SEQUENCE STRATIGRAPHY OF LOWER CRETACEOUS (BARREMIAN–ALBIAN) CARBONATE PLATFORMS OF NORTHEASTERN MEXICO: REGIONAL AND GLOBAL CORRELATIONS

CHRISTOPH LEHMANN[1]*, DAVID A. OSLEGER[2], AND ISABEL MONTAÑEZ[2]
[1] *Department of Earth Sciences, University of California, Riverside, California 92521, U.S.A.*
lehmanct@bp.com
[2] *Department of Geology, University of California, Davis, California 95616, U.S.A.*

ABSTRACT: **The Lower Cretaceous Cupido and Coahuila platforms of northeastern Mexico form part of the extensive carbonate platform system that surrounded the ancestral Gulf of Mexico. A sequence-stratigraphic model for these Barremian to Albian platforms was constructed from regional correlations of vertical cycle stacking patterns constrained by newly acquired biostratigraphic data and C and Sr isotope stratigraphy. The Cupido shelf lagoon (Barremian–Aptian) is composed of up to 150 peritidal cycles, which stack into high-frequency sequences that are correlated across the shelf. Cupido high-frequency sequences build into a lower partial composite sequence (Cu1), an overlying full composite sequence (Cu2), and the transgressive base of a third composite sequence (Cu–Co3) related to backstepping of the Cupido platform. The highstand part of Cu–Co3 is recorded in evaporite and carbonate facies of the Coahuila platform (Aptian–Albian). More than 80 meter-scale evaporite-to-carbonate cycles characterize the restricted interior of the Coahuila platform and stack into two full composite sequences (Co4, Co5). The Coahuila platform was drowned in the latest Albian or earliest Cenomanian, terminating shallow-water carbonate sedimentation in the region.**

Regional correlations of the depositional sequences in northeast Mexico with coeval platforms in Texas and the northern Gulf coast indicate that the lower two composite sequences of the Cupido shelf correlate with the lower part of the Sligo–Hosston platform in Texas. The transgressive systems tract of the third composite sequence of the Cupido–La Peña is recorded in Texas by the upper Sligo and Pearsall formations. The highstand systems tract and the disconformable top of the third composite sequence (Coahuila platform) is likely coeval with the upper Glen Rose platform in Texas. The fourth and fifth composite sequences are correlative with the Fredericksburg platform and the Washita–Devils River platforms of Texas, respectively. We conservatively correlated our sequence-stratigraphic framework with composite ''global'' sequences and ''eustatic'' curves derived from several other basins. Given the available time resolution, results are variable, but sequence boundaries at the top of Cu–Co3 and Co5 appear to have clear interbasinal equivalents.

INTRODUCTION

The Cupido and Coahuila carbonate platforms of northeastern Mexico span an extensive area between the coeval Sligo and Comanche platforms in Texas and the Valles and Golden Lane platforms in east-central Mexico (Fig. 1A). These platforms collectively formed the western flank of the ancestral Gulf coast during the Barremian to Albian (Scott 1990; Wilson and Ward 1993). The platforms of Texas and east-central Mexico have been extensively studied because of their economic potential as hydrocarbon reservoirs, with most stratigraphic interpretations derived from seismic and wellbore data. In contrast, the Cupido and Coahuila platforms remain relatively underinvestigated. Well-exposed carbonates and evaporites of these two platforms crop out in numerous ranges throughout the semiarid region and provide improved visualization of less well-exposed coeval platforms to the north and south.

Previous work on the Cupido and Coahuila platforms over the last several decades has focused primarily on the lithostratigraphy and biostratigraphy of formations cropping out in the Sierra Madre Oriental near Saltillo and Monterrey (Fig. 1A). Important recent work by Wilson and Ward (1993) synthesized large-scale depositional patterns of the Cupido and Coahuila platforms. The first attempt to place the strata of these two platforms into a sequence-stratigraphic framework was by Goldhammer et al. (1991), who distinguished four major ''second-order supersequences'' spanning the Middle Jurassic through the Early Cretaceous. Furthermore, their work used cycle stacking patterns in the upper part of the Cupido Formation to distinguish several intermediate-scale (10^5 yr) sea-level events.

Much less work has been done on more remote exposures in the Sierra de Parras to the west of Saltillo and in mountain ranges overlying the Coahuila basement block to the northwest. Our work focused on outcrops in these areas because they provide crucial information about the vast interior of the Cupido platform and its paleogeographic and genetic relationship with the younger Coahuila platform. The sequence-stratigraphic framework of the Cupido and Coahuila platforms described in this paper builds upon the detailed facies descriptions and depositional interpretations laid out in Lehmann et al. (1998). Furthermore, the sequence-stratigraphic framework described in this paper is integrated into previously established biostratigraphic and isotope chemostratigraphic data (Lehmann et al. 1999).

The objectives of this paper are to: (1) use stacking-pattern analysis and new age control to document the sequence-stratigraphic units that constitute the Cupido and Coahuila platforms, (2) correlate the sequence-stratigraphic model for these carbonate platforms with coeval platforms in Texas and the northern Gulf coast, and (3) interpret global correlations of composite sequences constituting the Cupido and Coahuila platforms with ''global'' sequences and ''eustatic'' curves generated from coeval platforms worldwide. The results of this research contribute to the discrimination of regional versus global controls on Lower Cretaceous carbonate platform genesis, the ultimate aim of which is to construct a high-resolution sea-level curve that would act as a predictive tool for basin analysis.

DATA COLLECTION

Thirty-seven sections totaling 17,000 m were logged on a decimeter scale throughout the >80,000 km² study area (Fig. 1B). Most sections were measured on the Coahuila block (9 sections) and in the northern part of the Sierra de Parras (14 sections) where Lower Cretaceous restricted evaporite interior, shallow shelf-lagoon, and high-energy shoal-margin deposits are exposed. Cycle stacking patterns are best developed in these shallow-water localities and form the primary database for the sequence-stratigraphic interpretations. Fourteen sections of deep-platform facies were measured in the southern part of the Sierra de Parras, in the Sierra Madre Oriental near Saltillo and Monterrey, and in isolated mountain ranges east of the Sierra de Paila.

Biostratigraphic zonation for the Barremian–Albian of northeastern Mexico has previously been established on the basis of planktic foraminifers (Longoria and Gamper 1977; Ice and McNulty 1980; Ross and McNulty 1981; Longoria 1984), nannoconids and colomiellids (Bonet 1956; Trejo 1960, 1975), ammonites (Böse and Cavins 1927; Imlay 1944, 1945; Young

* Present address: BP Amoco, 501 WestLake Park Blvd., Houston, Texas 77253-3092, U.S.A.

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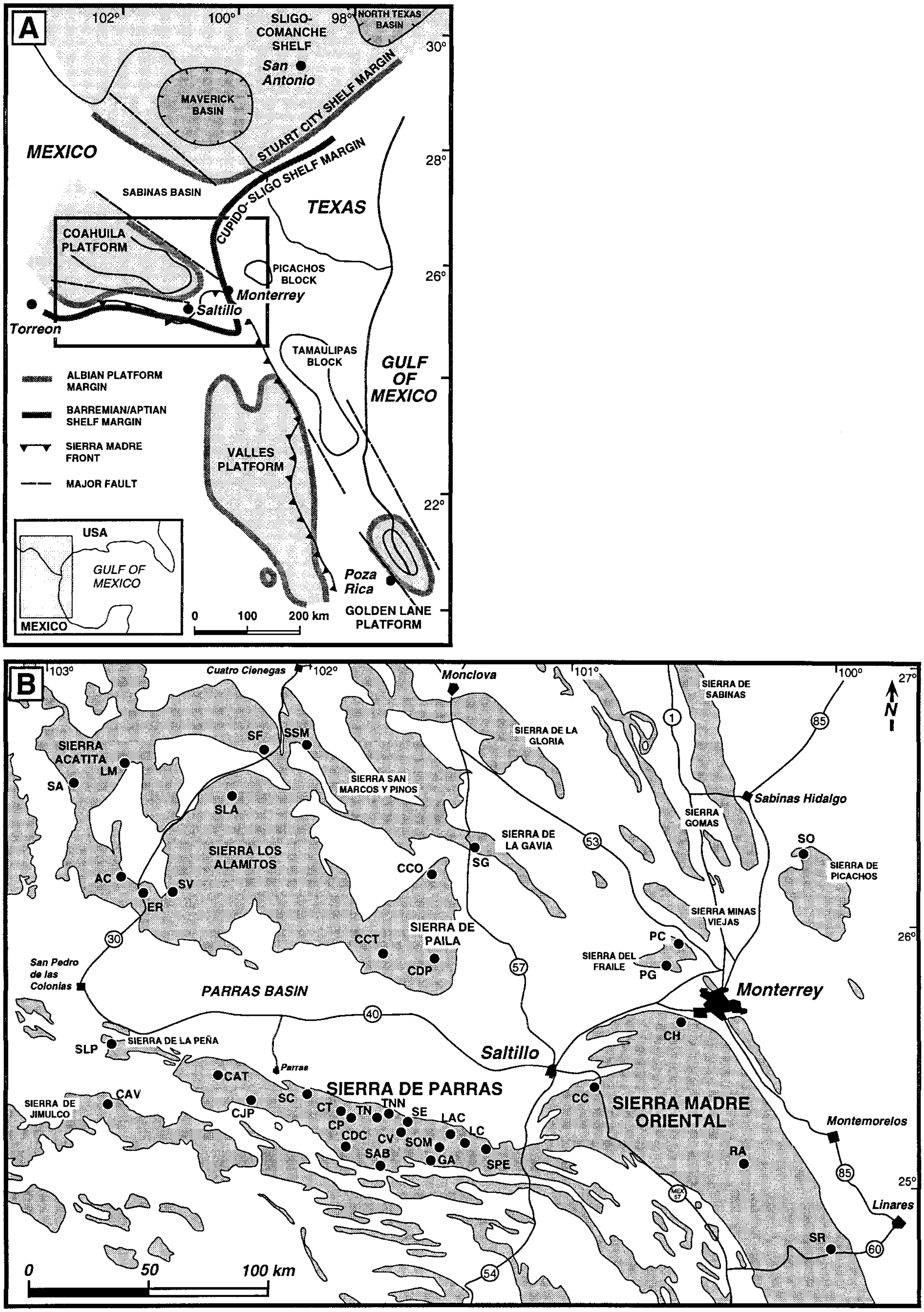
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102°
100°
98°
SLIGO-COMANCHE SHELF
NORTH TEXAS BASIN
30°
San Antonio
MAVERICK BASIN
STUART CITY SHELF MARGIN
MEXICO
CUPIDO-SLIGO SHELF MARGIN
28°
SABINAS BASIN
TEXAS
COAHUILA PLATFORM
PICACHOS BLOCK
26°
Monterrey
Saltillo
Torreon
TAMAULIPAS BLOCK
GULF OF MEXICO
ALBIAN PLATFORM MARGIN
BARREMIAN/APTIAN SHELF MARGIN
SIERRA MADRE FRONT
MAJOR FAULT
VALLES PLATFORM
22°
USA
GULF OF MEXICO
MEXICO
Poza Rica
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GOLDEN LANE PLATFORM
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Cuatro Cienegas
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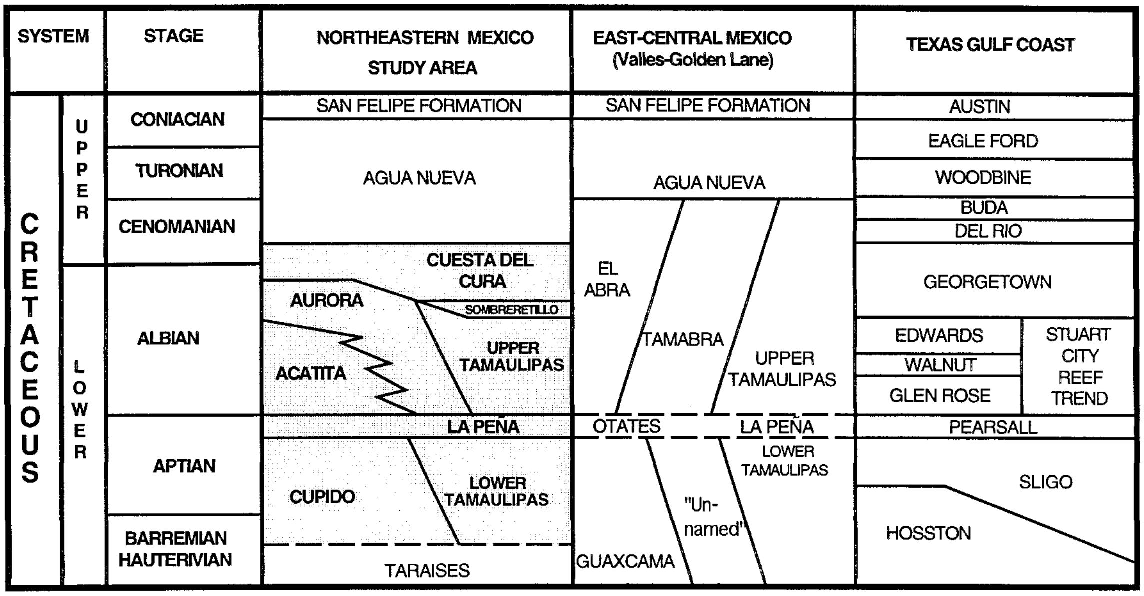

FIG. 2.—Correlation chart for the Cretaceous of Mexico and Texas (modified from Wilson and Ward 1993 and Lehmann et al. 1999). Units discussed in this study are shaded.

