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Barremian-Albian Larger Benthic Foraminiferal Zones (Lower Cretaceous), Gulf of Mexico Region: A Key to Correlating Carbonate Reservoirs

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ABSTRACT

For about 30 m.y. from about 130 to 100 Ma during the Early Cretaceous Barremian to Albian ages, the proto-Gulf of Mexico was partly encircled by a giant carbonate shelf from Florida to Texas and south into northern Mexico and by isolated carbonate platforms in eastern Mexico, the Yucatan Peninsula/Platform and Central America. These strata have been important hydrocarbon reservoirs associated with source rocks. In addition, these southern North and Central American carbonate strata archive important oceanic signals such as carbon chemozones, oceanic anoxic events and sea-level changes.

The Early Cretaceous Caribbean Biotic Province was composed of many of the same marine species as in the Mediterranean and Asian provinces as well as endemic species. Biostratigraphic zonation of the Barremian, Aptian, and Albian stages in the Gulf region has evolved since 1956 and is now more precisely defined by first appearance and last appearance datums (FAD/LAD) of calcareous nannofossils, nannoconids, colomiellids, and planktic foraminifers in numerous outcrop and drill hole sections. Rudist bivalve zones are recognized in cores and outcrops. However, larger benthic foraminiferal zones have not been updated until now. Stratigraphic correlation of these complex carbonates and associated rocks establishes the context of reservoir facies and their chronostratigraphic relations globally. The principal goal of this contribution is to present a practical biostratigraphy of the larger benthic foraminifers.

Six Barremian to Albian benthic foraminiferal biozones are here defined by the first occurrences or overlapping ranges in the Gulf of Mexico region of the United States, Mexico, and Central America. These zones are in ascending order: (1) *Choffatella decipiens* Interval Range Zone (IRZ), Barremian from FAD of C*hoffatella decipiens* to FAD of *Palorbitolina lenticularis*; (2) *Palorbitolina lenticularis* Total Range Zone (TRZ), lower Aptian; (3) *Paracoskinolina sunnilandensis* IRZ, lower to upper Aptian from LAD of *Palorbitolina lenticularis* to FAD *Mesorbitolina texana*; (4) *Mesorbitolina texana* IRZ, uppermost Aptian to lower Albian from FAD *Mesorbitolina texana* to FAD of *Carseyella walnutensis*; (5) *Carseyella walnutensis* IRZ, middle to lower upper Albian, from FAD to FAD of *Paracoskinolina coogani*; and (6) *Paracoskinolina coogani* TRZ, uppermost Albian.

INTRODUCTION

For about 30 m.y. from about 130 to 100 Ma during the Barremian to Albian ages, the proto–Gulf of Mexico westward from Florida to Texas and south into Mexico and Central America was partly encircled by a giant carbonate shelf and by isolated carbonate platforms in eastern Mexico and the Yucatan Peninsula/Platform and Central America (McFarlan and Menes, 1991; Padilla y Sánchez, 2016; Wilson and Ward, 1993). This Caribbean biotic province shared many marine species with the Mediterranean and Asian provinces. Lower Cretaceous strata overlie Upper Jurassic rocks and underlie Upper Cretaceous strata. These southern North American and Central American Lower Cretaceous carbonate strata record important oceanic signals such as oceanic anoxic events and sea-level changes (Phelps et al., 2014; Scott et al., 2019). Furthermore, these carbonates have been important hydrocarbon reservoirs and are commonly associated with source rocks (Fritz et al., 2000; Scott, 1993; Waite, 2009). The lithostratigraphy of the region documents vertical and lateral changes that are classified as different groups and formations (Fig. 1). Stratigraphic correlation of these complex carbonates and associated marls and shales establishes the context of reservoir facies and their chronostratigraphic relations globally.

The principal goal of this contribution is to present a practical biostratigraphy of the larger benthic foraminifers. A biostratigraphic zonation of the Barremian, Aptian, and Albian stages in Mexico was first based on colomiellids and benthic foraminifers from a limited set of drill holes (Bonet, 1956). The succession of larger benthic foraminifers in the Gulf Coast and particularly in the Trinity, Fredericksburg, and Washita groups was related to

