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Caribbean Basins, Tectonics, and Hydrocarbons
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## Table of Contents

Three-dimensional relationships between synchronous normal faulting, folding, and sedimentation in the Columbus Channel, offshore southern Trinidad ........................................... 1

GIS-based hydrocarbon resource map of the Mexican sector of the Gulf of Mexico........... 2

Hydrocarbon potential of the Nicaragua Rise based on reevaluation of vintage seismic and well data from the 1970s and 1980s ........................................................................................................ 3

Tectonostratigraphic and hydrocarbon framework of the Colombian offshore margin from the Magdalena Delta to Panama .................................................................................................. 4

Mesozoic Caribbean plate reconstructions based on a revised fit of Precambrian and Paleozoic terranes in northwestern South America and Central America ............................................. 5

Tectonic and stratigraphic setting of gas fields of the north coast marine area, offshore northern Trinidad and Tobago basin ............................................................................................... 6

Tectonic controls for three main subsidence phases of the Eastern Venezuelan Foreland Basin in the region of the Orinoco Delta. ........................................................................................................... 7

Impact of tectonic setting and diagenetic history on the reservoir potential of Eocene to Miocene on- and offshore, deepwater sandstones, northern South America ............................... 8

Index of authors ................................................................................................................................................................................................................. 9
**SCHEDULE OF CBTH PRESENTATIONS**

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<table>
<thead>
<tr>
<th>Time</th>
<th>Monday 08 June 09</th>
<th>Tuesday 09 June 09</th>
<th>Wednesday 10 June 09</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00</td>
<td>Emmet et al.: Hydrocarbon potential of the Nicaragua Rise based on reevaluation of vintage seismic and well data from the 1970s and 1980s [page 3]</td>
<td>Norton et al.: Mesozoic Caribbean plate reconstructions based on a revised fit of Precambrian and Paleozoic terranes in northwestern South America and Central America [page 5]</td>
<td>Alveez et al.: Three-dimensional relationships between synchronous normal faulting, folding, and sedimentation in the Columbus Channel, offshore southern Trinidad [page 1]</td>
</tr>
<tr>
<td>01:00 pm</td>
<td>Nolte et al.: Mesozoic Caribbean plate reconstructions based on a revised fit of Precambrian and Paleozoic terranes in northwestern South America and Central America [page 5]</td>
<td>5:00 pm</td>
<td></td>
</tr>
<tr>
<td>5:00 pm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

« iii »
Three-dimensional relationships between synchronous normal faulting, folding, and sedimentation in the Columbus Channel, offshore southern Trinidad

Tricia Alvarez, Lesli Wood, and Paul Mann

Analysis of 9000 km² of 3D seismic data combined with eight wells in the Columbus Basin shows the three-dimensional relationships between synchronous listric normal faults, folds, and sedimentary infilling during the late Quaternary (last 500,000 yrs). Previous tectonic models have emphasized either convergent structures related to the active Columbus foreland basin or the extensional structures produced by gravitational sliding or strike-slip faulting and pull-apart basin formation. 3D seismic data shows that normal faults are gravitationally-driven and synchronous with orthogonal to broad open folding of the Columbus Basin shelf.

Northwest-to-southeast-striking normal listric faults and the northeast-to-southwest striking anticlines created structural traps which contain the three billion barrels of proven oil and 22 trillion feet of gas stored in vertically-stacked reservoirs. Within this complex tectonic framework, 12-15 km of Plio-Pleistocene sediments were deposited on the shelf and slope at extremely high sedimentation rates of ~3 mm/yr. Synclines are parallel to the direction of shelfal sediment transport and contain thickened sections along their synclinal axes. Margin-parallel listric normal faults were formed during oversteepening of the shelf and slope margin at the southeastern margin of the Columbus foreland basin. Prograding sediments of the Orinoco Delta combined with eustatic lowstands leads to pulses of activity for the listric normal faults.