1974, 1977, 1978; Stinnesbeck 1991), and rudists (Young 1984). Additional biostratigraphic control was collected in this study along with carbon and strontium isotope data (Lehmann et al. 1999), which provide critical time constraints for our sequence-stratigraphic model. Hand samples were collected at 10–20 m intervals at selected platform-margin and platform-interior sections and at 5–10 m intervals at selected deep-platform sections. Petrographic study of $>$ 300 of these samples provided important detail about the depositional and diagenetic attributes of individual lithofacies.

Analysis of two-dimensional stratal geometries on seismic sections or continuous outcrop profiles has been the classical approach to defining sequences on carbonate platforms (Sarg 1988; Sonnenfeld and Cross 1993; Kerans and Fitchen 1995; Osleger 1998). In deformed terranes such as the Sierra Madre Oriental fold-and-thrust belt, however, this approach has several limitations. Seismic-scale outcrops that define large-scale geometries are rare, and surfaces of chronostratigraphic significance, such as transgressive surfaces, maximum flooding surfaces, or sequence boundaries, are difficult to physically trace because of Laramide structural deformation. Furthermore, lateral transitions between paleogeographic elements are commonly not well exposed. For instance, the Parras basin physically separates sections on the Coahuila block from coeval intervals in the Sierra de Parras (Fig. 1B), obscuring cross-platform relationships. Because of these tectonic and geographic constraints, data in this study were collected mainly from vertical sections, with genetic interpretations constructed from correlations of vertical stacking patterns within a hierarchy of cyclicity. This is the standard approach used in many similar field studies (Montañez and Osleger 1993; Goldhammer et al. 1993) and is naturally the primary technique in subsurface exploration, where drillholes provide the only rock data. It is important to emphasize that cross-platform correlation of genetically unique intervals between vertical sections collected in this study are integrated into a chemostratigraphic and biostratigraphic framework.

REGIONAL FRAMEWORK

Barremian through Albian time along the western flank of the ancestral Gulf of Mexico was marked by two major episodes of carbonate-platform development separated by an intervening phase of flooding, shale deposition, and backstep (Fig. 2). In Texas, limestones of the Sligo–Hosston shelf (Barremian to Aptian) are separated by shales and lime mudstones of the Pearsall Group (middle to upper Aptian) from overlying Albian-age Glen Rose/Fredericksburg/Stuart City platform carbonates (Wilson 1975; Bebout et al. 1981; Moore 1995). In east-central Mexico on the Valles and Golden Lane platforms, the shaly Otates Formation separates the underlying Guaxcama/El Abra/Lower Tamaulipas Formations from overlying El Abra/Tamabra/Upper Tamaulipas platform carbonates (Coogan et al. 1972; Enos 1974, 1983). In the study area of northeastern Mexico, shallow-water carbonates of the Cupido shelf are separated by La Peña shales from evaporites and carbonates of the Coahuila ramp (Acatita/Aurora Formations) and coeval Upper Tamaulipas deeper-water deposits. The resemblance of the large-scale stratigraphic pattern of all three regions suggests a common depositional history along the ancestral Gulf of Mexico.

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FIG. 1.—**A)** Tectonic map of northeastern Mexico and south Texas showing distribution of Barremian–Aptian and Aptian–Albian carbonate platforms (modified after Wilson and Ward 1993 and Lehmann et al. 1998). Shaded areas are for the Albian platforms only. Solid thin line within Coahuila platform is the interpreted edge of Permo-Triassic granodioritic basement (Coahuila block). Rectangle outlines the study area shown in Part B. **B)** Location map of measured sections and mountain ranges with Lower Cretaceous exposures (modified from Lehmann et al. 1998). Sections are indicated by filled circles. Ranges constituting the Coahuila block include the Sierra Acatita, Sierra Los Alamitos, and Sierra de Paila. AC = Agua Chico, CAT = Cañon Taraises, CAV = Cañon Viobora, CC = Cañon del Chorro, CCO = Casa Colorado, CCT = Cañon Corazón del Toro, CDC = Cañon de Cobra, CDP = Cañon de los Perdidos, CH = Cañon de Huasteca, CJP = Cañon de Juan Pérez, CP = Cerro Prieto, CT = Cerro de Tunal, CV = Chile Verde, ER = El Roya, GA = Garambullo, LAC = La Casita, LC = La Concordia, LM = Las Margaritas, PC = Potrero Chico, PG = Potrero García, RA = Rayones, SA = west-side Sierra Acatita, SAB = Sabinilla, SC = west-side Sierra Cabrera, SE = Sierra Escondida, SF = Sierra La Fragua, SG = Sierra de La Gavia, SLA = north-side Sierra Los Alamitos, SLP = Sierra de la Peña, SO = Sombreretillo, SOM = Sombrero, SPE = Sierra de Parras, east-side, SSM = Sierra San Marcos y Pinos, SR = Cañon de Santa Rosa, SV = Sierra Venado, TN = Tanque Nuevo, TNN = Tanque Nuevo north.

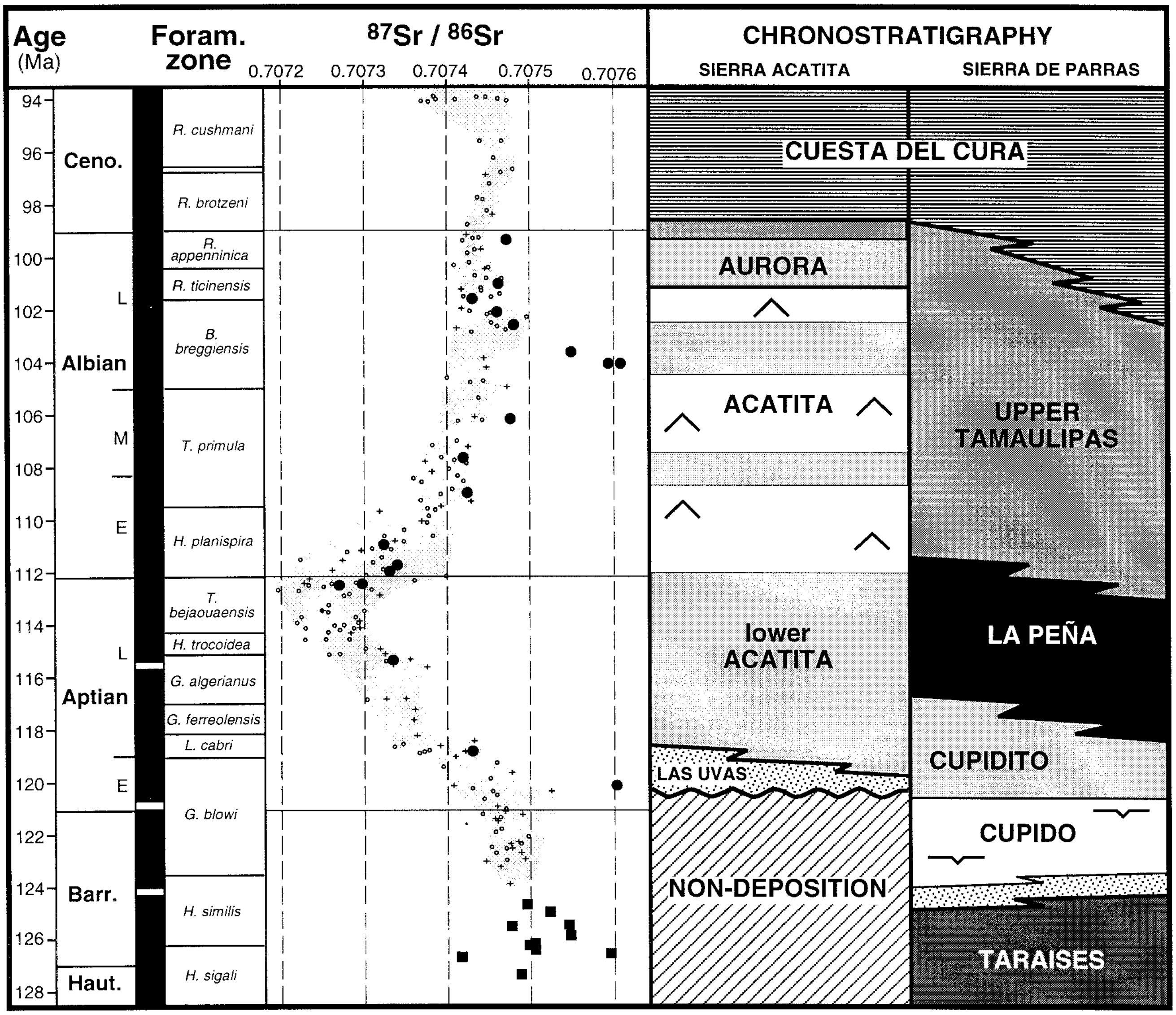


FIG. 3.—Chronostratigraphic relationships for Barremian to Albian strata of this study. Chart illustrates temporal relationships between the Coahuila block to the northwest (centered over the Sierra Acatita) and the Sierra de Parras to the south-southeast. The absolute ages and magnetostratigraphy are from Gradstein et al. (1995). The planktonic foraminiferal zonation is from published literature cited in the text and from Lehmann et al. (1999). The shaded trend in the Sr isotope stratigraphy is derived from data in Bralower et al. (1997; small open circles) and Jenkyns et al. 1995 (small crosses). Sr isotope data from Lehmann et al. (1999) is shown by the large dots (Sierra Acatita) and dark squares (Sierra Escondida).

A chronostratigraphic framework was constructed by Lehmann et al. (1999) that illustrates the temporal relations between the formations constituting the Cupido and Coahuila platforms (Fig. 3). Considerable detail concerning the alignment and correlation of absolute ages, Sr isotopic data, biostratigraphic data, and lithostratigraphic boundaries can be found in Lehmann et al. (1999). This temporal framework permits the documentation of the chronology of platform evolution in the study area and the construction of time-slice paleogeographic maps. Strata of the Cupido shallow-marine platform accumulated between the Coahuila basement block (composed of Permo-Triassic granodiorite and metasediments) and a shelf margin that varied along strike (Fig. 4A). To the east, the Cupido margin consisted of a rudist–coral ''reef'' (Conklin and Moore 1977; Wilson 1981; Wilson and Pialli 1977; Selvius and Wilson 1985; Goldhammer et al. 1991), whereas to the south the margin consisted of a high-energy grainstone shoal (Lehmann et al. 1998). A broad, shallow shelf lagoon developed in the lee of the margin, where up to 660 m of cyclic peritidal deposits of the Cupido Formation accumulated. Hemipelagic lime mudstones (Lower Tamaulipas Formation) were deposited on the surrounding deep shelf. During the mid- to late Aptian, a significant phase of flooding forced a retrograde backstep of the Cupido platform, shifting the locus of shallow-marine sedimentation northwestward toward the Coahuila block (Figs. 3, 4B). This transgressive event is recorded in the upper Cupido Formation by an upward-deepening interval of shallow subtidal facies termed the ''Cupidito'' by Wilson and Pialli (1977). Cupidito carbonates backstepped in concert with deposition of fine siliciclastics and lime mudstones of the La Peña Formation, which ranges in age from mid-Aptian to earliest Albian (Trejo 1975; Tinker 1985). This diachronous flooding event recorded by the Cupidito–La Peña reflects both the demise of the Cupido shelf and the initiation of the Coahuila ramp.