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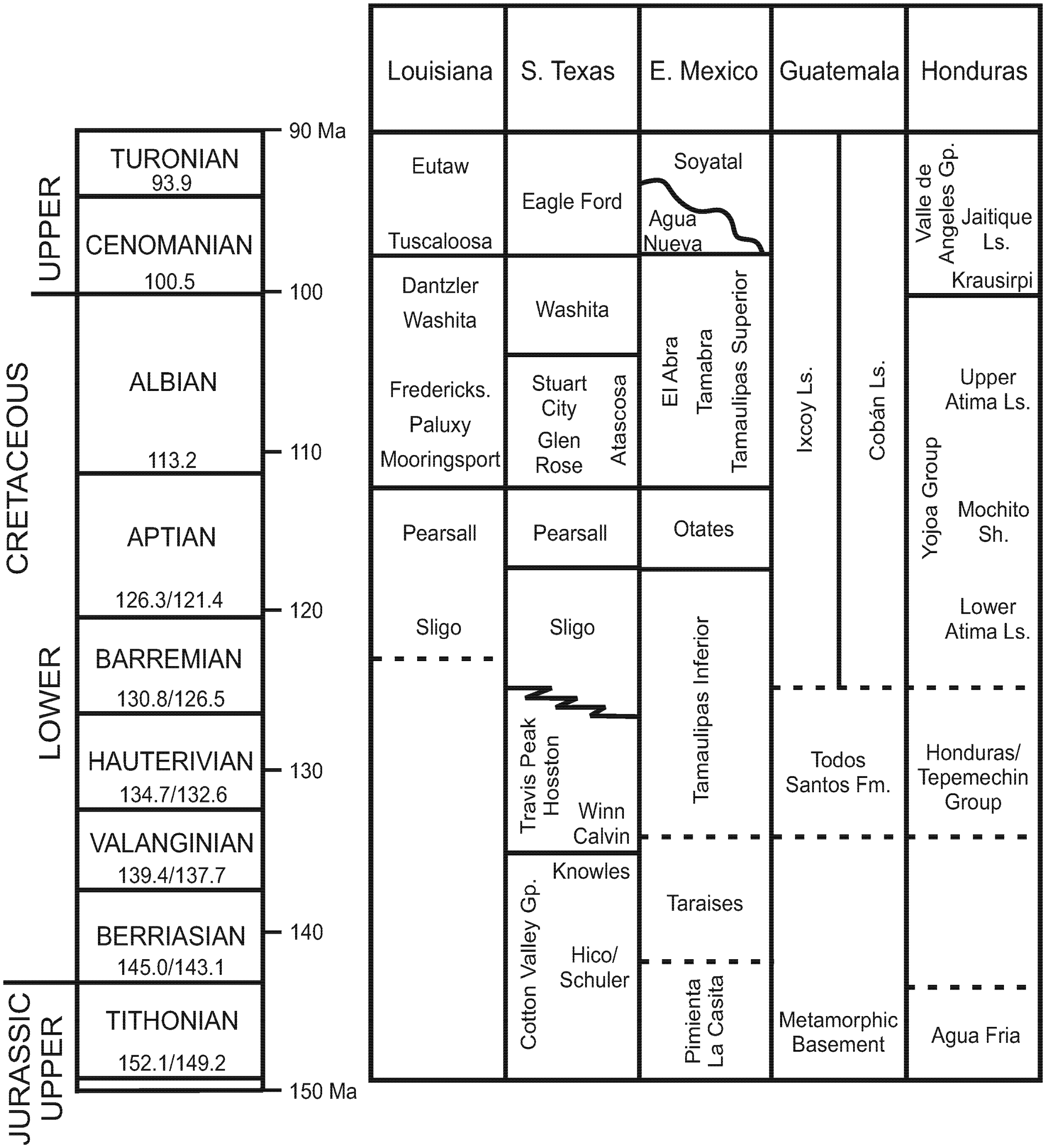


Figure 1. Lower Cretaceous lithostratigraphy of North American Gulf Coast: Louisiana and South Texas stratigraphy (Bartberger et al., 2003; Donovan et al., 2015; McFarlan and Menes, 1991; Scott, 1990, 1993; Scott et al., 2019, 2020); eastern Mexico (McFarlan and Menes, 1991; Omaña et al., 2016); Guatemala (Scott, 1996); and Honduras (Molina Garza et al., 2017; Scott and Finch, 1999). Numerical ages from GTS2016/GTS2020.

rudist and ammonite successions formulating a basis of a practical zonation (Coogan, 1977). Subsequently, carbonate biostratigraphy in the Gulf of Mexico region, New Mexico, Arizona, and northern Mexico was more precisely defined by pelagic calcareous organisms including nannofossils, nannoconids, colomiellids, and planktic foraminifers (Longoria, 1984; McNulty, 1985). However, these microfossils are not present in the shallow-water platform carbonates where larger benthic foraminifers such as orbitolinds are common. The larger foraminifers are readily identified in thin sections of cores and drill cuttings because of their complex internal wall structures and diameters greater than 1–2 mm. More recently, the large rudist bivalves commonly seen in cores and outcrops have been used to define biozones in Mexico and Texas (Scott and Filkorn, 2007; Scott and Hinote, 2007).

Fossil stratigraphic ranges in this study are cataloged in Cret2017CS database, which is composed of 123 global outcrop and drill hole sections calibrated in mega-annums (Ma) to the 2016 geologic time scale (GTS2016) (Ogg et al., 2016). The process of integrating and calibrating numerical ages is by X/Y plots of each section to the GTS2016 and extending the ranges by the correlation line of synchroneity (CLS). This database was constructed using the graphic correlation technique (Carney and Pierce, 1995) and the GraphCor software (Hood, 1995) and builds on a previous database (Scott, 2014).

