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The Origin Of The Gulf Of Mexico, Its Sedimentary Basins And The Type And Abundance Of Its Hydrocarbon Deposits Were Mainly The Product Of The Evolution Of A Hotspot Since The Early Middle Jurassic Time

KEYWORDS: Gulf of Mexico, Hot Spot, Oil basins, Jurassic.

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ABSTRACT *The origin of the Gulf of Mexico, based on the existence of a triple junction hot spot, allows us to understand the origin of the "Hispanic Corridor", the oil and gas systems, and the hydrocarbon deposits found in the Texas-Louisiana subplate and in the Mexican Petroleum basins. This model was based on red beds, conglomerates and salt Palynostratigraphy and Inorganic Geochemistry data obtained from Mexican Oil productive and unproductive Basins. It has implications about the origin and evolution of the Texas-Louisiana Subplate, bounded by the Lewis-Clark and Texas-Boquillas-Sabinasmegashears, about its northwestward movement and 800 km displacement of the Ouachita System and its relation, since the Jurassic (during Cordilleran Orogeny), to tectonic phenomena in the Pacific subduction region such as Sevier and Laramideorogenies. Furthermore, the model can help explain the origin and evolution of the Western Region of Mexico, the Chiapas-Yucatán subplates and their Gulf oil and gas basins.*

Introduction

The North American Stratigraphic Code defines an Allostratigraphic Unit as a mappablestratifom body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities. Frequently, it is not easy to differentiate and to place these units geochronologically, as they are composed by red-beds, evaporitic rocks and conglomerates, which are considered as azoic bodies between the sedimentary sequences deposited in grabens and half-grabens. Nevertheless, Paleopalynology and Inorganic Geochemistry proved to be two very useful sciences in order to place red beds in time and space. During the early twentieth century, three Mesozoic red-bed units were differentiated (Huizachal, La Joya and Cahuasas) in the Mexican NE region (Figure 1), but were chronologically placed from the Late Triassic to the Late Jurassic. As they were considered the base of the marine sequence containing oil and gas in some Mexican Gulf of Mexico sub-basins, it was stratigraphically very important to place them properly, in particular where they were not found alone.

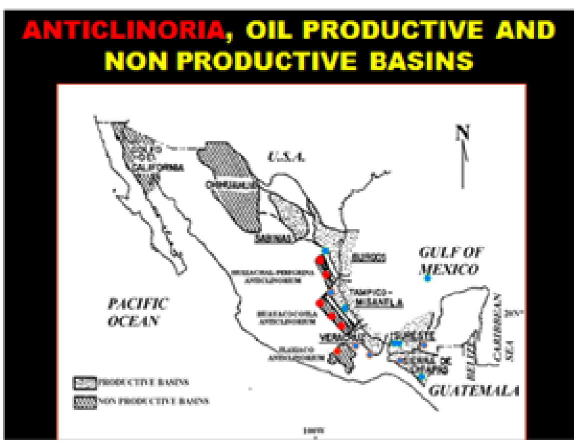

Figure 1

During 1969, palynological analyses allowed to date to the Middle Jurassic the Cahuasas Formation red-beds located in the Tampico-Misantla sub-basin and to correlate them with evaporitic rocks drilled by the Glomar Challenger vessel from the caprock of the Challenger Knoll in the central region of the actual Gulf of Mexico (Kirkland D.W. and Gerhardt, J.E., 1971). The correlated pollen and spores found in both regions allowed us to identify the presence of a continental environmental connection between those places (Rueda Gaxiola, J., 1972) (Figure 1). Based on these results, the Palynostratigraphical Method was created in 1970 at the Mexican Petroleum Institute (Rueda-Gaxiola., J. 1999) in order to study the origin and evolution of the Mexican sub-basins around the Gulf of Mexico. Since 1971, this method has been applied in Mexican oil producing and non-producing oil basins because it provides the basis to obtain stratigraphic conclusions useful for reconstructing the evolution of the basins and their petroleum potential. The results allowed us to: 1) characterize lithological units (Lithostratigraphy), 2) know the organic matter components of lithological units (Biostratigraphy), 3) establish the age of lithological units, 4) reconstruct paleoenvironmental conditions (Paleoecology), 5) deduce the sedimentary conditions and geographic distribution of lithological units (Paleogeography), and 6) interpret the burial history and diagenesis of lithological units in order to know how hydrocarbons generated, migrated and accumulated in the basin (Rueda-Gaxiola, J. and Santillán, M. A. 1986).