The backstepped Coahuila ramp (Aptian–Albian) consisted of a shallow ramp-crest margin separating an interior evaporitic lagoon (Acatita Formation) from a low-energy, muddy deep ramp (Upper Tamaulipas For-

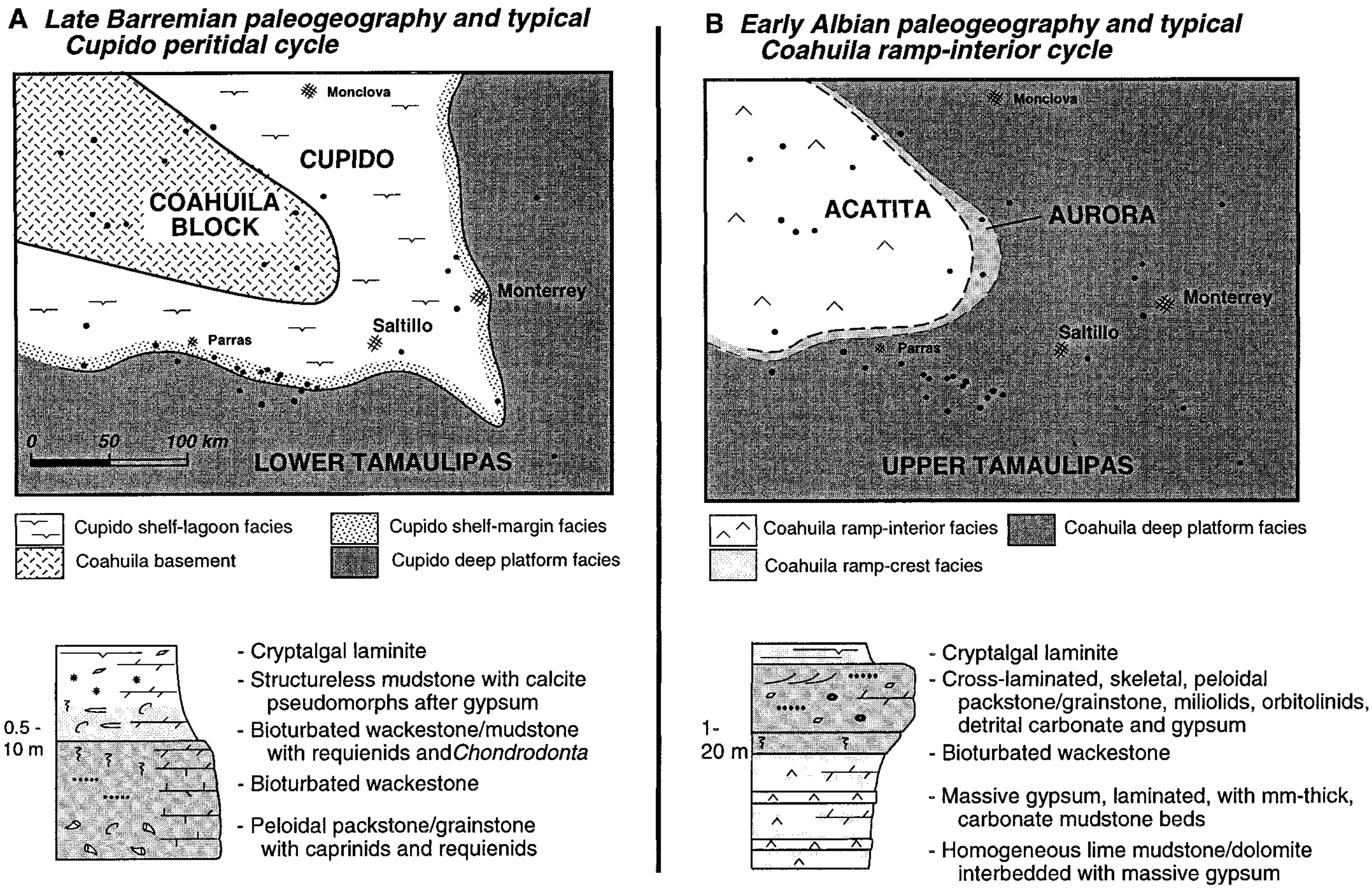


FIG. 4.—**A)** Paleogeographic map of Cupido shelf during the late Barremian (not palinspastically corrected) and typical Cupido shelf-lagoon peritidal cycle. Dots represent section locations. Telescoping of facies in the Sierra de Parras is related to a 30–50% shortening during the Laramide Orogeny (R. Marrett, personal communication 1995). **B)** Paleogeographic map of Coahuila ramp during the early Albian (not palinspastically corrected) and typical Coahuila ramp-interior evaporitic cycle.

mation; Fig. 4B). More than 500 m of cyclic carbonates and evaporites accumulated in the Acatita lagoon during the early to mid-Albian. The platform interior became less restricted by mid- to late Albian time with the deposition of peloidal, miliolid-rich packstone/grainstones of the Aurora Formation. The Coahuila platform drowned during latest Albian time with the deposition of pelagic and turbiditic facies of the Sombreretillo and Cuesta del Cura Formations (Bishop 1972; Ice 1981; Longoria and Monreal 1991).

CYCLES, FACIES, AND PALEOENVIRONMENTS

Barremian to Albian platform carbonates and evaporites of the study area form genetic associations of lithofacies that define five paleoenvironmental settings: restricted evaporite interior, peritidal to shallow-subtidal shelf lagoon, shallow-subtidal restricted to open-marine platform, high-energy shoal margin, which changes along strike to a rudist-reef margin, and deep-subtidal low-energy platform (Fig. 4). The short discussion below is a summary of the fundamental cycle types and paleoenvironments that characterize the Cupido and Coahuila platforms, specifically focusing on the shallow-marine cycles that provide the best expression of stacking patterns and the resulting sequence-stratigraphic framework. Greater detail on lithofacies and paleoenvironmental interpretations is provided in Lehmann et al. (1998), and regional paleogeographic patterns and time-slice maps are illustrated in Lehmann et al. (1999).

Cupido Peritidal Cycles.—Peritidal lithofacies dominate the Cupido Formation and reach thicknesses of 400 to 660 m. These lithofacies are systematically arranged into upward-shallowing cycles whose thickness ranges from 0.5 to 28.5 m with an average of 4.9 m (total of 686 measured cycles; Fig. 4A). Contacts between adjacent cycles are typically sharp, whereas lithofacies transitions within individual cycles are gradational and progressively fine upward. These peritidal cycles are identical to most others described throughout the stratigraphic record, the primary difference being the presence of Cretaceous biota such as caprinid and requienid rudists and *Chondrodonta* bivalves.

These cycles are interpreted to reflect the migration of broad tidal-flat complexes across the low-energy, shallow-subtidal lagoon developed behind the Cupido shelf margin in response to high-frequency, low-amplitude sea-level fluctuations (Lehmann et al. 1998). During relative sea-level falls, peritidal islands prograded and partly infilled the shallow lagoon. The distribution of sediment and progradation directions may have been controlled by the dominant storm-track orientation, similarly to many modern shallow carbonate settings. During relative sea-level rises, peritidal islands became flooded and eventually were colonized by shallow-marine biota. Individual Cupido peritidal cycles are laterally continuous over the length of the typical outcrop (~50–250 m) but are difficult to correlate between structurally isolated measured sections. This lateral complexity is typical of many flat-topped peritidal platforms and is attributed to background autogenic and climatic processes acting upon a physiographically variable platform (Lehmann et al. 1998). Intervals of peritidal cycles ranging from tens to hundreds of meters in thickness exhibit stacking patterns that can be recognized and correlated between sections spanning the broad platform.

Coahuila Evaporitic Cycles.—Carbonate and evaporite lithofacies of the Coahuila ramp interior (Acatita Formation) attain thicknesses of up to

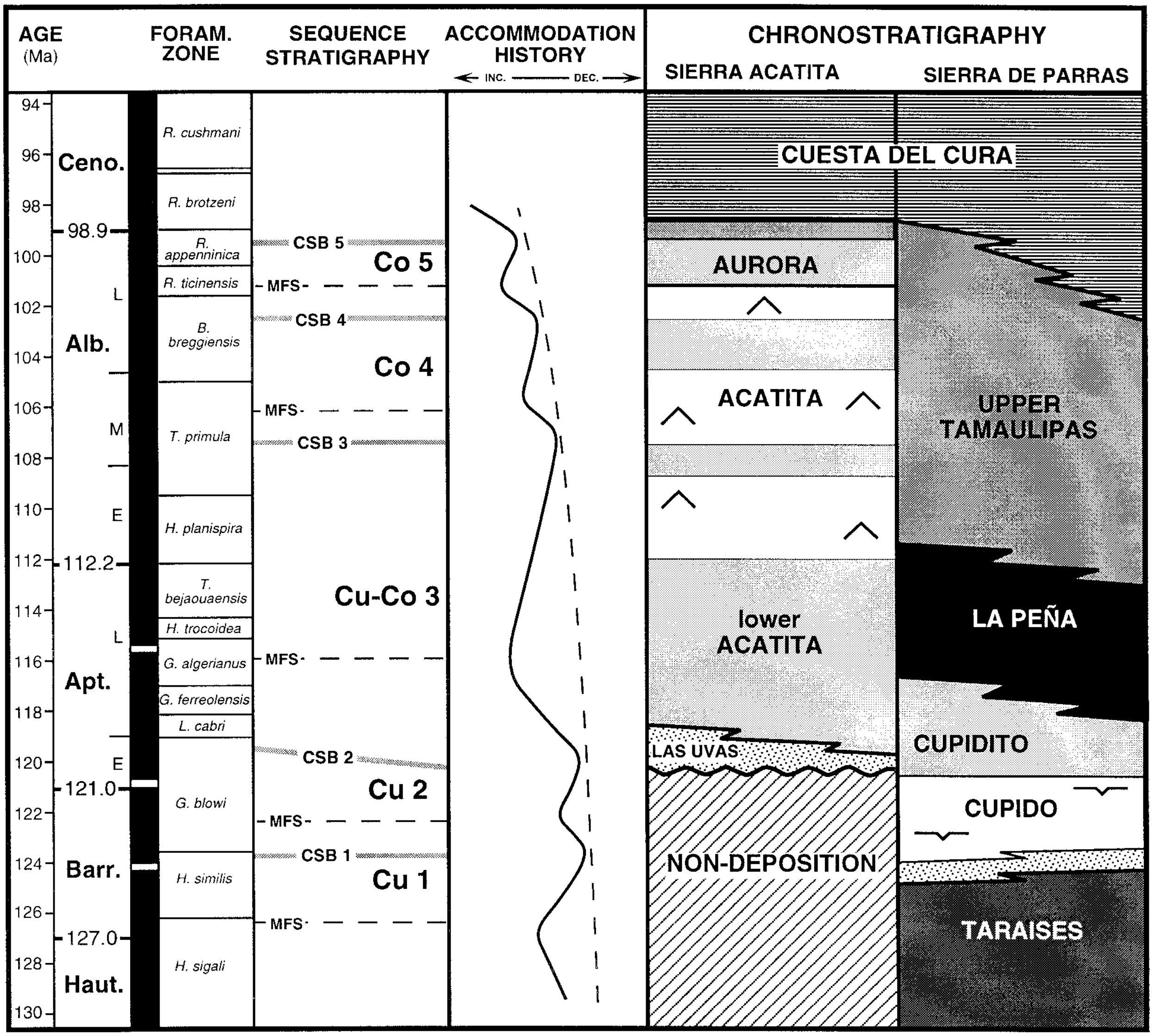


FIG. 5.—Generalized chronostratigraphy for the Sierra de Parras and Coahuila block juxtaposed with the sequence-stratigraphic framework of this study, planktic foraminiferal zonation, and absolute ages from Gradstein et al. (1995). We recognize four full composite sequences (Cu2, Cu–Co3, Co4, Co5) and a lower partial composite sequence (Cu1). Data for this sequence-stratigraphic framework were derived mainly from shallow-platform sections. The accommodation plot was constructed from interpretations of correlated vertical stacking patterns and the relative ''intensity'' of composite sequence boundaries. Minimal accommodation is inferred to occur at sequence boundaries and maximum accommodation coincident with maximum flooding intervals. The accommodation plot (solid) is superimposed on an interpretive long-term accommodation history (dashed).

500 m (Fig. 4B). These facies form cyclic arrangements, with evaporitic facies grading upward into carbonate facies over 1 to 20 m (average of 7.8 m over 220 measured cycles). Contacts between individual cycles are abrupt, with lagoonal evaporitic facies juxtaposed above peritidal carbonate facies.

This cyclic association of genetically related lithofacies is interpreted to have accumulated in a restricted, hypersaline lagoon rimmed by a high-energy ramp-crest shoal (Lehmann et al. 1998). With each rise in sea level, the Coahuila shoal margin aggraded and narrowed, restricting the exchange of open marine waters with the ramp interior and enhancing the deposition of massive gypsum and nonfossiliferous, muddy carbonates. During relative sea-level falls, the Coahuila ramp-crest margin and interior mobile sand belts prograded across the lagoon, accompanied by an expansion of the low-energy peritidal zone developed in the lee of the sand shoals. Similarly to the Cupido peritidal cycles, cycle development across the Coahuila evaporitic interior was apparently spatially variable, influenced by preexisting depositional relief, differential subsidence, and ambient environmental conditions across the platform. As with the Cupido cycles, however, intervals exhibiting similar stacking patterns can be correlated between sections and thus permit the recognition of larger-scale depositional sequences.

SEQUENCE STRATIGRAPHY

The classification scheme of Mitchum and Van Wagoner (1991) is used in the following discussion of sequence stratigraphy: large-scale ''composite sequences'' are internally composed of ''high-frequency sequences'' (HFSs), which in turn are composed of ''meter-scale cycles''. Each of these three hierarchical units and their bounding surfaces are interpreted to be unique chronostratigraphic entities that developed through one rise–fall cycle of relative sea-level change. The internal architecture of each of these genetic units consists of facies associations that are interpreted to have migrated across the platform in a predictable retrogradational, to aggradational, to progradational pattern, with the exact proportions determined by the form and magnitude of the accommodation signal and variations in production of carbonate sediment.

On the Cupido and Coahuila platforms, the composition of meter-scale cycles within HFSs ideally evolves from intervals of purely subtidal cycles to stacked peritidal cycles with thin tidal-flat caps, to stacked peritidal cycles that exhibit tidal-flat facies that constitute $>$ 30% of the cycle thickness. Variations on this ideal arrangement are common, but evidence for relative deepening near the bases of individual HFSs and progressive upward shallowing toward the tops of HFSs is clear. The apparent lateral thickness differences within individual HFSs may be attributable to variations in platform physiography, subsidence rates, sediment production rates, or sediment distribution patterns. Systematic changes in cycle thickness and composition at the HFS scale are consistent through each section, however, regardless of total thickness differences between sections.

At the larger scale, HFSs constituting the Cupido and Coahuila platforms typically stack into lower ''transgressive'' HFSs dominated by subtidal facies and overlying ''regressive'' HFSs that exhibit progressively greater proportions of peritidal facies. Thus, successions of HFSs build into larger-scale composite sequences. Abrupt offsets in facies tracts and cycle types are not evident in vertical successions of the Cupido and Coahuila platforms. Therefore, we interpret composite and high-frequency sequence boundaries to occur at the contact between the thinnest tidal-flat-dominated cycles in a stack and overlying thicker, subtidal-dominated cycles. These sequence boundaries are considered to be transitional, disconformable zones rather than abrupt, unconformable surfaces and are thus interpreted to reflect rates of long-term sea-level fall less than background subsidence rates.