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3 Institute for Geophysics, John A. & Katherine G. Jackson School of Geosciences, The University of Texas, Austin, Texas, USA.
GIS-based hydrocarbon resource map of the Mexican sector of the Gulf of Mexico

Lisa Bingham¹, Alejandro Escalona², and Paul Mann¹

In order to better understand the structure and stratigraphy of the Mexican sector of the Gulf of Mexico and their implications for hydrocarbon potential, we have constructed an ESRI ArcGIS geodatabase containing over 200 data features compiled from more than 80 published references.

The main purpose of the geodatabase is to compile published hydrocarbon data for the Mexican sector of the Gulf of Mexico into a geographic information system. Seismic lines, well logs, stratigraphic columns, cross sections and outcrops that could be accurately georeferenced were digitized. Each digitized feature was assigned a unique identification number. Other attributes for the features include: source information, digitized coordinates, and one representative graphic from the original publication. This database can be easily updated as newer data becomes available.

This type of database allows the geoscientist to quickly scan an area and see previous work in the region, to view the interpretations and obtain relevant information. One example of the use of this type of database is for field work preparation and outcrop sample collections. The geoscientist may review outcrop sample locations in relation to geologic and topographic maps and may plan sample locations on this information.

The geodatabase also contains information to provide either fast interpretation from published data or as a check to surface mapping by creating contours from well log picks. The surface mapping must be created first in the interpretation software of choice (for example, Petrel or ZMap) and exported into an ArcGIS raster (or grid). The well log picks from the published data can be used as a point check or—if there is sufficient amount of data—the well log picks can be contoured to analyze trends. This allows the newly-interpreted and contoured data to be overlain and compared with existing maps of the area.

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Hydrocarbon potential of the Nicaragua Rise based on reevaluation of vintage seismic and well data from the 1970s and 1980s

Peter A. Emmet1 and Paul Mann2

The 270,000 km² area of the Nicaragua Rise (NR) offshore Honduras and Nicaragua (defined by 2,000 m isobath) remains underexplored from 33 exploration wells drilled from 1970-80 with numerous oil and gas shows but no commercial production. Assessment of offshore prospectivity is limited; only two exploration wells on NR have been drilled in water depths >100 m. Synthesis of 13 wells and 6,200 km of 2D seismic (1970-80) in Honduran waters and construction of regional structure and isopach maps clarify the evolution of this modern carbonate bank with deep-water reentrants. U. Jurassic syn-rift clastics are overlain by U. Cretaceous carbonates. Regional N-S shortening in the Cenomanian led to the demise of the carbonate platform with accumulation of organic-rich carbonates and gypsum in restricted basins. An U. Cretaceous basal chert-bearing conglomerate is overlain by fine-grained redbeds of U. Cretaceous age. An angular unconformity separates deformed Mesozoic strata from overlying Tertiary clastic and carbonate rocks. Eocene strata locally present above the unconformity are clastic on the northern flank of NR and carbonate on the southern flank. An Oligocene section is thin or absent but Miocene and Pliocene strata are locally very thick and predominately clastic. The northern flank of NR (Tela basin) is a continental borderland across which Miocene turbidites and Eocene (?) and Cretaceous strata drape over deep-seated basement structures, and numerous deep (>4000 m) subbasins remain unexplored with modern seismic or drilling. Drilling in 1973 documented an active hydrocarbon system comprising rich M. Eocene source rocks and fractured M. Eocene carbonate reservoir rocks in the Mosquitia basin which straddles the crest of the east-plunging NR. North-trending grabens that cross NR may bury M. Eocene strata sufficiently to have charged commercial oil accumulations. The top Cretaceous marker is a broadly-arched angular unconformity below which is a thrust-fold belt comprised of U. Cretaceous strata. An active oil-prone Cretaceous hydrocarbon system is suspected, and the presence onshore of coal-bearing clastics of U. Jurassic age suggests that a pre-Cretaceous gas-prone hydrocarbon system is possible.

