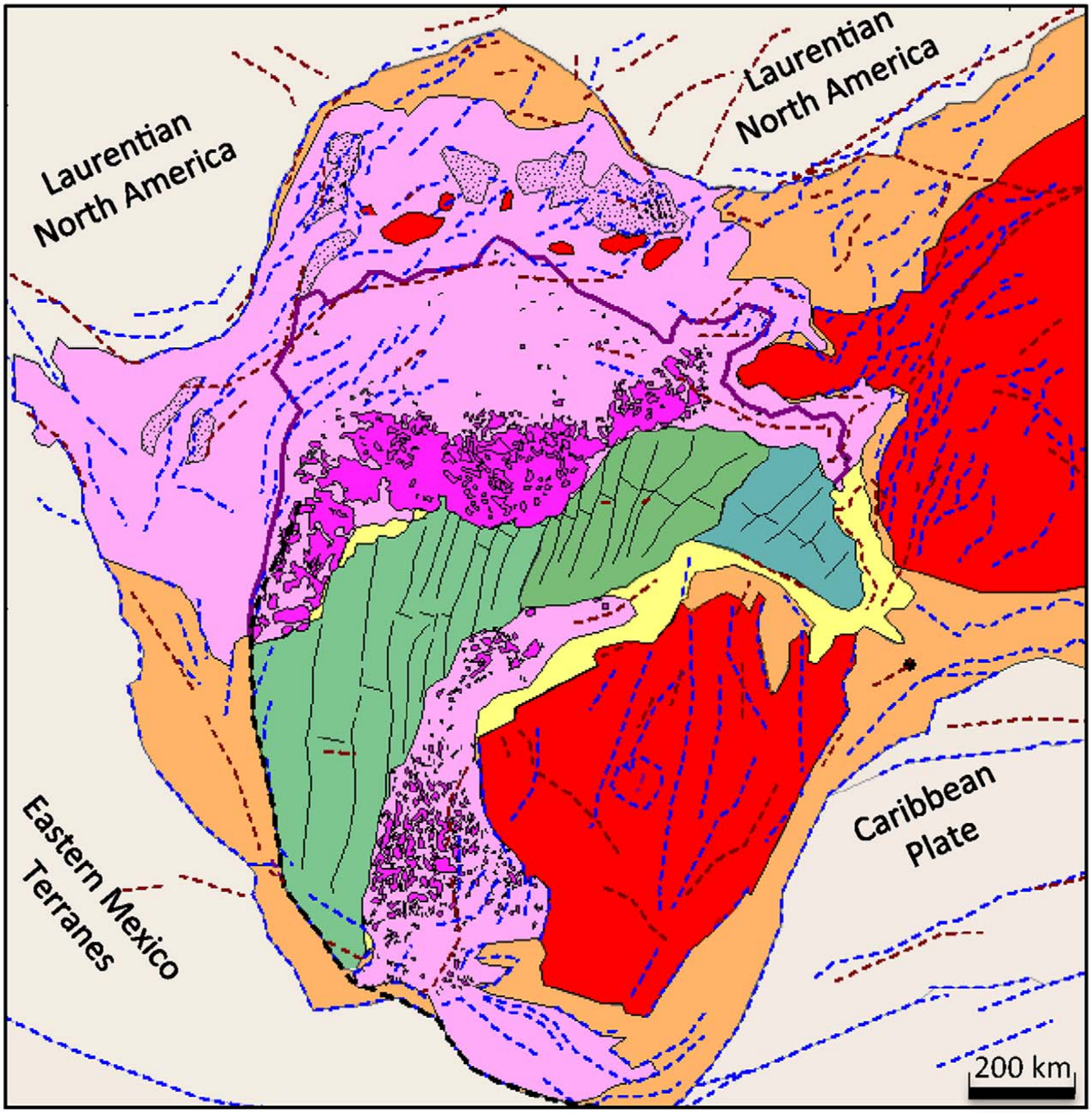

35th Annual GCSSEPM Foundation Perkins-Rosen Research Conference
December 8—9, 2016, Houston, Texas

Mesozoic of the Gulf Rim and Beyond: New Progress in Science and Exploration of the Gulf of Mexico Basin

Editors: Christopher M. Lowery, John W. Snedden, and Norman C. Rosen

Program and Abstracts

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Foreword

Thirty-two years ago, the Gulf Coast Section of SEPM convened its 3rd Annual Research Conference on the Jurassic of the Gulf Rim (Ventress *et al*., 1984). At that time, the Mesozoic was being explored onshore as conventional carbonate and sandstone reservoirs, the Cantarell Field (Mexico) was in its early stages of production, and offshore areas of the U.S. Gulf of Mexico were primarily Cenozoic reservoir targets. Today, the Mesozoic is known to contain large discovered volumes in unconventional shale reservoirs onshore, Cantarell is in decline, and Mesozoic discoveries are being made in the ultradeep water of the Desoto and Mississippi canyons. Mexico has opened for international exploration, and political events in Cuba may eventually cause it to follow suit.

This increased economic interest in the Mesozoic of the Gulf of Mexico has in turn spurred a huge volume of scientific research and increased investment in research and access to samples from wells in previously undrillable regions. New seismic refraction surveys are revealing the deep crustal structure of the basin and its early Mesozoic history. In particular, attention is beginning to focus on the presalt rift basins. State of the art seismic reflection surveys are illuminating the subsalt domain of both the U.S. and Mexico deep water. New techniques, such as detrital zircon geochronology, are reconstructing the continental scale drainage systems that feed into the basin, while new exploration in the deep water has identified sand fairways farther offshore than anyone expected. Advances and new concepts in economically important disciplines such as salt tectonics, depositional systems, source rock development, migration, and charge have proved equally important scientifically and have yielded new insights into the formation and evolution of the Gulf of Mexico Basin.

The 2016 GCSSEPM Perkins-Rosen Research Conference presentations included in this proceedings volume focus on the Mesozoic of the Gulf Basin, from the mountain source terranes to the deep-water abyssal plain and range in time through the Triassic pre-salt rift basins to the basin-wide event beds associated with the Chicxulub Impact at the K-Pg Boundary. As a whole, this publication demonstrates just how far our understanding of the Mesozoic of the Gulf of Mexico has advanced since that 3rd Annual GCSSEPM Research Conference in 1984.

Of particular note are a the contributions to a special session on the source-to-sink depositional history of the Gulf of Mexico, including a number of papers using detrital zircon geochronology to untangle the source terranes of terrigenous deposits in the shallow and deep water. These include a number of notable siliciclastic units in the Gulf, including the pre-salt Eagle Mills, the Haynesville, and the Tuscaloosa.

Although our understanding of the Mesozoic Gulf of Mexico is miles ahead of where it was 32 years ago, the data presented here also highlights how much is still unknown and undiscovered in this interval. Very little is currently known about the timing rift basin formation in the Triassic or the paleoenvironments represented there. How much time is missing between the top of those synrift sediments and the emplacement of salt? How old, exactly, is the Louann Salt? Our knowledge of many Mesozoic source-rock and reservoir intervals are restricted to areas of active oil exploration. This observation borders on tautology, of course, but highlights important questions about the extent of these plays, and the existence of as-yet undiscovered plays. For example, the organic-rich facies of the Cenomanian-Turonian Eagle Ford Shale are well-known from Texas, but how does it correlate to the age-equivalent Tuscaloosa? Or into southern Mexico? Or the deep water? We have learned a great deal about the Mesozoic of the Gulf of Mexico, but there is still a great deal left to do.

The conveners are indebted to the technical program committee for their assistance soliciting and contributing research for this volume: Erik Scott, Luke Walker, Rick Reuquejo, Thomas Hearon, Richard Denne, Robert Pascoe, Hilary Olson, Felipe Ortuño Arzate, James Pindell, Barbara Radovich, Rich Adams, Ian Norton, Sophie Warny, Amy Weislogel, and Ricardo Padilla. In addition, the assistance of Gail Bergan and Patty Ganey Curry in preparing this volume and advertising this conference was invaluable. We appreciate the kind offer of Marathon to allow us to use their meeting space for this meeting. Finally, we are grateful for the guidance and editorial oversight provided by Norman Rosen, without whom none of this would have happened.

Chris Lowery

Mesozoic of the Gulf Rim and Beyond: New Progress in Science and Exploration of the Gulf of Mexico Basin

35th Annual Gulf Coast Section SEPM Foundation Perkins-Rosen Research Conference

2016

Program

Wednesday, December 7

Optional Core Workshop at the BEG Core Facility in Houston. Details will be sent to participants.

6:00–8:00 P.M. Registration and refreshments at the Sheraton Suites Houston, 2400 West Loop South.