Cross-platform correlation of sequence boundaries and cycle stacking patterns has permitted us to identify four full composite sequences and a lowermost partial composite sequence spanning the Barremian through Albian Cupido and Coahuila platforms (Fig. 5). The Cupido shelf lagoon is composed of up to 150 meter-scale peritidal cycles that systematically stack into several HFSs that can be correlated across the platform. In turn, Cupido HFSs stack into a lower partial composite sequence (Cu1), a full composite sequence (Cu2), and the transgressive base of a third composite sequence (Cu–Co3).

The Coahuila restricted platform interior is composed of more than 80 meter-scale evaporite-to-carbonate cycles whose stacking patterns define several high-frequency sequences that can be correlated across the platform. Stacking patterns of Coahuila HFSs are interpreted to comprise two full composite sequences (Co4, Co5) overlying the upper part of composite sequence Cu–Co3, which overlaps with the Cupidito–La Peña retrograde backstep of the Cupido platform.

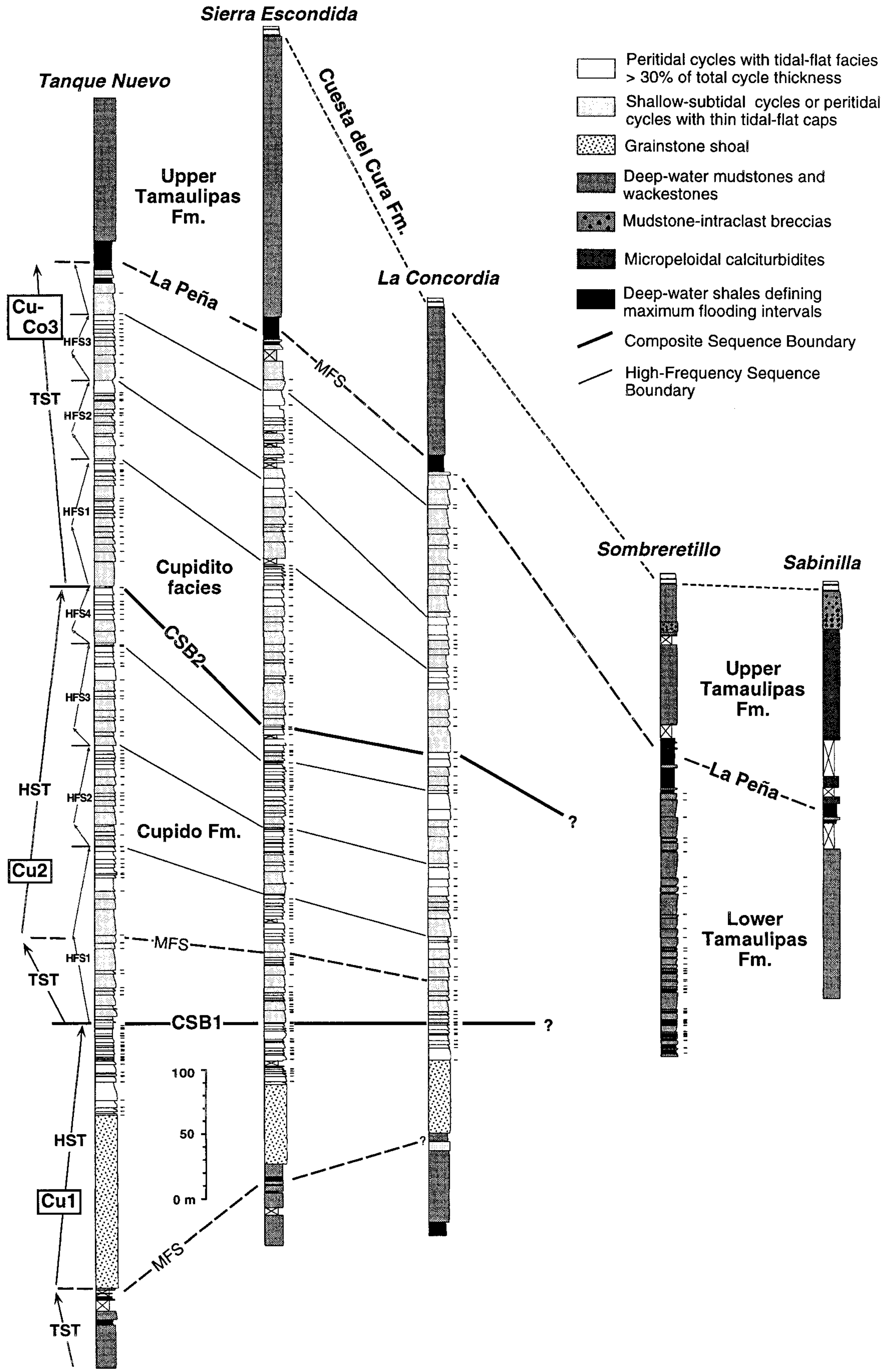
The sequence-stratigraphic framework for the Barremian through Albian interval of northeastern Mexico proposed by Goldhammer et al. (1991) was based primarily on data from the Sierra Madre Oriental near Saltillo and Monterrey. The genetic model of this study is derived mainly from several sections in the Sierra de Parras and mountain ranges centered above the Coahuila block, and from six sections in the Sierra Madre Oriental near Monterrey and Saltillo. Throughout the following section, evidence for our sequence-stratigraphic interpretation is integrated with that of Goldhammer et al. (1991) to provide a unified sequence-stratigraphic model that significantly enhances the chronostratigraphic resolution for the Barremian through Albian interval of northeastern Mexico.

Composite Sequence Cu1

The lowest composite sequence of the Cupido platform spans the uppermost Taraises through the lower Cupido, including the shelf-margin grainstone shoal (Table 1; Figs. 6, 7). Cu1 is only a partial composite

TABLE 1.—*Summary of Sequence Stratigraphic Framework for Cupido and Coahuila Platforms.*

Composite Sequence	Average Thickness (Range) (m)	Upper Composite Sequence Boundary (CSB)	Highstand Systems Tract (HST)	Transgressive Systems Tract (TST)	Estimated Age of Upper CSB (Ma) (Gradstein et al., 1995)	Duration of Composite Sequence (Myr)	Average Accum. Rate (m/Myr)
Co5	270 (220–330)	Solution-collapse breccia in western part of study area; no exposure surface in eastern areas—placed at the contact of shallow subtidal carbonates and overlying foraminiferal mudstone/wackestone	Predominantly composed of shallow subtidal to peritidal carbonate cycles	Lower part of Co5 is composed of evaporite-to-carbonate cycles; MFS is placed at top of thickest evaporite cycle within HFS1	99	3	90
Co4	200 (175–240)	Composite sequence boundary placed at top of thin tidal-flat-dominated cycles in HFS4; overlying transition into thick evaporite cycles	Entirely composed of evaporite-to-carbonate cycles; ratio of carbonate-dominated cycles progressively increases toward top of Co4	Entirely composed of evaporite-dominated cycles of HFS1 and part of HFS2; MFS placed at thickest cycle of HFS2	102	5	40
Cu-CO3 lower Acatita La Peña Cupidito	 250 (225–285) 50 (35–72) 230 (200–305)	CSB placed at top of thin carbonate-dominated cycles of HFS7 and below thick evaporite-dominated cycles of the overlying TST of Co4; no prominent exposure features evident	Entirely composed of evaporite-to-carbonate cycles arranged into three HFSs (HFS5–7)	*Coahuila platform*: TST composed of fossilliferous sandstone (Las Uvas Fm.) and massive, skeletal packstone-grainstone; MFS placed at the contact between carbonates and evaporites; *Cupido platform*: MFS placed toward middle of La Peña shale; TST composed of mostly shallow-subtidal cycles (Cupidito) arranged into 3 HFSs and 20–30 m thick interval of shallow-subtidal carbonates below La Peña	 107	 13 5 5–7 1–3	 50 7–10 75–230
Cu2	240 (180–340)	CSB 2 placed on top of laterally correlative stack of thin tidal-flat-dominated peritidal cycles; overlain by thick subtidal cycles of Cupidito facies	Begins in first peritidal cycles above TST; overlying HFSs progressively thin upward and shallow upward with progressively greater evidence of peritidal deposition	MFS placed at base of thickest shallow-subtidal-dominated cycle in HFS1; TST composed of thick shallow-subtidal cycles in basal part of Cu2	120	4	60
Cu1 (HST)	150 (HST) (80–210)	Laterally extensive solution-collapse breccia at Tanque Nuevo; at all other locations, CSB1 located at top of stack of thin, tidal-flat-dominated cycles showing greatest evidence of exposure	Lower HST composed of massive peloidal-skeletal-oolitic grainstone with interbedded rudist packstone; upper HST composed of thin peritidal cycles	Incomplete; composed of foraminiferal mudstone/packstone (Taraises Fm.); MFS is placed within a 4–8 m interval of thin-bedded silty mudstone and shale	124	<3	50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La Concordia
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Sabinilla
Cuesta del Cura Fm.
Upper Tamaulipas Fm.
Cupidito facies
Cupido Fm.
Lower Tamaulipas Fm.
La Peña
MFS
CSB2
CSB1
Cu-Co3
Cu2
Cu1
TST
HST
HFS3
HFS2
HFS1
HFS4
100
50
0 m
Peritidal cycles with tidal-flat facies > 30% of total cycle thickness
Shallow-subtidal cycles or peritidal cycles with thin tidal-flat caps
Grainstone shoal
Deep-water mudstones and wackestones
Mudstone-intraclast breccias
Micropeloidal calciturbidites
Deep-water shales defining maximum flooding intervals
Composite Sequence Boundary
High-Frequency Sequence Boundary

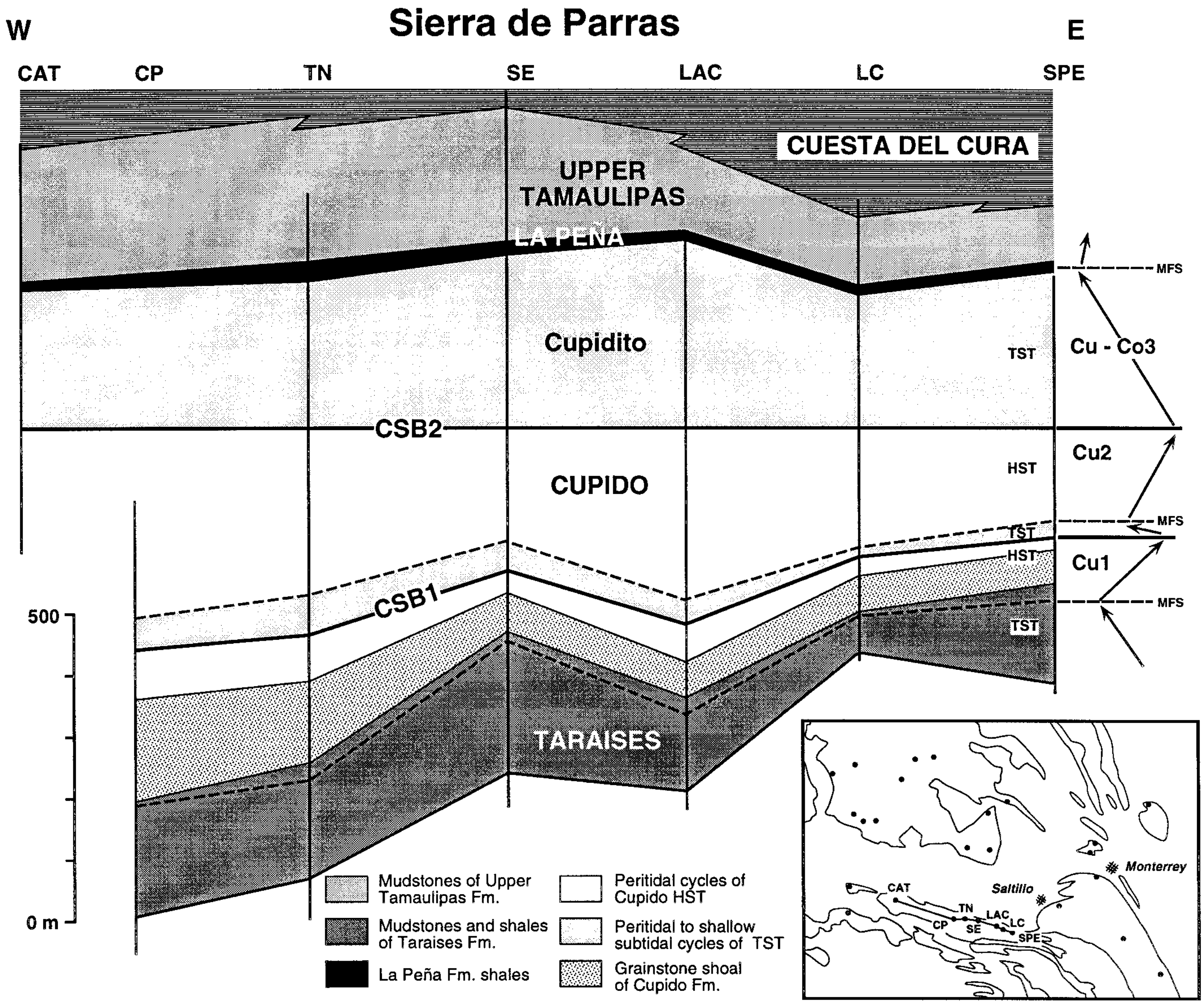

FIG. 7.—Simplified sequence-stratigraphic framework for the Cupido platform showing strike-oriented lateral relations between seven sections in the Sierra de Parras. The composite sequence boundary at the top of Cu2 was used as the datum. The La Peña Formation is mostly covered at La Casita (LAC), La Concordia (LC), and Sierra de Parras, east-side (SPE), so we estimated thicknesses at these locations.

sequence in this study because the lower part of the transgressive systems tract (TST) in the Taraises is not well exposed. The underlying composite sequence boundary was not recognized but may occur toward the top of progradational siliciclastics within the La Casita Formation (Goldhammer et al. 1991, *after* Fortunato and Ward 1982). The maximum flooding surface (Table 1) might coincide with a similar shaly unit beneath reefal facies in exposures of the Cupido near Monterrey recognized by Conklin and Moore (1977) (within their Unit B). Similarly, Goldhammer et al. (1991) identified fine-grained mixed clastics and carbonates near the Taraises–Cupido contact as a major ''second-order'' maximum flooding surface (their 118 Ma MFS).