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Tectonostratigraphic and hydrocarbon framework of the Colombian offshore margin from the Magdalena Delta to Panama

Xiangyun Jiang1, Paul Mann1, and Alejandro Escalona2

The offshore margin of Colombia is underlain by the South Caribbean or Sinu belt, a northwest-facing and active accretionary wedge composed of folded and thrusted sedimentary rocks of at least Oligocene-Recent age. Using 10,000 km of industry seismic data and 12 offshore wells, we identify four tectonostratigraphic sequences within the deformed wedge or in the less deformed basins overlying it that range in age from Oligocene to Pleistocene and extend as semi-continuous features for 380 km from the Magdalena delta to Panama. We have mapped 10 major thrusts and associated anticlines which deform the underlying prism and can be followed for 90 km along strike of the prism. Sequence 1 of Oligocene age has low frequency and variable amplitude on seismic data, is deformed as part of the main accretionary prism, and is correlated to coarse conglomerate of the Pavo Formation in 2 offshore wells and onshore outcrops of the Sinu belt in coastal Colombia. Sequence 2 of early Miocene age has low frequency and high amplitude, is 300-1000 m in thickness, is deformed as part of the main prism, and is correlated to mud, silt, sand and limestone of the Floresanto Formation in 8 offshore wells and onshore outcrops of the Sinu belt in coastal Colombia. The top of Sequence 2 is defined by a widespread angular unconformity of middle Miocene age that separates the highly deformed prism sequences 1 and 2 from the less deformed sequences 3 and 4 deposited in two overlying piggyback basins (San Bernardo and Fuerte). Sequence 3 of late-middle Miocene to Pliocene age has high frequency, variable amplitude, is 250-1500 m in thickness, and is correlated to turbiditic siltstone of the Pajuil Formation in 11 offshore wells and onland outcrops. Sequence 4 of late Pliocene-Pleistocene age has low frequency, low amplitude, is 200-1800 m in thickness, and is correlated to conglomerate of the Corpa Formation in 10 offshore wells and onland outcrops. The piggyback basins are formed during late Miocene to Pliocene age. The San Bernardo basin, located in the modern shelf margin, has a subsidence pattern that may relate with Oblique-slip. The Fuerte basin in the southern part of the area may relate with the Panama subduction. Source rocks in the area correspond to early Oligocene and early Miocene age organic-rich source rocks with generation potential since the middle Miocene. Reservoir rocks are middle Miocene-Pliocene deepwater turbidites sourced by Magdalena River and more localized sources in the adjacent mountain belts.

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Mesozoic Caribbean plate reconstructions based on a revised fit of Precambrian and Paleozoic terranes in northwestern South America and Central America

*Ian Norton¹, Alejandro Escalona², Paul Mann¹, and Lawrence A. Lawver²*

A fundamental problem in the Pangea reconstruction of North and South America is an overlap between Precambrian and Paleozoic continental fragments in Mexico, Central America and northwestern South America. This overlap, as much as 400 km in some reconstructions, reflects either post-rifting (Cretaceous and younger) plate motions that have shifted crustal blocks towards the Caribbean and/or syn- or post-rift extension (late Jurassic and younger) of these older blocks that needs to be restored. A problem is that the crust of many of the overlapping areas is now covered by either water or younger rocks (Trans Mexican Volcanic Belt, Yucatan Peninsula, E. Honduras and Nicaragua, Nicaraguan Rise, areas of northern South America). Recent work in southern Mexico has begun to decipher the Mesozoic accretion history of this area and there is more data on crustal thicknesses and hence extension magnitudes in Jurassic rift basins in northern South America. In addition to Mesozoic extension, the shape of South America has been changed by large strike slip faults such as the Bocono Fault and faults bounding the Santa Marta Massif. We use displacement constraints on these faults and also constraints from deformation within the Andean foldbelts to generate improved Mesozoic plate reconstructions.