Figure 2

The first application of this method was carried out during 1971-1975 for studying the organic and inorganic constituents found in the palynological residue of Liassic

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rocks from the Tampico-Misantla Oil Sub-basin (Figure 2). The abundance and regional distribution of pollen, spores and wood fragments show that during the Early Jurassic, a transitional and high and large continental area covered with trees was present toward the eastern part of the Liassic Huayacocotla Formation (Rueda-Gaxiola, J., 1975).

Theme development

The Palynostratigraphic Method has been the most successful tool for establishing the correlation, in terms of allostratigraphic units, between three sections of the Late Triassic-Early Jurassic half-graben, named El Alamar-Tlaxiaco, more than 1000 km long, related to the origin of the Gulf of Mexico. X-Rays diffraction and fluorescence analyses, as well as Miall's method of facies analysis applied to fluvial deposits, supported the palynostratigraphic results. These sedimentary continental sequences of the Huizachal-Peregrina, Huayacocotla and Tlaxiaco anticlinoria, bordering the western Gulf of Mexico, were deposited in three sectors of the same half-graben, one of two basins parallel to the western border of Pangea, but crossing perpendicularly three main tectonic blocks delimited by long faults (Figures 1, 8 and 16).

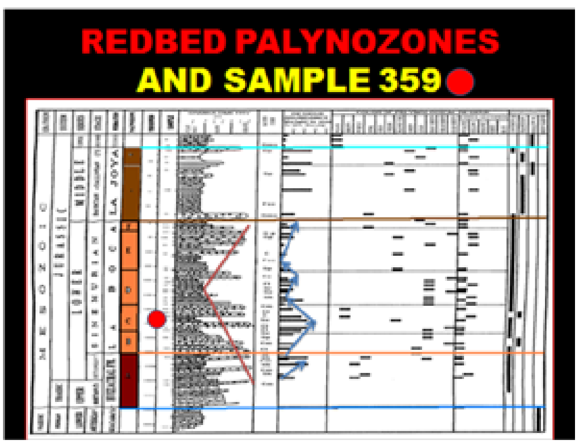

Figure 3

The first regional palynostratigraphic analysis was made during 1988-1994 on the red-bed sequence outcropping at the northern Huizachal-Peregrina Anticlinorium (Figure 1); the results allowed to know that it is composed by three units (Huizachal, La Boca and La Joya) characterized by 8 palynozones based on the color and abundance of palynological residues (Figure 3). The first two are alloformations of the Los San PedrosAllogroup; the third one is the La Joya Formation (Rueda-Gaxiola, J. *et al.*, 1999). Microscopic analyses of palynological residues showed mainly continental organic matter but continental and marine palynomorphs from the Sinemurian and Pliensbachian ages were found in sample 359 from palynozone B.

X-Rays Diffracction and Fluorescence analyses of rocks and palynologicalresidues, supported the idea of a marine environment, based on the presence of glauconite in rocks above and beneath sample 359 (Rueda-Gaxiola, J., 2010 and 2011). Structural and palynostratigraphic data allowed us to conclude that a Liassic allostratigraphic sequence was deposited in a half-graben (named Huizachal-Peregrina), bordered by alluvial fans along an anastomosed fluvial system invaded by marine incursions (Figure 4).