The highstand systems tract (HST) of Cu1 in the Sierra de Parras includes massive shelf-margin grainstones that correlate with Cupido shelf-margin reefal boundstones in the Sierra Madre Oriental near Monterrey. Overlying peritidal cycles exhibit a thinning- and shallowing-upward trend toward the composite sequence boundary. The HST of Cu1 reflects the seaward progradation of protected shelf-lagoon environments behind the shelf-margin grainstone shoal (Lehmann et al. 1999).

←

FIG. 6.—Cross section illustrating correlation of high-frequency sequences and composite sequences between three representative sections across the shallow Cupido platform in the northern part of the Sierra de Parras and two representative sections from deeper-platform localities. On the shallow platform, facies changes and cycle stacking patterns were used to define sequence boundaries and maximum flooding intervals. We hesitate to force sequence boundaries and other sequence-stratigraphic components out into deeper platform sections because few unequivocal surfaces exist for confident interpretations. Dashes to the right of each section represent tops of individual cycles. CSB, composite sequence boundary; MFS, maximum flooding surface. Thin dashed lines are formation boundaries. The La Peña Formation is mostly covered at La Concordia and the thickness is therefore estimated. See Figure 1B for section locations.

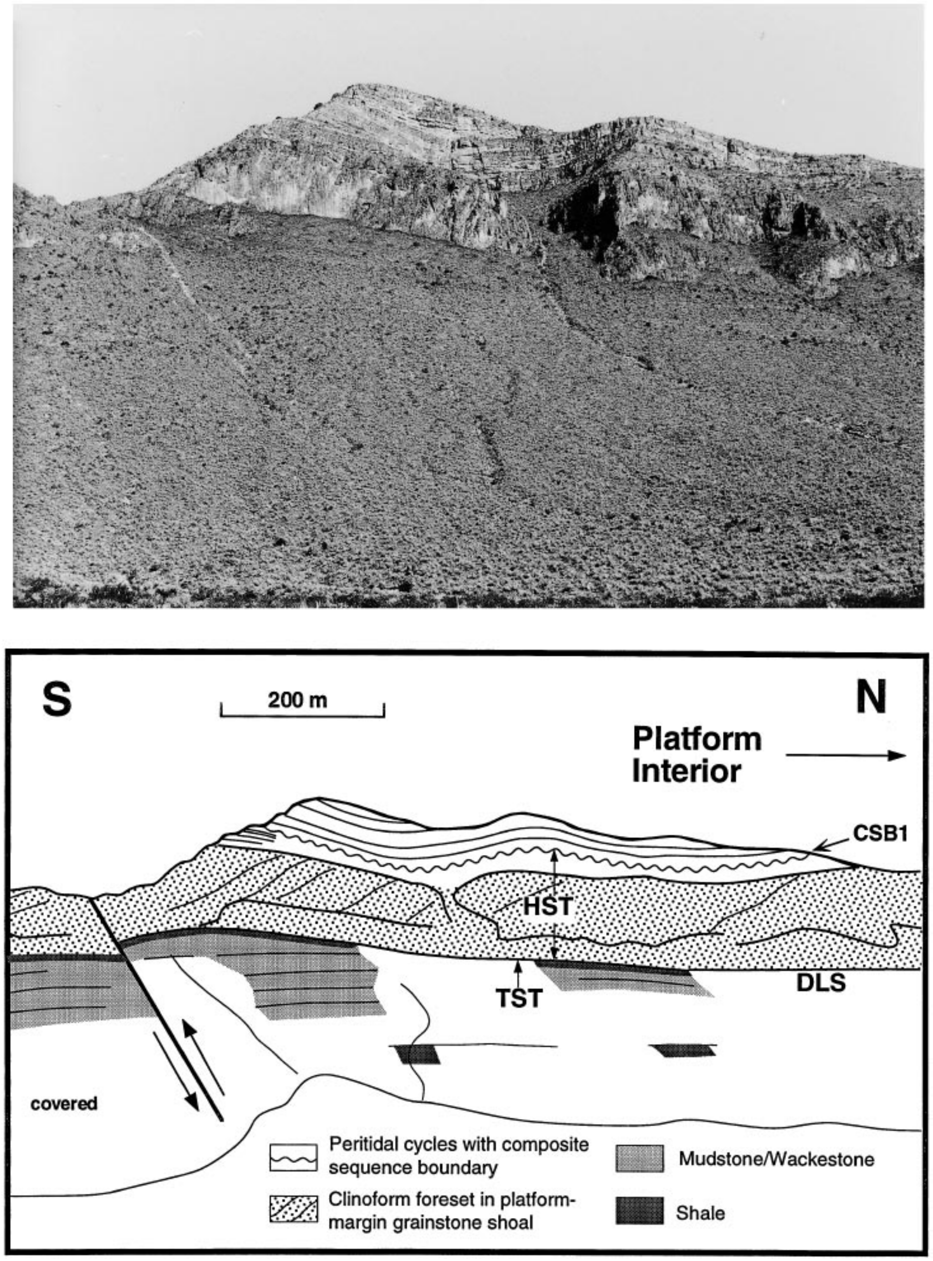

FIG. 8.—Paired photograph and sequence-stratigraphic interpretation of outcrop near Tanque Nuevo, northern Sierra de Parras. TST = transgressive systems tract, HST = highstand systems tract, DLS = downlap surface, CSB = composite sequence boundary.

An extraordinary outcrop at Tanque Nuevo reveals seismic-scale relationships within composite sequence Cu1 at the Cupido shoal margin (Fig. 8). Although structurally complicated by a faulted anticline, several critical surfaces of genetic significance can be traced approximately 2 km along the outcrop, allowing for a sequence-stratigraphic interpretation. A downlap surface separates the underlying, horizontally bedded TST from the overlying progradational HST. The massive grainstone shoal of the lower HST exhibits progradational foreset beds that toe out onto fine-grained facies near the maximum flooding surface. Foreset bedding planes indicate a south-southwest progradation toward the basin. The massive grainstone shoal is overlain by peritidal cycles that thin and shallow upward, culminating in a locally extensive intraclast breccia that is interpreted to be the unconformable upper boundary of composite sequence Cu1. The breccia can be physically traced for about 2 km along the outcrop and ranges in thickness from 2.5 m in the south to 10 m in the north. The breccia is not tectonic in origin because it is bounded above and below by horizontally bedded tidal-flat facies.

Composite Sequence Cu2

Cu2 is composed of shallow-subtidal cycles and peritidal cycles whose intermediate-scale stacking patterns define four high-frequency sequences that appear to be correlatable across the platform (Table 1, Figs. 6, 7). The four HFSs in Cu2 are interpreted to reflect a single long-term cycle of accommodation change. Judging by the interpreted position of the maximum flooding interval, Cu2 is strongly asymmetric (TST thickness $<<$ HST thickness), reflecting the dominant progradational migration of the shelf lagoon behind the reef- and shoal-barrier margins of the Cupido platform at this time.

The composite sequence boundary above Cu2 appears to be in a strati-

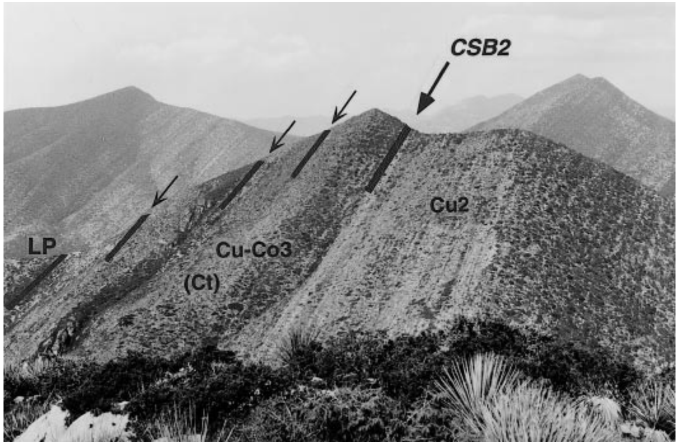

FIG. 9.—Outcrop photograph showing Cupido–Cupidito–La Peña dipping to the north, Sierra Escondida, northern Sierra de Parras (stratigraphic ''up'' is to the left). In general, darker, more vegetated slopes are composed of shallow-subtidal-dominated cycles whereas lighter gray slopes are composed of tidal-flat-dominated cycles. The thick arrow in the middle of the photograph marks the composite sequence boundary between composite sequence Cu2 of the Cupido Formation and basal composite sequence Cu–Co3 of the Cupidito (Ct). Smaller arrows mark the boundaries between HFSs of Cu–Co3 within the Cupidito. The La Peña Formation (LP) is exposed in the notch on the left (north) side of the mountain.

graphic position similar to the ''112 Ma'' supersequence boundary defined by Goldhammer et al. (1991) in sections from the Sierra Madre Oriental near Monterrey. At Potrero García, Goldhammer et al. (1991) describe the supersequence boundary as a ''1–4 m thick, polymictic, clast-supported breccia'', which they interpret to be a karst solution breccia. They state that this same breccia can be recognized over 100 km to the southwest in the Sierra Madre Oriental. The composite sequence boundary above Cu2 in the Sierra de Parras does not exhibit significant evidence for karstification (Table 1). The apparent difference in degree of subaerial exposure and associated diagenesis may be due to the upraised rim of the Cupido platform along the reefal margin near Monterrey, perhaps enhancing potential karstification, versus the more rapidly subsiding shelf lagoon behind the margin, perhaps inhibiting prolonged exposure. Both sequence boundaries record minimal or negative accommodation, however, and directly underlie subtidal facies of the ''Cupidito'' that reflects subsequent accommodation increase at the base of composite sequence Cu–Co3. Furthermore, Goldhammer et al. (1991) recognized that regressive, progradational facies of the Patula Arkose and La Virgen evaporites in the northern Sabinas basin (Smith 1981) are erosionally truncated by the composite sequence boundary at the top of Cu2.

Composite Sequence Cu–Co3

Cu–Co3 extends from the upper part of the Cupido (''Cupidito'' facies), through the La Peña, and laterally into evaporites of the lower Acatita (Table 1; Figs. 6, 7). Cu–Co3 bridges the Cupido and Coahuila platforms and genetically links exposures in the Sierra de Parras with those on the Coahuila block. In the Sierra de Parras, the Cupidito and part of the overlying La Peña are interpreted to form the TST of Cu–Co3, with maximum flooding occurring in the deepest-water facies of the La Peña. Goldhammer et al. (1991) recognized four HFSs in the Cupidito near Monterrey, but it is unclear how these may correlate with the three HFSs recognized in the Sierra de Parras (Fig. 9). Cupidito facies thin to the east, measuring from 100 m to only a few meters in sections near Monterrey. The westward-thickening, wedge shape of the Cupidito is interpreted to reflect a diachronous, intertonguing, backstepping relationship with the overlying La Peña shales (cf. Goldhammer et al. 1991).

The Cupidito backstep marks the initial inundation of the Coahuila block, in which flooding is recorded by transgressive fossiliferous sandstone of the Las Uvas Formation and massive, skeletal packstone/grainstone of the lower Acatita Formation (Figs. 10, 11). This lithologic interval is interpreted to be the upper part of the TST of Cu–Co3, with the lower part occurring in the Cupidito exposed in the Sierra de Parras. The exact lithologic record of maximum flooding coeval with peak La Peña onlap is not clearly evident on the Coahuila block because the La Peña pinches out before reaching the block. The late Aptian timing of peak flooding is constrained by biostratigraphic and isotopic evidence in the Sierra Acatita to occur near the carbonate-to-evaporite turnaround in the lower Acatita Formation (Fig. 3; Lehmann et al. 1999).

High-frequency sequences of the HST of Cu–Co3 on the Coahuila platform are dominated by evaporitic cycles of the interior lagoon (Figs. 10, 11). The architecture of individual meter-scale cycles on the Coahuila block records gradual upward shallowing from evaporitic lagoonal environments to peritidal high-energy grainstone shoals or low-energy tidal flats (Fig. 4B). At a larger scale, HFSs of the Coahuila platform are similarly constructed of lower evaporite-dominated cycles that evolve upward into carbonate-dominated cycles. The arrangement of HFSs in the HST of Cu–Co3 illustrates this pattern (Fig. 12). HFS5 is interpreted to represent high accommodation space with upbuilding of the carbonate rim and consequent restriction of the interior lagoon and aggradation of evaporitic facies. The overlying HFS6 and HFS7 reflect a progressive decrease in accommodation and consequent progradation of carbonate environments over the interior lagoon.