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Tectonic and stratigraphic setting of gas fields of the north coast marine area, offshore northern Trinidad and Tobago basin

Stefan Punnette¹, Paul Mann², and Alejandro Escalona³

The North Coast Marine Area 1 (NCMA1) exploration block is a 500 km² exploration block that is located 40 km north of the island of Trinidad and 60 km west of the island of Tobago. The block straddles the east-northeast-trending continental shelf of northern offshore Trinidad and slope of the 14 km-deep Tobago basin. Gas was discovered in 1971 and wells drilled at shelfal depths commenced development on two (Hibiscus, Chaconia) of three large gas fields in 2001. All gas production is presently restricted to the NCMA shelf edge although present exploration for gas and condensate is being carried out along the deeper water slope of the Tobago basin. In this presentation, we show a series of academic, deep penetration 2D lines to illustrate:

1. The deep and shallow structure of the Hinge Line fault zone (HLFZ), the main structure underlying the NCMA1 production area and responsible for structural traps within the field that is producing from Pliocene reservoirs. The HLFZ is a down-to-the-northwest fault with apparent normal throw.

2. The presence of the Middle Miocene unconformity beneath the NCMA1 and onto the Trinidad shelf; this unconformity is locally angular and may act as a structural trap.

3. The correlation of Paleogene and Neogene units present in the adjacent 14 km-thick Tobago basin and thinning across the shelf-slope break and onto the northern Trinidad shelf; the deep Tobago basin is filled by two megasequences (1 and 2) of Paleogene to Middle Miocene age and totaling 11.5 km in thickness. And,

4. Possible gas and condensate updip migration routes located from a zone of potential mature source rocks at depths of 8 to 11 km beneath the Tobago basin. Thermal modelling shows that Paleogene rocks are mature at depths of 5.4 to 9 km in the Tobago basin and may have generated thermogenic gas; updip migration of gas from these depths indicates that faults of the HLFZ at the basin edge are non-sealing and allow the migration of basin-derived gas into shallow reservoirs beneath the shelf area.

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Tectonic controls for three main subsidence phases of the Eastern Venezuelan Foreland Basin in the region of the Orinoco Delta.

Gustavo Taboada1, Paul Mann2, and Alejandro Escalona3

We use subsidence analysis of three deep wells to basement combined with sequence stratigraphic mapping of seismic data to show that a 6684 km² area of the Eastern Venezuelan foreland basin in the region of the Orinoco Delta underwent three main stages of foreland-related subsidence that followed a protracted Cretaceous - Late Oligocene period of precollisional, passive margin formation. Phase 1 consists of increased foreland basin subsidence in the late Oligocene to middle Miocene (23 - 13 Ma) at average sedimentation rates of 0.09 mm/yr. Clastic rocks of Phase 1 include the Freites Formation, a 1.2 km-thick section of greenish-gray fissile shale and shaly sandstone deposited in shallow marine-neritic environments. Seismic facies show progradation of Phase 1 clastic rocks as a wedge from the NE and NNE. Clastic rocks deposited during the accelerated Phase 2 in the middle to late Miocene (13-11 Ma at sedimentation rates of 0.92 mm/yr) include the La Pica Formation, a 2.7 km-thick section of gray silt and fine-grained sandstone deposited in shallow marine/coastal proximal environments. Seismic facies show progradation of Phase 2 clastic rocks as a wedge to the NE. Phase 3 consists of decelerating foreland basin subsidence in the period of Late Miocene-Mid Pliocene (11-6 Ma at average sedimentation rates of 0.36 mm/yr). Sedimentary rocks deposited during this period include the Las Piedras Formation a 1.45 km-thick section of sandstone, carbonaceous siltstone and shale deposited in deltaic environments. Seismic facies show a progradation of Phase 3 clastic rocks as a wedge to the NE and ENE. Deeper marine environments and more rapid subsidence rates of Phases 1 and 2 are interpreted as an underfilled foreland basin stage related to active thrusting along the Serrania del Interior along the northern flank of the basin. Deltaic environments and slower rates of Phase 3 are interpreted as an overfilled foreland stage related to rapid seaward progradation of the Orinoco delta and its filling of the former dynamically-maintained interior seaway.