Thursday, December 8, Marathon Auditorium

7:15 A.M. **Continuous registration (coffee will be available)**
7:40 A.M. Welcome remarks, Tony D'Agostino (Executive Director, GCSSEPM Foundation)
7:45 A.M. Introduction to the Conference, John Snedden (Technical Committee Chairman)

Session 1: Early Gulf of Mexico/Evolution of Gulf of Mexico

John Snedden and James Pindell, Morning Co-Chairs

10:00–10:45 A.M. Extended coffee break with time to view posters.

Friday, December 9

7:15 A.M. **Continuous registration (coffee available)**

Session 4: Gulf of Mexico Source to Sink

Mike Blum and Ricardo José Padilla y Sánchez Morning Co-Chairs

Session 5: Late Cretaceous

Posters Only

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Cover Image

The cover image chosen for this year's conference is Figure 3 from Pascoe et al., which shows Mesozoic Gulf of Mexico Basin salt distribution superposed on crustal architecture.

Gulf of Mexico Tectonic Evolution from Mexico Deformation to Oceanic Crust

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Extended Abstract

Although the final stage of formation of the Gulf of Mexico is fairly well constrained, earlier evolution is still debated. The final stage was rotation of Yucatan about a Florida Straits Euler pole that created most of the observed oceanic crust (Pindell and Dewey, 1982). From observations of salt overlying seaward-dipping reflectors (diagnostic of volcanism during the rift to drift transition) in the northeast Gulf of Mexico, we suggest that salt was deposited at the onset of sea floor spreading, which coincides with initiation of the rotational motion of Yucatan. It is important to understand Yucatan motion that preceded this rotation because delineating any presalt play that might exist would be dependent on understanding of depositional systems developed during this early motion of Yucatan. Very little is known about the nature of presalt deposition in the northern Gulf of Mexico. Salt is Callovian or earliest Oxfordian in age, and the next oldest rocks known from the northern Gulf of Mexico are Late Triassic red beds found in what are generally regarded as proximal grabens formed during early rifting. This gap in knowledge, what we refer to as the "50 million year gap," can potentially be bridged by incorporating analogs with known systems in Mexico and northern South America. There are uncertainties here, however, mostly based on how Mexico and northern South America are palinspastically restored and the fact that these rocks are in a proximal location. In particular, we note that there was a long-lived continental margin arc in Mexico that lasted from the Permian through the Middle Jurassic (Barboza-Gudino *et al.*, 2012). A lot of the rocks of this age seen in Mexico that are linked to Gulf of Mexico rifting are in fact associated with this arc. In this presentation, we will review reconstructions of the region and develop a tectonic model that forms the basis for further understanding of rifting in the Gulf of Mexico.

An Initial Quantitative Attempt to Estimate How Much Louann Evaporite was Deposited in the Gulf of Mexico Basin

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Abstract

Published estimates for the original volume of Mid-Jurassic Louann evaporites found throughout the entire Gulf of Mexico Basin vary widely. Volume totals derived from both map data and actual volume numbers, range from about 10,500 km^3 (2,500 mi^3) to 839,000 km^3 (200,000 mi^3), an 80 fold variation. Little new information has been published during the past twenty-five years to address this disparity. But gaining knowledge of the present day volume of salt would be an important metric if debates concerning the origin of the salt and the nature of the Gulf of Mexico Basin during salt deposition are to be reconciled.

A methodology now exists to estimate more accurately and quantitatively the volume of salt present in a given area. Multiple, recent generations of 3-D seismic depth volumes in the offshore Gulf of Mexico require that salt velocities be inserted. This vital processing step includes a systematic picking and interpretation of the tops and bases of all salt bodies encountered. The resulting models of salt velocity allow salt volume in the 3-D data sets to be calculated. Combining the salt volumes calculated from multiple seismic surveys offers new stratigraphic insights across large portions of the original salt basin.

A comparison of salt volumes derived from seismic data cubes and volumes derived from published maps can now be made. The comparisons should give some suggestion as to the accuracy of the map data. By extrapolation it should also give a more accurate and quantitative estimation of the original salt volume deposited in the Gulf of Mexico basin.

Stratigraphy and Mineralogy of the Oxfordian Lower Smackover Formation in the Eastern Gulf of Mexico

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Abstract

The Oxfordian Smackover Formation is generally acknowledged to be a hydrocarbon source for numerous reservoirs in the Gulf of Mexico, both onshore and offshore. More than 25 wells in the eastern Gulf of Mexico have penetrated the Smackover since 2003. Offshore, the Smackover consists predominantly of limestone and shale containing thin organic layers. Immediately above the lower Smackover is a widespread shale marker. This thin shale is correlated as the base of the upper Smackover Formation, which consists of interbedded shale and limestone.

This study will demonstrate that the lower Smackover Formation in the eastern Gulf of Mexico (Mississippi Canyon and De Soto Canyon offshore areas) is composed of a series of seven units that occur in the same sequence in virtually every well in which the lower Smackover has been encountered. Although the seven individual units can be resolved readily with the proper wireline suite, each has a sub-seismic thickness. The overall thickness of the lower Smackover is about 300 +/-100 feet. Unlike the lower Smackover, the surrounding Mesozoic formations, from Cotton Valley to Norphlet, vary greatly in thickness in the eastern Gulf.

The initial correlations of the units in the lower Smackover were made by comparing the gamma ray, resistivity, and density log patterns with the computed mineralogy of Elemental Capture Spectroscopy (ECS) wireline logs. It was immediately obvious that the same sequence of beds/units was present in the lower Smackover in well after well. Within the lower Smackover Formation is a conspicuous zone characterized by iron-bearing minerals having a matrix density in excess of 3.0 g/cm^3 throughout.

However, X-Ray Diffraction (XRD) data from rotary sidewall cores was necessary to validate the mineralogy. Because the mineralogy of the ECS log is a model-based calculation from the elemental concentrations of iron, calcium, aluminum, etc,. rather than a direct measurement, the modeled mineralogy can be inaccurate as was the case in the bottom two units.

Mineralogy of the seven units has been verified by XRD analyses, albeit from a limited number of rotary sidewall cores obtained in only five wells. The top three units are limestones which vary in carbonate, clay, and pyrite content. The fourth and fifth units contain significant amounts of high density minerals, particularly siderite and pyrite. The sixth zone is dominated by anhydrite. The seventh unit is a hematite-rich shale and its base is an unconformity.

Although wireline data are plentiful, analysis of the seven units within the lower Smackover is hampered by the limited amount of rock data and the complete lack of whole core. Many depositional and geochemical questions suggested by the unusual mineralogy and sequence of beds remain unanswered.

Implications of Early Gulf of Mexico Tectonic History for Distribution of Upper Jurassic to Mid-Cretaceous Source Rocks in Deep-Water Exploration Areas of the US and Mexico

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Abstract

The central Gulf of Mexico Basin formed by Callovian rifting followed by oceanic spreading during anticlockwise rotation of Yucatan Block between Oxfordian (160Ma) and Valanginian (140Ma). The rotation pole was in the Straits of Florida, resulting in a wiper-blade motion having greatest sweep along a transform paralleling the coast offshore Tampico-Misantla Basin. Oceanic crust progressively separated the 160-140Ma stratigraphy, creating bands of ocean crust lacking Oxfordian, Kimmeridgian, Tithonian and, near the ridge, even Berriasian deposition: present day, these stages appear progressively absent towards the spreading center.

After a basin-wide 140Ma (Valanginian) unconformity on the rimming shelves at the end of spreading, thermal subsidence resumed and water deepened further, in the basin. However, an arch separating the Gulf of Mexico and paleo-Caribbean basins across the Florida Straits remained a bathymetric sill to deep ocean circulation post-140Ma as before.

The impact of this tectonic/bathymetric evolution on the presence and ultimate expellable potential (UEP) of source rocks in the basin center is profound. Using a scheme of basin-wide correlated organic matter depositional acmes (recently developed by Petroleum Systems LLC, where the acme age is expressed in Ma), candidate source rocks in the Gulf of Mexico are: Acme A157 (late Oxfordian); A154 (Kimmeridgian); A148 (Tithonian); A144 (Berriasian/ Portlandian). All four acmes have zones of nondeposition due to oceanic spreading, and older acmes are absent over a greater area. Some workers have proposed the main deep-water basin source rock in the United States is Tithonian; however, new work (so far limited to eastern deep water Mississippi Canyon, Atwater Valley, and Desoto Canyon) indicates that A157 (*i.e.*, the oldest, most susceptible to nondeposition) is the most effective source rock.

Risk on Acme 157-144 non-deposition can be mitigated if source rocks younger than 140Ma, having significant ultimate expellable potential, were deposited in the deep basin. Based on recent reappraisal of data in DSDP Leg 77, Cuba and rafted sediment blocks in U.S. waters, significant ultimate expellable potential does exist in five younger Early to mid-Cretaceous acmes: A138 (Valanginian); A120 (early Aptian); A110 (early Albian); A101 (late Albian); and A98 (early Cenomanian). A138 may result from restricted circulation, reinforced during the 140Ma uplift of rimming shelves, while A120, A110, and A101 can be correlated with oceanic anoxic events OAE1a, b, and d.