In summary, the Cu–Co3 composite sequence records both the demise of the Cupido platform and the initiation of the Coahuila platform in response to retrogradational backstep forced by a relative sea-level rise. This transition occurs simply by landward migration of the locus of shallow-marine sedimentation back toward the Coahuila block during the Cupidito–La Peña backstep. Thus, the termination of the Cupido carbonate platform should not be considered either a ''drowning unconformity'' (Schlager 1989) or a sequence boundary in the standard usage. The La Peña shales did not ''drape'' the Cupido platform, causing its demise, but rather diachronously onlapped the platform as a transitional flooding event (cf. Goldhammer et al. 1991).

Composite Sequence Co4

Composite sequence Co4 is composed of four laterally correlatable HFSs that exhibit the characteristic Coahuila pattern of lower, aggradational, evaporite-dominated cycles overlain by progradational, carbonate-dominated cycles (Table 1, Figs. 10, 11). The thickness and composition of individual HFSs in Co4 are variable, perhaps related to depositional topography or differing accumulation rates between carbonate and evaporite environments. The Sierra Acatita and Cañon Corazón del Toro sections exhibit HFSs with thick accumulations of evaporites relative to the other two sections, suggesting the possible existence of at least two hypersaline subbasins separated by a shallower area on the Coahuila platform during Co4 deposition.

The ratio of carbonate-dominated cycles to evaporite-dominated cycles within HFS1–4 increases toward the top of composite sequence Co4. The composite sequence boundary is placed at the top of tidal-flat-dominated cycles in HFS4 on the basis of the overlying transition into thick evaporite cycles of composite sequence Co5.

Composite Sequence Co5

The lower part of composite sequence Co5 is dominated by evaporites of the Acatita Formation whereas the upper part is composed of progressively upward-shallowing peritidal carbonates of the Aurora Formation (Figs. 10, 11). This evaporite-to-carbonate transition records the termina-

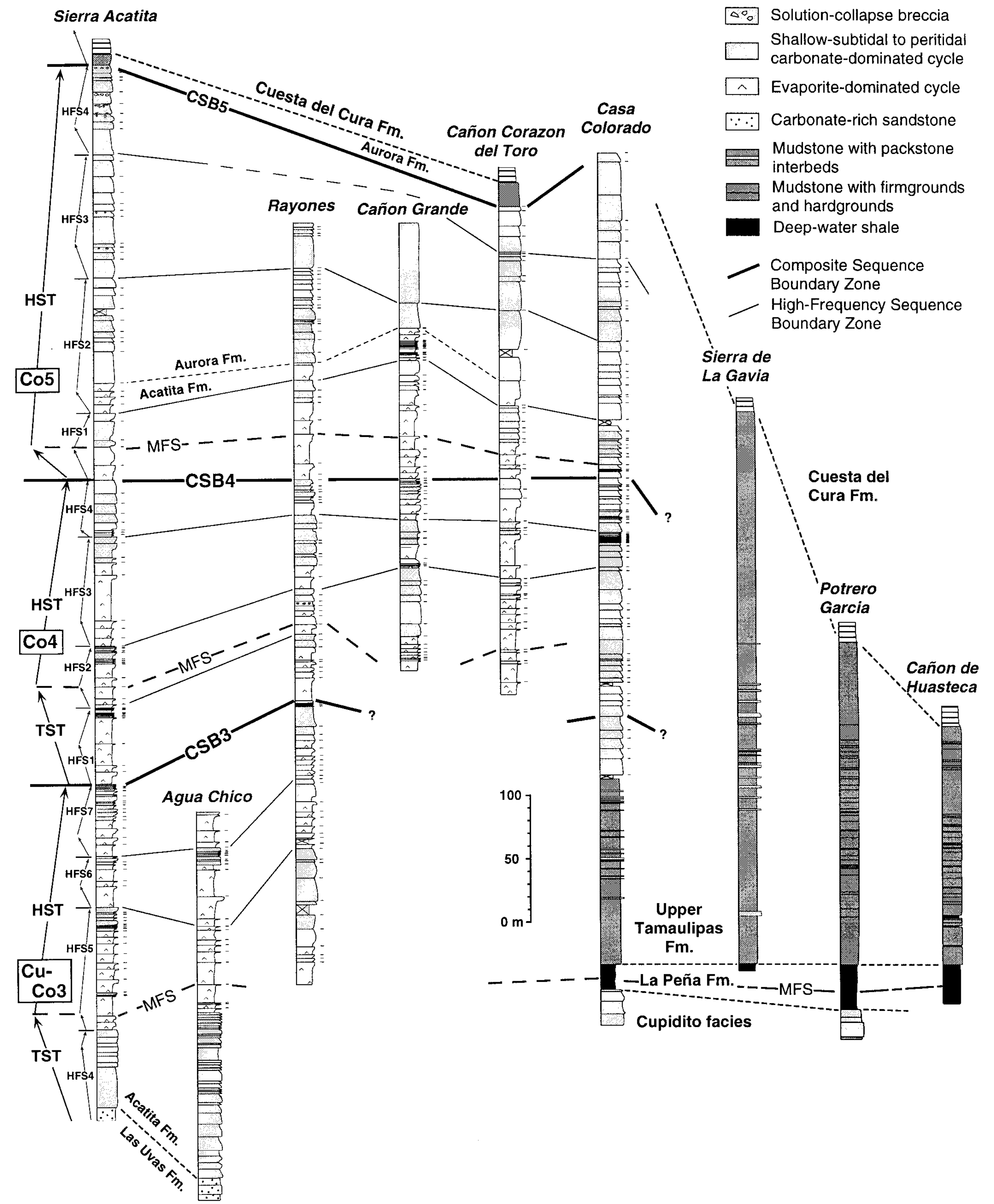

FIG. 10.—Cross section illustrating correlation of high-frequency sequences and composite sequences between the shallow Coahuila platform (5 sections), the ramp crest (Casa Colorado), and the deep platform (3 sections). As in the previous cross section (Fig. 6), we do not force correlations of composite sequence boundaries between the shallow and deep platforms because of the lack of clear lithologic evidence for ''correlative conformities'' in deeper-water sections. Dashes to right of each shallow-water section represent tops of individual cycles. CSB, composite sequence boundary; MFS, maximum flooding surface. Thin dashed lines are formation boundaries. See Figure 1B for section locations.

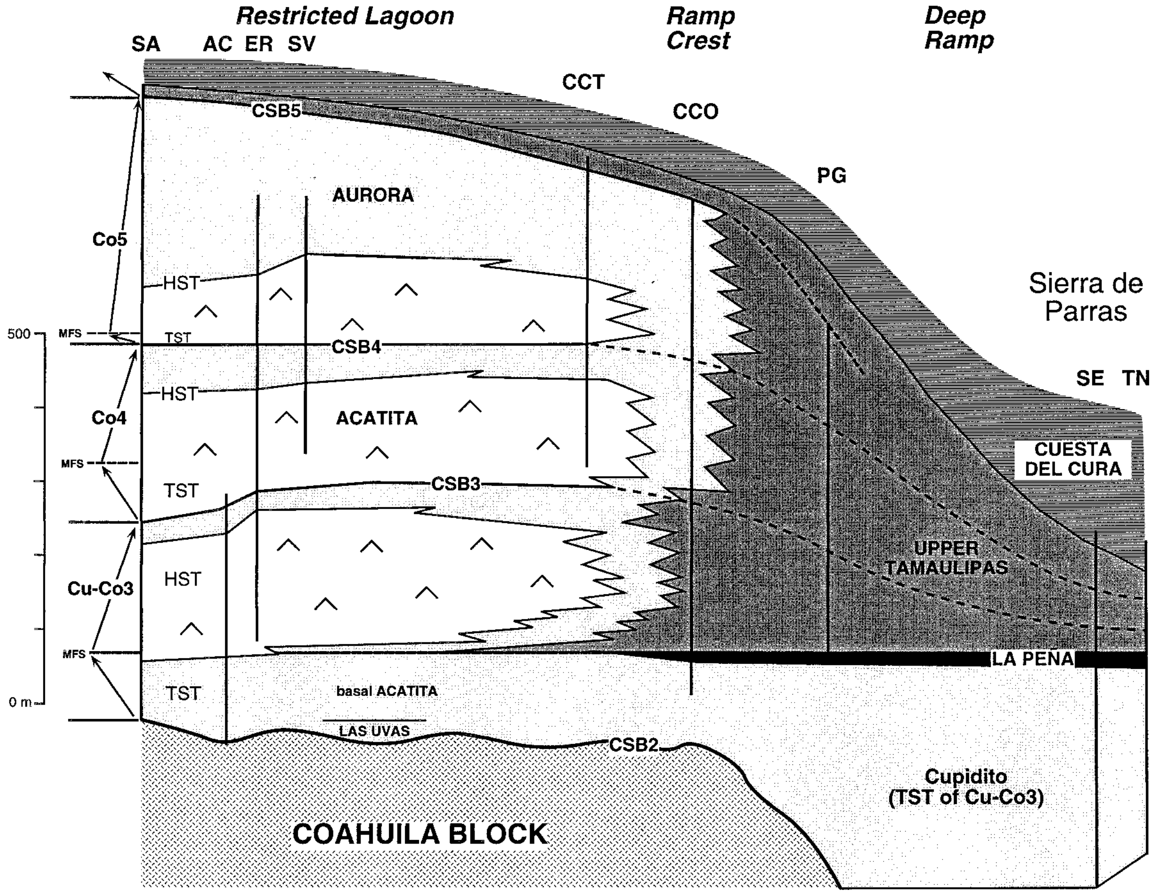

FIG. 11.—Correlation between five Coahuila platform-interior sections, a ramp-crest margin section (CCO), and three deep-ramp sections illustrating the genetic link between the Coahuila block and the Sierra de Parras (see Figure 1B for locations). Two datums were used in the diagram. The top of the La Peña was used to correlate the deep-ramp sections with the lower parts of the sections on the Coahuila block (constrained by biostratigraphic and isotopic data). The second datum is the base of the transgressive evaporites of Co5. Correlation of sequence boundaries from shallow-platform settings on the Coahuila block to deep-platform settings in the Sierra de Parras (dashed lines) is speculative because of the lack of clear lithologic evidence in the Upper Tamaulipas Formation.

tion of the Acatita lagoon and the establishment of the Aurora open-marine carbonate ramp.

The character of the upper composite sequence boundary of Co5 is variable across the Coahuila block (Figs. 10, 11). At Sierra Acatita, solution-collapse breccias are common toward the top of HFS4 of Co5. Gradational shallowing and evidence for subaerial exposure is also exhibited at a section in the Sierra de La Peña to the south (SLP, Fig. 1B). Coeval carbonates to the west and south outside of the study area exhibit subaerial exposure features at the same stratigraphic position near the top of the Aurora Formation (Eguiluz de Antuñano 1991; Cantú-Chapa 1993). In contrast, to the east at Cañon Corazón del Toro, uppermost HFS4 exhibits gradational shallowing into grainstone shoal deposits but no evidence for subaerial exposure. In all localities on the Coahuila block, however, the composite sequence boundary at the top of Co5 is overlain by forminiferal mudstones and wackestones (Upper Tamaulipas facies), which conformably grade upward into deep-water laminites of the Cuesta del Cura Formation. Thus the uppermost composite sequence boundary of Co5 changes character from an apparent drowning unconformity in the eastern part of the Coahuila platform (Cañon Corazón del Toro, Cañon de los Perdidos) to an exposure unconformity in the western part (Sierra Acatita). These regional differences may indicate possible paleotopographic control or active tectonism at this time on the Coahuila block.

The upper composite sequence boundary of Co5 records the termination of shallow-marine carbonate sedimentation in this area of Mexico. Overlying muddy facies similar to the Upper Tamaulipas Formation that grade up into the Cuesta del Cura facies record progressively deeper-water sedimentation. Diachroneity of the Upper Tamaulipas–Cuesta del Cura contact (Ice 1981; Longoria and Monreal 1991) suggests a backstepping, retrogradational relationship (Fig. 11). The timing of the demise of the Coahuila platform is constrained to the latest Albian (*Rotalipora appenninica* zone) on the basis of the co-occurrence of *Ticinella primula*, *Ticinella madecassiana*, and *Praeglobotruncana stephanie* near the contact between the Aurora and Cuesta del Cura Formations at Cañon Corazón del Toro, Cañon de los Perdidos, and Sierra de la Peña (Lehmann et al. 1999).

REGIONAL CORRELATIONS

The Barremian through Albian Cupido and Coahuila platforms are coeval with the Sligo–Hosston and Comanche platforms to the north in Texas and the northern Gulf coast, and with the Valles–San Luis Potosi isolated platform of east-central Mexico (Figs. 1A, 2). These platforms were part of a larger carbonate system encircling the Early Cretaceous Gulf of Mexico (Winker and Buffler 1988; McFarlan and Menes 1991) and have been the subject of extensive study because they host hydrocarbons (Wilson 1975). In the following sections, we correlate depositional sequences on the Cupido and Coahuila carbonate platforms with coeval sequences constituting the Sligo and Comanche platforms (Fig. 13). Age relations in the Valles–San Luis Potosi isolated platform are not well constrained, so high resolution regional correlations are not attempted.