HYDROCARBON EXPLORATION-PRODUCTION SIGNIFICANCE

The Comanche Carbonate Shelf in the U.S. Gulf Coast and in eastern Mexico and Yucatan Peninsula has a long history of challenging hydrocarbon exploration from the shelf margin and in the landward shallow shelf since the mid-twentieth century. During the twenty-first century, however, exploration in the Eagle Ford Group has overshadowed exploration of Lower Cretaceous limestones. The Poza Rica Trend in Veracruz, Mexico, was discovered in 1930 (Barnetche, 1951) in the El Abra Limestone (Fig. 1) and has been one of the most significant reservoirs in the Comanche Shelf. Primary intergranular porosity in shelf-margin facies was greatly modified by early cementation and lithification, followed by leaching and then fracturing (Enos, 1977). Forereef slope grainstones comprise the associated Tamabra Limestone (Fig. 1) and are also important reservoirs (Fritz et al., 2000).

The middle-upper Albian Stuart City Limestone, aka Edwards Formation (Fig. 1), in Texas was the early exploration target on the U.S. Comanche Shelf. Three phases of exploration and production were late 1950s to early 1960s, late 1970s to early 1980s, and a revival in 1999 to 2008 (Waite, 2009). In 1954, Stanolind discovered the Stuart City Field in LaSalle County (Bebout and Loucks, 1974). During the following 8 years, 16 additional fields were discovered. By 1976, 115 hydrocarbon fields had been discovered in Lower Cretaceous carbonates in the Gulf Coast that produced at least 10 MMBO (million barrels of oil) or 60 BCFG (billion cubic ft of gas) (Nehring and Van Driest, 1981). Porosity is facies-controlled in part and consists of intraparticle, interparticle. and fracture types of about 5% and rarely up to 20%; permeability generally is 0.5 md and rarely up to 10 md (Bebout et al., 1977; Waite, 2009).

Exploration was revived in 1999–2008 in part because of 3D seismic records, horizontal drilling techniques, sequence stratigraphic concepts, and new depositional models. Progradation of shelf facies and down-to-the-basin faulting of the Stuart City/“Edwards” Limestone has potential where porosity is enhanced by faulting (Fritz et al., 2000). An example of the successful utility of new technology is in Pawnee Field, Bee County, Texas, discovered by Shell in the early 1960s. Beginning in the late 1990s, Pioneer Natural Resources began an extensive horizontal drilling program in Pawnee Field in the Stuart City Limestone (Waite et al., 2007). Estimated ultimate reserves were projected at ~300 BCF dry gas from about 11,000 to 15,000 ft depth. Eight other fields in South Texas produce from 15 to 600 BCF dry gas (Waite, 2009).

In the 1980s, the Barremian-Aptian Sligo Limestone (Fig. 1) was an active exploration play producing mainly natural gas (Modica and Katz, 2008). Karstification was a major source of porosity in the shelf-margin play, although complex diagenetic processes made reservoir prediction difficult (Bebout et al., 1981). Subsequently, Sligo foreslope carbonate wedges were promoted as a new play concept analogous to the Tamabra Limestone (Fritz et al., 2000).

AN ARCHIVE OF CRETACEOUS OCEANIC EVENTS

During Barremian through Albian time, 130 to 100 Ma, the Gulf of Mexico Basin was near 30° north latitude and was open eastwards towards the Atlantic Ocean and westwards into the Pacific Ocean (Hay et al., 1999). The several Mexican tectonic blocks were conjoined in place and Central American blocks were in transit southward along the Pacific coast of Mexico (Hay et al., 1999; Padilla y Sánchez, 2016). Major sea-level rises in the Aptian and in early and in middle-late Albian inundated North America and the Arctic (McFarlan, 1977; Oboh-Ikuenobe et al., 2008; Phelps et al., 2014; Scott et al., 1988, 2019; Young, 1986). Aptian-Albian sea-surface currents were principally clockwise from the west across Caribbean islands then northwestward across Mexico then eastward across the U.S. Gulf Coast (Johnson, 1999).

Rudist bivalves are the most commonly recognized fossil in Barremian-Albian reefal paleocommunities. However massive and branching colonial corals are equally or even more abundant than rudists in some buildups (Scott, 1988, 1990, 1995). Both groups had different modes of life, corals cemented upon a substrate and built a framework below normal wave base, and Barremian-Albian rudists reclined upon or were implanted into the coarse-grained substrate above wave-base. Rarely did they encrust one another forming clumps but not frameworks. During the Albian, however, rudists replaced corals in abundance and importance in shelf-margin and interior-shelf patch reef buildups. Environmental factors were important in the replacement of the more stenotopic corals by the more eurytopic rudists (Scott, 1988, 1995). Larger benthic foraminifers are associated with both rudists and corals in shallow-water, oxygenated environments and in upper slope deposits. During this 25 m.y. span, the oceans warmed and became more nutrient-rich; low-oxygen bottom water masses shoaled flooding the shelf margins and shallow shelves stressing the paleocommunities (Alexandre et al., 2010; Petrizzo et al., 2008). Early Cretaceous oceanic anoxic events are recorded in Comanchean shelf carbonates and basinal mudstone in Texas, Arizona, Nuevo Leon, and Sonora (Madhavaraju et al., 2015; Scott et al., 2018).

