5-22-2006

A Geological Interpretation of 3D Seismic Data of a Salt Structure and Subsalt Horizons in the Mississippi Canyon Subdivision of the Gulf of Mexico

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Recommended Citation

Mejias, Mariela, "A Geological Interpretation of 3D Seismic Data of a Salt Structure and Subsalt Horizons in the Mississippi Canyon Subdivision of the Gulf of Mexico" (2006). *University of New Orleans Theses and Dissertations*. 438.
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A GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA OF A SALT STRUCTURE AND SUBSALT HORIZONS IN THE MISSISSIPPI CANYON SUBDIVISION OF THE GULF OF MEXICO

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
Geology

by

Mariela Cecilia Mejias F.

B.A. Universidad del Zulia, 2000.

May, 2006

DEDICATION

This thesis is dedicated to my mother Juana, father Gilberto and brother Gilberto Jr, grandmother Aura and Veronica who from the distance have been there for me always.

ACKNOWLEDGEMENT

Thanks to God, always God first. For being closer to me than the vein that gives me the life.

Thanks to the University of New Orleans, for believing in me and for believing in the international students. I have learned a lot from this school and specially after surviving Katrina. I know that UNO is and will be the school ready to go on and do always better.

Special thanks to my Thesis advisor, Dr. Mostofa Sarwar, for being an example to follow, a great professional in geophysics, a brilliant mind and a nice person. Thanks to my Course advisor, Dr. Laura Serpa, for being there for me each time I had a doubt about what course to take, for being a friend and a great geophysicist. Thanks to Dr. Mathew Totten, for being there sharing knowledge with the students and always bringing the best. To Dr. Ronald Stoessel, for making my dream comes true, for the scholarship, for what I have achieved. To Dr. Mark Kulp, for being an inspiration for me, an example to follow and simply a great scientist. To Dr. Enrique Reyes for giving me my first summer job, for being a good professor and friend. Also very special thanks to Dr. George and Juliette Ioup for taking the physics department and classes to another scope, higher and toward the excellence always. For incentive the students to attempt luncheons and talks, you are what I would like to become as a professional in the future.

Infinite Thanks to Murphy Oil and Exploration, for open their doors to UNO students including me, specially during and after Katrina. For your advise, for the example that Murphy Oil represents to me. An example of hard and quality work. Many people in Murphy have my infinite gratitude, some of them are: Mr. James Murphy, Mr. Dave Wade, Mr. Ralph Depauw, Mr Dave cope, Mr. Harold Battalora, Mr. Mistretta, miss Caroline, Mr. Mike Lundrige, Mr Dave Tiemen, Eddie, Rodney, Norman, Sherrie Richardson. Thanks for providing me with the data and all the tools I needed to do this thesis work. Without Murphy Oil I wouldn't never improve my vision of exploration.

Thanks to my new sisters: Rosa Atena and Anna Pizzo, without you guys my hopes would have never rise after Katrina. You were my family then and now.

Thanks to Knowledge Reservoir.

Thanks to my friends and colleagues: Andrew Tipton, for being an excellent scientist, colleague and friend. Thanks to Sheri Sullivan, for teaching me each new word I know even the ones I can not say in public. Kiranmayi Sristy, for listening to me when I needed to talk to someone, for being my little sister, thanks for taking care of me when I had the terrible tooth pain. To Mamoon, for helping me with my car when it didn’t start that Sunday.

Thanks to my parents, Juana, Gilberto and my brother, for letting me know that besides the distances and the circumstances they were there for me.

Thanks to Aura Duarte, my grandmother. Simply a woman ahead of time. Thank you Veronica for your prayers.

Thanks to: Omar Akbar, Francisco Gamarra And Karime Gabriel, Eudomar Silva, Mike and Rose Ann Vasely.

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ABSTRACT

The Gulf of Mexico (GOM) represents a challenge for exploration and production. Most of the sediments coming from North America has bypassed the shelf margin into Deep Water. In an Attempt to attack this challenge this thesis pretends to break the GOM's false bottom, mainly comprised by diverse salt structures and growth fault families. In this attempt, geological and geophysical data are integrated to find clues to potential hydrocarbons indicator (PHI) that could be of Reservoir Quality (RQ). 3D Pre stack depth migrated data comprised of Mississippi Canyon blocks, were interpreted: Top and base of salt, leading to the identification of a PHI represented by a consistent Amplitude Anomaly (AA) below and towards a salt structure. This AA may be of RQ and feasibility evaluation for further decisions may be taken. Following the structural sequences that Govern central GOM during Oligocene through out Miocene was important to support the results.

CHAPTER 1: INTRODUCTION

The Gulf of Mexico (GOM) is a simple semicircular and overfilled basin that has been supplied by sediments from North America. It is lying in between the North American plate and the Yucatan Block. Beyond the believe that the GOM is a mature province from where all the oil and gas in the basin have been discovered, major deep water discoveries has thrown that this is not a yet mature province and that subsurface geology studies from deep water settings has had to be the new direction on GOM exploration. A description of the Paleocene-Miocene section in the GOM set the geologic context to sequences deposited during a time period where sediments bypassed the shelf and slope into deep water accommodation space created mostly during the Cenozoic.

This project intends to explore Central GOM, deep water, Mississippi canyon subdivion area, throughout the integration of well information, 3D depth seismic data and paleographic reports. The procedure followed was the interpretation of seismic lines and cross lines across the MC area, producing a seismic map view grid with the Top and Base of salt interpreted, being this structure the prevailing one in the subdivision. This interpretations where controlled with paleogeographic reports from wells. By identifying the specific age of events recognized in wells already integrated in the Depth migrated data, it is possible to interpret the age of the horizons interpreted. After the interpretation of top and base of salt, an amplitude anomaly (AA) consistent in all directions in the data was identified toward one of the salt structures.

This project intends to improve the understanding of Middle Miocene subsalt strata, and intend to identify amplitude anomalies that could be of reservoir quality. The salt interpretation could be used for data enhancement purposes.

The way that this work will develop will go from a general review about central GOM structural features and stratigraphy pointing to the Deep water challenge. After this the

Methods used to produced the results are presented as well as the hypothesis and conclusions.

1.1. Area Overview

The GOM basin is a relatively simple, roughly circular structural basin, approximately 1,500 Km in diameter, fills in its deeper part with 10 to 15 Km of sedimentary rocks that range in age from late Triassic to Holocene (Salvador, 1991). (Figure 1).

Sediment supply from the North American continent has filled nearly one half of the basin since its inception, primarily by offlap of the northern and northwestern margins. The marine basin was initiated and deepened during the Mesozoic creating a broad abyssal plain that extended north beneath the present continental shelf to and beyond the local coastline. Onto this abyssal plain, depositional loading and continental margin offlap, beginning in the early Cenozoic and continuing through the Holocene, depressed the crust to its current 10-16 Km below sea level (Galloway, et al; 2004).

The GOM is an overfilled basin, consisting on offlapping, sigmoidal sedimentary sequences deposited by a succession of depositional episodes as shown in figure 3. More than two thirds of the sediments entering the Gulf has bypassed the shelf margin into deep water during most of the Cenozoic, because that is where the ultimate accommodation space was located. Deep water accommodation has been the rule not the exception (Galloway, et al; 2004).

Superimposed on the basin are second-order structural features. One group of structures are salt diapirs and related structures, formed from flow of Jurassic salt that lies at the base of the sediment column. Different original salt thickness and different loading histories have created distinct salt diapirs provinces characterized by their style and age of diapirism. (Salvador, 1991). The structural framework of the GOM can be subdivided into major structural provinces. The northwestern progradational margin, which is subdivided into