Chronostratigraphic Views of Gulf of Mexico Tectonic and Deposystem Evolution in the Mesozoic

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Abstract

We cannot hope to predict Mesozoic depositional processes and sediment properties well enough to plan effective regional exploration strategies without considering the big picture of Gulf of Mexico deposystem evolution. The two critical big picture elements are the kinematics and timing of the Yucatan Block's detachment and separation from North America and the various major expansions and contractions and the ultimate disappearance of the Western Interior Seaway.

Although a number of authors, including this one, have speculated on the timing of separation of Yucatan from North America (Fillon, 2007a), no definitive evidence exists: *i.e.*, drilled samples of the ocean crust and the sediments directly overlying it. Without that unambiguous information we must infer the paleogeographic evolution of the early Gulf of Mexico Basin from deposystem architecture by asking questions such as when do Gulf of Mexico deposystems transition from architectures consistent with deposition in a youthful block-faulted basin underlain by actively attenuating continental crust to deposition in a mature basin having stable margins surrounding a central region underlain by subsiding ocean crust. An understanding of the paleogeography and paleoceanography of the Gulf of Mexico Basin derived from deposystem architecture can help provide answers to crustal kinematic questions and to more exploration focused questions such as: where, and in section of what age should we look to find facies similar to the organic rich, generative Haynesville Shale facies of eastern Texas and western Louisiana.

Although we all know something about the Western Interior Seaway, most of us working on the Mesozoic of the Gulf of Mexico Basin have not spent much time considering what effects it might have had on the prospectivity of Gulf of Mexico deposystems. Through much of Albian and Late Cretaceous time the Western Interior Seaway connected the Gulf of Mexico Basin with the Arctic Ocean Basin. The effects of the establishment and intermittent blocking of this major seaway connecting arctic and tropical water masses on global paleoceanography, on global paleoenvironments, and locally on onshore and offshore Gulf Basin deposystems cannot be ignored in our quest to understand the Mesozoic of the Gulf Rim.

This paper is a "big picture" review of Gulf of Mexico Basin deposystem evolution within the Late Jurassic (Oxfordian)–Late Cretaceous (Maastrichtian) interval. Seventeen Mesozoic chronosequences are defined therein based on chronostratigraphic data garnered from over 130,000 industry well and pseudowell penetrations of Mesozoic section in the Gulf of Mexico Basin region. Examination of the collected data suggests that grouping the seventeen Gulf of Mexico Mesozoic chronosequences into seven super-chronosequences optimally distinguishes key phases of deposystem and basin evolution.

The oldest super-chronosequence defined in this study, dubbed "MG," encompasses *ca.* 16.45 Ma of Norphlet through lowermost Cotton Valley Late Jurassic deposition. Sediment distribution and accumulation rates within the MG interval clearly define the rectilinear configuration of the earliest Gulf of Mexico Basin. This early basin geometry is consistent with fault controlled attenuation and foundering of North American continental crust, associated flooding, and rapid depositional infill concurrent with the earliest detachment of the Mayan (Yucatan) crustal block from North America. The Yucatan block, although showing an affinity with South American (Amazonian) terranes (Martens, 2009), was left attached to the North American plate when North America began pulling away from Gondwana during the initial breakup of Pangea (Fillon, 2007a).

The next younger super-chronosequence, "MF," contains a. *ca.* 13.47 Ma record of Cotton Valley, Boss-

ier, Knowles limestone., Late Tithonian through mid Hauterivian, deposition. The “MF” interval reflects the same rectilinear outline as the “MG,” but is marked by decreased accumulation rates, suggesting that the fault bounded crustal attenuation, rapid sediment infill phase had markedly slowed.

The *ca.* 9.4 Ma of Hosston, Sligo, Sunniland limestone, James limestone, mid-Hauterivian through Early Aptian section contained within the succeeding “ME” super-chronosequence records modification of the early rectilinear basin outline by a temporary reactivation of attenuation and foundering in the western portion of the Gulf of Mexico Basin. “ME” sediment distribution patterns also indicate development of a depositional continental margin and accumulation of true continental margin type deltaic and reef systems. These observations suggest that during this interval a deep continental basin, probably floored by ocean crust, was beginning to form outboard of the attenuated continental crust.

Sediment distribution and accumulation rates within the *ca.* 23.5 Ma Rodessa through lower Washita, Early Aptian through Early Cenomanian “MD” super-chronosequence reflect growth of the Wisconsin interior seaway and a stable phase of relatively low accumulation rates throughout the entire Gulf of Mexico Basin deposystem. During this interval, deposition was very likely influenced by a vigorous tidal and thermohaline current circulation driven by strong temperature contrasts within the Gulf of Mexico–Wisconsin interior seaway–Arctic Ocean connection.

The next younger super-chronosequence, “MC,” contains a *ca. ca.* 16.0 Ma record of Dantzler, Washita, Lower Pine Key, Eutaw, Woodbine, Eagle Ford, Austin, and Early Cenomanian through Late Santonian (Late Cretaceous) deposition. During this phase, there is a marked reduction of accumulation rates in the northwestern portion of the basin, attributable perhaps to expansion of the Western interior seaway and continued subsidence of the old Gulf of Mexico Basin margin. Associated small, perhaps tidal submarine delta-like depopods developed, perhaps in response to the regional Western interior seaway transgression (Blakey, 2014). These delta-like depocenters appear to define a new basin margin presaging the modern curved shape of western Gulf of Mexico so familiar to us today. Here also we see the first unambiguous evidence of abyssal deposition in the deepest portion of the Gulf of Mexico Basin underlain by ocean crust.

The succeeding *ca.* 12.82 Ma interval of Late Santonian through Early Maastrichtian upper Pine Key, upper Selma, upper Austin, Taylor, Olmos, Saratoga, and low accumulation rate mainly chalk and marl deposition contained within the “MB” super-chronosequence provides evidence of transgressive onlap associated with an expanding and deepening interior seaway during “MB” time. “MB” onlap has the effect of temporarily reemphasizing structural trends inherited from crustal attenuation that took place during “ME” time.

Finally, the *ca.* 5.4 Ma long terminal Mesozoic “MA” super-chronosequence consists of Maastrichtian, Navarro equivalent, low accumulation rate marls deposited along the basin margin. These low accumulation rate basin rim sediments and low accumulation rate slope sediments are punctuated by high accumulation rate canyon fill and lobe-shaped slope depopods which are probably attributable to sediment reworking, transport and deposition by transitional Cretaceous-Paleogene (K/P) interval mega-tsunami backwash flows immediately following the Chicxulub impact. Higher accumulation rates in the deeper parts of the basin underlain by ocean crust are also consistent with high volume backwash flows.

Constraints on the Timing of Continental Rifting and Oceanic Spreading for the Mesozoic Gulf of Mexico Basin

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Abstract

The Mesozoic Gulf of Mexico Basin is considered in this discussion as the set of contiguous, Triassic and Jurassic sub-basins directly involved in the counter-clockwise rotation of the Yucatan Block from North America in the Late Jurassic. The rifting and seafloor spreading history of the basin is less well understood than analogous salt basins of the Atlantic margins, largely because the base salt surface is significantly deeper and has hereto widely been considered acoustic basement.

In 2012, 17,000 km of 2D PSDM reflection seismic data (*SuperCache*) were acquired across the deep water of the U.S. Gulf of Mexico. The unique acquisition configuration of long-offset, powerful source, and deep-tow of both source and receivers was designed to optimize the imaging of the presalt architecture of the basin to a depth of 40 km. On these seismic data, the base of the salt and its correlative unconformity, continental and oceanic basement, and the Moho are evident. In combination with vintage, reflection seismic data, shipboard and regional gravity data, and regional refraction profiles, a crustal interpretation has been extended to the greater Gulf of Mexico Basin.

The continental crustal architecture is described in terms of crustal thinning: from low (<30%) to transitional (>70%). Synkinematic sequences are recognized within the Late Triassic to the Middle Oxfordian (~70 my). The final break-up phase occurred within 15 my, ending with a basin-wide open marine transgression and initial emplacement of oceanic crust at 160±1 Ma; continued extension may have occurred in the eastern part of the basin in the latest Jurassic. The basin margins are considered to be intermediate between magma-poor and volcanic end-members. The ocean crust tapers from a maximum width of 700 km in the west, where it is anomalously thin, to anomalously thick as it approaches the pole of rotation in the Straits of Florida. The architecture of extinct spreading valleys and fracture zones is analogous to the modern, slow spreading mid-Atlantic ocean, suggesting that spreading continued until the latest Jurassic (~142 Ma), possibly as late as within the early Cretaceous (~132 Ma).