LARGER BENTHIC FORAMINIFERAL BIOSTRATIGRAPHY

Six biozones are here defined by the first occurrences or overlapping ranges of Barremian to Albian benthic foraminifers in the Gulf of Mexico region from the U.S. Coastal Plain west to Arizona and south to the states of Sonora, Coahuila and Nuevo Leon in Mexico; the biozones are recognized in Central America as well. Key datum points are first/last occurrences (FO/LO) in a section that are extended and compiled in multiple sections as more complete ranges of first/last appearance datums (FAD/LAD) (Fig. 2). The FADs of zone name-bearers were calibrated to numerical ages in GTS2016 (Gradstein et al., 2004; Ogg et al., 2016) that compose the CRET2017CS Database (Scott, 2014). This was the most well documented time scale at that time; these ages have not yet been updated to 2020 geologic time scale (GTS2020) (Gale et al., 2020). The foraminiferal zones are summarized below in ascending stratigraphic order.

Choffatella decipiens (Schlumberger) Interval Range Zone (IRZ) (Fig. 3.14); Barremian; FAD of *Choffatella decipiens* to FAD of *Palorbitolina lenticularis*. Associated species are the total range of *Sabaudia minuta* and the lowermost part of the range of *Paracoskinolina sunnilandensis*. *Choffatella decipiens* in the Honduran Atima Limestone identifies this zone in the Chortis block (Scott and Finch, 1999). This species is also in the lower part of the Ixcoy Limestone in Guatemala above *Nannoconus bucheri* (Scott, 1996).

The stratigraphic range of the *Choffatella decipiens* IRZ in the Cupido Formation exposed in the Potrero Garcia section, Nuevo Leon State, Mexico, is approximately 335 m thick, and it is overlain by *Palorbitolina lenticularis*. Nearby in the Bustamante Canyon section it overlaps with the FO of *Palorbitolina lenticularis* (Conklin and Moore, 1977; Selvius and Wilson, 1985).

Palorbitolina lenticularis (Blumenbach) Total Range Zone (TRZ) (Figs. 3.12 and 3.13); lower Aptian; FAD approximates