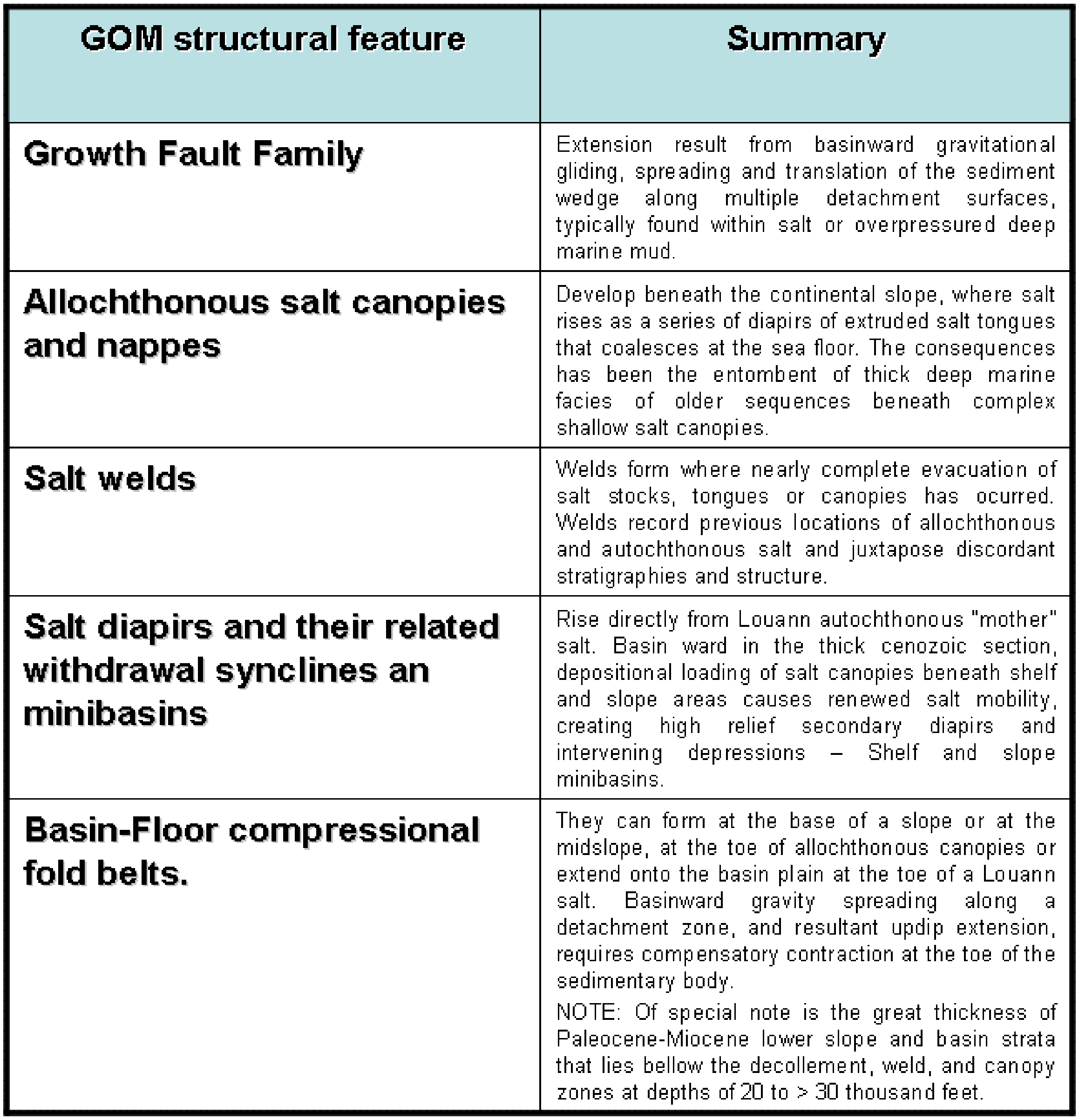
Figure 1. Location of most important geographic features.

Figure1. Location of the most important geographic features in the Gulf of Mexico. Figure modified from Salvador et al, 1991. The Gulf of Mexico Basin: Boulder, Colorado, Geological Society of America, v. J, p. 1-11.

Interior zone and coastal zone. The coastal zone, characterized by Mesozoic strata buried beneath a thick wedge of upper cretaceous and Cenozoic coarse clastic sediments, which have prograded the shelf margin hundred of kilometers seaward and generated growth faults systems and coastal and offshore salt diapirs provinces (Salvador, 1991).

The combination of basin-flooring Louann salt, rapid sediment loading and offlap of high-relief, continental margin has resulted in mass transfer of salt up-section and basinward throughout the gulf's history. (Rowan et al., 1999).

The structures that result from salt mass transfer are described by Galloway et al., 2004 and summarized in table I.



GOM structural feature	Summary
Growth Fault Family	Extension result from basinward gravitational gliding, spreading and translation of the sediment wedge along multiple detachment surfaces, typically found within salt or overpressured deep marine mud.
Allochthonous salt canopies and nappes	Develop beneath the continental slope, where salt rises as a series of diapirs of extruded salt tongues that coalesces at the sea floor. The consequences has been the entombent of thick deep marine facies of older sequences beneath complex shallow salt canopies.
Salt welds	Welds form where nearly complete evacuation of salt stocks, tongues or canopies has ocurred. Welds record previous locations of allochthonous and autochthonous salt and juxtapose discordant stratigraphies and structure.
Salt diapirs and their related withdrawal synclines an minibasins	Rise directly from Louann autochthonous "mother" salt. Basin ward in the thick cenozoic section, depositional loading of salt canopies beneath shelf and slope areas causes renewed salt mobility, creating high relief secondary diapirs and intervening depressions – Shelf and slope minibasins.
Basin-Floor compressional fold belts.	They can form at the base of a slope or at the midslope, at the toe of allochthonous canopies or extend onto the basin plain at the toe of a Louann salt. Basinward gravity spreading along a detachment zone, and resultant updip extension, requires compensatory contraction at the toe of the sedimentary body. NOTE: Of special note is the great thickness of Paleocene-Miocene lower slope and basin strata that lies bellow the decollement, weld, and canopy zones at depths of 20 to > 30 thousand feet.

Table I. Panoply of structures and related features in the GOM.

Multi-tiered salt systems in the GOM present an abundant and diverse array of sub salt exploration opportunities to the hydrocarbon industry. The Mad Dog, Atlantis and crazy horse sub salt discoveries demonstrate the large hydrocarbon potential of the play and have given importance to sub salt drilling activity in the deep water fold belt and turtle inversion play fairways. Recent deep water drilling disappointments emphasize that there is involved substantial technical and financial risks. The benefits of advanced seismic techniques not withstanding, inaccurate trap assessments remain the primary cause of sub salt exploration failure. Therefore, the accurate assessment of traps attributes remains a primary determinant of sub salt exploration success. GOM 3D seismic datasets, subsalt well results, and kinematic models have been integrated into a calibrated methodology for assessing sub salt geometry and prospectivity (Hart et al., 2001).

Decollement zones, allochthonous salt bodies and welds have created a “false bottom” to the Gulf basin sedimentary “suitcase”. Stratigraphy and structure bellow such structural discontinuities are unrelated to that above and must be imaged and interpreted in their own context. The complexity of the shallow and mid-depth structure and the great depth of the target section represent great difficulties in seismic imaging of the deeper structure, stratigraphy and fluids. More recent ultra deep and sub salt drilling has confirmed that the late Paleocene upper Wilcox, Oligocene Frio/Vicksburg, and Miocene sequences are sand prone in the deep slope and abyssal plain systems comprising the reservoir system associations that lie bellow the “False bottom” created by weld, canopy, and decollement zones. They are potentially high-volume reservoir systems, characterized by thick, aggradational gravity flow transport deposits. Those lower slope abyssal plain reservoirs within the Paleocene, Oligocene, and Miocene are the next great frontier for northern GOM exploration . (Galloway et al., 2004).

Galloway mentions the apparent gap existing in the central and northern GOM where more exploration efforts are made in the lower slope and abyssal plain reservoirs within the Paleocene, Oligocene and Miocene, the challenge is the location of preferred sequences and places where high hydrocarbon indicators can be located (Galloway et al., 2004).

Salt is one of the most effective agents in nature for trapping oil and gas. Salt flows when overlying sediment’s density exceeds that of salt. And differential stresses allow salt moves, another driver for salt to flow is related to differential sediment loading over salt or to gravitational forces due to surface slope (Nelson et al., 1991). As a ductile material, salt can move and deform surrounding sediments, creating traps. Salt is also impermeable to hydrocarbons and acts as a seal.

Within the complex salt systems of the northern GOM, subsalt strata geometries are highly variable. Narrow, three ribbon truncation closures and steep strata dips pose generic exploration risks, while trap prospectivity may greatly improved where subsalt strata have been counter rotated, inverted, and or downwardly flexed. Structural elements that enhance or destroy subsalt trap viability evolve with the deformation of ubiquitous, deeper allochthonous and autochthonous salt (Hart et al., 2001).

1.1.1 Location

The Mississippi canyon area is located 257.5 km south-east from New Orleans at depth water of approximately 2000 Ft. (Figure 2). The study area includes 15 Mississippi canyon blocks (Figure 3). The main sands developed in the area depend on the salt movement, and an understanding of the salt top and bottom resulting very helpful in determining the real thickness of sediments. Also it is necessary to understand the deposition history and sequences during the Miocene in the Mississippi canyon subdivision to be integrated with the structure interpretation in the area and come up with stratigraphy inferences of the horizons mapped.