Figure 4

Marine palynomorphs and glauconite also served to explain why an especimen from the piscivore pterosaur*Dimorphodonweintraubi*was unearthed(Clark, J.M., *et al.*, 1998) from this half-graben. This genus was initially found in english marine Liassic rocks from Dover. In order to prove the existence of an ancient marine environment between red-beds, it was necessary to make X-ray analyses of selected rock samples and palynological residues from the red-bed units. X-ray analyses successfully proved that the palynostratigraphic determination of a marine environment was correct due to the presence of glauconite, dolomite and calcite in some greenish limolites and shales containing also abundant illite, just below the palynological sample with marine palynomorphs. The analyses also proved that the palynological characterization of red-bed units was correct using the general mineral and element content obtained from thediffraction and fluorescence of X-ray analyses (Figure 5). Finally, all these data were used for differentiate the paleoclimatic and tectonic conditions existing during the original formation of these red-bed units and the related transgressive-regressive sediments.

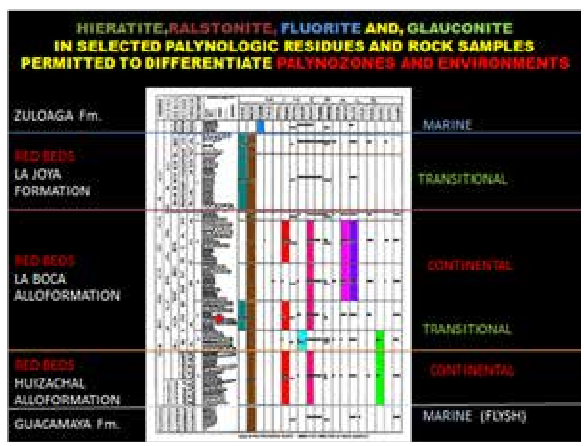

Figure 5

Thus, in order to reconstruct the regional Liassic Paleogeography, it was necessary to establish the continuity of the south-trending half-graben. It was not found toward the SE of the Tampico-Misantla Basin, as was thought, but at the Huayacocotla Anticlinorium. Both sedimentary sequences correlated very well because the palynozones from the Los San Pedros Allogroup have equivalent units in the Huayacocotla Group established by Schmidt-Effing, R., 1980 (Figures 6 and 7), but show more and more marine influence toward the SE (Rueda-Gaxiola, J., 2003).

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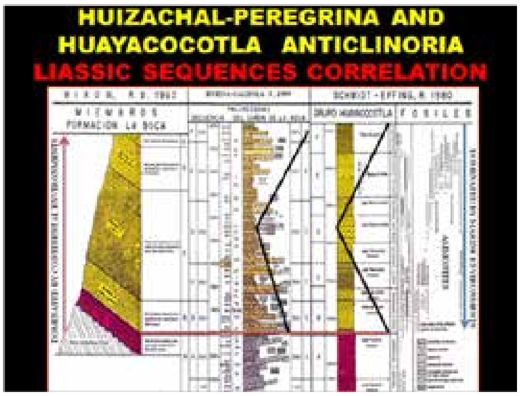

Figure 6

Figure 7

On the other hand, the palynostratigraphic and X-ray data show a Toarcian-Aalenian southwestward displacement of the Huayacocotla Block, wich is at the origin of the Tampico-Misantla Basin, with an initial lacustrine and shallow marine sedimentation, caracterized by palygorskite and sepiolite argillaceous minerals (Figures 6 and 7).

The next step was to reconstruct the paleogeographic distribution of red-beds from the Huizachal-Peregrina and Huayacocotla anticlinoria. Thus, it was necessary to correlate the red-beds with other Liassic sequences from the S and SW of Mexico. This correlation allowed us to know that these Liassic units were deposited in the same Huayacocotla-El Alamarsemigraben, which was cut by the Tampico-Lázaro Cárdenas and Acapulco-Teziutlánmegashears, allowing the southwestward displacement of the Huizachal-Peregrina, Huayacocotla and Tlaxiaco blocks during the Toarcian-Aalenian (Figure 8).