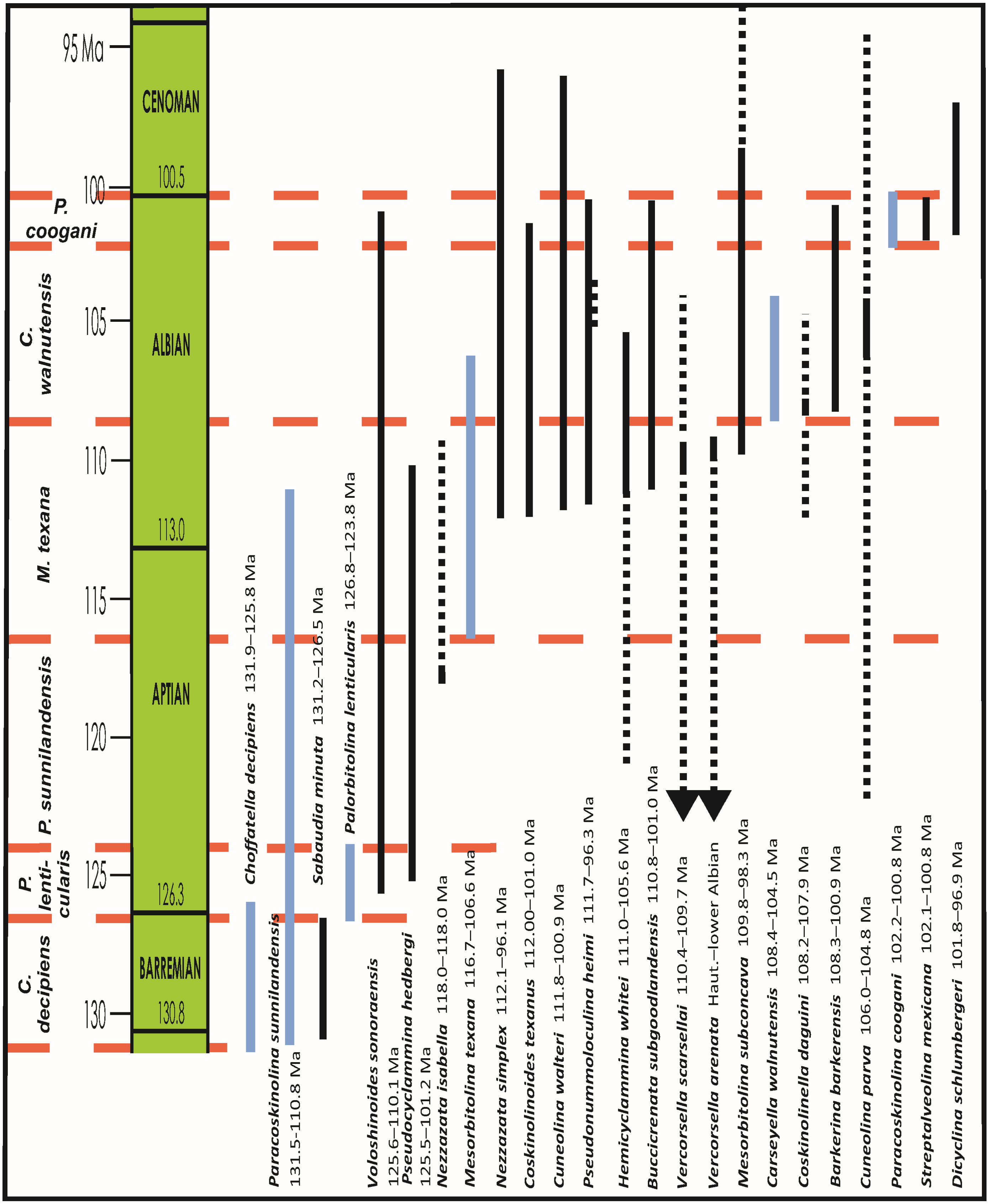


Figure 2. Barremian to Albian benthic foraminiferal biozones in the North American Gulf of Mexico region. Ranges in Cret-2017CS database composed of 123 global outcrop and drill hole sections calibrated to mega-annums (Ma) in the Geologic Time Scale 2016 (Ogg et al., 2016; solid bar). Dashed range bar is published range (Arnaud-Vaneau and Premoli Silva, 1995; Arnaud-Vanneau and Sliter, 1995). Blue bars highlight ranges of zone named species.

base Aptian in the Sligo Formation in Texas and in equivalent carbonate units in Mexico, Spain, France, and Croatia. Associated species are the FAD of *Voloshinoides sonoraensis* and *Pseudocyclammina hedbergi*, which are overlapped by *Paracoskinolina sunnilandensis* (Fig. 2).

The base of *Palorbitolina lenticularis* is in the uppermost part of the Cupido Formation in Nuevo Leon, and in three out of four sections it is stratigraphically higher than the LO of *Choffatella decipiens* (Selvius and Wilson, 1985). However, in one section it overlaps slightly with the uppermost range of *Choffatella decipiens* in the basal Aptian (Fig. 2). *Palorbitolina lenticularis* is globally distributed in the Tethyan Realm and ranges from uppermost Barremian to lowermost upper Aptian (Husinec, 2001; Peybernès, 1982; Schroeder and Cherchi, 1979; Simmons and Williams, 1992; Simmons et al., 2000).

Paracoskinolina sunnilandensis (Maync) Interval Range Zone (Figs. 3.9–3.11); lower to upper Aptian; LAD of *Palorbitolina lenticularis* to FAD *Mesorbitolina texana*. Associated species are *Voloshinoides sonoraensis* and *Pseudocyclammina hedbergi* and the FAD of *Nezzazata isabella*.

The characteristic species, *Paracoskinolina sunnilandensis*, first appears in the Barremian and its LAD is in the lower Albian.

Mesorbitolina texana (Roemer) Interval Range Zone (Figs. 3.6–3.8); uppermost Aptian to lower Albian; FAD *Mesorbitolina texana* to FAD of *Carseyella walnutensis*. Associated are the FOs of *Nezzazata simplex*, *Coskinolinoides texanus*, *Cuneolina walteri/parva*, *Pseudonummoloculina heimi*, *Hemicyclammina whitei*, *Buccicrenata subgoodlandensis*, *Vercorsella scarsellai*, *Vercorsella arenata*, and *Mesorbitolina subconcava*. *Coskinolinoides texanus* in the Honduran Atima Limestone identifies this zone in the Chortis block (Scott and Finch, 1999). *Mesorbitolina subconcava*, uppermost Aptian to upper Albian (Schroeder and Neumann, 1985), was reported from the top of the Atima Limestone, Honduras; also, in the uppermost Atima interval is the upper Albian rudist *Kimbleia* sp. (Scott and Finch, 1999). In Guatemala, *Mesorbitolina subconcava* is in the Cobán Limestone (Scott, 1996).

The FO of *Mesorbitolina texana* is in the uppermost Aptian in the basal Glen Rose Formation, Texas. The lowermost interval of this zone is associated with the LAD of *Nannoconus bucheri*, which is in the upper Aptian *Rhagodiscus angustus* Zone (Ogg et al., 2016; Özkan-Altiner, 1999). The uppermost Aptian correlation is also supported by the FO of *Favusella washitensis* in the Upper Tamaulipas Formation, Chapman core (Scott, 1990), which is above the LO of *Nannoconus bucheri* and below the FO of *Colomiella mexicana*. The *Favusella washitensis–Nannoconus bucheri* assemblage characterizes the uppermost Aptian K–13 biozone in the Chihuahua Trough (Longoria, 1984). Longoria's K–13 biozone is the interval between the FO of *Ticinella bejaouaensis* and the FO of *Ticinella primula*. In the Gulf of Mexico, the LAD of *Nannoconus bucheri* is in the upper Aptian *Nannoconus boletus* Zone and stratigraphically below the lower Albian *Colomiella* Zone (McNulty, 1985). In Middle East carbonates, *Mesorbitolina texana* ranges from upper Aptian to lower Albian (Simmons et al., 2000). In the Mediterranean region, however, *Mesorbitolina texana* is reported to range into the middle Albian (Schroeder and Neumann, 1985).