Aeromagnetic Map Constrains Jurassic-Early Cretaceous Synrift, Break Up, and Rotational Seafloor Spreading History in the Gulf of Mexico

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Abstract

We present a reduced-to-pole, total magnetic intensity map derived from merged aeromagnetic surveys in and around the Gulf of Mexico. Most of the deep central Gulf crust has a magnetic pattern of orthogonally intersecting features similar to, and interpreted as, fracture zones and ridge segments of oceanic crust formed by seafloor spreading. This spreading or drift phase occurred after the primary synrift phase of continental stretching across the greater Gulf of Mexico region, and thus the ocean crust rests within a broader zone of stretched continental crust with Yucatán, western Florida, the southern USA, and eastern Mexico forming the surrounding continental margins. We identify three regional magnetic anomaly trends that can be used to constrain the Gulf of Mexico's Late Jurassic through earliest Cretaceous spreading history. A central magnetic anomaly trend is interpreted to accord with the later increments and cessation of seafloor spreading, for which a stage pole of rotation is estimated. Two flanking magnetic anomaly trends to the north and south of the central one, respectively, occur just basinward from the inferred depositional limits of autochthonous Callovian-Early Oxfordian salt. These anomalies appear to define the landward limits of oceanic crust in the northern and southern Gulf, and probably lie in crust that is medial or Late Oxfordian in age. They have similar mapped patterns that can be reconstructed onto one another and hence are probably genetically related but separated by spreading. These landward anomalies are best fit around a different stage pole than the central anomaly; thus the rotation pole appears to have jumped during spreading in the Gulf. Seismic reflection data show that the two outer anomalies occur at the basement "step ups" to the oceanic crust or the basinward shoulders of the "outer marginal troughs." Until specific magnetic source modelling is done on the outer anomaly pair, we favor an edge-effect interpretation caused by the intrusive interface between Oxfordian oceanic crust and serpentinized and exhumed subcontinental mantle, the latter of which we infer forms the step ups to the oceanic crust. In addition, the aeromagnetic map shows a north-south trending "Campeche Magnetic Anomaly" downslope from the western shelf edge of Yucatán that we argue helps to constrain the reconstruction of Yucatán along Texas at the start of the synrift stage. Thus, the aeromagnetic map provides vital insights into the kinematics of all three stages of the basin's development, namely the synrift, the drift, and the interpreted intervening transitional phase of crustal hyperextension/mantle exhumation along the Gulf's magma-poor continent-ocean transitions.

Pre-Albian Biostratigraphical and Paleoecological Observations from the De Soto Canyon Area; Gulf of Mexico, USA

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Abstract

A biostratigraphical review of eight exploration boreholes located within the De Soto Canyon protraction area in the Gulf of Mexico yields a repeatable and predictive evolutionary and paleoecological sequence with implications to paleogeography. The Oxfordian section within these boreholes contains primitive planktic foraminifera such as *Globuligerina oxfordiana*. Near the end of the Kimmeridgian (or slightly above the nannofossil *Calcivascularis cassidyi* extinction), nannofossils are of low abundance, and dominated by *Cyclagelosphaera* spp. Weakly developed benthic foraminifera abundance gives rise to *Reinholdella* A which is coincident with a nannofossil dominance switch to *Polycostella* spp. Planktic foraminifera are not observed in this section

In the overlying section, the extinction of nannofossil genus *Polycostella*, the origination and dominance of *Nannoconus*, and minute benthic foraminifera gradually increase. Here, the suggested datum, *Polycostella beckmanii* extinction, is observed consistently higher than the *Reinholdella* A extinction in the early Tithonian. The fossil assemblage change through this section suggests a change in water masses, which has implications to major reorganization in oceanic circulation.

The Lower Cretaceous continues with multiple nannofossil originations that persist into the Valanginian. Here, a significant, diverse, and abundant benthic foraminifera and ostracod assemblage occurs in multiple, rapid abundance increases followed by gradual upward decreases, suggesting cyclical change in the shallower, upslope paleoenvironments. The cause of cyclical changes is unclear and may be the result of sea level change, progradation, and/or changes in ocean composition.

The Hauterivian to Aptian section varies greatly in thickness with the maximum thickness in the northern De Soto Canyon area and thinning to the south. *Nannoconus* continues to dominate the nannofossil assemblage through the Aptian; benthic foraminifera and ostracods disappear rapidly during the Hauterivian and remaining sparse until the Albian when there is an increase of *Nezzazata* spp. The significance of these fossil sequences and respective assemblages are discussed in a paleoecological and paleogeographical context, which has implications to depositional history and correlation.

Relationship Between the Depositional Episodes of the Woodbine/Eagle Ford of East Texas and the Eagle Ford of South Texas

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Abstract

A chronostratigraphic framework was developed for the subsurface Eagle Ford of South Texas in conjunction with a log-based regional study that was extended across the San Marcos Arch and into East Texas using biostratigraphic and geochemical data to constrain log correlations of 12 horizons from 1729 wells in South and East Texas. Seven regional depositional episodes were identified by the study. The clay-rich Maness Shale was deposited during the Early Cenomanian in East Texas and northern South Texas where it correlates to the base of the Lower Eagle Ford. After a fall in sea-level, East Texas was dominated by the thick siliciclastics of the Woodbine Group, whereas in South Texas deposition of the organic-rich EGFD100 marls of the Lower Eagle Ford began during the subsequent Lewisville transgression. A shift in depositional style to the limestones and organic-rich shales of the Eagle Ford Group occurred in East Texas during the Middle-Late Cenomanian EGFD200 and EGFD300 episodes produced by the continued rise in sea-level. Erosion along the Sabine Uplift shifted the focus of deposition in East Texas southward to the Harris delta and deposited the "clay wedge" of northern South Texas during the EGFD400 episode. The introduction of an oxygenated bottom-water mass onto the Texas shelf produced the considerable decrease in TOC preservation that marks the Lower/Upper Eagle Ford contact. This event coincided with the onset of Oceanic Anoxic Event 2 (OAE2) and the Cenomanian-Turonian Boundary sea-level high, which starved much of the Texas shelf of sediment. The only significant source of sediment was from the south; within the study area, the EGFD500 interval is essentially absent north of the San Marcos Arch. Deposition recommenced on much of the Texas shelf during the Late Turonian EGFD600 episode with the Sub-Clarksville delta of East Texas and the carbonate-rich Langtry Member of South Texas and eastern West Texas. Bottom-waters became oxygenated at approximately 90 Ma, initiating the transition from the Eagle Ford Group to the Austin Chalk.

The Mesozoic of Nuevo Leon, Mexico: An Ancient Extension of the Gulf of Mexico. Paleogeography and Tectonics

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Abstract

The Mesozoic of Nuevo Leon is composed of more than 10,000 m of sedimentary rocks displaying abrupt physical changes and containing abundant planktonic foraminifera, allowing precise chronostratigraphic determinations. This succession has been deposited in the western extension of the ancestral Gulf of Mexico (Mexican Sea). Its paleogeographic setting corresponds to the oblique subduction of the Kula-Farallon plate under the North American plate. Active oblique subduction of the western margin of Mexico has resulted in the structural features of the Mesozoic sedimentary cover, forming a folded belt made of an intricate array of mountain ranges corresponding to the Nuevo Leones Cordillera characterized by: (1) kilometric-scale anticlinal ridges and narrow synclinal valleys of the Jurassic-Cretaceous sedimentary cover commonly displaying box (fan-shaped) folds; (2) a well-developed pattern of *en echelon* anticlinal folds; (3) juxtaposition of tectonostratigraphic domains; (4) asymmetrical, overturned, doubly plunging anticlines evolving into faulted anticlines; (5) disrupted, long and sinuous fold trends; (6) lack of large horizontal displacement due to overthrusting; (7) folding being predominant over faulting; (8) local thrusting with opposite vergence; and (9) lack of volcanism and regional metamorphism. Those features are the result of transpressional tectonics since the mid-Jurassic including a greater basement involvement in the tectonic deformation.

Analysis of the megastructures exposed in the region using SIR-A and LANDSAT imagery of northeast Mexico revealed that the megastructures of the Mesozoic Cordillera between parallels 22°00' and 26°00' and meridians 99° 00’ and 101°00’ can be referred to deformation of the thin sedimentary cover above transcurrent faults following the morphological pattern of the lab experiment by Odonne and Vialon. The folding styles of the Nuevo Leones Cordillera were analyzed in light of tectonic transpression and wrench-fault tectonics driven by transcurrent faults in the basement as established by Harland, Lowell, and Beck, resulting in the recognition of subsurface faults in the basement. We associate the geometric arrangement of the megastructural trends to sense of displacement of strike-slip (transcurrent) faults and fold patterns as demonstrated by Odonne and Vialon (1983) and the well-known strike-slip tectonic setting of New Zealand as described by Bishop (1967).

