

Cretaceous (Aptian-Cenomanian) Gastropods of Mexico and their Biogeographic Implications

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ABSTRACT

Detailed and extensive studies of Cretaceous (Aptian-Cenomanian) gastropods from 19 localities in Mexico (Baja California, Sonora, Jalisco, Colima, Michoacán, Querétaro, Puebla, Guerrero, and Oaxaca) yielded gastropod species that also have been reported from other regions in the world and, thus, support a paleobiogeographic relation with similar faunas in the United States (New Mexico and Texas), the Caribbean region (Cuba), South America (Peru, Brazil), the Mediterranean region (Spain, France, Italy, Switzerland, Rumania, Syria, Lebanon, Algeria, Morocco, Tunisia, and Somalia), and Japan. The widely distributed taxa imply that an ample marine faunistic province existed, which included parts of the southwestern United States, western and southeastern Mexico, and the Caribbean and Mediterranean regions.

INTRODUCTION

Since the early 1990s, studies of Aptian-Cenomanian gastropods have been carried out in different regions of the Mexican Republic (Jacques et al., 1990; Buitrón et al., 1991; Buitrón, 1993a, b; Buitrón and Pantoja-Alor, 1994, 1998; Buitrón and López, 1995; Hernández-Romano et al., 1998; Buitrón et al., 1999). However, no studies ever attempted to understand the geographic distribution of Mexican Cretaceous gastropods and their paleobiogeographic affinity.

The purpose of this study is to yield new insights into the geographic distribution, stratigraphy, and paleogeography of the Cretaceous gastropods of Mexico, and the establishment of the occidental boundary

of the Caribbean province of the Tethys domain using Cretaceous gastropods that are known from several localities in Mexico.

FOSSILIFEROUS LOCALITIES

The areas in Mexico (Figure 1) with relevant Cretaceous gastropods groups are: Punta China, in Baja California; Arivechi, Caborca, and Lampazos, in Sonora; Cerro de Tuxpan, Tamazula, and Soyatlán in Jalisco; Tepames, in Colima; Coalcomán, Río Tupitina, Huetamo, and Chumbitaro, in Michoacán; Jalpan and Ahuacatlán, in Querétaro; Cuautla, in Morelos; San Juan Raya, in Puebla; Zitlala, in Guerrero; and Tepelmeme de Morelos and Coixtlahuaca, in Oaxaca.



Figure 1. Map with gastropod localities in Mexico.

FOSSIL PRESERVATION

It is worth mentioning that most of the studied gastropods preserve the original pigmentation of the shell bands and striae. Pigmentation varies from ocher to dark brown, particularly in cassioid gastropods (*Gymnentome helvetica*, *G. zebra*, *G. strombiformis*), which are widely distributed in some Aptian-Albian localities of Mexico, the Albian of Texas, and the Aptian-Albian of Utrillas, Spain. Preservation of original pigmentation of the shell is important because it provides information on water depth. Shells in shallow waters develop a wide variety of colors and designs, whereas colors and designs of deep-water shells are more uniform and tend to disappear at greater depths (Foerste, 1930).

LOCALITIES

Locality 1: Punta China, Baja California State

Punta China is located in the vicinity of Santo Tomas, south of Ensenada and approximately 120 km south of the United States border (Figures 1, 2, and 3). Boese and Wittich (1913) first reported Lower Cretaceous outcrops along the coast of the Baja Peninsula. Allison (1955) determined and characterized not only

gastropods, but also abundant caprinids-rudists, other bivalves, brachiopods, bryozoans, echinoderms, ostracods and foraminifers. Our specimens come from outcrops of the Alisitos Formation, in an approximately 160-m-thick section. It is divided into an upper member consisting mainly of biohermal limestone and interbedded pyroclastic sediments that contain caprinid-rudists, ostreids, nerineid-gastropods, and *Orbitolina*; and a lower member that consists of fine-grained sedimentary rocks with turritellid gastropods, trigoniid bivalves and solitary corals (Table 1).

Allison (1955) established a late Aptian–early Albian age for this formation using 54 species of gastropods. Only 20 species have strati-

graphic and geographic value, and their distribution is known in America (Texas), the Caribbean region and South America, the Mediterranean, and Asia. Years later, Allison (1974) confirmed an Aptian-Albian age of the bivalves contained in the Alisitos Formation at the Punta China locality, indicating affinity with the fauna in the Mediterranean region.

New outcrops at Los Torotes, la Bocana, El Cuervito, and San José areas between Ensenada and Guerrero Negro were reported by Almazán-Vazquez and Buitrón (1984). The studied fauna indicate a tropical shallow-marine environment.

Locality 2: Sierra El Chanate, Caborca, Sonora State

Cretaceous outcrops of El Chanate and Arroyo Sá-sabe Formations are exposed near Caborca, in the northern part of Sonora State (Figures 1, 2, and 3). The lithology of Arroyo Sá-sabe Formation consists of limestone, siltstone, and dolomite with some conglomerates, which indicate a small reef structure. Underlying El Chanate Formation consists of deltaic interbedded siltstone, limestone, and occasional sandstone (Jacques et al., 1990). These two formations contain marine fauna of Aptian-Albian age (Table 2).

