Albian
No ammonites**	*Hoplites dentatus*[2]	
Douvilleiceras quitmanense[6]	*Douvilleiceras mammillatum*[3]	Lower Albian
Quitmanensis ceratosus[6] *	*Leymeriella tardefurcata*[3]	
*Hypacanthoplites mayfieldensis**	*Hypacanthoplites jacobi*[3]	Upper Aptian
Kazanskyella trinitensis[6]	*Parahoplites nutfieldensis*[3]	
*Dufrenoyia justinae**		
	Cheloniceras martinoides[3]	
Cheloniceras spp.[1]		

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*Endemic faunas.

**No ammonites; sedimentary development would indicate endemic faunas in subsurface.

1. May include Lower Aptian.
2. Modified from Breistroffer (1947).
3. Modified from Casey (1961).
4. From Spath (1926).
5. Modified from Young (1966a).
6. From Young (1969).

oceanopelagic organisms. In addition, the Central Texas Platform and its subsidiary extension, the San Marcos Platform (fig. 3), separated West Texas from that part of the Comanche Shelf to the east. The same zones have the same species in common both west and east of the Central Texas Platform. On the other hand, in the lower part of the Washita Division, the ratios between different species in the west are different from the ratios between the same species in the east, and faunas from the two areas can be distinguished on this basis (Young, 1966a). Species of the *Budaiceras hyatti* zone, upper Washita endemic hemicycle, also occur in different ratios east and west of the Central Texas Platform. Communication across the Central Texas Platform may have been via the North Texas Shelf (early Washita) or via low spots on the San Marcos Platform (Buda Limestone).

CONCLUSIONS

Episodic endemism behind the Stuart City barrier reef trend is (1) not coincident with Cretaceous stages, and (2) has made correlation by ammonites of rocks representing deposition during periods of endemism more uncertain. Correlation to other parts of the world are more difficult with endemic faunas. Such faunas can usually be bracketed with accurate correlations by underlying and overlying cosmopolitan faunas.

Some cosmopolitan invasions were circuitous, apparently advancing in from Mexico west of the Del Carmen trend (Smith, 1970) through West

Texas, then entering behind the barrier from northwest of the Devil's River trend (Lozo and Smith, 1964). Flooding of the barrier and entrance of cosmopolitan faunas accompanied basin—basin-margin adjustment.

Modern corals from the Alacran reef north of the Yucatan Peninsula are similar to Middle Albian Edwards Limestone corals of Central Texas. It is possible that modern types of corals first evolved behind the Lower Cretaceous barrier reef of the Gulf Coast of the United States and Mexico. Johnson (1968) has already pointed out that modern types of algae first appeared as an endemic flora behind this same barrier in the Lower Cenomanian (Johnson stated late Albian) Buda Limestone.

ACKNOWLEDGMENTS

Although this paper was not directly supported financially, the detailed work that led to this synthesis was supported by a number of grants from The University of Texas at Austin Research Institute, by two National Science Foundation grants, and by three Department of Geological Sciences chairmen at The University of Texas at Austin—S. P. Ellison, Jr., S. E. Clabaugh, and W. R. Muehlberger. The collections of W. S. Adkins and F. L. Whitney at The University of Texas at Austin have been of tremendous aid. F. E. Lozo has provided sets of fossils that were most important, as have other collectors too numerous to mention. Although they may not agree with all of it, the paper has greatly benefited by the criticism of Peter U. Rodda and Peter B. Rose.

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