Triple-Porosity Diagram Proposed to Characterize Complex Carbonate Reservoirs—Examples from Mexico

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Abstract

Limestone and dolomite reservoir rocks are by far the more important producers of oil and gas in Mexico compared to sandstone reservoirs. Many of the carbonate reservoirs are complex in that they display three types of pores: matrix porosity; vugs, and cavernous porosity; and fracture-induced porosity. This combination of three types of porosity can be described as "triple porosity." Each pore type presents a different pore-throat size range and each has a different effect on permeability.

In order to better characterize these reservoirs, this paper proposes to visualize the relative abundance of each of these three pore types by plotting them on a triple-porosity pore-type ternary diagram (Fig. 1).

The Siliciclastic Upper Cretaceous Play of Eastern Mississippi Canyon

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Abstract

The eastern Mississippi Canyon area has been largely a Miocene oil and gas province in which recent discoveries in the Jurassic Norphlet Formation have been made. This paper focuses on a nascent Cretaceous play targeting the eastern Tuscaloosa fan comprised of large symmetric and asymmetric structures created by an expulsion-rollover system in the pre-Miocene interval. The top of the Cretaceous interval is found between 15,000' and 27,000', is up to 15,000' thick, and is underlain by a mature Tithonian source rock. The play extends downdip from the Cretaceous shelf edge and the reservoir is interpreted to be the equivalent of the Tuscaloosa Formation of onshore South Louisiana. This paper will examine the idea that the central Cretaceous basin is in the optimal zone for the trend of appropriate subsurface temperatures, depth, and significantly expanded reservoir section in the Upper and Lower Cretaceous intervals.

A Petroleum Systems Perspective on the Siliclastic Cretaceous Play of the Eastern Mississippi Canyon, Gulf of Mexico

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Abstract

The eastern Mississippi Canyon area has long been known as a prolific Miocene oil and gas province. Organic rich shales and marls of Tithonian and Oxfordian age strata are considered the major source rocks in the region. Recently however, attention has been directed towards the intervening siliciclastic Cretaceous strata as an enticing exploration target.

This presentation focuses on the duality of the Cretaceous section as both a "first carrier" for hydrocarbons expelled from Late Jurassic source rocks and as a potentially significant "container" for hydrocarbon accumulations as well.

Examined are the petroleum system elements and processes of eastern Mississippi Canyon. Emphasis is placed on the relative roles of vertical versus lateral secondary hydrocarbon migration from source to trap. Fluid properties from sampled accumulations help constrain model-derived estimates of thermal maturation, migration timing, loss en route and potentially available hydrocarbon yield.

The "carrier/container" nature of the Cretaceous is characterized through multiple scenarios that address: Subsurface pressure relationships, bed-seal and fault properties; as well as seismically derived lithology and facies distributions. Fetch area constrained source rock expulsion through the Cretaceous is modeled, taking into account known Miocene accumulations. The results of such analyses lend insight into hydrocarbon potential within the Cretaceous.

Resolving Presalt Sediment Source Terrains and Dispersal Pathways for the Northern Gulf of Mexico Basin

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Abstract

As part of a larger intercollegiate effort to reconstruct late Triassic, presalt sediment provenance and routing environments for the Gulf of Mexico sedimentary basin, an integrated geochronologic approach leveraging more traditional biostratigraphic, sedimentologic, and sequence stratigraphic provenance constraints from geologic cores, cuttings, and geophysical well logs was initiated. This paper presents the initial results of this ongoing study and details detrital zircon U-Pb extraction methodologies while Inductively Coupled Plasma Mass Spectrometry analyses are pending. Eagle Mills Formation sandstone samples were collected from well core and cuttings, at five subcrop locations extending from Texas to South Carolina to the West Florida shelf, in preparation for U-Pb detrital zircon provenance analysis. Prior to separation of detrital zircon grains, a sedimentologic-stratigraphic analysis was conducted including detailed core description, well log evaluation, and thin-section petrography assessment. These findings confirm a hypothesis that late Triassic Eagle Mills siliciclastics were derived from the erosion of an active horst-graben rift block topography with associated igneous intrusives. Specifically, preliminary results reveal pervasive very fine-grained mottled gray to red bed sandstone lithology confirming synrift continental alluvium having little or no marine component, and probable deposition in a warm, humid environment but with increasing aridity. Classic fluvial facies features are highlighted including depositional cross strata typifying dynamic braided to meandering channel belts and alluvial floodplain deposits. Less common siltstone and shale lithologies were likely deposited amidst lower energy subfacies including potential shallow lakes, marshes, and/or ephemeral ponds. Bioturbated trace fossils were only rarely preserved, and there was no evidence of marine or eolian facies incursion. Igneous magmatism was prevalent in most subsurface Eagle Mills Formation samples including intrusive diabase, basalt flows, and volcanic ash.

Triassic-Jurassic Provenance Signatures in the Nascent Eastern Gulf of Mexico Region from Detrital Zircon Geochronology

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Abstract

By comparing new detrital zircon provenance analysis of Triassic synrift sediments from the Tallahassee graben (FL), the South Georgia rift basin (GA), and Deep River rift basin (NC) with our previous detrital zircon provenance data for the Jurassic Norphlet Formation erg in the Eastern Gulf of Mexico, we have developed a regional model of Triassic-Jurassic erosion and sediment transport. In the Eastern Gulf of Mexico, detrital zircon ages observed in Triassic synrift clastics from the Tallahassee graben and southern South Georgia rift system contain not only Gondwanan-aged and Grenville-aged zircon grains but also an abundance of Paleozoic detrital zircon grains, reflecting sediment influx from rocks associated with the Paleozoic orogens of eastern Laurentia. Although Paleozoic detrital zircon grains are present in the younger Norphlet deposits, they are less abundant than in Triassic rift sediments. In southwest Alabama, the most abundant detrital zircon age population in the Norphlet Formation is Grenville-aged (950-1,250 Ma). In the Conecuh embayment of southeastern AL and western FL panhandle, Norphlet samples show a marked decrease in Grenville detrital zircon and an increase in 525-680 Ma zircon ages, interpreted to represent influx from rocks associated with the Gondwanan Suwannee terrane. In the Apalachicola Basin, the proportion of Gondwanan zircon ages increases to nearly 40% of the total population and Grenville-aged grains constitute just ~20% of the population. We suggest that the difference between Triassic and Jurassic detrital zircon signatures in the Eastern Gulf of Mexico reflects significant unroofing of Paleozoic rocks during early Mesozoic rifting of the easternmost Eastern Gulf of Mexico, possibly including rocks equivalent with those exposed in the Talladega slate belt units. Subsequent erosion of rift-flanking highlands to expose older Gondwanan and Grenville rocks and/or input from northern sediment sources supplied the older Grenville-aged detrital zircon grains present in the Norphlet erg in the area to the west and within the Conecuh embayment.

Provenance of Cenozoic Siliciclastic Units in the Southern Gulf of Mexico by Heavy-Mineral Determinations and Geochemistry, and Detrital Zircon U-Pb Geochronology

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Abstract

We established provenance of Cenozoic sequences sampled in wells in the southern and southwestern Gulf of Mexico by heavy mineral analysis and LAICPMS detrital zircon U-Pb ages. The age spectra are dominated by Cenozoic ages. Other populations are of Cretaceous, Late Permian-Early Triassic, and Neo-Mesoproterozoic ages. Minor Jurassic, Devonian, and Ordovician ages are included.

Paleoproterozoic-Archean ages are related to the Amazonian craton. Meso-Neoproterozoic ages (1 Ga) are ubiquitous in Mexico (Oaxaquia terrane) and are related to the Grenville orogen. Neoproterozoic ages (750-550 Ma) were possibly derived from sedimentary rocks on the Panafrican orogen. Cambrian-Ordovician ages (490-450 Ma) might relate to plutons of the Esperanza suite of the Acatlán complex. Carboniferous and Permian ages (350-290 Ma) were possibly derived from the western Gondwanan arc. Permian and Triassic ages (290-250 Ma) may represent the east Mexican arc. Late Triassic and Jurassic ages (210-170 Ma) suggest a derivation from the Nazas arc in north-central Mexico. Late Jurassic ages (160 Ma) may represent the Jurassic magmatism associated with an extensional regime. Cretaceous ages (145 Ma) might be derived from Early Cretaceous arc of Mexico. Cretaceous ages (135-90 Ma) were possibly derived from the Alisitos-Peninsular Ranges arc. Late Cretaceous-Early Palaeogene ages (90-55 Ma) suggest relations with Laramide magmatism and the Late Cretaceous volcanic province in southern Mexico.

Paleogene-Neogene zircons (50 Ma and younger) are likely related to Cenozoic volcanic arcs in Mexico such as the Sierra Madre Occidental. Three earlier recognised ignimbrite flare-ups in the Eocene-Oligocene, early Oligocene, and early Miocene, match our detrital zircon populations. Furthermore, Miocene units contain kyanite-sillimanite possibly related to medium- to high-grade rocks such as the Acatlán complex or the Guatemalan Chuacús complex. We discuss the provenance based on geochemistry of the heavy minerals.