Figure 8

It was also known that the Huayacocotla half-graben was connected to a LiassicEpicontinental Sinemurian Sea, named "El Portal del Balsas", joined at the SW with the Pacific Ocean (Figure 16). In addition, it was recently possible to deduce that during the Early Middle Jurassic this epicontinental sea was invaded from the NE by the Tethysian waters coming through the "Hispanic Corridor" across the new Gulf of Mexico, formed by a triple junction hotspot (Figure 18).

Recently, sedimentary results from two thesis works (De Anda-García, A., 2008 and Osorio-Nicolás, M. A., 2009) improved our palynostratigraphic knowledge of the northern region of the Tlaxiaco Anticlinorium, previously established by the thesis work of Jiménez-Rentería, J., 2004. These new data were used for deducing that the Liassic and Middle Jurassic sedimentary sequences were also deposited in a half-graben bordered by alluvial fans and invaded by estuarine waters (Figure 9).

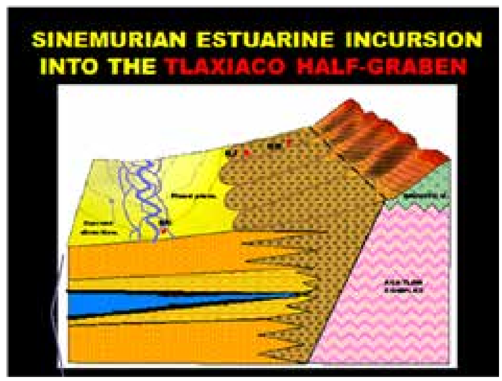

Figure 9

Thus, Jurassic allostratigraphic units outcropping at the three known anticlinoria were correlated successfully and compared to those from the subsoil of the Tampico-Misantla Basin (Figure 10). Nevertheless, the main conclusion was the northern sedimentary provenance of the quartzose units deposited in the upper part of the Los San PedrosAllogroup, in the Huizachal-Peregrina, and in the proposed Consuelo Allogroup, at the Tlaxiaco Anticlinorium; metamorphic clastic sediments from these units had a cratonic source in the central region of the actual Gulf of Mexico. The Liassic sedimentary sequences and structural data of the three anticlinoria showed that there were not three isolated basins, but only one and unique half-graben, the Alamar-Tlaxiaco Basin. The basal units were formed by northwestward rhyolites (Allomember Río Blanco at Huizachal-Peregrina) and southeastward andesites (DiquiyúAlloformation at Tlaxiaco).

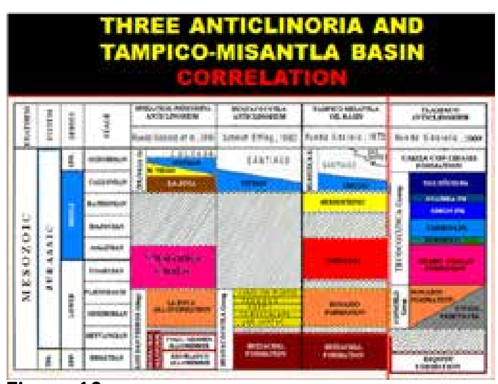

Figure 10

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Paleogeographic evolution of the Gulf of Mexico

All these stratigraphic and tectonic data were the base for reconstructing the origin of the Gulf of Mexico and its paleogeographic evolution. They have implications about the origin and evolution of the Texas-Louisiana Subplate, delimited by the Lewis-Clark and Texas-Boquillas-Sabinas-megashears, its northwestward movement and the 800 km displacement of the Ouachita System and its relation to tectonic phenomena in the Pacific subduction region since Jurassic times (during the Cordilleran Orogeny), including Sevier and Laramideorogenies. In addition, these data are also related to the origin and evolution of the Western Region of Mexico and the Chiapas-Yucatán subplates, and their Gulf Oil and Gas Basins (Rueda-Gaxiola, J., 2004).