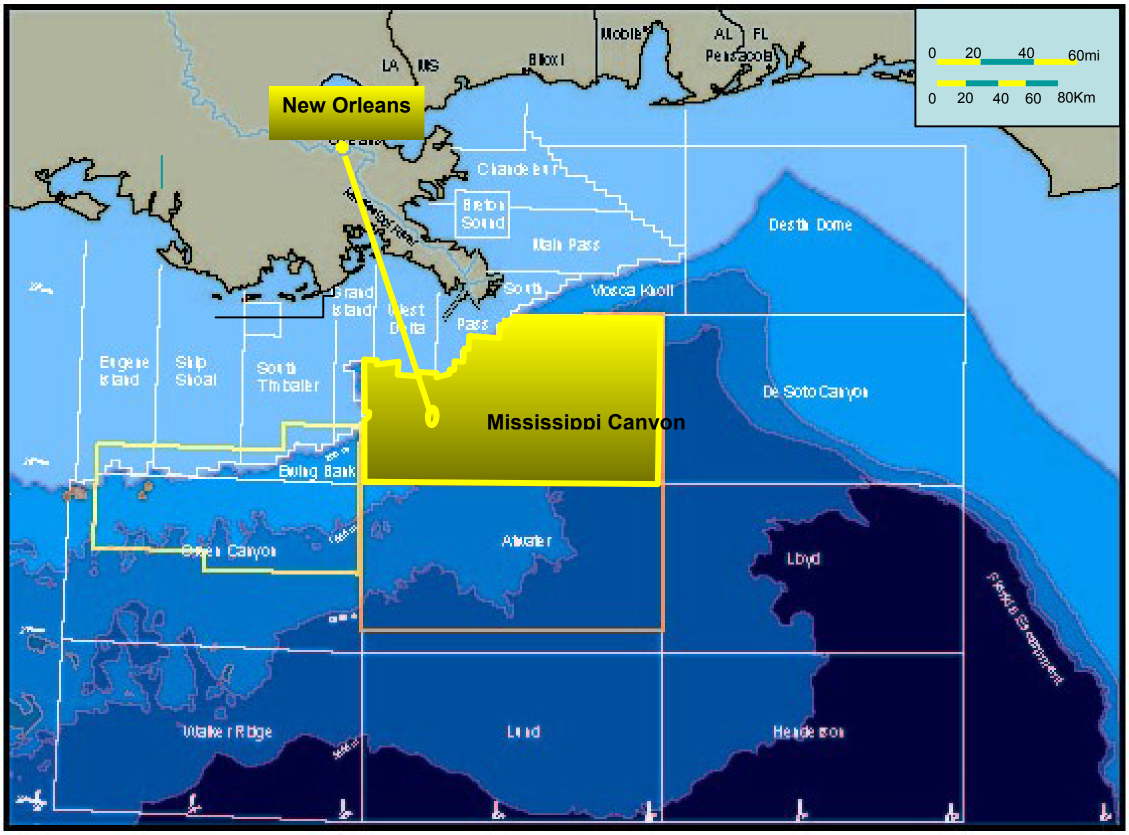


Figure 2. Location of the study area.

To achieve the best geologic interpretation in deep water exploration it is important to count on 3D and 2D seismic data as well as well logs and paleogeographic reports.

Advances in seismic-reflection imaging have arguably been the most important element in allowing companies to explore deepwater, because seismic imaging often reduces geological risk to acceptable levels (Rudolph, 2001). Prestack depth migration (PSDM) has become critical for imaging deepwater traps, particularly along steeply dipping salt flanks and underneath salt. (Weimer et al., 2004).

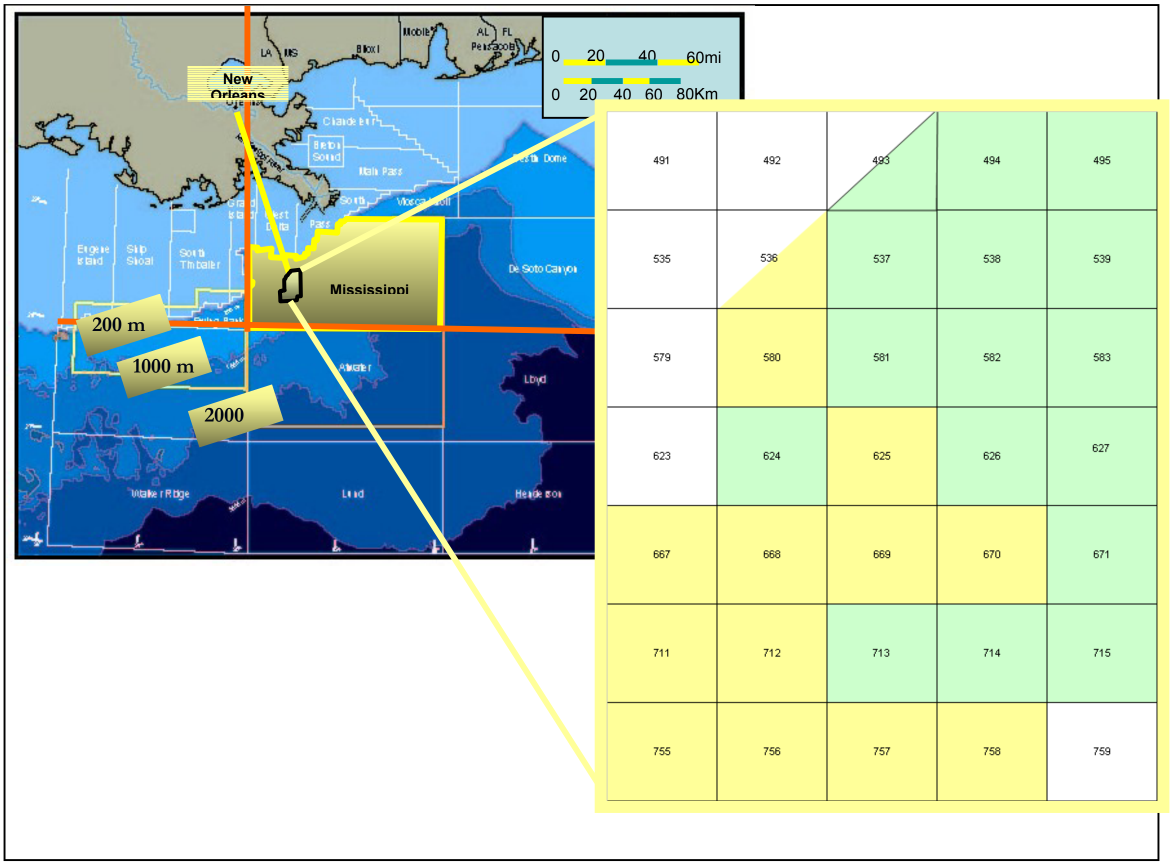


Figure 3. Blocks studied in the Mississippi Canyon area.

Part of the new frontier that is being reached in the GOM includes the interpretation of deep basins and subsalt horizons. Deepwater discoveries and deep wells require three main and general aspects:

- Development of appropriate facilities where deep drilling can be achieved followed by the best completion technology.
- Development and management of reservoir dimensions and properties.
- Development of the geologic model that best fits the reservoir dynamics and for sure that guarantee an accurate approach to subsurface earth geometry.

This last statement requires of the integration of acquisition design technology and data processing in order to provide the interpreter of the data with the real subsurface signatures. This is why Oil companies spend lots of resources to generate subsurface maps, keeping those confidential.

This thesis provides the salt interpretation of 15 blocks of MC subdivision, the generation of subsalt deep horizon in the lower middle Miocene with amplitude extraction map and the interpretation of a shallower horizon pertaining to the Upper middle Miocene.

1.2 Thesis Objective

The objective of this thesis is to interpret the salt in the area and its effect on subsalt horizons and in one of the main sands. This will lead to a better understanding of hydrocarbon traps by integrating geological and geophysical data within the area. The results are presented in the salt top and bottom interpretation grid, Lower to Middle Miocene subsalt unexplored horizon structure map accompanied by the amplitude extraction map.

1.3 Thesis Significance

The significance benefits of this study are to enrich our understanding of the geological history of deep water Mississippi canyon study area (Medusa field) providing an interpretation of the Lower to Miocene subsalt horizon and of Middle to Miocene horizon accompanied by a complete interpretation of top and salt bottom. The result of this study can provide clues to potential prospect and leads in the area. The provided data can also be used for seismic attribute analysis and quality enhancement.