Late Triassic-Late Cretaceous Paleogeography of Mexico and the Gulf of Mexico

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Abstract

Most plate tectonic models for the opening of the Gulf of Mexico focus on the fit of different crustal blocks, regional faults, the areal extent of abnormal oceanic crust, transitional crust, and continental crust, as well as on today's geophysical data, but only a few include paleogeographic data. High quality paleogeographic maps are available for the northern part of the Gulf of Mexico, but the same type of information for the southern part is difficult to obtain. However, information from many published sources has been used to compile a series of maps of the entire country of Mexico, including the Gulf of Mexico.

The main objective of this project is to build-up palinspastic paleogegraphic maps of Mexico through the Mesozoic, where the various marine and transitional sedimentary facies are restored to their original geographical positions prior to folding and faulting, and then are overlapped on the tectonic blocks involved in the most popular plate tectonics models. The data contained in these maps correspond to outcrops in continental Mexico and to published subsurface data in the marine areas.

Detrital Zircon Evidence for Amazonian Provenance of Upper Jurassic Norphlet Formation in North Central Gulf, Mobile Bay: Implications for Paleoriver Systems in South and Central America

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Abstract

Detrital zircon from the Upper Jurassic Norphlet Formation in the vicinity of Mobile Bay, AL reflects a Laurentian provenance, with U-Pb age populations including dominant Paleozoic (265-490 Ma) and Grenville (950-1250 Ma) age. Twenty-three zircon grains from a sandstone sample recovered from the upper part of the Norphlet formation in well permit# 9863-OS-46-B show a population of 850-920 Ma zircon that is not observed in stratigraphically older samples. As there are very few sources for zircon of this age in southeastern United States, we interpret derivation from either the Goiás magmatic arc of Brazil; the conglomeratic sandstone of the eastern Yucatan peninsula; and/or Mixteca terrain of Mexico as probable sources. Previous study of 850-920 Ma zircon grains from the Goiás magmatic arc shows an origin from a depleted mantle without any crustal contamination ($Hf_{(t)}$= +8 to +12); however, the same age zircons in eastern Yucatan and Mixteca terrain indicate crystallization from magmas having a strong crustal signature ($Hf_{(t)}$= -3.2 to -3.8). Detrital Neoproterozoic zircon grains in the Norphlet Formation shows a wide $Hf_{(t)}$ range (-5.1 to +11.9) for the 850-920 Ma zircons, indicating sediments influx to the Gulf of Mexico basin during late Norphlet time was a mix of material from all of these sources during the Norphlet deposition. We propose that sediments from the Goiás magmatic arc probably were transported to the Mixteca terrain through a paleo-fluvial system; given the proximity of Mixteca terrain to southern North America during Late-Early Jurassic, we infer that erosion of Mixteca terrane sedimentary rocks supplied sediment to the Norphlet erg in the eastern Gulf of Mexico. Alternately, the Neoproterozoic grains may have been derived directly from the Goiás arc and transported to the eastern Gulf of Mexico by a proto-Orinoco river that developed during Jurassic-Early Cretaceous time.

Evolution of Late Cretaceous–Paleogene Foreland Sediment-Dispersal Systems of Northern and Central Mexico

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Abstract

Upper Cretaceous-Paleogene strata of northern and central Mexico were deposited in a retroarc foreland basin that was at first narrow but expanded eastward during the Paleogene. New petrographic data and U-Pb detrital zircon ages yield insights into stratigraphic age of the basin fill, sediment sources, and sediment-dispersal pathways. The basin differs from the contemporary Cordilleran foreland basin of the US to the north in having a dominant volcanic-lithic component in all of its sandstones. Like its northern counterpart, the Mexican basin migrated eastward with time, ahead of an advancing orogenic wedge. Provenance data indicate that the dominant sediment source for all strata was the coeval continental margin arc of western Mexico. Nevertheless, temporal differences in zircon content indicate distant sediment sources in basement and derivative sedimentary rocks of southwestern Laurentia during early (Cenomanian–Turonian) and late (Campanian–Maastrichtian and Paleogene) stages in basin evolution; during an intermediate stage (Coniacian–earliest Campanian), the Laurentian sources were absent and most pre-arc grains were derived from accreted rocks of western Mexico. The initial basin possessed a narrow foredeep filled by sediment-gravity flow deposits filled with dominantly axial sediment transport. Carbonate platforms of eastern Mexico supplied calclithites to the foredeep during early stages of basin formation, indicating the importance of pre-foreland paleotopography on sediment fill.

Sediment-dispersal systems evolved in concert with the stages of basin development. During the Cenomanian–Turonian stage, turbidites deposited in the Mesa Central had headwaters as far away as northern Sonora, but headwaters for Coniacian–Campanian deep-water deposits probably lay closer to central Mexico. Although late-stage uppermost Cretaceous–lower Eocene shallow marine and continental strata in the foreland of northeast Mexico were linked to a fluvial drainage basin whose extent was probably the greatest in Mexico, it is unclear if these clastic sediments ever reached the Gulf of Mexico. Partitioning of the distal foreland by inversion of Jurassic extensional basins in Santonian–Campanian time was probably effective at isolating dispersal systems of northern Mexico from time-equivalent sediment-routing systems of northeasternmost Mexico and southwestern Texas.

Regional Correlation of Lithofacies Within the Haynesville Formation from Onshore Alabama: Analysis and Implications for Provenance and Paleostructure

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Abstract

Although the Upper Jurassic Haynesville Formation is a proven hydrocarbon reservoir in the onshore eastern Gulf of Mexico, the unit remains understudied because exploration has been focused on the older and more productive Norphlet and Smackover Formations. In this study, we use cores, gamma ray logs, and spontaneous potential logs from 49 wells in southern Alabama to analyze the Haynesville Formation. We point-counted 18 sandstone samples from seven cores, and six sandstone samples from four of those cores were analyzed for detrital zircon age distributions. Core and well log analyses indicate that the Haynesville Formation can be subdivided into anhydrite, sandstone, and carbonate lithofacies. The thickness and distribution of these lithofacies suggests that relict basement topography derived from the opening of the eastern Gulf of Mexico during Late Triassic-Early Jurassic time is the primary influence on Upper Jurassic sediment distribution. Framework grain compositions indicate that the sandstone lithofacies was derived from a recycled orogenic provenance, indicating a primarily Laurentian terrane source with some mixing from the Gondwanan Suwannee terrane. Detrital zircon age distributions from Haynesville Formation sandstones contain major age populations that correspond with derivation from both the Laurentian Grenville Province and Appalachian Mountain source rocks, with some mixing from the Gondwanan Suwanee terrane. Haynesville Formation detrital zircon ages and sandstone compositions are similar to that of the underlying Norphlet Formation, indicating that the provenance and sediment transport pathways remained similar through deposition of the Upper Jurassic units.

Cenomanian Gulf of Mexico Paleodrainage from Detrital Zircons: Source-to-Sink Sediment Dispersal and Prediction of Basin-Floor Fans

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Abstract

U-Pb dating of detrital zircons in fluvial sandstones provides a method for reconstruction of drainage basin and sediment routing systems for ancient sedimentary basins. This paper summarizes a detrital-zircon record of Cenomanian paleodrainage and sediment routing for the Gulf of Mexico and U.S. midcontinent. Detrital zircon data from Cenomanian fluvial deposits of the Gulf of Mexico coastal plain (Tuscaloosa and Woodbine formations), the Central Plains (Dakota Group), and the Colorado Front Range (Dakota Formation) show the Appalachian-Ouachita orogen represented a continental divide between south-draining rivers that delivered sediment to the Gulf of Mexico, and west- and north-draining rivers that delivered sediment to the eastern margins of the Western Interior seaway. Moreover, Cenomanian fluvial deposits of the present-day Colorado Front Range were derived from the Western Cordillera, flowed generally west to east, and discharged to the western margin of the seaway. Western Cordillera-derived fluvial systems are distinctive because of the presence of Mesozoic-age zircons from the Cordilleran magmatic arc: the lack of arc zircons in Cenomanian fluvial deposits that discharged to the Gulf of Mexico indicates no connection to the Western Cordillera.

Detrital zircon data facilitate reconstruction of contributing drainage area and sediment routing. From these data, the dominant system for the Cenomanian Gulf of Mexico was an ancestral Tennessee River (Tuscaloosa Formation), which flowed axially through the Appalachians, had an estimated channel length of 1200-1600 km, and discharged sediment to the east-central Gulf of Mexico. Smaller rivers drained the Ouachita Mountains of Arkansas and Oklahoma (Woodbine Formation), had length scales of <300 km, and entered the Gulf through the East Texas Basin. From empirical scaling relationships between drainage-basin length and the length of basin-floor fans, these results predict significant basin-floor fans related to the paleo-Tennessee River system and very small fans from the east Texas fluvial systems. This predictive model is consistent with mapped deep-water systems, as the largest fan system was derived from rivers that entered the Gulf of Mexico through the southern Mississippi embayment.