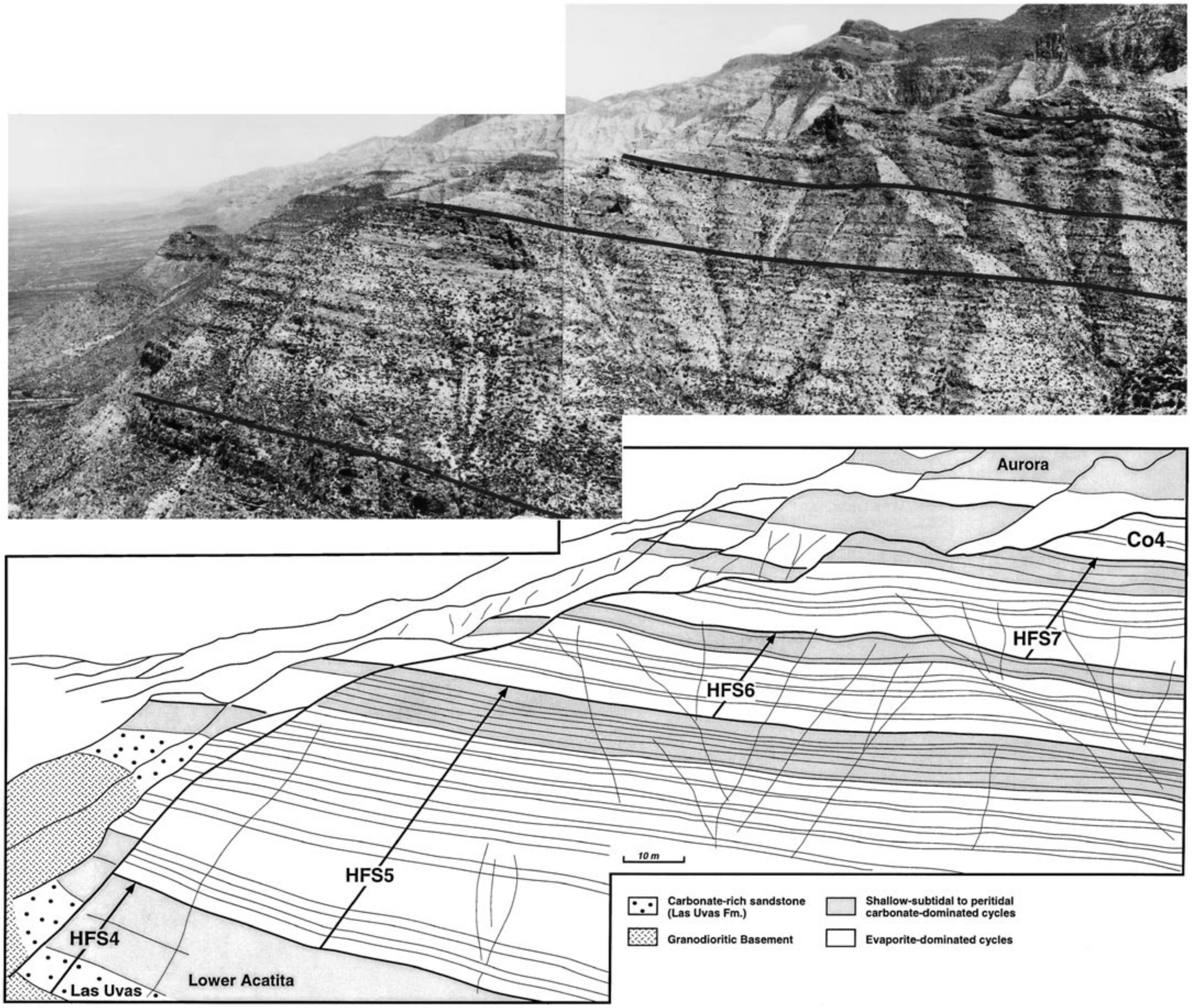

FIG. 12.—Outcrop photographs of the west side of the Sierra Acatita paired with interpretive line drawing showing high-frequency sequences within Cu–Co3 of the restricted evaporite interior. Knob in the left background is exposed granodioritic basement overlain by carbonate-rich sandstone of the Las Uvas Formation. Shallow subtidal carbonates of the lower Acatita Formation form the lower cliff. Evaporites (lighter-colored intervals) and carbonates (darker intervals) of the Acatita Formation are exposed above the lower cliff. The cliff in the far right distance is composed of shallow-subtidal deposits of the Aurora Formation.

Barremian to Lower Aptian

The Sligo–Hosston platform consists of carbonates, siliciclastics, and lesser sabkha evaporites deposited on a broad (160 km), gently sloping shelf (Bebout et al. 1981). These strata onlap Paleozoic basement updip and thicken downdip to more than 300 m at the shelf margin (Bebout 1977). Relative to the modest thickness of the Sligo, the tremendous accumulations of coeval Barremian–Aptian carbonates constituting the Cupido (up to 1000 m) and Valles (up to 2700 m) platforms suggest a southward-increasing gradient in subsidence and accumulation rates along the western margin of the ancestral Gulf coast at this time.

Lower Sligo and Hosston dolomitic–siliciclastic shelf facies mainly record deposition on an arid alluvial plain flanking broad tidal flats (Bebout 1977). The lower Sligo exhibits numerous peritidal cycles, which Bebout et al. (1981) interpreted as ''onlapping progradational'' cycles. These lower Sligo facies reflect paleoenvironments similar to (and coeval with) those recorded in the Cu1 and Cu2 composite sequences of the Cupido Formation (Fig. 13). This genetic interval in the Cupido is progradational to aggradational, and seismic data and well-log cross sections of the Sligo (McFarlan and Stone 1977; Winker and Buffler 1988) indicate that it is generally regressive and progradational also.

Mid- to Upper Aptian

Upper Sligo shelf facies exhibit a diverse open-marine fauna and oolitic shoal development, interpreted to reflect a shallow-water lagoonal environment and significant landward backstep with respect to the lower Sligo Formation (Bebout et al. 1981; Yurewicz et al. 1993). This transgressive event in Texas is recorded on the Mexican Cupido platform by the Cupidito retrograde backstep toward the Coahuila block (Figs. 11, 13).

Shallow-marine carbonate production on the Sligo platform was terminated with deposition of the Pearsall Group, composed of lower (Pine Is-

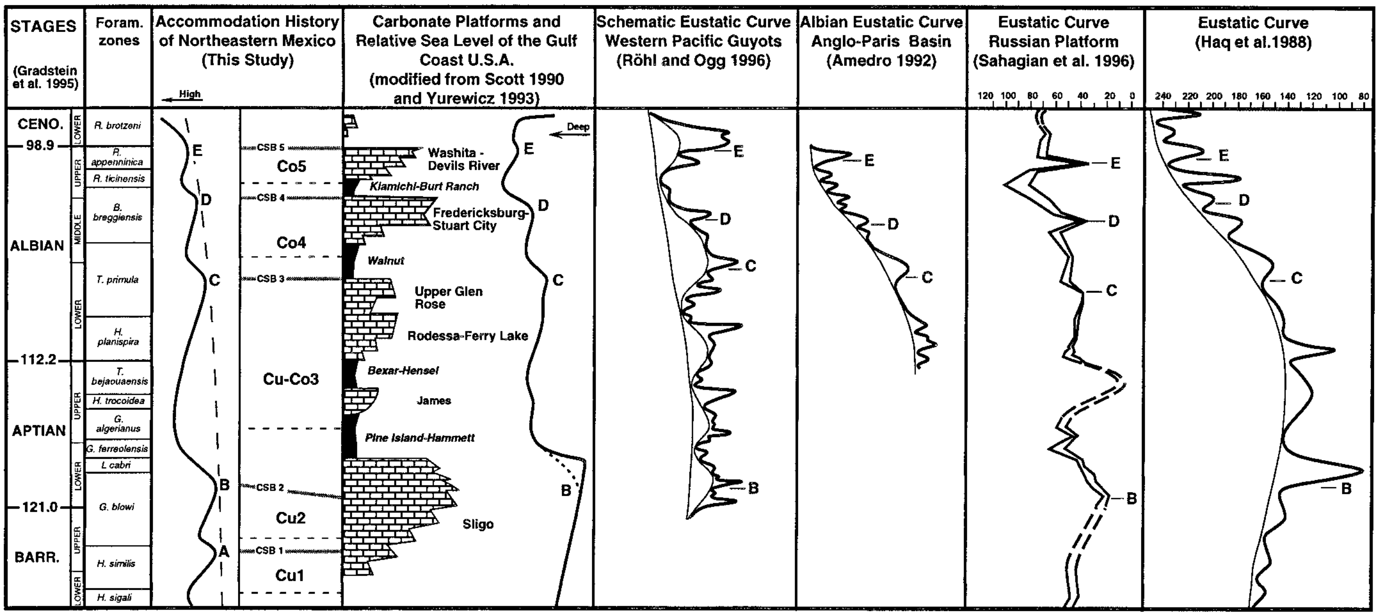

FIG. 13.—Interbasinal comparison of the accommodation history of northeastern Mexico with the ''relative sea-level curve'' of Scott (1990), the ''schematic eustatic curve'' of Röhl and Ogg (1996), the ''eustatic'' curve of Amedro (1992), the ''relative eustatic change'' curve of Sahagian et al. (1996), and the eustatic curve of Haq et al. (1988). Correlations between curves were interpreted using biostratigraphically constrained stage boundaries rather than ''absolute'' ages. All curves were calibrated to the time scale of Gradstein et al. (1995). Dotted line on Scott's Gulf Coast curve is our suggested modification. Letters A–E next to curves represent proposed correlations discussed in text.

land/Hammett) and upper (Bexar/Hensel) shaly units and an intervening limestone (Loucks 1977; James/Cow Creek; Fig. 13). This distinct tripartite subdivision has not been observed in the coeval La Peña Formation of northeastern Mexico, but does appear to span the same mid- to late Aptian time interval (Tinker 1985). This suggests that La Peña equivalents to the Pine Island and Bexar may be juxtaposed without an intervening James equivalent. The La Peña is significantly thinner (up to 100 m) than the Pearsall Group (up to 170 m), indicating that this time interval in northeastern Mexico experienced condensed sedimentation, greater subsidence or accommodation rates, or some combination of the two.

Albian to Lower Cenomanian

The Albian Comanche shelf established itself as the second major carbonate platform in the area after late Aptian flooding waned. The accretionary, rimmed shelf margin (Read 1985) of the Comanche platform, the Stuart City reef trend, maintained the same position as the underlying Sligo margin to the northeast, but seismic data illustrate increasing backstep of up to 50 km toward the Texas–Mexico border (Bebout and Loucks 1974; Goldhammer et al. 1991). In the study area of northeastern Mexico, the time-equivalent Coahuila platform margin backstepped ~ 100 km landward of the earlier Cupido margin, as measured from outcrops near Monterrey to the edge of the Coahuila block (the estimated position of the Coahuila ramp-crest margin).

The Comanche shelf in Texas is internally composed of three major, genetically discrete carbonate platforms: the lower Albian Glen Rose, the mid- to upper Albian Fredericksburg, and the upper Albian to Cenomanian Washita (Fig. 13). Carbonate production on the lower Glen Rose (Rodessa–Ferry Lake) platform began after deposition of Bexar shales waned during the latest Aptian to earliest Albian (Scott 1993; Yurewicz et al. 1993). Coeval deposition on the Coahuila platform is recorded by mixed evaporite and carbonate facies of the lower to middle part of the Acatita Formation. Judging from their apparent temporal overlap, evaporitic facies of the Ferry Lake Formation in the subsurface of the northern Gulf Coast (Yurewicz et al. 1993) may be contemporaneous with the lowermost evaporites of composite sequence Cu–Co3 in the Acatita Formation (Fig. 11).

The disconformable top of the Glen Rose carbonate platform is a hardground exhibiting early lithification and boring, red oxidation staining, and vertical cracks filled with oyster marl of basal Fredericksburg facies (Rose 1972). Seismic data from the northern Gulf coast shows the top–Glen Rose surface to be defined by toplap and erosional truncation near the platform margin and by onlap of Paluxy lowstand deposits (Yurewicz et al. 1993). We correlate the upper sequence boundary of Cu–Co3 with the top of the Glen Rose (Fig. 13), but we were not able to correlate higher-frequency sequences documented by Yurewicz et al. (1993) for the northern Gulf coast and Fitchen et al. (1994) for Texas because of lack of higher-resolution chronostratigraphic control. It may be, however, that several of the seven HFSs that build Cu–Co3 in Mexico correlate with sequences spanning the same time range to the north.

On the Comanche shelf, floodback above the Glen Rose is recorded by the Walnut Formation, with maximum onlap occurring in the argillaceous Bee Caves Member (Scott 1993; Kerans et al. 1994). Overlying carbonates of the Fredericksburg platform shallow upward to peritidal facies capped by a disconformity placed either at a sharp, irregular surface with locally developed soil ''breccias'' (Rose 1972), or alternatively at the top of Kirschberg evaporitic solution-collapse breccias (Fischer and Rodda 1969). To the east, Yurewicz et al. (1993) recognize erosional truncation of the top-Fredericksburg in seismic sections crossing the northern Gulf Coast. On the Coahuila platform, the sequence boundary at the top of composite sequence Co4 (near top *T. primula* zone) is interpreted to correlate with the top of the Fredericksburg.