1.4. Previous Work

I needed to understand the tools used to interpret subsalt images in seismic data, where velocity error increases and imaging problem becomes a problem. In this direction it was found a study In December 2001, William Hart published a paper on GCSSEPM Foundation 21st Annual Research conference of the Deep water Basins entitled “

Subsalt Trap archetype Classification: A diagnostic Tool for predicting and prioritization GOM Subsalt traps". Hart and Colleagues exposed a calibrated methodology for assessing subsalt trap geometry and prospectivity, very useful in the complex salt structures governing the Northern GOM, including the North of Mississippi Canyon. This paper explains that a way to reveal the predictable influence of common salt styles on specific trap attributes is by grouping subsalt traps into archetype families. These archetype families can be ranked for exploration value according to their inherent trap risks, forming a basis for evaluating the prospectivity of even poorly imaged subsalt objectives, which is a challenge for deep water horizons exploration. To achieved the trap risk values. Hart and Colleagues defined three kinematically root types. These three root types are a tool to predict subsalt strata geometry that allow the interpreter to predict trap attributes that has been obscured by the overlying salt. This prediction is based in empirical observations and the integration of 3D seismic datasets, subsalt well results and kinematic models. The used of vertical linkage as a concept is utilized by Hart and describes the relationship between deep salt movement and the magnitude and mode of subsalt trap deformation.

Hart and colleagues through this paper offer a method very useful to address a long-standing need to characterize subsalt traps obscured by overlying salt, sometimes this imaging problem occurs in well processed 3D data. This paper is designed for exploration application by inferring subsalt attributes that can improve or diminish the prospectivity.

E.A. Diegel and colleagues published on 2001 a paper entitled *"Cenozoic Structural evolution and tectono-stratigraphy framework of the northern* ***Gulf*** *Coast Continental Margin".* They numerated the factors that affected the wide variety of structural styles in the northern GOM as well as explained the tectono-stratigraphic provinces that describe regions of contrasting structural styles and ages. They worked on the need of understanding Cenozoic tectonics in the northern GOM. They changed the view of the northern GOM continental margin from a passive margin with vertical rooted salt stocks and massifs with intervening steep growth faults, to a complex mosaic of diachronous detachment fault systems and variously deformed allochthonous salt sheets.

In June 2001 AAPG published a paper by Marc Rowan and colleagues called "Emplacement and evolution of Mahogany salt body, central Louisiana outer shelf, northern Gulf of Mexico". As one of the objectives of this study is to interpret the Northern Mississippi Canyon salt body, it has been useful to study the Mahogany salt body as a case study of the northem GOM outer shelf. This is an excellent case study where 2D and 3D seismic data, well and stratigraphy constrain were used to create the history of emplacement and subsequent modification of the Mahogany salt body. The results suggested the value and limitations of published simple models for allochthon salt and the reconstruction of the salt body yields to as William Harts and colleagues will call in their paper, the vertical linkage in between the salt deformation style and the sedimentation. The results of this study specifically suggest that the Mahogany salt body did not influence the trap style of the subsalt field or hydrocarbon migration into the pay sands, but it did affect sediment transport pathways and, or a lesser degree, reservoir facies distribution.

Thomas Nelson in 1991 published a paper in the Geological society of America called "Salt tectonics and listric normal faulting". He describes the mechanism by which salt structures and listric normal faults form. This has been important to understand the characteristics of the northern Mississippi canyon salt body. He concludes that the GOM basin region contains structural features that, for the most part, have been created by gravity acting on an unstable substrate in a nonorogenic environment. The salt tectonic and listric normal faults are interacting with each other, and this interaction creates a wide variety of features.

Thomas Nelson in his paper exposes that in the GOM the salt needed to produce structures of the scale observed is deposited in sill basins where a physical barrier (The sill) between the basin and the open oceans restricts water circulation, and arid climatic conditions created a high rate of surface evaporation. Such basins are product of continental break up. Salt deposition in the GOM occurred in the late Triassic and Jurassic, resulted in salt deposition over a wide geographic area. Here is where salt provinces are distinguished in the interior basin and in the coastal and offshore basins.

The interior basin includes a small isolated bid of salt in onshore south Texas, plus the extensive salt basins of northeast Texas, North Louisiana, southernmost Arkansas, Mississippi, Alabama, the Florida Panhandle and the northeast GOM. The coastal and offshore basins lie to the south of the early cretaceous shelf margin and include areas of onshore Louisiana and southeast Texas, and almost all of the Louisiana and Texas shelf and slope. He explains mechanisms that cause the salt deformation as well as the different salt stages which I summarize in Table II.

Driving Models of Salt flow	Salt Stages
1. Salt flow driven by gravity acting on a upper sediment surface. **2. Salt flow driven by differential loading related to surface deposition. Salt flow in the less loading weigh direction.** **3. Salt flow driven by differential loading when sediments on top of salt are horizontally stratified. Flow direction of the salt is dependant on the density of stratified sediments column.**	• Active piercement: Refers to a diapir in its early stage. Its characteristics include: • Thick prediapiric sediments overlying the salt. • A major normal fault bounding one side of the rising salt body. • The asymmetric nature of the overall structure. • Passive state of piercement: • Top of the salt will remain at or above the level of the surrounding sea floor. • Symmetry shape.

Table II. Models that drive salt flow and Salt stages summarized from Thomas Nelson paper.

Nelson, also mention the salt sheets. An experiment that simulates salt with overlaying sediments that represent nature was established to understand salt mobilization through sediments. Under a strong gravitational force imposed on the model by the centrifuge, the salt, driven by the load of the more dense overburden, rises diapirically toward the surface. Because the materials are viscous, that portion of the diapir which penetrates the shallow, low density layer is laterally unconstrained, as a result salt in this part of the diapir flows outward, intruding the encasing section. The intrusion occurs when the outward stress acting on the salt is greatest.

Ricardo I. et al, published a paper on AAPG on march 2006. The paper title is " Depositional and structural evolution of the middle Miocene depositional episode, east-central GOM". As in my study I am pursuing interpretation of horizons that belong to the upper and middle Miocene this study helped me to understand the different depositional episodes and genetic cycles that occurred during the middle Miocene. Also they relate the paleo with eustatic sea level changes which I could directly relate to my area and have a regional understanding of Mississippi canyon paleogeografy.

CHAPTER 2: METHODOLOGY

2.1 Study of the Area

Interpreters of seismic data need to understand the area they are going to analyze. When the interpretation is in deep water, the interpreter must use all the data available, but in this environment, data quality can be poor to come up with some qualitative interpretations of the structure and stratigraphy of the area. Papers that helped in understanding the salt evolution in the area and its relationship with subsalt strata where image problems are imperative were used. William Hart et al., 2001 and Thomas Nelson et al., 1991 , helped enormously to understand some of the mechanism that support salt mobilization and the concept of vertical linkage to predict the subsalt strata settings in order to prioritize subsalt trap prediction risks. Also an understanding of the salt features in the northern GOM and its history in terms of deep water exploration was needed in order to improve the interpretations of the area.

The Methodology followed will include:

- Data Preparation.
- Salt interpretation in the seismic volume.
- Subsalt horizon interpretation at a regional scale.
- Amplitude extrapolation for the subsalt horizon.
- Structure map and Cross section of a shallower Late Middle Miocene horizon.

2.2. Geological Interpretation

2.2.1 Data Collection and Preparation

Murphy Oil and exploration provided me with fifteen blocks of prestack migrated depth data pertaining to Mississippi canyon area. This area contains Medusa field as well as Zia Field and South Medusa. Medusa area is uplifted by salt and contains wells that contain production data, perforations, sands, reservoir, etc. This is a deep water discovery that has been developed in an uplift created by salt mobility. See figure 4 for Location of Medusa field.