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Impact of tectonic setting and diagenetic history on the reservoir potential of Eocene to Miocene on- and offshore, deepwater sandstones, northern South America

Xiangyang Xie¹, Paul Mann¹, and Alejandro Escalona²

The deep structure and stratigraphy of 3- to 12-km-thick Eocene to Miocene clastic sedimentary basins have been studied using seismic reflection data and compilation of existing well data from on- and offshore basins of the Lesser Antilles arc and forearc, the Barbados accretionary prism, and the Maracaibo and Falcon basins of western Venezuela. Offshore basins of northern South America remain largely undrilled and consequently have yielded only a major giant gas field and small discoveries of oil and gas. In this study, we summarized results of a petrographic study of 80 sandstone samples from Eocene to Miocene wells and outcrops from the region of northern South America to show the importance of the basin’s tectonic setting and diagenetic history on the reservoir potential of Eocene-Miocene sands; we also compare producing onland reservoirs with potential offshore reservoirs of roughly equivalent age. Point counting of sandstone grain types show that samples from Eocene foreland basin settings in the Maracaibo basin (Q85F5L10), Falcon Basin (Q75F13L12), Trinidad (Q92F5L3), and Barbados (Q95F3L2) are compositionally mature with higher quartz percentages (>75%), characteristic of the recycled orogenic and cratonic provinces in Gazzi-Dickinson’s sandstone model. In contrast, outcrop samples from the Eocene forearc basin near Margarita Island show higher percentages of volcanic rock fragments and clay (Q42F33L25) consistent with their location adjacent to a now inactive part of the Lesser Antilles arc. Quartz cementation, especially quartz overgrowth is a major cause of primary porosity-loss and secondary porosity in all samples along with dissolution of feldspars, calcite cementation, and leaching of other unstable rock fragments. Outcrop samples from Barbados exhibit unusual diagenetic effects not seen in other areas that include leaching and fracturing of quartz grains which cause much higher secondary porosity. Interpreted diagenetic stages for both outcrop and well samples include: clay rims, mechanical compaction, quartz overgrowths, generation of secondary porosity by dissolution, precipitation of kaolinite in the secondary pore, and iron-oxide cementation. Potential Eocene to Miocene reservoir rocks from the Falcon, Trinidad and Barbados show similar reservoir characteristics and quality as those known reservoirs in the Maracaibo Basin. However, basins near arcs like Margarita have less potential.

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## Index of authors

<table>
<thead>
<tr>
<th>Author</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alvarez, Tricia</td>
<td>1</td>
</tr>
<tr>
<td>Bingham, Lisa</td>
<td>2</td>
</tr>
<tr>
<td>Emmet, Peter A.</td>
<td>3</td>
</tr>
<tr>
<td>Escalona, Alejandro</td>
<td>2, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>Jiang, Xiangyun</td>
<td>4</td>
</tr>
<tr>
<td>Lawver, Lawrence</td>
<td>5</td>
</tr>
<tr>
<td>Mann, Paul</td>
<td>1, 2, 3, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>Norton, Ian</td>
<td>5</td>
</tr>
<tr>
<td>Punnette, Stepfan</td>
<td>6</td>
</tr>
<tr>
<td>Taboada, Gustavo</td>
<td>7</td>
</tr>
<tr>
<td>Wood, Lesli</td>
<td>1</td>
</tr>
<tr>
<td>Xie, Xiangyang</td>
<td>8</td>
</tr>
</tbody>
</table>