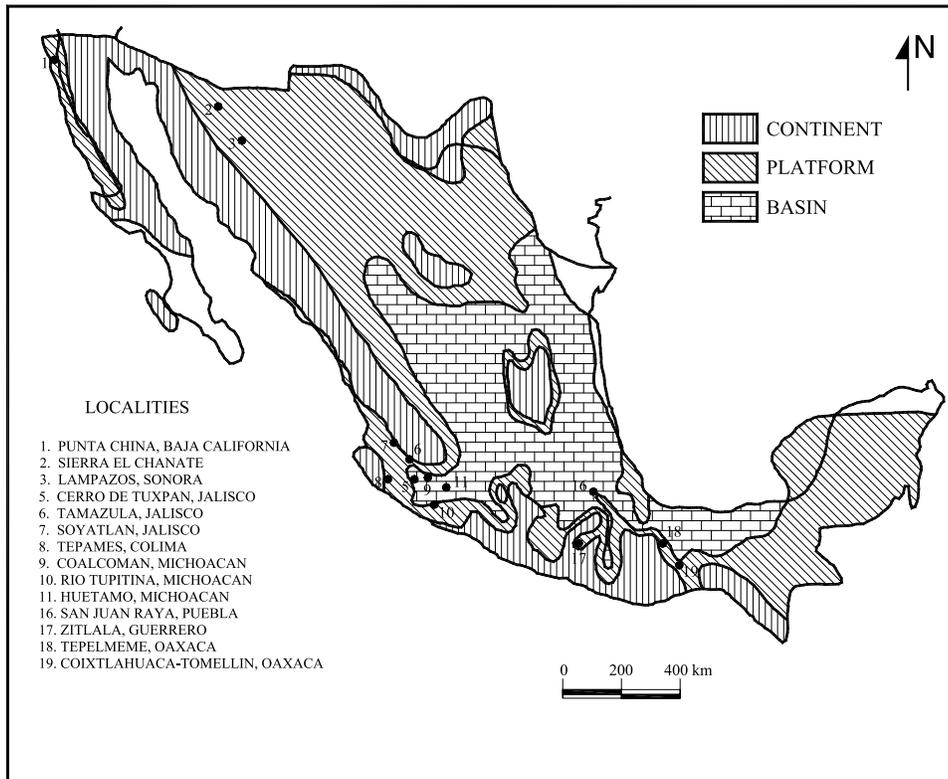


Figure 2. Neocomian-Aptian paleogeographic map with studied gastropod localities.

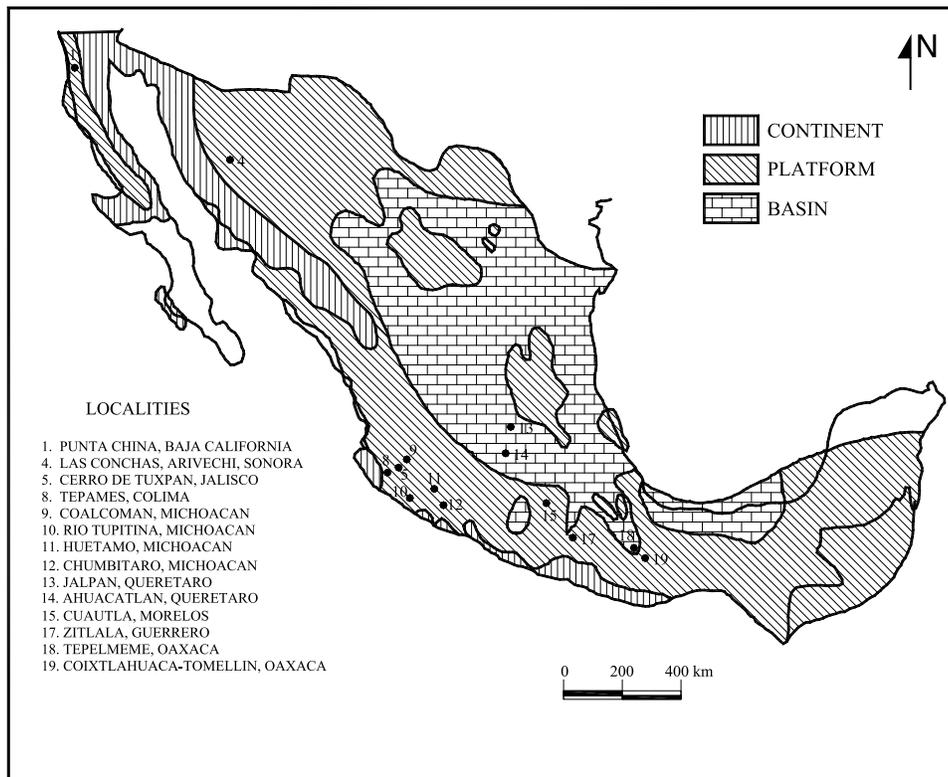


Figure 3. Albian-Cenomanian paleogeographic map with studied gastropod localities.

Table 1. Gastropods of Punta China reported in other areas (modified from Allison, 1955).