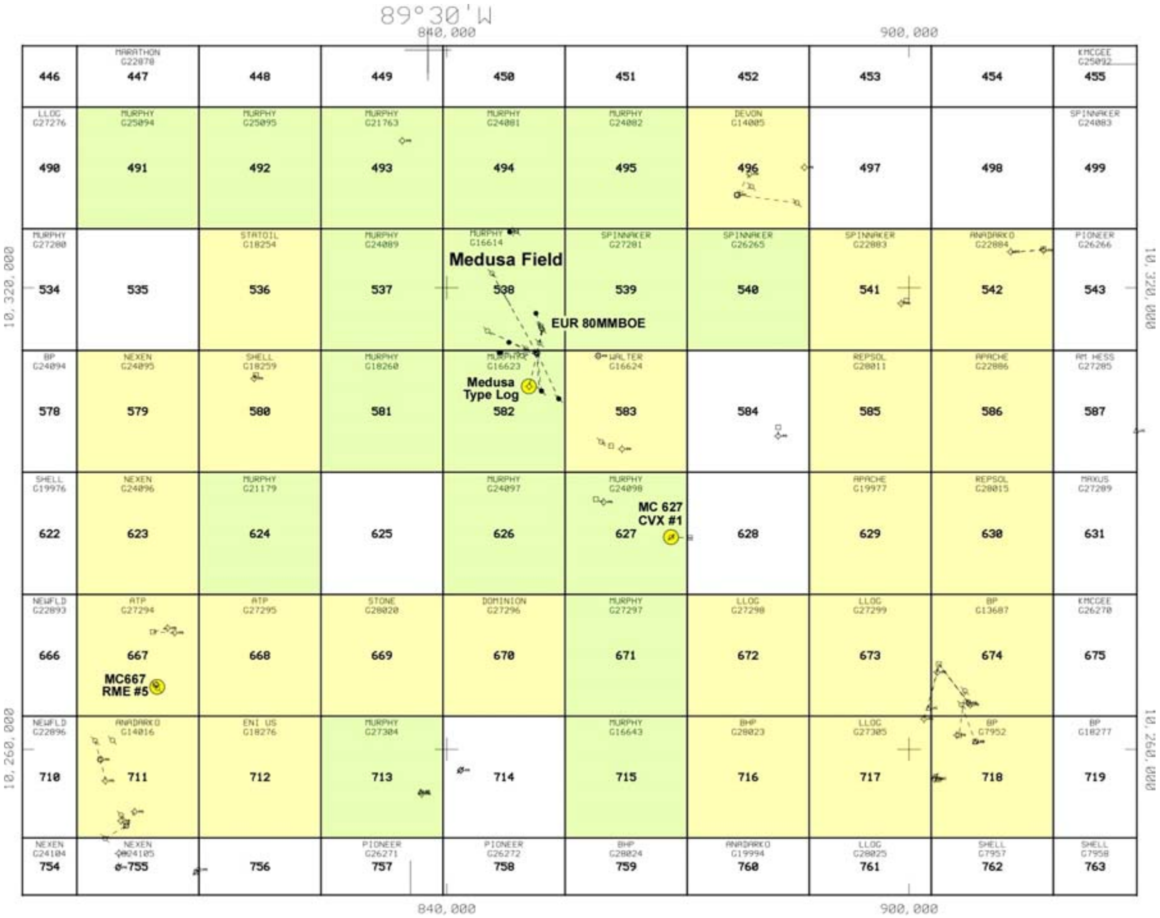


Figure 4. Location of Medusa Field. Courtesy of Murphy Oil and Exploration.

It can be observed in table III the visualization scheme used in this project. Also in table IV, is summarized the recommended procedure followed to persue the 3D seismic interpretation.

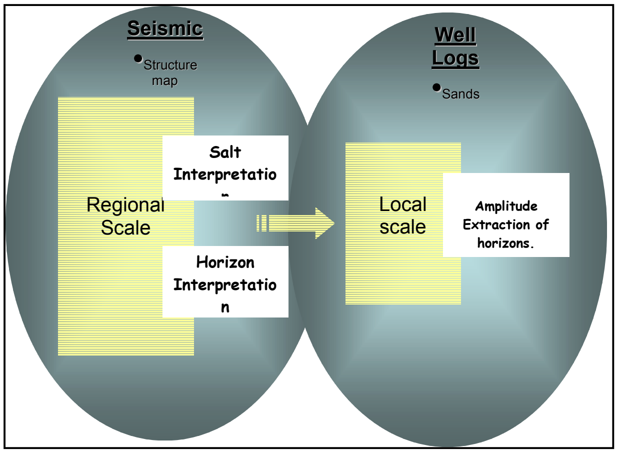


Table III. Visualization plan to be implemented on the data volume.

Recommended Procedure
1. Preview the data on composite displays and movies.
2. Horizon identification at wells. Assessment of data phase and polarity.
3. Fault framework by tying together with horizontal sections.
4. Revision of horizons and faults, and rerun of auto tracking.
5. Final depth structure maps and horizons slices with chosen amounts of griddling or smoothing.
6. **Detailed reservoir studies.**

Table IV recommended procedure for 3D data interpretation[1].

Two data sheet tables were also generated which allowed to have well control in the area. See Table V and VI.

The hard copy of the well logs that I required for the area that covered my fifteen blocks was facilitated by Murphy oil exploration team. In this way I could work in the regional scale part of my project.

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[1] Table adapted from Allistais Brown. 3D Seismic Interpretation. 5th Edition. AAPG, Memoir 42.

PALEO CONTROL

Mariela Mejias

Medusa ***Middle - Late Miocene***

#	Block	Well	API	Paleo/T and sands	Chron	Depth MD (ft)
	580	EEX 580 1	608174080900	Cat Mex Paleo	Middle upper Mio.	16,600
	580	EEX 580 1	608174080900	Disc Prepenta	Middle upper Mio.	17,530
	580	EEX 580 1	608174080900	Disc Bollii	Middle upper Mio.	18,640
	580	EEX 580 1	608174080900	bol thalm	Middle upper Mio.	17,650
	580	EEX 580 1	608174080900	Disc. Ham	Middle upper Mio.	19,390
	667	RME 667 4	608074062600	Rob. E.	Middle Upper Mio.	12,370
	667	RME 667 4	608074062600	Disc loeb	Middle Upper Mio.	13,000
	667	RME 667 4	608074062600	Miny con	Middle Upper Mio.	13450
	667	RME 667 4	608074062600	Bol. Thalm	Middle Upper Mio.	13,660
	667	RME 667 4	608074062600	Disc Prepenta	Middle Upper Mio.	13,750
	667	RME 667 4	608074062600	Disc Bollii	Middle Upper Mio.	14,320
	627	CHE 627 1	608174045500	Rob. E.	Middle upper Mio.	12,461
	627	CHE 627 1	608174045500	cris K	Middle upper Mio.	16,111
	627	CHE 627 1	608174045500	Disc 12	Middle upper Mio.	16,260
	582	MUR 582 1	608174085200	Glob. Dehis	Middle upper Mio.	16,110
	582	MUR 582 1	608174085200	Disc loeb	Middle upper Mio.	16,230
	582	MUR 582 1	608174085200	Cat Mex Paleo	Middle upper Mio.	16,350
	582	MUR 582 1	608174085200	Disc Prepenta	Middle upper Mio.	16,500
	582	MUR 582 1	608174085200	Disc Prepenta	Middle upper Mio.	16,500
	496	1ST2 Shell	608174081700	Disc Prepenta	Middle upper Mio.	14,200
	496	1ST2 Shell	608174081700	Glob leng	Middle Upper Mio.	17260-17290
	496	1ST2 Shell	608174081700	Glob desh	Middle Upper Mio.	21730-21760
	493	MUR 493 1	608174101700	Glob desh	Middle Upper Mio.	13,440

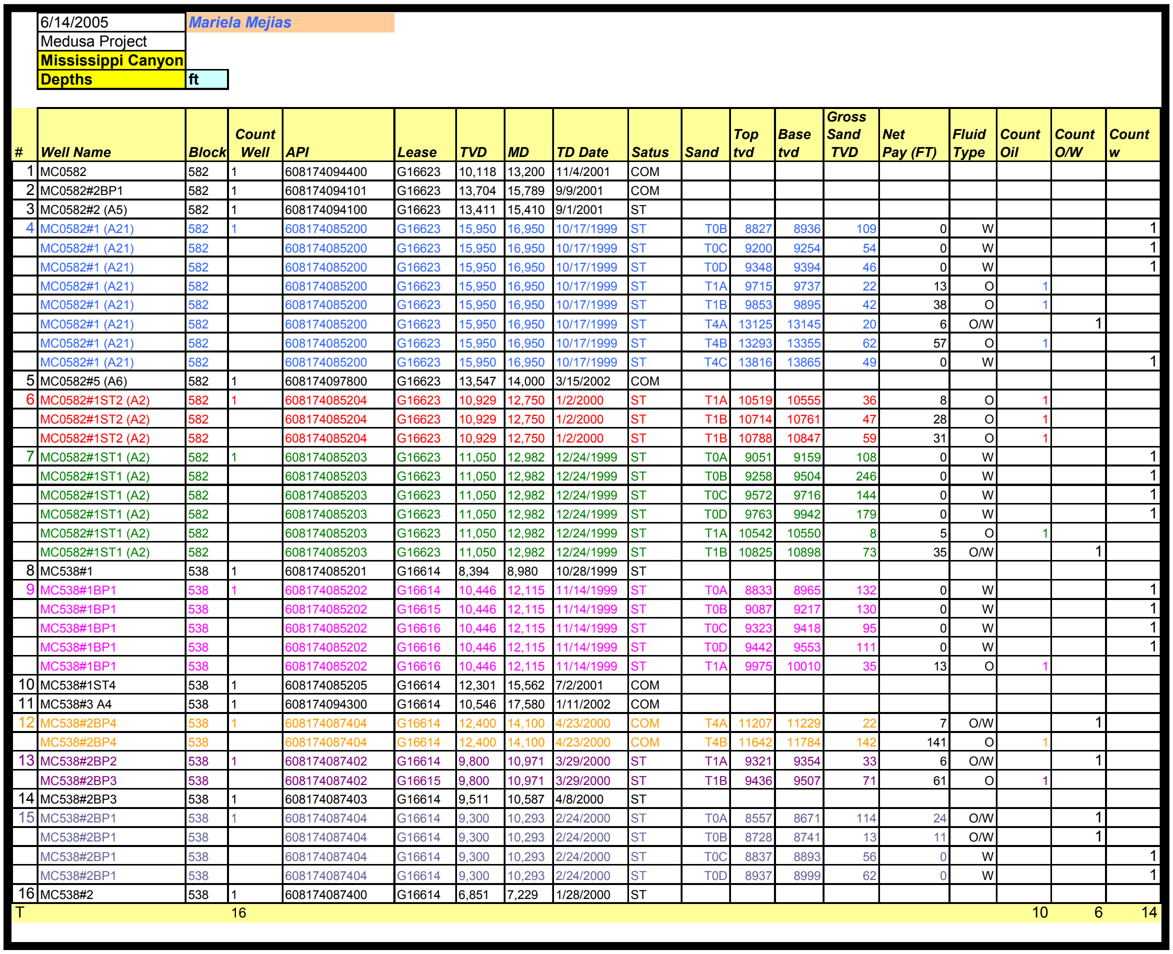
Table V. Paleo control of Medusa field and surrounded area.