Cenomanian Gulf of Mexico Paleodrainage—Application of Channel-Belt Scaling to Drainage Basins

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Abstract

Fluvial systems possess a range of scaling relationships that reflect drainage-basin controls on water and sediment flux. Quaternary channel-belt thickness (as controlled by bank-full water discharge) has been documented as a reliable first-order proxy for drainage basin size if climatic regimes are independently constrained. In hydrocarbon exploration and production, scaling relationships for fluvial deposits can be utilized to constrain drainage basin size with implications for sequence-stratigraphic interpretations.

This study documents the scales of channel belts within Cenomanian fluvial successions from the Gulf of Mexico. Data on single-story channel-belt scales were compiled from well logs and utilized to constrain contributing catchment areas of fluvial systems. The data indicate that the Cenomanian fluvial systems were significantly smaller than the Cenozoic fluvial systems, which can be related to drainage basin reorganization. These scaling relationships can be validated by regional paleogeographic maps and provide additional insight into the variability of sediment routing systems through time.

New Models of Early Cretaceous Source-to-Sink Pathways in the Eastern Gulf of Mexico

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Abstract

This study provides an assessment of two source-to-sink sediment routing systems of the Early Cretaceous and highlights sedimentologic changes that occurred in response to major tectonic reorganization of the eastern Gulf of Mexico during the Valanginian-Hauterivian stages. Depth-imaged 2D and 3D seismic data, well log correlation, sand grain size, and detrital zircon U-Pb data obtained from the Valanginian intervals of the cores of a key well, facilitates source-to-sink analysis of Early Cretaceous deep-water deposits, as well as construction of a new depositional model of Hosston equivalent-siliciclastics previously investigated only in the western Gulf of Mexico onshore areas.

U-Pb dating of detrital zircon grains suggests that Hosston siliciclastics observed in the 200-km-long base-of-slope sandy progradational delta-fed apron at the Florida Escarpment originated in a peninsular Florida source terrane – the Ocala Arch. Interpretation of 3D seismic data with nearby well control also allows conclusions to be drawn about the Appalachian-sourced Hosston fan system in Mississippi Canyon. This Appalachian-sourced sandy fan is believed to have terminated updip of a series of salt-related asymmetric expulsion rollovers, although we know sediment accommodation in these inverted basins was not confined to the Valanginian-Hauterivian age Hosston interval and extended from the Jurassic Cotton Valley-Bossier supersequence to the Late Cretaceous Navarro-Taylor supersequence. Two plausible models of Appalachian-sourced fan length are considered, incorporating calculations of salt rafting to estimate a best-case scenario fan length of 90-km, while a more probable fan geometry is determined from seismic observations and well control, yielding a Valanginian-Hauterivian submarine fan of 70-km length. The study presents a new paleogeographic model, with special focus on the eastern Gulf of Mexico and the interpreted sand-prone fan and progradational delta-fed apron. It also provides a robust model for source to sink transport during a critical phase of Gulf of Mexico basin evolution. The shorter fan length calculated in this study suggest the majority of asymmetric expulsion rollovers in Mississippi Canyon are either sandstone-poor or were sourced from a different, likely younger, source-to-sink system (*e.g.*, Late Cretaceous, Cenomanian-Turonian-age Tuscaloosa fluvial system).

Mesozoic Structure and Petroleum Systems in the De Soto Canyon Salt Basin in the Mobile, Pensacola, Destin Dome, and Viosca Knoll Areas of the MAFLA Shelf

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Abstract

Large parts of the De Soto Canyon Salt Basin are unexplored, and structural and petroleum system models may facilitate continued hydrocarbon exploration, as well as the development of geologic CO_2 storage programs. The basin contains four structural provinces: (1) Destin fault system, (2) salt pillow province, (3) diapir province, and (4) salt roller province. The Destin fault system bounds half grabens that formed near the updip limit of salt. The faults have variable displacement and were active mainly during the Cretaceous. Broad salt pillows occur basinward of the Destin fault system, and the largest of these structures forms the core of Destin Dome. Salt pillows basinward of Destin Dome began forming shortly after Smackover deposition, whereas Destin Dome largely post-dates the Destin fault system. The diapir province is in the structurally deepest part of the salt basin, and diapirism occurred from the Jurassic into the Tertiary. The salt roller province contains a complex array of normal faults and rollover structures that record gravitational shelf spreading during Jurassic time. Petroleum systems analysis indicates that the basin contains a distinctive suite of source rocks, sealing strata, reservoir strata, and trap types. Exploration efforts have thus far proven successful in structures that formed before or during hydrocarbon expulsion, and many such structures remain untested.

The Expression of the Cenomanian-Turonian Oceanic Anoxic Event 2 in the Gulf of Mexico: A Review

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Abstract

The Cenomanian-Turonian Oceanic Anoxic Event 2 (OAE2) is the last major OAE of the Mesozoic and probably the best studied. In marine rocks around the Gulf of Mexico it is associated with a variety of different environments, from well-oxygenated carbonate platforms to anoxic, organic-rich outer shelf environments and un-studied basinal muds. This paper reviews the current level of knowledge about the geographic distribution and stratigraphic expression of OAE2 in the Gulf of Mexico in order to synthesize this disparate data and attempt to draw some conclusions about regional oceanography during this critical interval of the Cretaceous.

A large number of localities with varying local redox states have been tied to OAE2, including the Valles-San Luis Potosí and Guerrero-Morelos platforms in southern Mexico, deep shelf sites in northern Mexico, the well-studied outcrops and cores of west Texas on the Comanche platform, cores and wells along the Barremanian-Albian shelf margin of south Texas, geophysical data in the East Texas basin, cores in the Marine Tuscaloosa Formation of Louisiana, Alabama, and Mississippi, and deep wells in the deep water Gulf of Mexico. The distribution of anoxic sediments at these sites during OAE2 appears to be determined by water depth. Shallow sites, like the Mexican carbonate platforms and the Comanche platform of Texas, are oxygenated during the event. Deeper shelf sites, like the south Texas Rio Grande submarine plateau and the noncarbonate platform parts of the Mexican shelf, are anoxic and enriched in organic carbon; it seems likely that this trend continues across the rest of the Cretaceous Gulf shelf, although data is sparse. Whether this oxygen minimum zone only impacts the deeper parts of the shelf or extends all the way to the basin floor is the most significant outstanding question about OAE2 in the Gulf of Mexico.

The KPg Impact Deposits in the Tampico-Misantla Basin, Eastern Mexico

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Abstract

The impact of the asteroid (KPg impact event) at Chicxulub is now a well-documented geologic event which took place at the Cretaceous/Paleogene (KPg) boundary (Schulte *et al.*, 2010). However, the effect of this event is relatively unknown in the Tampico-Misantla Basin, which is only about 900 km to the west of the impact site.

In the detailed well reports in the Tampico-Misantla Basin, it is noted that a "brecha" (breccia) is often described at the top of the Cretaceous in many of the wells.. The breccia is described as being gray or white, containing mudstone clasts, having a sandy matrix, recrystallized *Globotruncana*, and traces of chert, amber, and bentonite (for example, in the Marques-1 well). Early geologists thought the breccia had been deposited in response to the Laramide uplift of the Sierra Madre Oriental. To our knowledge, none of the 100 project wells cored the breccia.

The same KPg breccia crops out in the southern part of the Tampico-Misantla Basin to the southwest of the town of Martinez de la Torre (Figs. 1 and 2). Here, the breccia is a clast-supported conglomerate consisting of cobbles and boulders of limestone, sandstone (medium to coarse grained), and quartz. The matrix is a medium- to coarse-grained sandstone. The KPg contact has been documented just to the west of this outcrop (Mark Bitter, personal communication). The limestone clasts are thought to have been derived from the Tuxpan platform to the northeast, and the sandstone clasts are thought to have been derived from the Sierra Madre Oriental to the west by the backwash of the tsunami generated by the impact event.

In many of the well reports, the wellsite geologists also note that the "Velasco Formation" overlies this breccia. The Velasco Formation is always described as a shale, red, gray, or brown, and compacted. The Velasco Formation has been cored in the Entabladero-101 well from 1140-1149 m and the core has been described as compacted grey/brown shale (Fig. 3). It is devoid of sand.

In this study, the presence and thickness of both the breccia and the Velasco Formation were noted and mapped from the well reports. The wells were drilled between 1936 and 2010 and the early wellsite geologists were probably not always aware of the detailed stratigraphic sequence and certainly not aware of the relevance of the breccia in the basin. The thicknesses of both the breccias and Velasco Formation were estimated from the cuttings descriptions in the wells.