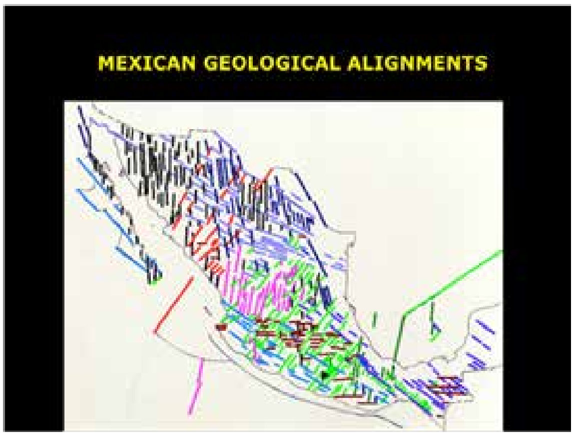

Figure 11

The paleogeographic reconstruction of southern North America began with the application of the Morpho-Tectonic-Stratigraphic Method, based on the interpretation of the geographic distribution of the alignements observed in relief maps of Mexico (Figure 11), and supported by stratigraphic and tectonic data (Figure 12).

Figure12

Thus, it was possible to know that the major alignements are ancient faults, mainly NE-SW (Paleozoic megashears after Rueda-Gaxiola, J., 2003) and NW-SE (Precambrian megashears after Karlstrom, K. E. et al., 2001) at the borders of tectonic blocks that are now displaced. Putting these blocks in their original places allowed us to reconstruct the paleogeography from this North American region before (Figure 13), during and after Pangea (Figures 14 and 15).

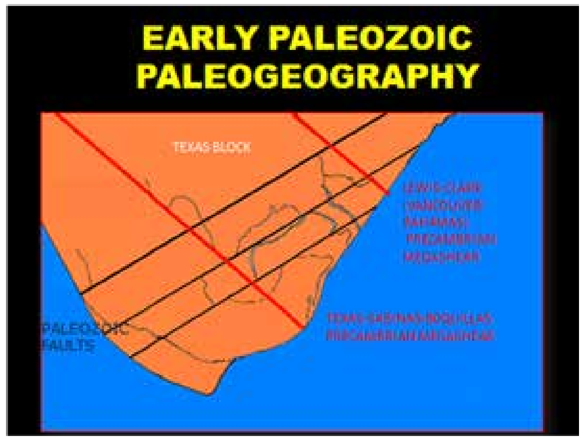

Figure 13

Batholiths (Figure 14) originated during the time range from the Carboniferous to the Early Triassic, in collision zones between the North American and Gondwana continents, in the interior of the Appalachian and Ouachitan mountains. The largest Permian batholithic zone included the present Yucatan basement. During the Late Triassic, two parallel NW-SE grabens, named El Alamar-Tlaxiaco and Sierra del Catorce-Huamuchtitlán basins were formed at the western margin (Figure 15), where the fluvial red-bed Huizachal Formation was deposited. These bassins cut the Huizachal-Peregrina, Huayacocotla and Tlaxiaco blocks almost perpendicularly. A water transgression from the Pacific Ocean above the Huizachal-Peregrina and Huayacocotla blocks deposited the Zacatecas marine sedimentary formation.