2.3 Geophysical and Geological Integration

Tying wells to seismic data and tracking main sands may help us to find seismic reflections that corresponds to geological formations. The two Methods used are:

- Using Check shot data which are time-Depth pairs.
- Using Synthetic seismograms.

In this case I used wells downloaded already in the depth data, in this way I didn't have to do the time-depth conversions. In the other hand on the well logs the paleontological data for the main sands, as well as water depths to assure that the picks were on right position. To do this it was used enter pick function on seisworks and well data management.



6/14/2005 | Mariela Mejias

Medusa Project

Mississippi Canyon

Depths | ft

#	Well Name	Block	Count Well	API	Lease	TVD	MD	TD Date	Satus	Sand	Top tvd	Base tvd	Gross Sand TVD	Net Pay (FT)	Fluid Type	Count Oil	Count O/W	Count w
1	MC0582	582	1	608174094400	G16623	10,118	13,200	11/4/2001	COM									
2	MC0582#2BP1	582	1	608174094101	G16623	13,704	15,789	9/9/2001	COM									
3	MC0582#2 (A5)	582	1	608174094100	G16623	13,411	15,410	9/1/2001	ST									
4	MC0582#1 (A21)	582	1	608174085200	G16623	15,950	16,950	10/17/1999	ST	T0B	8827	8936	109	0	W			1
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T0C	9200	9254	54	0	W			1
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T0D	9348	9394	46	0	W			1
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T1A	9715	9737	22	13	O	1		
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T1B	9853	9895	42	38	O	1		
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T4A	13125	13145	20	6	O/W		1	
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T4B	13293	13355	62	57	O	1		
	MC0582#1 (A21)	582		608174085200	G16623	15,950	16,950	10/17/1999	ST	T4C	13816	13865	49	0	W			1
5	MC0582#5 (A6)	582	1	608174097800	G16623	13,547	14,000	3/15/2002	COM									
6	MC0582#1ST2 (A2)	582	1	608174085204	G16623	10,929	12,750	1/2/2000	ST	T1A	10519	10555	36	8	O	1		
	MC0582#1ST2 (A2)	582		608174085204	G16623	10,929	12,750	1/2/2000	ST	T1B	10714	10761	47	28	O	1		
	MC0582#1ST2 (A2)	582		608174085204	G16623	10,929	12,750	1/2/2000	ST	T1B	10788	10847	59	31	O	1		
7	MC0582#1ST1 (A2)	582	1	608174085203	G16623	11,050	12,982	12/24/1999	ST	T0A	9051	9159	108	0	W			1
	MC0582#1ST1 (A2)	582		608174085203	G16623	11,050	12,982	12/24/1999	ST	T0B	9258	9504	246	0	W			1
	MC0582#1ST1 (A2)	582		608174085203	G16623	11,050	12,982	12/24/1999	ST	T0C	9572	9716	144	0	W			1
	MC0582#1ST1 (A2)	582		608174085203	G16623	11,050	12,982	12/24/1999	ST	T0D	9763	9942	179	0	W			1
	MC0582#1ST1 (A2)	582		608174085203	G16623	11,050	12,982	12/24/1999	ST	T1A	10542	10550	8	5	O	1		
	MC0582#1ST1 (A2)	582		608174085203	G16623	11,050	12,982	12/24/1999	ST	T1B	10825	10898	73	35	O/W		1	
8	MC538#1	538	1	608174085201	G16614	8,394	8,980	10/28/1999	ST									
9	MC538#1BP1	538	1	608174085202	G16614	10,446	12,115	11/14/1999	ST	T0A	8833	8965	132	0	W			1
	MC538#1BP1	538		608174085202	G16615	10,446	12,115	11/14/1999	ST	T0B	9087	9217	130	0	W			1
	MC538#1BP1	538		608174085202	G16616	10,446	12,115	11/14/1999	ST	T0C	9323	9418	95	0	W			1
	MC538#1BP1	538		608174085202	G16616	10,446	12,115	11/14/1999	ST	T0D	9442	9553	111	0	W			1
	MC538#1BP1	538		608174085202	G16616	10,446	12,115	11/14/1999	ST	T1A	9975	10010	35	13	O	1		
10	MC538#1ST4	538	1	608174085205	G16614	12,301	15,562	7/2/2001	COM									
11	MC538#3 A4	538	1	608174094300	G16614	10,546	17,580	1/11/2002	COM									
12	MC538#2BP4	538	1	608174087404	G16614	12,400	14,100	4/23/2000	COM	T4A	11207	11229	22	7	O/W		1	
	MC538#2BP4	538		608174087404	G16614	12,400	14,100	4/23/2000	COM	T4B	11642	11784	142	141	O	1		
13	MC538#2BP2	538	1	608174087402	G16614	9,800	10,971	3/29/2000	ST	T1A	9321	9354	33	6	O/W		1	
	MC538#2BP3	538		608174087402	G16615	9,800	10,971	3/29/2000	ST	T1B	9436	9507	71	61	O	1		
14	MC538#2BP3	538	1	608174087403	G16614	9,511	10,587	4/8/2000	ST									
15	MC538#2BP1	538	1	608174087404	G16614	9,300	10,293	2/24/2000	ST	T0A	8557	8671	114	24	O/W		1	
	MC538#2BP1	538		608174087404	G16614	9,300	10,293	2/24/2000	ST	T0B	8728	8741	13	11	O/W		1	
	MC538#2BP1	538		608174087404	G16614	9,300	10,293	2/24/2000	ST	T0C	8837	8893	56	0	W			1
	MC538#2BP1	538		608174087404	G16614	9,300	10,293	2/24/2000	ST	T0D	8937	8999	62	0	W			1
16	MC538#2	538	1	608174087400	G16614	6,851	7,229	1/28/2000	ST									
T			16													10	6	14

Table VI. Well control in Medusa Field.

2.3.1 Salt Interpretation and Map Generation

Starting with the salt picking was important, for considering it the main structure that governs the area. Following the procedure contained in table IV. The salt top and bottom of the salt body in the fifteen blocks pertaining to Mississippi Canyon were interpreted (see figure 4). In 3D seismic data the interpreter has the opportunity of generating accurate subsurface structure maps. This can be achieved only by managing also data available. If a better understanding of the salt structure in the area will help in analyzing possible quality traps is wondered. This part of this study has been important to develop the ability of understanding seismic signatures for salt recognition and its effect on sub salt and underlying strata. Also if it is planed to go from a regional scale to a local scale for sands recognition in an area of Mississippi Canyon surrounding the main Medusa Field, where data is scarce, a few but important aspects have to be understood.

Interpretation of seismic reflections terminations against salt is a very important matter because many hydrocarbon traps are found in this structural position (Allistair Brown, 1999).

2.3.2 Deep Horizon Picking

The data pertaining to sub salt horizons was scarce in the area. There was a well in south Medusa that reached Middle Lower Miocene and a subsalt well that went into the Middle Miocene Top, RME 667 and CHE 627 respectively (See Figure 4 and 5). The only purpose was to generate an Isochron to predict the age of a sub-salt horizon identified (See figure 4 and 5).

2.3.3. Event Tracking

The recognition of an amplitude anomaly (AA), consistent in different directions in the seismic view, represented a subsalt horizon that I tracked using the procedure in table IV. In the stratigraphy chart on figure 5 on the red spot we can see the location. On figure 4 is the map view.