Late Albian flooding above the Fredericksburg is recorded in Texas by argillaceous lime mudstones and shales (Kiamichi–Burt Ranch facies; Fig. 13). Overlying carbonate facies of the Washita–Devils River platform developed their thickest accumulations along the flanks of the Comanche shelf at the margins of the Maverick and North Texas intrashelf basins, with lesser volumes of evaporitic tidal-flat facies veneering the central platform

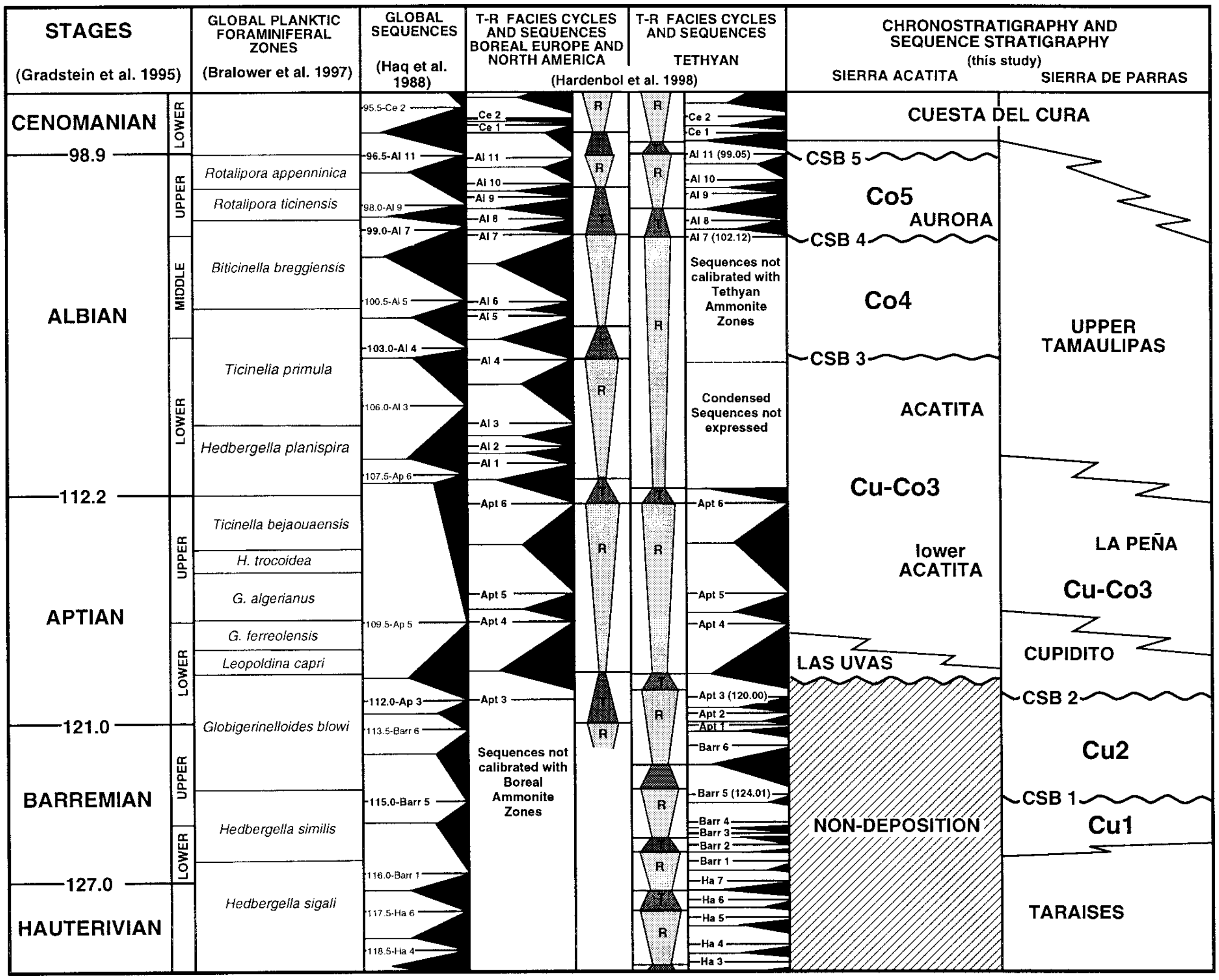

FIG. 14.—Sequence-stratigraphic interpretations of the Lower Cretaceous of this study compared with interpretations of global sequences defined by Haq et al. (1988) and by Hardenbol et al. (1998). Stage boundaries are after Gradstein et al. (1995), tied into global planktic foraminiferal zones from Bralower et al. (1997). Numbers in parentheses next to selected sequence boundaries are ages interpolated by Hardenbol et al. (1998) from the Gradstein et al. (1995) scale.

(Fig. 1A; Rose 1972). We correlate this Washita phase of platform development on the Comanche shelf with the Late Albian Co5 composite sequence on the Coahuila platform. Judging by the stratigraphic position within each platform, thick evaporites in the lower part of Co5 in the upper Acatita of the Coahuila ramp might be coeval with evaporitic solution-collapse breccias of the Allan Ranch Member on the Edwards plateau and upper McKnight of the Maverick basin. Termination of shallow-marine sedimentation on the Comanche shelf is typically placed at the top of Buda Formation carbonates capping the Washita Group, on the basis of evidence for deep erosion prior to Woodbine deposition (Fig. 2; Scott 1990). Alternatively, two earlier phases of shallowing and exposure on the central Comanche shelf may be correlative with the top Co5 composite sequence boundary in Mexico. The older phase is characterized by regionally correlative soil horizons (''Black bed''), whereas the younger phase of prolonged exposure is marked by a widespread unconformity underlying shales of the Del Rio Formation (Rose 1972). Regional age control is not precise enough to determine which of these three major exposure unconformities is the exact correlative of the top Co5 composite sequence boundary, but the latest Albian to earliest Cenomanian timing of these events appears to be clear.

GLOBAL CORRELATIONS

In order to estimate ages for the Mexican sequence-bounding disconformities, we calibrated our sequence-bounding disconformities with global sequence correlations for boreal North America–Europe and the Tethyan realm constructed by Hardenbol et al. (1998), who tied the Gradstein et al. (1995) time scale to the Haq et al. (1988) time scale (Fig. 14). We conservatively estimated the correlations using all available biostratigraphic and chemostratigraphic data, relative trends in shallowing and deepening, and the relative positions of sequence boundaries. Where direct biostratigraphic or chemostratigraphic data were unavailable, we were forced to resort to stratigraphic thickness to interpret possible correlations. Our estimates of ''absolute'' ages of composite sequence boundaries, durations of composite sequences, and accumulation rates for Cupido and Coahuila sequences are compiled in Table 1.

We understand the pitfalls of pattern matching of ''global sequences'' and ''eustatic'' curves, primarily because of the inherent imprecision of available time control. Other likely local to regional complications, such as the influence of variable sediment production rates and distribution patterns (Schlager 1993) and the differential effects of diagenesis on exposure surfaces (Fouke et al. 1996), are difficult to factor out from the accommodation history. We therefore acknowledge that our correlations are speculative. If regional sea-level curves are to have a broader application, however, interbasinal correlations need to be attempted, using all available time constraints. Only in this way might we eventually arrive at a reasonable global curve that would have predictive value for basin analysis. We submit these correlations not as the final word, but rather as testable hypotheses that may or may not hold up under further scrutiny.

Cu1.—The composite sequence boundary at the top of Cu1 (top *H. similis,* base *G. blowi*) is interpreted to correlate with the Barr 5 event (∼ 124 Ma) of Hardenbol et al. (1998) and Haq et al. (1988) (Fig. 14). The sea-level event that resulted in the deposition of Cu1 is not recognized within the Sligo platform of the Gulf coast (''A'' in Figure 13; Scott 1990; Yurewicz et al. 1993). Cu1 is not clearly defined on the other curves.

Cu2.—The upper composite sequence boundary of Cu2 is correlative with the Cupido–Cupidito contact in the Monterrey area (Goldhammer et al. 1991) and is correlated with the top of a major regression in Tethyan strata (Apt 3 event; ∼ 120 Ma; upper *G. blowi*) on the Hardenbol et al. (1998) and Haq et al. (1988) schemes (Fig. 14). Scott (1993) and Yurewicz et al. (1993) inferred the same sequence boundary to occur at the top of the Sligo, but evidence for exposure followed by gradual deepening at the Cupido–Cupidito boundary suggests that the actual sequence boundary should occur lower in the Sligo, likely near the lower Sligo to upper Sligo contact (''B'' in Figure 13). Correlative sea-level lows and corresponding sequence boundaries may occur on guyots in the western Pacific and on the Russian platform. This uppermost Lower Aptian sequence boundary overlying the Sligo–Cupido platforms may equate with the disconformity at the top of the Shuaiba Formation, a major producer in the Middle East containing numerous giant reservoirs (Scott et al. 1988).

Cu–Co3.—Composite sequence Cu–Co3 spans the lower Aptian to lower Albian and is estimated to be ∼ 13 Myr in duration on the basis of correlation of the upper sequence boundary with Al 4 (∼ 107 Ma; middle *T. primula* zone) of the Hardenbol et al. (1998) and Haq et al. (1988) interpretations (Fig. 14). We do not recognize the major regressive event (Apt 6) earlier in Aptian time noted on the Hardenbol et al. (1998) scheme. Significant sea-level lowstands occur at roughly the same biozone in the other basins and may be correlative with the top Cu–Co3 sequence boundary (''C'' in Fig. 13). The Cupido platform drowning by mid- to late Aptian La Peña shales coincides with a major episode of shallow-platform demise throughout the peri-Tethyan region (Föllmi et al. 1994).

Co4.—Composite sequence Co4 is interpreted to correlate with a major regressive trend on the Hardenbol et al. (1998) chart that culminates at the Al 7 (∼102 Ma; top *B. breggiensis*) sequence boundary in the lower part of the Upper Albian (Fig. 14). This same Al 7 event on the Haq et al. (1988) time scale occurs at 99 Ma. We correlate the Al 7 sequence boundary in Mexico with the top of the Fredericksburg sequence in Texas (''D'' in Figure 13). However, Yurewicz et al. (1993) correlated the top of the Fredericksburg sequence with Al 9, which is interpolated on the Haq et al. (1988) time scale to occur at 98 Ma. Similarly, Goldhammer and Wilson (1991) correlated the top of McKnight evaporite solution-collapse breccias in the Maverick basin with the 98 Ma sequence boundary (101 Ma on the Gradstein et al. 1995 time scale). These differences illustrate clearly the inherent difficulty of precise correlation of sequence boundaries.

Co5.—The late Albian age of the upper sequence boundary of Co5 is constrained by *Praeglobotruncana stephanie*, *Ticinella primula,* and *Ticinella madecassiana* found in mudstones of the uppermost Aurora Formation immediately overlying the Co5 sequence boundary and in the lowermost Cuesta del Cura Formation. The top of Co5 is interpreted to correlate with the top of a major latest Albian regressive event (Al 11; 99.05 Ma) on the Hardenbol et al. (1998) chart (Fig. 14). All of the other curves exhibit a significant sea-level lowstand toward the end of Albian time (''E'' in Figure 13). The interpolated age of this Al 11 boundary (99.05 Ma) places it very near the Albian to Cenomanian transition (98.9 Ma) on the Gradstein et al. (1995) time scale and within the *Rotalipora appenninica* planktic foraminifera zone. A significant drop in sea level prior to a rise of even greater amplitude is recognized globally within this biozone (Grötsch et al. 1993; Vahrenkamp et al. 1993; Sliter 1995), and we infer the contemporaneous occurrence of this sequence of events on the Coahuila platform.

Immenhauser and Scott (1999) demonstrated convincingly that the absolute synchroneity of most Albian sea-level events cannot be accurately constrained. Our correlations also reveal that their conclusions may be a fundamental truth, inherently limited by the available fossil record. This does not negate the potential utility of these interbasinal correlations, however, because the judicious refinement of ''global'' curves may ultimately result in a clearer understanding of regional versus global controls on sequence development and a predictive tool for basin analysis.

CONCLUSIONS

(1) Correlation of vertical cycle stacking patterns in the Cupido and Coahuila platforms of northeastern Mexico reveals four complete composite sequences and a lowermost partial composite sequence. These sequences span approximately 28 Myr of time from the Barremian through the Albian, according to the Gradstein et al. (1995) time scale. The composite sequences recognized in the Cupido shelf (Cu1, Cu2) are linked to those constituting the Coahuila ramp (Co4, Co5) by an intermediate composite sequence (Cu–Co3) that genetically bridges the two platforms.

(2) Regional correlations between the two Mexican platforms and coeval platforms in Texas and the northern Gulf coast reveal similar large-scale depositional patterns, within the limits of the biostratigraphic resolution. These correlations suggest that each of the major episodes of carbonate platform development in Texas and the northern Gulf Coast has a counterpart of similar duration and architecture in northeastern Mexico.

(3) Calibration of the sequence-stratigraphic model for the Cupido and Coahuila platforms with ''global'' sequences (Hardenbol et al. 1998), combined with interbasinal correlation with several ''eustatic'' curves, reveals variable results. Given the available time resolution, only the sequence boundaries at the top of Cu–Co3 and Co5 appear to have clear interbasinal equivalents. The other three sequence boundaries recognized in this study either may have only regional significance or may have equivalents elsewhere that may require better time control for accurate correlation.

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