The breccia is absent in the northern third of the Chicontepec Basin. The thickness of the breccia deposit varies between 4 m and 38 m, and is generally about 10-15 m thick. The deposit is fan-shaped, the source is interpreted to be from the northeast (Tuxpan platform), and it pinches out to the southwest (Fig. 4). The only carbonate source area that is present to the northeast is the Faja de Oro atoll, an Albian age reef complex. Additionally, the distribution of the Velasco Formation seems to mimic the distribution of the breccia, albeit covering a slightly larger area. The Velasco Formation varies in thickness between 16 m and 145 m, but it is generally in the range of 30 to 40 m thick.

It is proposed that the breccia plus the Velasco Formation are actually a "megabed" created by the huge tsunami (estimated by some authors to have been over 300 m high) from the KPg impact event (Fig. 5). Many other megabeds around the world show these same characteristics (Cossey and Ehrlich, 1979). The breccia would represent the basal Bouma "A," or graded division. The Velasco Formation would represent the muddy top, or Bouma "E" division. A good analog for this megabed is from the Jurassic of northern Tunisia (Cossey and Ehrlich, 1979) where a carbonate megabed up to 90 m thick is exposed.

Prior to the KPg impact event, the Tampico-Misantla Basin is primarily a site of carbonate deposition throughout the Cretaceous. Afterwards, the Chicontepec Basin forms as a foredeep in front of the rising Sierra Madre Oriental to the west. The overlying Paleocene Chicontepec Formation consists of turbidite sands composed of over 50% carbonate material (Bitter, 1993) derived from the uplift and erosion of the Sierra Madre Oriental.

Deep-Seated Dynamics Including Crust and Upper Mantle Impacting Hydrocarbon Localization Within Sediment-Filled Basins

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Abstract

Hydrocarbons occur within sediments in basins within the uppermost crust. Localization is affected by regional temperature and pressure gradients as well as anomalies in sediment distribution; porosity and permeability; and breakages (faults, joints and fractures) in both soft and hard materials. In our search for these hydrocarbons, we map and record geophysical and geochemical anomalies, generally caused by sediment and crustal tectonics. Many of these in turn appear influenced and guided by lower crust-upper mantle interactions that include, among others, buoyant mantle plumes and lateral plate tectonics. In order to better understand how such a total geologic system operates, it is necessary to think of this entire sediment - basin - crust - upper mantle complex as a single unit. We must seek new and pertinent explanations for hydrocarbon occurrences including these mantle and crust influences as we extend our exploration models into new frontiers.

In summary, the cumulative actions of the entire geologic system including upper mantle to upper crust create forces and dynamics capable of modifying overlying basins and hydrocarbon-bearing sediments recording these underlying forces. We suggest that the whole petroleum system concept needs examination in light of upper mantle and crust dynamics.

With mantle plumes causing the Late Triassic North Atlantic Rifting, the evolutionary scenario here is appropriate explanation for continental rifting followed by basin initiation and subsequent deepening and in-filling and locating hydrocarbons. Plume and crust interactions and derivatives are a constant input impacting hydrocarbon formation.

Lithological and Geochemical Analysis to Reduce Uncertainty in the Exploration of Unconventional Gas Deposits in the Burro-Picachos Basin, Northeastern Mexico

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Abstract

In the search for unconventional reservoirs, one of the geological formations most studied in the United States is the Eagle Ford (Upper Cretaceous), which extends from the state of Texas in United States to the northeastern portion of the Mexican republic. The Eagle Ford Formation consists of argillaceous limestones and calcareous siltstone deposited in a mixed environment. These lithologies have petrophysical and geochemical characteristics sufficient to be considered as producing gas and/or oil, depending on the content of organic matter and the degree of maturity thermal reached.

In the northeast of the State of Coahuila, based on lithology, paleontological content, and TOC, Eagle Ford formation can be divided into three units:

Biozone A:

- *Heterohelix sigali* and *Helvetoglobotruncana helvética*, dominated by limestone, in platform environments, thicknesses of 16 to 100m, and TOC content of 0.56% to 1.65%.

Biozone B:

- *Whiteinella archaeocretacea*, limestone and calcareous shales, interbedded lithologies, deposited in slope environment, thickness of 30 to 70 m, and TOC content of 0.91% to 2.51%.

Biozone C:

- *Rotalipora*, black shales deposited in suboxic basin, thicknesses of 60 to 95m, and TOC content of 1.86% to 5.2.

With the thickness distribution of the proposed units, it can be interpreted that the variation in the water depth depends on the topographic relief that prevailed in the Late Cretaceous (Cenomanian–Turonian) in the northeastern portion of Mexico: in a shelf and basin environment, influenced by Maverick Basin. Geochemical data analyzed and the proposed subdivision, indicates that Biozone C drive is the thickest, and has more TOC content in the northeastern part of the Burro-Picachos Basin; the predominant type of kerogen in the area is the type III.

Using the Dykstra-Parson method to determine the homogeneity of the distribution of values of each proposed unit, Biozone A has a higher degree of homogeneity than Biozone C. However, based on TOC and degree of homogeneity, Biozone B has a lower degree of exploration.

Stratigraphy of Fredericksburg-Washita Division (Albian), Comanche-Cretaceous, Texas, Emphasizing Person and Georgetown Formations

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Abstract

A regional network of five interlocking stratigraphic cross-sections compiling the published work of many geologists throughout central and southwest Texas demonstrates the true stratigraphic relationships among formations of the Lower Cretaceous Fredericksburg and lower Washita subcycles. Strongly supported by a long-established ammonite zonation, these detailed stratigraphic cross-sections show lateral relations between Edwards Group formations (Kainer, Person, Fort Terrett, Segovia, Fort Lancaster, and Devils River) of the Central Texas Platform with equivalent formations of the East Texas Basin (Walnut, Comanche Peak, Goodland, Georgetown) and the Maverick Basin of South Texas (West Nueces, McKnight, Salmon Peak). These cross-sections document the following regional stratigraphic relationships:

1. The Burt Ranch Member (basal Segovia Formation), the Regional Dense Member (basal Person Formation), and the Kiamichi Member (basal Georgetown Formation) are stratigraphic equivalents, all three being in the *Adkinsites bravoensis* Ammonite Zone (lowermost Washita)
2. The peritidal Person Formation is the shelf-interior equivalent of the pelagic-shelf Georgetown Formation, except for its uppermost member, the Main Street, which forms the thin remnant Georgetown Formation on the distal Central Texas Platform.
3. Thus the Person Formation is properly assigned to the lower Washita subcycle, not the Fredericksburg.

Integral Analysis of the Opening of the Gulf of Mexico and its Relationship with the Sedimentary Basins Generation

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Abstract

This paper integrates, analyzes, and interprets the existing geological and geophysical information related to the opening of the Gulf of Mexico. The analysis of this information has the objective to consider the opening of the Gulf of Mexico as a result of global tectonic processes. Without doubt, the opening of the Gulf of Mexico has its origin in the interaction of two important tectonic events that generated the separation of Pangea: the Farallon Plate subduction in the Pacific and on the opening of the Central Atlantic, whose start is marked by the presence of the Central Atlantic magmatic province.

A proposal of this work is that as much oceanic crust was generated in the Oxfordian, as part of the stage in the Central Atlantic Jurassic opening. This Oxfordian period is characterized by a large positive geomagnetic chron, which explains the absence of polarity changes in the magnetic response for the Gulf of Mexico.

Another proposal is that the Sierra de Chiapas is the transpressional front that represents the final stage in the gulf opening and is associated with the edge effect of gravity anomaly that can be observed in the overall gravimetric maps.

The proposed model assumes that the magmatic arc causes continental rifting, creating basins containing red beds deposits that are located parallel to the orientation of the arc; these rifting areas evolve to form the subbasins of Chihuahua, Sabinas, and Burgos in the northeast of Mexico and Tampico Misantla, Veracruz, and Southeastern basins in eastern Mexico.

Albian Stratigraphy of the San Marcos Platform, Texas: Why the Person Formation Correlates with Upper Fredericksburg Group not Washita Group

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Abstract

Uppermost Aptian-Albian-lower Cenomanian strata of the Texas Comanchean Series represent three long-term transgressive-regressive cycles: the Trinity, Fredericksburg, and Washita groups that are composed mainly of marine limestone and shale. Each group is composed of shorter term deepening-shallowing cycles. On the Central Texas San Marcos Platform and its downdip equivalents, subsurface strata above the Trinity Group are grouped into the Edwards and Washita groups. Correlations in the 1960s were based on wire-line well logs and inferred biostratigraphy that correlated the upper Edwards Group Person Formation with the lower parts of the Washita Group. This correlation crosses a widespread subaerial unconformity that separates the Washita from the underlying Fredericksburg in the northern East Texas Basin and in the Fort Stockton Basin. New biostratigraphic and sedimentological data show that the Person actually correlates with the upper part of the Fredericksburg in the Gulf Coast.

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