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Discotectus texanus</i> (Roemer)			NA		
<i>Microschiza scalaris</i> (Conrad)		Af			
<i>Otostoma japonicum</i> (Nagao)		As			
<i>Semineritina apparata</i> (Cragin)			NA		
<i>Torquesia seriatimgranulata</i> (Roemer)			NA		
<i>Pirazus austinense</i> (Roemer)			NA		
<i>Opalia (Crassiscala) riachuelanum</i> (Maury)			SA		
<i>Aptyxiella (Endiatrachus) parallela</i> (Anderson and Hanna)	?As		NA		
<i>Eunerinea pauli</i> (Coquand)	Af			NA	
<i>Ptygmatis tomasensis</i> (Allison)		NA			
" <i>Natica</i> " <i>importuna</i> Nagao		As			
" <i>Natica</i> " <i>japonicum</i> Nagao		As			
<i>Liocarenus (Liocarenus) formosum</i> (Cragin)			NA		?Af
<i>Actaeonella parvus</i> (Stanton)			NA		
<i>Actaeonella fusiformis</i> Coquand	E-Af				
<i>Peruviella dolium</i> (Roemer)		NA-SA-Af			
<i>Peruviella gerthi</i> (Olsson)		NA-SA-Af			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 2. Gastropods of Cerro de Las Conchas, Arivechi, reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Lunatia pedernalis</i> Roemer	NA				
<i>Gymnentome (Gymnentome) zebra</i> (Gabb)		NA			
<i>Torquesia seriatimgranulata</i> (Roemer)			NA		
<i>Cimulia rectilabrum</i> Gabb			NA		

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 3. Gastropods of Sierra El Chanate, Caborca, reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Rissoa</i> cf. <i>R. Dupiniana</i> d'Orbigny		E			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Locality 3: Lampazos area, Sonora State

In the Lampazos area, eastern Sonora (Figures 1, 2, and 3), more than 3000 m of shallow-marine sedimentary rocks are exposed in an area of approximately 240 km². The Aptian-Albian age of these strata was first established with invertebrate and microfossil faunas by Herrera and Bartolini (1983), who

also defined the depositional environments and Laramide structural styles, and introduced the lithostratigraphic nomenclature presently used in the area. These rocks have a rich fauna of foraminifers, corals, bivalves, gastropods, ammonites, and echinoderms (Table 3). These faunas are similar to those at Arivechi, Sonora (González-León and Buitrón, 1984).

Table 4. Gastropods of Lampazos reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Pleurotomaria</i> cf. <i>P. macilenta</i> Cragin	NA				
<i>Tylostoma aguilerai</i> Alencáster					NA
<i>Turritella marnochi</i> White			NA		
" <i>Cerithium</i> " <i>kansasense</i> Stanton			NA		
<i>Cassioppe branneri</i> (Hill)			NA		
<i>Mesoglauconia</i> (<i>Mesoglauconia</i>) <i>burnsi</i> (Stanton)			NA		
<i>Mesoglauconia</i> (<i>Triglaucoma</i>) <i>kleinPELLI</i> (Allison)	NA				
<i>Gymnemtome</i> (<i>Gymnemtome</i>) <i>helvetica</i> (Pictet and Campiche)			NA		
<i>Gymnemtome</i> (<i>Gymnemtome</i>) <i>paluxiensis</i> (Stanton)			NA		
<i>Actaeonella fusiformis</i> Coquand	E-As-NA				
<i>Actaeonella parvus</i> (Stanton)			NA		
<i>Peruviella dolium</i> (Roemer)			NA-SA-Af		
<i>Liocarenus</i> (<i>Liocarenus</i>) <i>formosus</i> Cragin			NA-?Af		

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Locality 4: Cerro de las Conchas, Arivechi, Sonora State

Cerro de Las Conchas is located near Arivechi in Sonora State (Figures 1, 2, and 3). Cretaceous outcrops in this locality and the neighboring hills are extremely fossiliferous. The Cretaceous section has been divided into Palmar and Potrero Formations, both of Albian age. The Palmar Formation consists of massive limestone, conglomerate, and andesite, and the overlying Potrero Formation consists of alternating sandy limestone, nodular limestone, fossiliferous siltstone, argillaceous siltstone, marly siltstone, and fossiliferous black siltstone.

The gastropods identified in this study previously were recorded in Texas and California by Gabb (1869), who also described serpulid worms, ammonites, bivalves, gastropods, echinoderms, and corals. Four gastropod species also are found in California, New Mexico, and Texas in the United States, and Baja California, Sonora, and Jalisco in Mexico (Table 4).

Locality 5: Cerro de Tuxpan, Jalisco State

Cretaceous fossiliferous strata are exposed at the northern edge of the Cerro de Tuxpan, 16 km southeast of Ciudad Guzmán, Jalisco State (Figures 1, 2, and 3). Buitrón (1986) described a sequence of pre-Cretaceous rhyolitic porphyry, felsic volcanic rocks overlaid by Cretaceous marine conglomerate, siltstone, and fossiliferous sandstone containing abundant cassioid-gastropods. The sandstone grades upward into marls

that contain abundant *Orbitolina*, which are overlaid in turn by reefal limestone with caprinids and rudists.