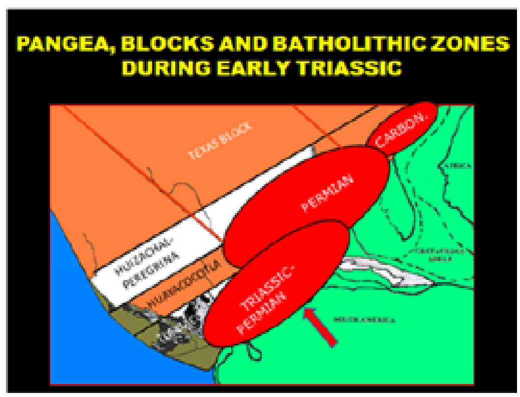

Figure14

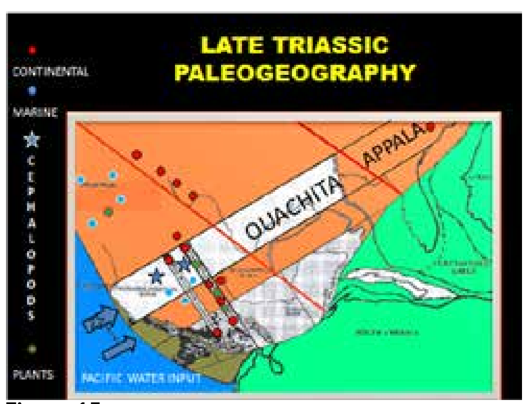

Figure 15

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During the Sinemurian-Pliensbachian times, the Huayacocotla Block was lower and filled by the Epicontinental Sea named "El Portal del Balsas", receiving the fluvial and marine sediments (known as the Huayacocotla Group) coming from the two remaining Huizachal-Peregrina (known as Los San PedrosAllogroup) and Tlaxiaco (proposed as Consuelo Allogroup) fragments. A hotspot appeared during the Late Liassic at the intersection of the Precambrian Texas-Boquillas-Sabinas and the Paleozoic Tampico-Lázaro Cárdenas megashears, in the central part of the present Gulf of Mexico. During the early doming stage, increasing volumes of cratonic metamorphic rocks were eroded and quartzose sediments began to be transported by fluvial systems toward W and SW (Figure 16).

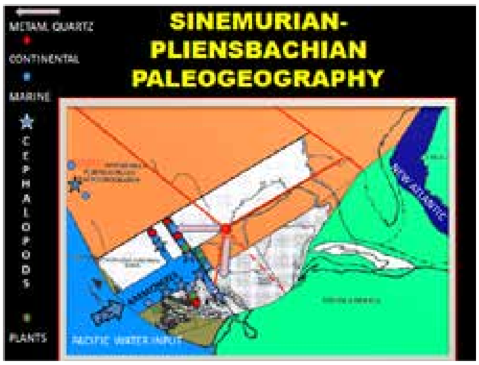

Figure 16

During the Toarcian-Aalenian times, an initial RRR triple junction system was formed, composed by the SE-NW Texas-Boquillas-Sabinas, SW-NE Campeche Escarpement and N-S Nautla-Pico de Orizaba arms, bordering the Texas-Louisiana, Western Region of Mexico, and Chiapas-Yucatán subplates (Figure 17). During this time, the Huayacocotla and Tlaxiaco blocks, and also South America, moved southwestward, and the Atlantic waters arrived at the same time that a hotspot (sensuJ. Tuzo Wilson, 1963) appeared at the NE forming a dome in the central part of the present Gulf of Mexico. During this doming stage, huge volumes of cratonic interior metamorphic rocks were eroded and quartzose sediments were conformably or unconformably deposited above the Lower Liassic red-bed sedimentary units; they are known, in the three sections of the Alamar-Tlaxiaco Basin, as the CuarcíticaCualac Formation at the Tlaxiaco basin, the Cahuasas Formation at the Huayacocotla basin and the CuarciticAllomember of the La Boca Alloformation at the Huizachal-Peregrina Basin (Figure 10).