2.3.3.1. The Amplitude Extraction of AA Event.

After tracking the subsalt event. Zap function was applied on openwork window. Also Amp function was activated to extract the maximum amplitude from the seismic map. Everything under seisworks, landmark product.

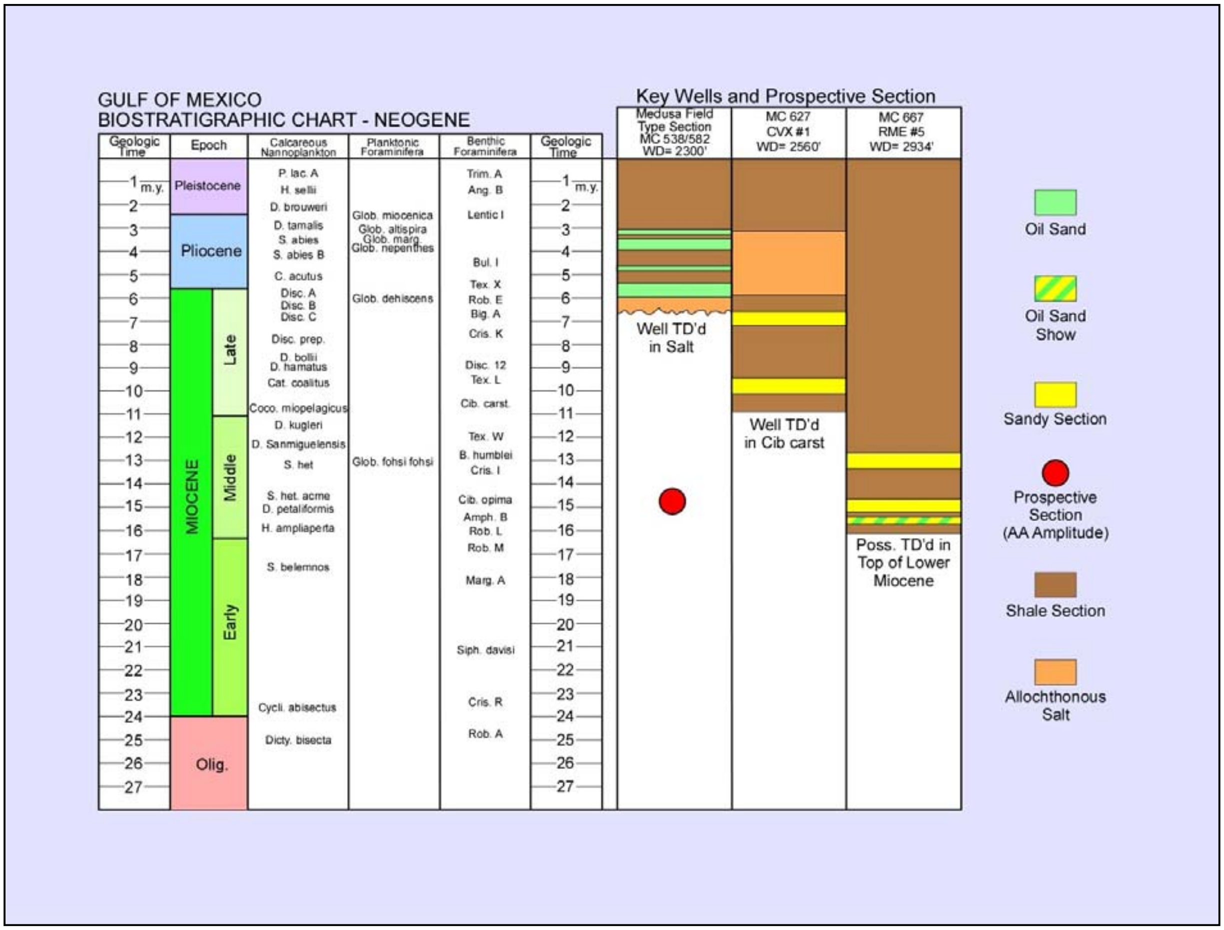


Figure 5. Stratigraphy Column of Wells MC581, MC627 and MC667. Estimating Sub-salt event age. Courtesy of Murphy Oil and Exploration.

CHAPTER 3: RESULTS AND ANALYSIS

This study includes data analyzed at both: a regional to a local scale. The reason I decided to start with the interpretation of the salt body was because I do believe that the interpretations have to be done in the following order:

1. Salt.
2. Faults and horizons.

In addition, the salt in northern GOM represents a false bottom because of the difficulties in producing good images bellow it. (Galloway et al., 2004).

Results are presented and discussed in as follow:

3.1. Salt interpretation

Using the 3-D seismic data in depth. It was possible to track the top and bottom of the salt structure comprising the study area, see figure 8 and 9.

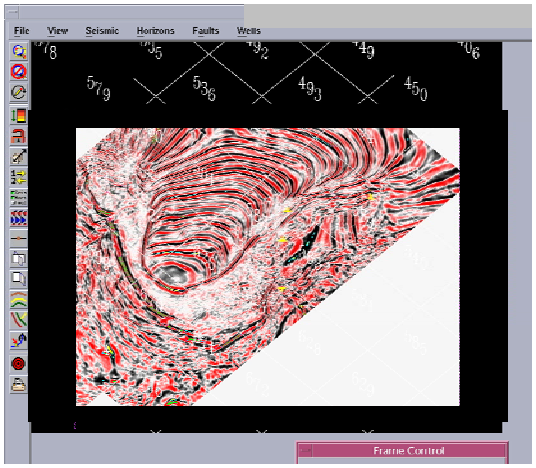
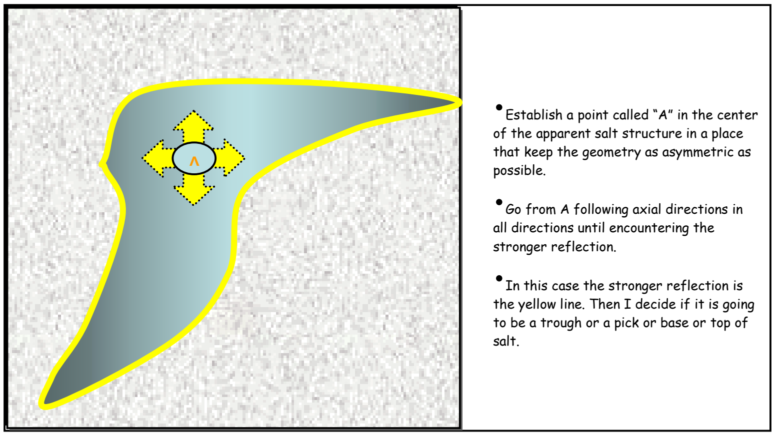


Figure 6. Aerial Depth slice. View of salt in the study area.

The first map produced was the top of salt by picking the first strong positive reflection (pick). To achieve this I formulated the next logic way of interpreting salt was formulated, this logic way is under ideal conditions. Which are: Perfectly processed data, with perfect migration and perfect velocity model that fit the 3 Dimensional earth.

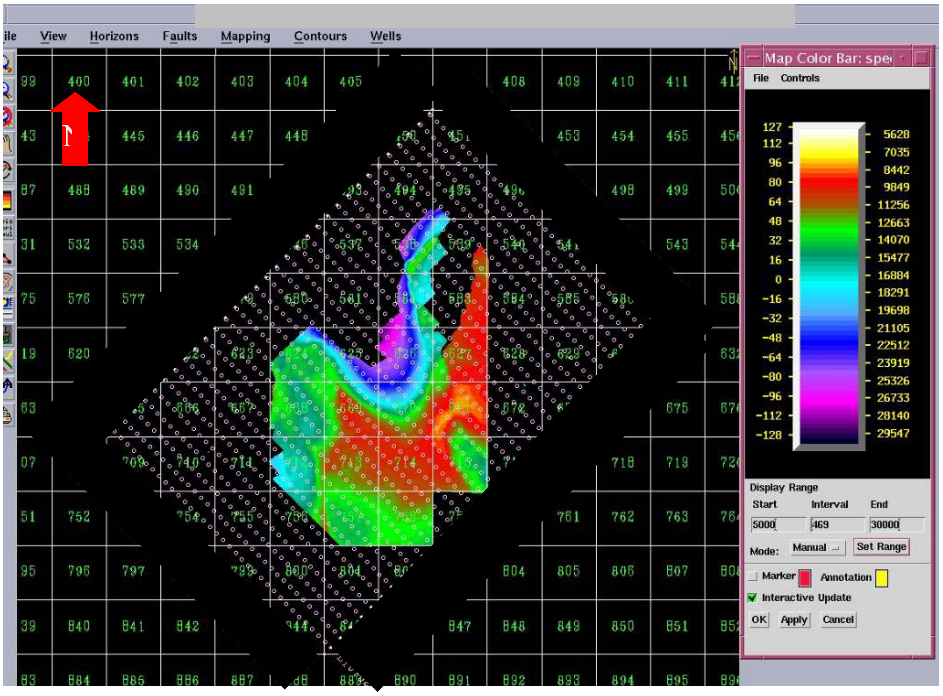


- Establish a point called "A" in the center of the apparent salt structure in a place that keep the geometry as asymmetric as possible.
- Go from A following axial directions in all directions until encountering the stronger reflection.
- In this case the stronger reflection is the yellow line. Then I decide if it is going to be a trough or a pick or base or top of salt.