Carseyella walnutensis (Maync) Interval Range Zone (Figs. 3.3–3.5); middle to lower upper Albian; FAD in the Fredericksburg Group, Texas, to FAD of *Paracoskinolina coogani*. Among many associated species are the FOs of *Coskinolinella daguini*, *Barkerina barkerina*, and *Cuneolina parva*. The genus *Carseyella* was recently defined to replace *Dictyoconus* (Schlagintweit, 2020).

Paracoskinolina coogani (Scott) Total Range Zone (Figs. 3.1–3.2); uppermost Albian (100.9 Ma); first appears in upper part of Washita Group in Central Texas associated with *Streptalveolina mexicana* and *Dicyclina schlumbergeri*.

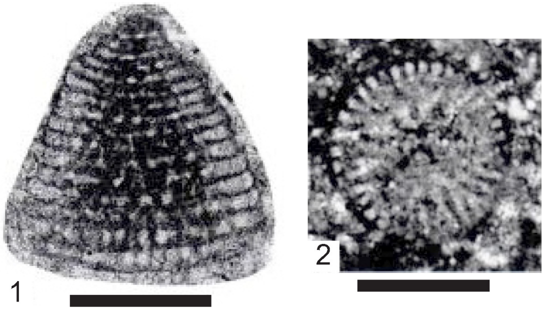
CORRELATION WITH OTHER GULF BIOZONES

Barremian-Albian carbonate strata in the Gulf of Mexico region exhibit other microfossil groups in addition to benthic Foraminifera that aid in the subdivision and correlation of stratigraphic sections. Planktic foraminifers are relatively common in thin sections of pelagic facies, and zonal schemes have been proposed for the Gulf region by Longoria (1984), McNulty (1985), and Bralower et al. (1999). In the Tamaulipas Formation of Mexico the FOs of a succession of species correlate with Barremian to upper Albian: *Caucasella hoterivica,* Barremian–lower Aptian; *Hedbergella similis,* upper Barremian–lower Aptian; *Hedbergella sigali* and *Globigerinelloides gottisi*, lower Aptian; *Globigerinelloides gottisi maridalensis,* upper lower Aptian–upper Aptian; *Leupoldia cabri,* lower upper Aptian; *Globigerinelloides gottisi ferreolensis,* upper Aptian; *Globigerinelloides gottisi algerianus*, *Globigerinelloides gottisi barri*, and *Planomalina cheniourensis,* upper upper Aptian; *Ticinella roberti*, lower Albian; *Ticinella breggiensis*, middle-upper Albian; *Thalmanninella ticinensis*, middle upper Albian; and *Rotalipora apenninica*, upper upper Albian–Cenomanian. These zones have been further refined and taxonomy updated by data of free three-dimensional specimens from DSDP and ODP cores (Huber and Leckie, 2011).

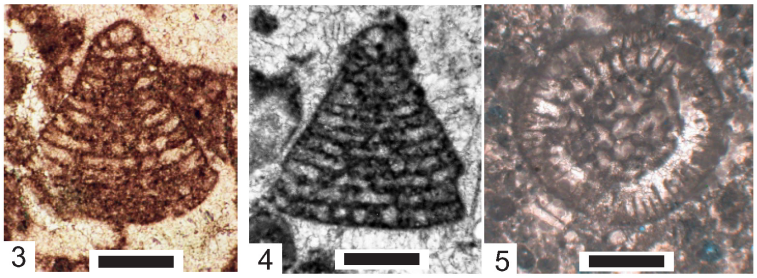
Barremian to Albian calcareous nannofossils define zones readily identified throughout the Tethyan Realm. A commonly used zonal scheme designated CC5–CC9 is based on FOs or LOs of coccoliths (Perch-Nielsen, 1985). The somewhat larger calcareous nannoconids are relatively common in carbonate thin sections and readily seen at magnifications at about 500X. Four zones span the Barremian to Albian (McNulty, 1985): (1) the Barremian *Nannoconus colomi* IRZ from the FAD of *Nannoconus wassalli* to the LAD of *Nannoconus colomi*; (2) the lower Aptian *Nannoconus bucheri* IRZ from the LAD of *Nannoconus colomi* to the LAD of *Nannoconus bucheri*; (3) the upper Aptian *Nannoconus boletus* TRZ; and (4) the Albian *Nannoconus donnatensis* TRZ.