The faunistic association at Cerro de Tuxpan is characterized by tropical shallow-water gastropods, rudists, echinoderms, and foraminifers whose ages range from Aptian to early Albian. The species of gastropods of the Cerro de Tuxpan are recorded in other regions of Mexico, the United States (Texas), and the Mediterranean region (Table 5).

Locality 6: Tamazula, Jalisco State

Outcrops of the Encino Formation occur northwest of Tamazula (Figures 1, 2, and 3). Upper Aptian–lower Albian strata of the Encino Formation consist of interbedded volcanic and sedimentary rocks that are rich in shallow-water rudists, nerineid gastropods, ammonites, corals, foraminifers, echinoids, and algae (Buitrón and López-Tinajero, 1995).

A fossil collection from a calcareous conglomerate exposed in the Mesa Blanca and Agua Zarca localities indicates that gastropods in this region also are found in other localities in Mexico, Texas, and the Mediterranean region (Table 6).

Locality 7: Soyatlán, Jalisco State

In Soyatlán de Adentro in the Valle de Soyatlán are calcareous conglomerates with exposed fossils. In addition to gastropods, the rudists *Coalcomana ramosa* characteristic of the early Albian, *Caprinuloides gracilis* of Aptian age, and trigoniids *Pterotrigonia*

Table 5. Gastropods of Cerro de Tuxpan reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Ostostoma japonicum</i> (Nagao)		As			
<i>Microschiza (Cloughthonia) scalaris</i> (Conrad)		Af			
<i>Torquesia seriatimgranulata</i> (Roemer)		NA			
<i>Mesoglauconia (Mesoglauconia) burnsi</i> (Stanton)			NA		
<i>Gymmentome (Gymmentome) helvetica</i> (Pictet and Campiche)			NA		
<i>Nerinella boehmi</i> Blanckenhorn	NA				
<i>Pygmatia tomasensis</i> Allison		NA			
<i>Aptyxiella supracostata</i> (Stanton)			NA		

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

plicatocostata of the Aptian and associated corals indicate shallow-water conditions (Table 7).

Locality 8: Tepames, Colima State

A small collection of Aptian-Albian gastropods identified from Tepames, in southwestern Colima (Figures 1, 2, and 3), suggests common elements of other faunistic provinces (Table 8).

Locality 9: Coalcomán, Michoacán State

This fossiliferous locality in southeastern Michoacán (Figures 1, 2, and 3) was studied by Urquiza (1882). He concluded that the Cretaceous series of Coalcomán is formed by alternating fossiliferous gray limestone, marly sandstone, and overlying interbedded

limestone, sandstone, marl, and limestone with nerineid gastropods (Table 9).

Locality 10: Tupitina River, Michoacán State

The authors collected specimens of nerineid gastropods from limestone outcrops in the Tupitina River, west of Playa Azul, in Michoacán (Figures 1, 2, and 3). These species were previously described by Allison (1955) in Punta China, Baja California (Table 10).

Locality 11: Huetamo, Michoacán State

At Huetamo, Michoacán (Figures 1, 2, and 3), Pantoja-Alor (1959) reported the Cretaceous San Lucas (Hauterivian-Aptian), Morelos (Albian-Cenomanian), and Mal Paso (Cenomanian-Maastrichtian) Formations.

Table 6. Gastropods of Tamazula reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Microschiza scalaris</i> (Conrad)		Af			
<i>Mesoglauconia (Mesoglauconia) burnsi</i> (Stanton)			NA		
<i>Mesoglauconia (Mesoglauconia) helvetica</i> (Pictet and Campiche)			NA		
<i>Cassiope strombiformis</i> (Schlotheim)	E-Af-As				
<i>Nerinella boehmi</i> Blanckenhorn	NA				
<i>Diptyxis forojuliensis</i> Parona		Af-E			
<i>Nerinea volana</i> Cragin				NA	
<i>Eunerinea hicoriensis</i> (Cragin)	NA				
<i>Eunerinea pauli</i> (Conrad)		Af		NA	
<i>Lunatia pedernalis</i> Roemer	NA				
? <i>Natica conradi</i> (Hill)	NA				
<i>Tylostoma aguilerai</i> Alencáster	NA				
<i>Tylostoma kentensi</i> Stanton				NA	
<i>Peruviella dolium</i> (Roemer)		NA-SA-Af			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 7. Gastropods of Soyatlan reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Microschiza scalaris</i> (Conrad)	NA			As	
<i>Mesoglauconia (Mesoglauconia) burnsi</i> (Stanton)	NA				
<i>Gymnentome (Gymnentome) zebra</i> (Gabb)	NA				
<i>Pyrazus (Echinobathra) valeriae</i> (Verneuil and Lorière)	NA				
<i>Lunatia pedernalis</i> (Roemer)		NA			
" <i>Natica</i> " <i>conradi</i> (Hill)	NA				
<i>Aptyxiella boehmi</i> Blanckenhorn	NA				
<i>Multiplexis prefleuri</i> (Delpey)	As-NA				
<i>Eunerinea hicoriensis</i> (Cragin)	NA				
<i>Phaneroptyxis anguillina</i> (Bárcena and Castillo)	NA				
<i>Peruviella gerthi</i> Olsson		NA-SA			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 8. Gastropods of Tepames reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Mesoglauconia (Mesoglauconia) reneviere</i> (Coquand)	NA-E				
<i>Ptygmatis tomasensis</i> (Allison)		NA			
<i>Phaneroptyxis anguillina</i> (Castillo and Bárcena)	NA				
<i>Peruviella dolium</i> (Roemer)		NA-SA-Af			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 9. Gastropods of Coalcomán reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Diptyxis forojuliensis</i> Parona		Af-E			
<i>Eunerinea hicoriensis</i> (Cragin)	NA				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 10. Gastropods of Tupitina reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Ptygmatis tomasensis</i> (Allison)		NA			
<i>Eunerinea pauli</i> (Coquand)		Af		NA	