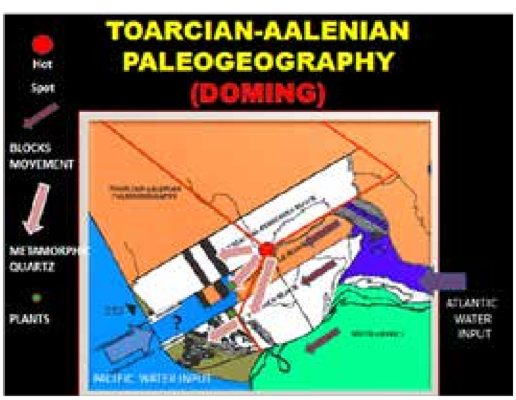

Figure 17

During the Bajocian-Oxfordian times, rifting, sinking and drifting tectonic stages gave origin, first, to the "Hispanic Corridor" and, later, to the Gulf of Mexico (Figure 18). Because the Chiapas-Yucatán subplate was joined to the South American plate, it was stable during the Jurassic, and only the Texas-Louisiana and Western Region of Mexico subplates were displaced northwestward, the first faster than the latter. The Texas-Boquillas-Sabinas arm became a megashear zone, parallel to the southern Chihuahua-Sabinasgraben. Thus, the original RRR triple armed graben formed two masses with a predominantly rift boundary, and a failed arm of a rift forming a trough. The northwestward displacement of the Texas Block was possible due to the formation of the NW-SE Pico de Orizaba-Laguna Superior megashear, and to the reactivation of the NW-SE Vancouver-Bahamas megashear, but also because a subduction zone existed at the Pacific border of the North-American Plate. This motion allowed the Campeche Escarpment and Nautla-Pico de Orizaba arms to become wider rifts and seafloor spreading zones, where the Gulf of Mexico formed.

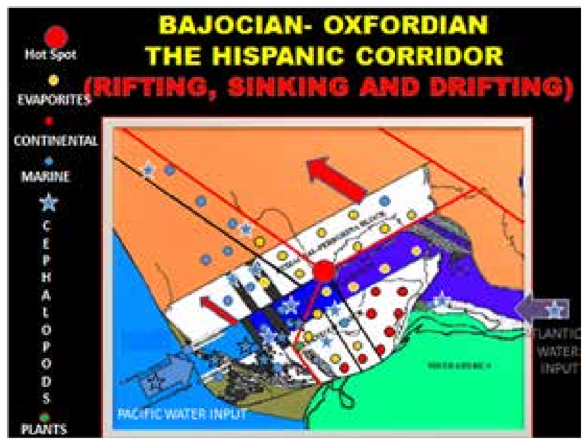

Figure 18

Since the Bajocian time, rifting, sinking and drifting stages originated, first, the "Hispanic Corridor" and, later, the Gulf of Mexico and its sedimentary sub-basins (Figure 19), the oil and gas systems, and the hydrocarbon deposits found in the Texas Block and Mexican Petroleum Sub-Basins (Rueda-Gaxiola, J., 2004) in Cretaceous and younger reservoirs (Figure 20).

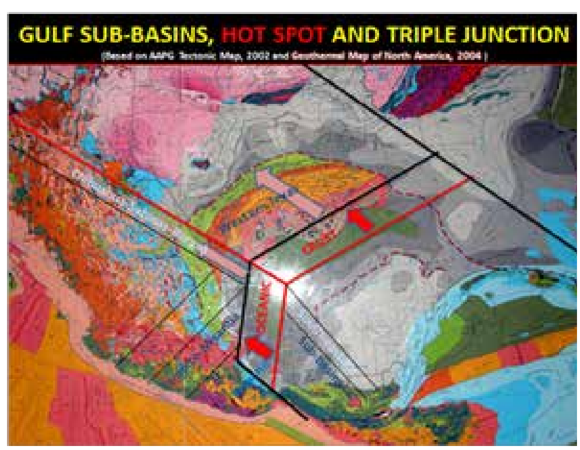

Figure 19

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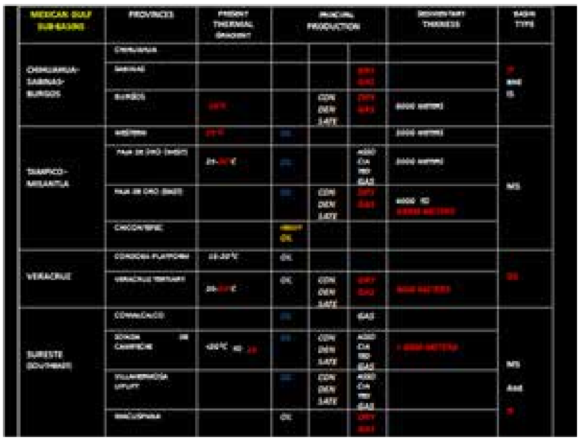

Figure 20

Conclusions

The origin of the Gulf of Mexico and the "Hispanic Corridor", as well as the type of sub- basins and the abundance and type of hydrocarbons found in them around the Gulf of Mexico have been mainly the product of a the evolution of a hotspot since the Early Middle Jurassic time.

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