The uppermost Aptian to lower Albian *Colomiella* Assemblage Zone characterizes the Lower Tamaulipas Formation in Mexico and Texas (Bonet, 1956; McNulty, 1985; Scott, 1990). Colomiellidae (Bonet, 1956) are calpionellids that consist of a single genus of calcareous microfossils composed of a vase-like lorica surmounted by a collar. Three species, *Colomiella mexicana*, *Colomiella recta*, and *Colomiella tunesisana* are common in lower Albian pelagic facies. These species first appear very close to the base of the Albian and extend into the middle Albian. Colomiellid ranges are also recognized in Spain, France, and Tunisia.

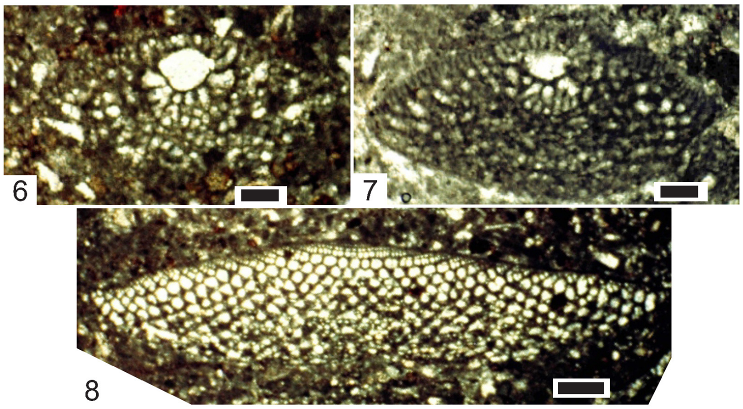
Barremian-Albian rudist biozones were defined for U.S. and Mexican carbonates (Scott and Filkorn, 2007; Scott and Hinote, 2007; Scott et al., 2014). The *Huetamia buitronae* Assemblage Zone characterizes the Cupido and Sligo formations in Texas and northern Mexico and the Comburindio Formation in Michoacán, Mexico (Scott and Hinote, 2007; Scott and Filkorn, 2007; Scott, 2014). The *Choffatella decipiens* and *Palorbitolina lenticularis* zones defined here correlate with this rudist zone. These zones overlie the Berriasian–lower Aptian *Nannoconus steinmanni* Zone (McNulty, 1985). The uppermost Aptian to lower Albian *Coalcomana ramosa* Interval Zone spans the Glen Rose Formation of Texas and the Mural Limestone of Arizona and correlates with the *Mesorbitolina texana* Interval Zone. The uppermost lower to lowermost upper Albian *Caprinuloidea* Interval Zone characterizes the middle to lower part of the upper Albian Fredericksburg Group in Texas, the subsurface Stuart City Formation, and equivalent units in northern Mexico, and correlates with the *Carseyella walnutensis* Interval Zone. The upper Albian *Kimbleia* Interval Zone ranges across the Devils River Formation in West Texas and El Abra Limestone in eastern Mexico and