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Our fossil collection from the San Lucas Formation included nerineid gastropods. The identified fauna is correlative with localities in Texas, Mexico, and the Mediterranean region (Buitrón and Pantoja-Alor,

1998). Our collection also included ammonites, corals, and miliolid-foraminifers (*Orbitolina*) (Table 11). The fossil assemblage indicates a shallow marine calcareous bank (Buitrón, 1993a, b).

Table 11. Gastropods of Huetamo reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Aptyxiella boehmi</i> (Blanckenhorn)	NA-E				
<i>Polyptyxiella dayi</i> (Blanckenhorn)	NA-As				
<i>Diptyxis azteca</i> (Alencáster)	NA				
<i>Pchelinsavia coquandiana</i> (d'Orbigny)		NA-E-As-Af			
<i>Diptyxis euphyes</i> (Felix)		Af-E			
<i>Diptyxis forojuliensis</i> (Parona)		NA-Af-E			
<i>Nerinea galatea</i> Coquand	NA-E				
<i>Diptyxis luttickei</i> (Blanckenhorn)	NA				
<i>Multiplyxis prefluriani</i> (Delpey)	NA-Af-E				
<i>Eunerinea hicoriensis</i> (Cragin)		NA			
<i>Eunerinea titania</i> (Felix)	NA				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Locality 12: Chumbítaro, Guerrero State

In the Chumbítaro region, outcrops of the Mal Paso Formation (Albian), in Guerrero, consist of more than 750 m of highly fossiliferous sedimentary rocks that are divided into two lithostratigraphic units. The lower deltaic member primarily is clastic in composition with abundant *Toucasia*; the upper carbonate member (reefal and lagoonal facies) is paleontologically diverse. Although collected fossils are extremely diverse, the ammonite *Mortoniceras* of middle to late Albian age was collected from the same beds. The most prominent and diverse group of gastropods are nerineids, cassiopids, and tylostomids (Table 12).

Locality 13: Jalpan, Querétaro State

The Valles-San Luis Potosí platform exhibits an 1800-m-thick sequence of cyclic carbonates, known as the El Abra Limestone (Aguayo-Camargo, 1998). At Jalpan, Querétaro (Figures 1, 2, and 3), the El Abra Limestone consists of more than 100 m of limestone containing molluscan shells (rudist bivalves and gastropods) and peloid miliolid lithofacies, interbedded with thick-to-massive, cross-laminated, well-sorted and rounded ooid bioclastic grainstones. The grainstone were transported from the high-energy windward southeastern margin and were deposited as calcarenite shoals into the back-reef facies (Table 13).

Locality 14: Ahuacatlán, Querétaro State

In northeastern Querétaro (Figures 1, 2, and 3), Cretaceous successions are extensively exposed in the forelimb of the Ahuacatlán syncline. They consist mainly

of marls, shales, and rare wackestone-sandstone pyroclastic intercalations that were deposited in a tropical calcareous platform (Buitrón et al., 1995) (Table 14).

Locality 15: Cuautla, Morelos State

The Albian-Turonian shallow-marine limestones that crop out in the states of Morelos and Guerrero were described as two separate formations by Fries (1960). The older unit, the Morelos Formation, was described as a succession 600–1,000 m of fossiliferous limestone and dolomite beds. An Albian-early Cenomanian age was assigned for this unit (Fries, 1960; Hernández-Romano et al., 1998).

Our studies were at La Calera, which is located near Cañón de Lobos, approximately 13 km southeastward from Cuernavaca, in north-central Morelos (Figures 1, 2, and 3). A fossil collection from the shallow-marine limestones indicates a late Cenomanian age for these strata (Table 15).

Locality 16: San Juan Raya, Puebla State

The San Juan Raya outcrops are located southeast of Tehuacán, in Puebla (Figures 1, 2, and 3). Pioneering studies include those by Nyst and Galeotti (1840), Aguilera (1897), and Burckhardt (1930). The Lower Cretaceous is represented by the Barremian Zapotitlán Formation and the Aptian San Juan Raya Formation (Calderón-García, 1956). These units contain abundant corals, rudists, other bivalves, gastropods, and ammonites (Table 16). In this locality, Alencáster (1956) and Buitrón and Barceló (1980) identified 39 species of gastropods, 16 of which have important biogeographic implications (Table 16).

Table 12. Gastropods of Chumbítaro reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Otostoma japonicum</i> (Nagao)			NA-As		
<i>Purpuroidea</i> sp.		NA			
" <i>Aporrhais</i> " <i>affinis</i> Coquand	NA-E				
" <i>Strombus</i> " <i>globulus</i> Coquand	NA-E				
" <i>Funius</i> " cf. " <i>F.</i> " <i>absconditus</i> Coquand	NA-E				
<i>Mesoglauconia</i> (<i>Mesoglauconia</i>) <i>burnsi</i> (Stanton)		NA			
<i>Gymnentome</i> (<i>Gymnentome</i>) <i>paluxiensis</i> <u>Stanton</u>		NA			
<i>Gymnentome</i> (<i>Gymnentome</i>) <i>zebra</i> (Gabb)		NA			
<i>Cassiopella</i> <i>branneri</i> (Hill)		NA			
" <i>Pyrazus</i> " <i>valeriae</i> (Verneuil and Loriere)		NA-E			
" <i>Natica</i> " <i>eryyna</i> d'Orbigny		NA-E			
" <i>Natica</i> " <i>gasullae</i> Coquand	NA-E				
" <i>Natica</i> " <i>martini</i> d'Orbigny					NA-E
<i>Tylostoma</i> <i>torrubidae</i> Sharpe		NA-E			
<i>Tylostoma</i> <i>ovatum</i> Sharpe	NA-E				
<i>Tylostoma</i> <i>princeps</i> White		NA			
<i>Tylostoma</i> <i>tumidum</i> Shumard			NA		
<i>Diptyxis</i> <i>luttickei</i> (Blanckenhorn)	NA				
<i>Polyptyxiella</i> <i>dayi</i> (Blanckenhorn)	NA-As				
<i>Eunerinea</i> <i>pauli</i> (Coquand)		Af		NA	
<i>Diptyxis</i> <i>azteca</i> (Alencáster)		NA			
<i>Diptyxis</i> <i>euphyes</i> (Felix)		NA-Af-E			
<i>Aptyxiella</i> <i>boehmi</i> (Blanckenhorn)	NA-E				
<i>Multiplex</i> <i>prefleuriaui</i> (Delpy)	NA-Af-E				
<i>Peruviella</i> <i>gerthi</i> (Olson)		NA-SA			
<i>Trochacteon</i> (<i>Neocylindrites</i>) <i>cumminsi</i> Stanton				NA	

Af: Africa, As: Asia E: Europe, NA: North America, SA: South America.

Table 13. Gastropods of Jalpan reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Cimolithium?</i> <i>Miyakoense</i> (Nagao)		NA-As			
" <i>Cerithium</i> " <i>pecosense</i> Stanton			NA		
<i>Discotectus</i> <i>crispus</i> (Blanckenhorn)		NA-As			
<i>Afrollonia</i> <i>matsushimensis</i> Kase		NA-As			
<i>Solariella</i> <i>serrata</i> Stanton			NA		
<i>Nerinea</i> <i>galatea</i> Coquand	NA-E				
<i>Ptygmatis</i> <i>tomasensis</i> (Allison)		NA			
<i>Nerinoidea?</i> <i>ashimensis</i> Kase	NA-As				
<i>Gymnentome</i> (<i>Gymnentome</i>) <i>zebra</i> (Gabb)		NA			
<i>Hanaibursa</i> <i>aquilana</i> (Parona)		NA-E-As			
<i>Trochactaen</i> <i>parvus</i> Stanton			NA		

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 14. Gastropods of Ahuacatlán reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Neoptyxis pre-olisiponensis</i> (Delpy)		NA			
<i>Diptyxis castilli</i> (Bárcenas)		NA			

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 15. Gastropods of Cuautla, Gastropoda, reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Nerinea</i> sp. cf. <i>N. dupiniana</i> d'Orbigny					NA-E

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 16. Gastropods of San Juan Raya reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>"Natica" sueurii</i> Pictet and Renevier	Af-E				
<i>Lunatia praegrans</i> (Roemer)		NA			
<i>Tylostoma aguilerai</i> (Alencáster)	NA				
<i>Harpagodes desori</i> (Pictet and Campiche)	Af-E				
<i>Pyrazus scalariformis</i> Nagao	NA-As				
<i>Uchaxia fraasi</i> (Blanckenhorn)	As				
<i>Mesoglaucania (Mesoglaucania) reneviere</i> Coquand	Af-E				
<i>Diptyxis azteca</i> (Alencáster)	NA				
<i>Diptyxis euphyes</i> (Felix)		NA-Af-E			
<i>Nerinea galatea</i> Coquand	NA-Af-E				
<i>Eunerinea hicoriensis</i> (Cragin)	NA				
<i>Diptyxis luttickei</i> (Blanckenhorn)	NA				
<i>Eunerinea pauli</i> (Coquand)	Af			NA	
<i>Eunerinea titania</i> (Felix)	NA				
<i>Eunerinea aptiensis</i> (Pictet and Campiche)	NA				
<i>Phaneroptyxis anguillina</i> (Castillo and Bárcena)	NA				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Locality 17: Zitlala, Guerrero State

The authors identified and correlated Aptian-Albian nerineid gastropods (Table 17) from outcrops in El Cerro del Tamborillo, near Zitlala village, in Guerrero (Figure 1).