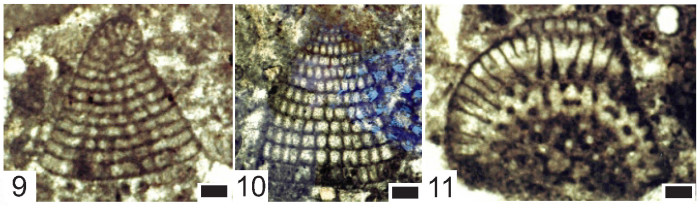
Paracoskinolina coogani 0.5 mm



Carseyella [Dictyoconus] walnutensis 0.5 mm

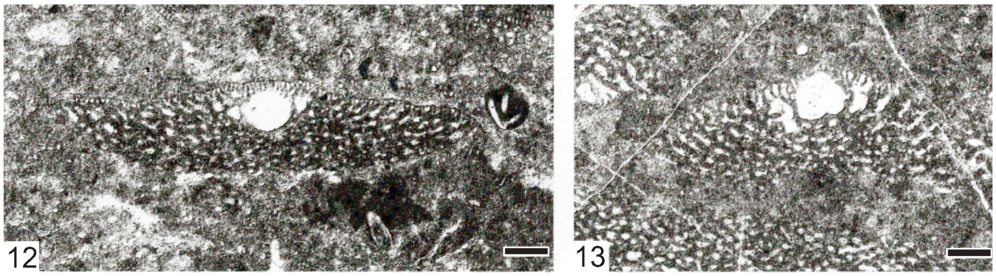


Mesorbitolina texana 0.1 mm



Paracoskinolina sunnilandensis 0.1 mm

Choffatella decipiens 1.0 mm



Palorbitolina lenticularis 0.2 mm

(FACING PAGE) Figure 3. Photomicrographs of zone-name species of Early Cretaceous benthic foraminifers, North American Gulf area and Central America. (1 & 2) *Paracoskinolina coogani* Total Range Zone, uppermost Albian; upper Albian Devils River Fm., Texas; axial section of holotype and transverse section of paratype; scale bars = 0.5 mm. (3–5) *Carseyella* [*Dictyoconus*] *walnutensis* Interval Range Zone, middle to lower upper Albian; two longitudinal sections each with proloculus, middle Albian Stuart City Limestone; basal section, Goodland Ls., SE Oklahoma; scale bars = 0.5 mm. (6–8) *Mesorbitolina texana* Interval Range Zone, uppermost Aptian to lower Albian; two sections each with proloculus, scale bar = 0.1 mm; oblique longitudinal section, scale bar = 0.5 mm, lower Albian, Cerro La Espina Fm., Sonora Mexico. (9–11) *Paracoskinolina sunnilandensis* Interval Range Zone, lower to upper Aptian; lower Albian Cerro La Espina Fm., Sonora, Mexico; scale bars = 0.1 mm. (12 & 13) *Palorbitolina lenticularis* Total Range Zone (TRZ), lower Aptian; Ogulin area, Croatia; scale bars = 0.2 mm (from Velić [2007]). (14) *Choffatella decipiens* Interval Range Zone, Barremian; "beds of early Trinity age"; Pinellas County, Florida; scale bar = 1.0 mm (from Applin and Applin [1965]).

correlates in part with the *Paracoskinolinella coogani* Range Zone.

CORRELATION WITH BARREMIAN-ALBIAN STAGES

The quantitative chronostratigraphic database, CRET17CS, was compiled in 2016–2018 based on numerical ages of GTS2016 (Ogg et al., 2016). The numerical age calibrations of the Lower Cretaceous stages were revised as GTS2020 (Gale et al., 2021). Both sets of ages are on Figures 1 and 2. Candidate GSSP (Global Section and Stratotype Point) sections for both the Barremian and Aptian stages have been proposed, and the Albian stage GSSP is ratified at Pre-Guittard, Drôme, France (Gale et al., 2020). Each section is incorporated in the CRET17CS database, so that stage boundaries are defined consistently with the relevant criteria. The numerical ages differ but the correlations of other taxa are reliable.

The candidate section for the Barremian Stage is at Río Argos, Caravaca, Spain, at the FO of the ammonite *Taveraidiscus hugii* (Reboulet et al., 2018), which is a section in the CRET17CS database. The numerical age of the base was revised from 130.8 Ma (Ogg et al., 2016) to 126.5 Ma is by correlation with Argentina (Gale et al., 2020).

The candidate GSSP section for the Aptian Stage is at Gorgo a Cerbara, Italy (Gale et al., 2020), which is a section in the CRET17CS database. Criteria of this boundary include Polarity Chron M0r and the FO of the ammonite *Deshayesites oglanlensis* (Ogg et al., 2016). In the CRET17CS database, the numeric ages of M0r are 126.30 Ma and the FAD of *D. oglanlensis* is 126.30 Ma. The revised age of 121.4 Ma of M0r is interpolated from U–Pb dates of an overlying bentonite in Polarity Chron M1r at Svalbard, Norway (Zhang et al., 2020).

The Albian GSSP section is at Pre-Guittard, Drôme, France, and the boundary criterion in this section is the FO of *Microhedbergella miniglobularis*, which is ~6.6 ft below the base of the Niveau Kilian marker bed.

CONCLUSIONS

Lower Cretaceous limestones representing shallow shelf, shelf margin and slope environments encircle the Gulf of Mexico and cap discreet isolated platforms in Mexico and Central America; they were deposited in the Barremian to Albian stages, about 130 to 100 Ma. These carbonates have served as important hydrocarbon reservoirs in Mexico and the United States for nearly ninety years. Exploration is challenging because of complex facies, diagenesis, burial history, and source rock proximity. New seismic and drilling technologies have created innovative exploration and exploitation possibilities. These North and Central American carbonate strata archive important oceanic signals such as carbon chemozones, oceanic anoxic events, and sea-level changes.

Accurate and precise stratigraphic correlation is essential to unraveling potential carbonate reservoir facies. One of the most common fossils in these carbonate strata are larger benthic foraminifers in addition to rudist bivalves, calcareous nannofossils, planktic foraminifers, and colomiellids. Based on nearly seventy years of experience, biostratigraphic zonation of the Barremian, Aptian and Albian stages in the Gulf region is precisely defined by FADs and LADs of larger benthic foraminifers in thin sections. Six benthic foraminiferal biozones are here defined by first occurrences or overlapping ranges in the Gulf of Mexico region of the United States, Mexico and Central America: *Choffatella decipiens* Interval Range Zone, Barremian; *Palorbitolina lenticularis* Total Range Zone, lower Aptian; *Paracoskinolina sunnilandensis* Interval Range Zone, lower to upper Aptian; *Mesorbitolina texana* Interval Range Zone, uppermost Aptian to lower Albian; *Carseyella walnutensis* Interval Range Zone, middle to lower upper Albian; *Paracoskinolina coogani* Total Range Zone, uppermost Albian.

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