Locality 18: Tepelmeme de Morelos, Oaxaca State

Avecilla (1974) reported two species of nerineids from the Huajuapán area, in western Oaxaca (Fig-

ure 1). These species also are found in other regions of the world (Table 18).

Locality 19: Coixtlahuaca-Tomellín, Oaxaca State

In the Coixtlahuaca-Tomellín area, in northwest Oaxaca (Figure 1), the Teposcolula Formation (lower Albian) is divided into two members (González-Alvarado, 1970a, b; Alencáster et al., 1984). The lower Teposcolula member represents platform facies, and the upper Ocotlán member records reef facies. These

Table 17. Gastropods of Zitlala reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Pchelinsevia coquandiana</i> (d'Orbigny)	NA-E-Af-As				
<i>Nerinea mutabilis</i> Delpy	AF-E				
<i>Eunerinea hicoriensis</i> (Cragin)	NA				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 18. Gastropods of Tepelmeme de Morelos reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Diptyxis euphyes</i> (Felix)		NA-Af-E			
<i>Eunerinea aptiensis</i> (Pictet and Campiche)	NA-E				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

Table 19. Gastropods of Coixtlahuaca-Tomellín reported in other areas.

SPECIES	Aptian	Albian			Cenomanian
		Lower	Middle	Upper	
<i>Ptygmatis hieroglyphica</i> Bárcena	NA				
<i>Pchelinsevia coquandiana</i> (d'Orbigny)	NA-Af-E-As				
<i>Aptyxiella</i> cf. <i>A. dalmatica</i>	NA				
<i>Tylostoma</i> sp. cf. <i>T. Regina</i> (Cragin)	NA				
<i>Ampullina collina</i> (Conrad)	NA				
" <i>Aporrahis</i> " <i>subfusiformis</i> (Shumard)	NA				
<i>Purpuroidea</i> sp. cf. <i>Sautieri</i> Coquand	NA-E				
<i>Harpagodes</i> sp. cf. <i>H. desori</i> (Pictet and Campiche)	NA-E				

Af: Africa, As: Asia, E: Europe, NA: North America, SA: South America.

rocks contain bryozoans, nerineid gastropods, rudist bivalves, and corals (Table 19).

PALEOBIOGEOGRAPHIC IMPLICATIONS

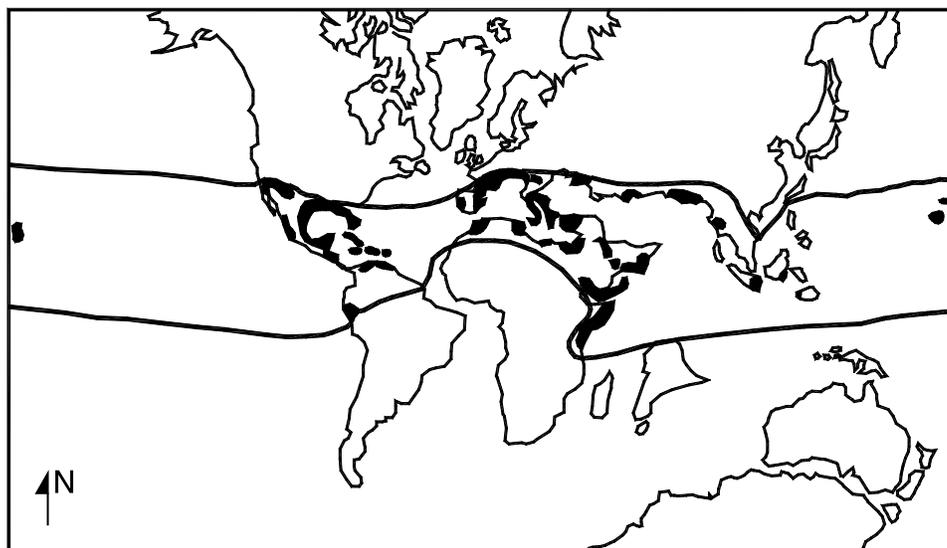
According to this investigation, complemented by studies from North America and the Caribbean region (Sohl, 1971, 1987; Kauffman, 1973, 1979; Alencáster, 1987), it is known that during the Cretaceous, the sea extended into a wide platform throughout the Atlantic coastal plain of the U.S.A. and the Gulf of Mexico. This large province favored the development of invertebrate faunas with common genera and species, and their presence in Mexico agrees with what Sohl considered to be the Caribbean region. Previously, only the invertebrate faunas of North America and those of the Caribbean region were sufficiently

known to establish adequate distributional patterns; therefore, this contribution has paleogeographic significance.

In 1971, Sohl elaborated a model based on gastropod associations with common genera that runs parallel (in bands) to the equator. This pattern probably denotes a latitudinal zonation controlled by temperature or other physical barriers. Sohl (1971) selected for his analysis the Albian and the Campanian-Maastrichtian time intervals because of the extensive outcrops of these ages, mostly in North America and the Caribbean region. According to Sohl's (1971) distribution pattern, the world could be divided into the following Cretaceous biotic provinces:

- 1) the Caribbean region, Central America, and Baja California region, characterized by tropical sea faunas with Tethyan affinities;

Figure 4. Cretaceous distribution of gastropods and associated fauna. Heavy solid lines define northern and southern limits of framework construction. Slightly modified from Sohl (1987).



- 2) the coastal plain of the Gulf of Mexico and Southern Western Interior region, characterized by subtropical faunas of temperate seas that share similar faunas with northern Europe; and
- 3) the California and Northern Interior regions, two areas that share faunas with the Indo-Pacific region (boreal faunas).

Regarding the distributional patterns of marine organisms (algae, foraminifers, corals, ammonites, bryozoans, echinoids), Kauffman (1973, 1979) developed a model that explains worldwide invertebrate provincialism and endemism during the Cretaceous. Kauffman's model divides the Caribbean province into the Antillean and the West-Central American province; on the other hand, it splits the American province into a Gulf–Atlantic Coast and North American Interior subprovince. When the assemblages naticid, nerineid, cassiopeid, and actaeonellid gastropods found in 19 localities of Mexico (that tend to bear wider geographic ranges) are compared with this model, strong affinities of the Mexican faunas with those of the Tethys domain are indicated. Some genera (Cassiopeidae, Tylostomidae) also are present in Gulf Atlantic subprovince located south of what Kauffman considers the North American province (Kauffman 1973, 1979). This overlap between two provinces (Caribbean and North American) may represent what Sohl (1971) considered to be a transitional zone. In this particular case, the Cretaceous gastropod assemblages might represent the western portion of the Caribbean region (Sohl, 1971), the Antillean subprovince (Kauffman, 1973, 1979), and the southernmost extension of the Gulf Atlantic Coast

subprovince (North American province) west of the Tethys domain (Figure 4).

DISCUSSION AND CONCLUSIONS

The fossil association, including the gastropod material, rudists and corals, strongly suggests that the deposits occurred in a shallow sea of the tropical region, possibly located between the coast and some rudist banks, which are abundant in many Cretaceous facies of Mexico. The gastropod association of the 19 localities studied show more specific affinities with faunas described from the United States (New Mexico and Texas), the Mediterranean region (Spain, France, Italy, Switzerland, Rumania, Syria, Lebanon, Algeria, Morocco, Tunisia, and Somalia), the Caribbean region (Cuba), South America (Peru, Brazil), and Japan (Figure 1, Table 20).

The widely distributed taxa imply that an ample marine faunistic province existed, and that it included at least parts of the southwestern United States, western and southeastern Mexico, the Caribbean region, and the Mediterranean region.

This information is congruent with the established model of the geologic evolution of the Tethys domain. The Caribbean province constituted the geologic framework of the biogeographic Mediterranean province that definitively had to include part of the present Mexican territory.

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Table 20. Cretaceous gastropod species with paleogeographic value (cont.).

SPECIES	USA		MEXICO										CARIBBEAN	SOUTH AM.	MEDITERRANEAN REGION													AFRICA	ASIA
	New Mex.	Texas	Baja Calif.	Sonora	Jalisco	Colima	Querétaro	Michoacan	Guerrero	Oaxaca	Puebla	Cuba	Perú	Brazil	Spain	France	Italy	Switzerland	Rumania	Syria	Lebanon	Algeria	Morocco	Tunisia	Somalia				
<i>Lunatia praegrandis</i> (Roemer)	•									•																			
" <i>Natica</i> " <i>conradi</i> (Hill)	•			•																									
" <i>Natica</i> " <i>japonica</i> (Nagao)		•																									•		
" <i>Natica</i> " cf. <i>N. sueurii</i>										•							•												
<i>Tylostoma aguilei</i> Alencáster				•						•																			
<i>Tylostoma kentense</i> Stanton	•			•																									
<i>Liocarenus formosum</i> (Cragin)	•	•																											
<i>Vernedia freisi</i> Kollmann and Sohl					•																								
<i>Peruviella gerthi</i> (Olsson)				•			•												•								•		
<i>Peruviella dolium</i> (Roemer)			•	•	•	•							•													•			
<i>Actaeonella parvus</i> (Stanton)	•	•																											
<i>Actaeonella fusiformis</i> Coquand			•						•						•														
" <i>Aporrahis</i> " <i>affinis</i> Coquand										•					•														
" <i>Strombus</i> " <i>globulus</i> Coquand										•					•														
" <i>Fusinus</i> " cf. " <i>F.</i> " <i>absconditus</i> Coquand															•												•		
<i>Hanaibursa aquilana</i> (Parona)							•																				•		
<i>Discotectus crispus</i> (Blanckenhorn)							•																				•		
<i>Nerinenoides</i> ? <i>ashimensis</i> Kase							•																				•		
<i>Afrollonia matsushimensis</i> Kase							•																				•		

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