Figure 7. Draw of proposed Logic way to interpret a salt model for exploration effects.

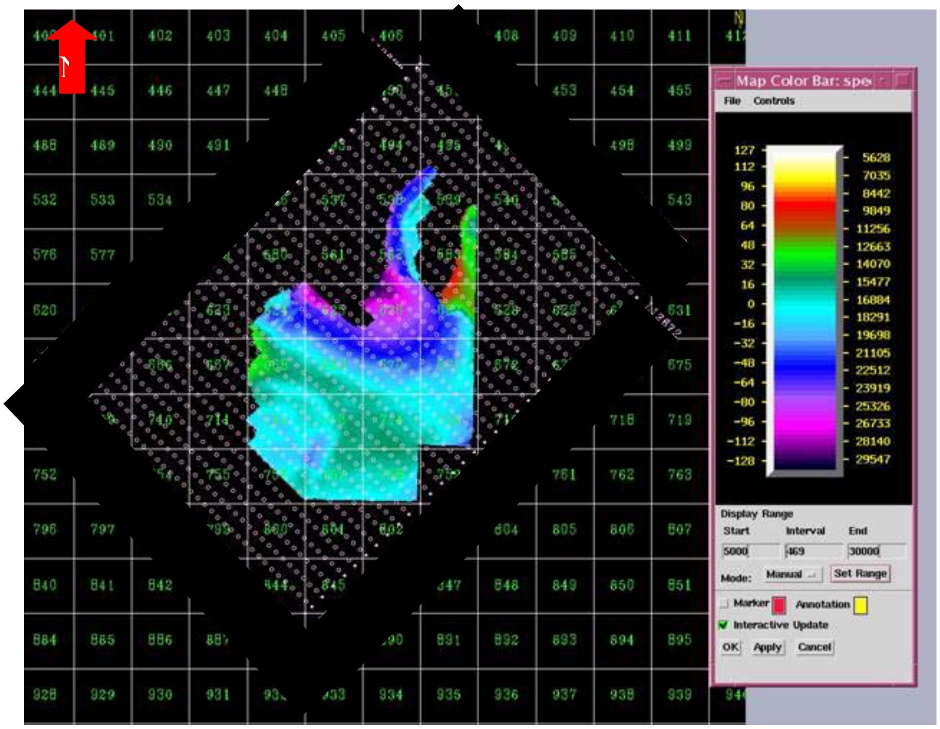
3.1.1. Top and Base of Salt

In this section the map seismic view from the top and base of salt are presented.



Display Range
Start 5000
Interval 469
End 30000
Mode: Manual
☑ Interactive Update

Figure 8. Top of salt



Display Range

Start: 5000

Interval: 469

End: 30000

Mode: Manual

☐ Marker

☑ Interactive Update

Figure 9. Base of salt.

The salt body in the study area is located in the north east of Mississippi Canyon block in deep water GOM. I will discuss a few aspects from the observations of this structure. The data used is a data processed by TGS and provided by Murphy oil and Exploration for study purposes. There are three basic observations about the data.

- ✓ Geometry.
- ✓ The error related with sediment thickness.
- ✓ The effect of salt thickness change on the resolution of the subsalt image. Is

The Salt structure is a concave toward the north or basinward in plan view. The salt body is apparently being emplaced with a North West - South East direction (Figure 6). This direction in salt mobilization is activated by differential loading mechanism where the density of sediments overlying the salt is higher than salt density, causing this to move to areas of less density. See figure 10.

Also it is observed on figure 10 in salt geometry that as it is truth that differential loading is activated in an early diapirism stage on the pivot point showed in figure 17, the salt body is not displacing as a sheet extending laterally in the North West - South east direction. It is observed that it is thickening toward the mobilization trend maybe encountering a salt body in the east side that caused the overhang and the detachment surface observed in the south western flank of the structure as shown in figure 10.

The maximum and minimum thickness in the salt structure is calculated in Figure 11

The error related with sediment thickness was calculated in two different points where wells penetrated the structure. See Figure 12.

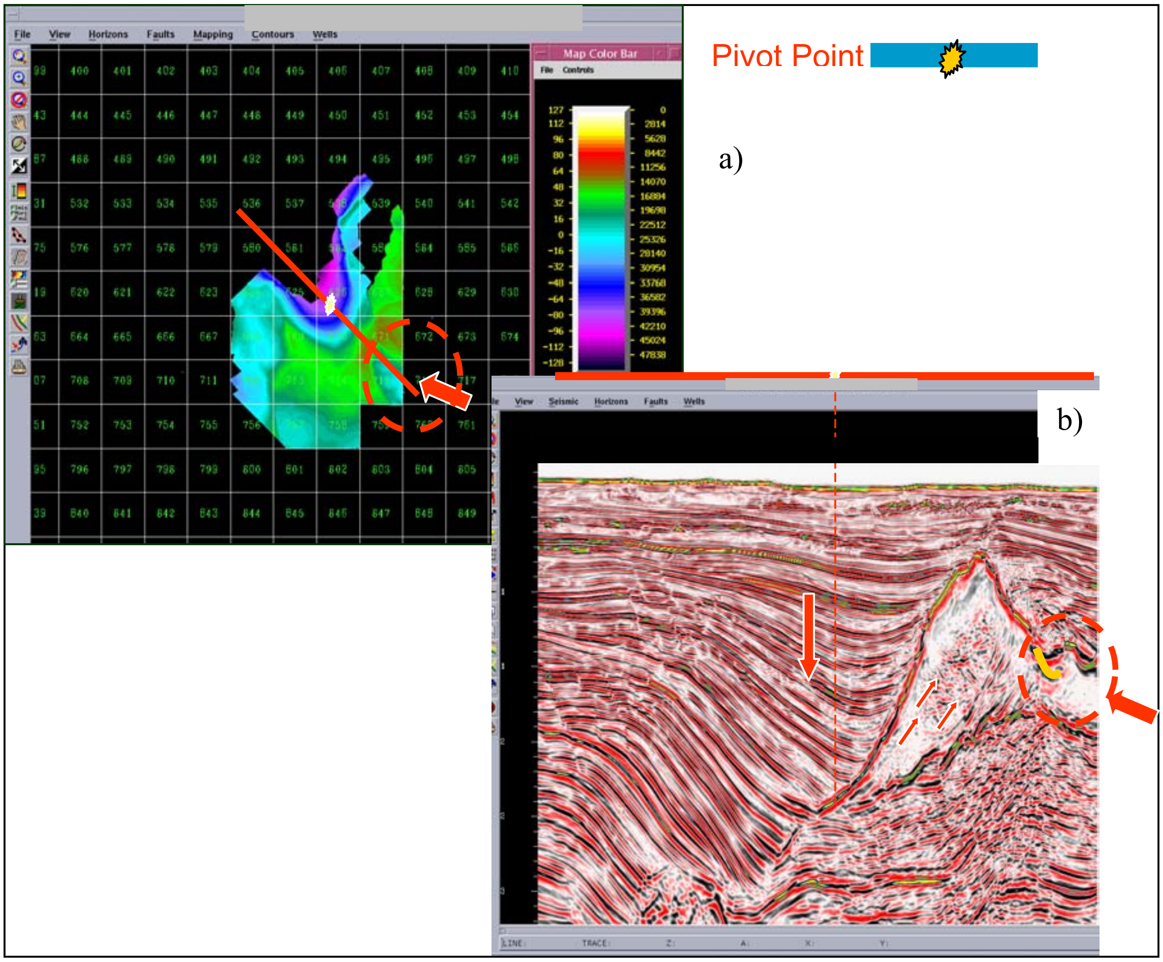


Figure 10. Differential Loading Mechanism a) Map view of the arbitrary line showing the pivot point where differential loading mechanism is causing the salt displacement in north west – south east direction, b) Also we notice the stage of early and active diapirism that forms a normal fault in the right flank. As we can appreciate in the right side of the body we notice an indication of an overlying salt that moving the arbitrary line keeping the pivot point 30 degrees in a counter wise clock direction. the formation of an

As can be observed there is a relationship in between the change in the salt thickness with the possible salt welds. As pointed in figure 12.

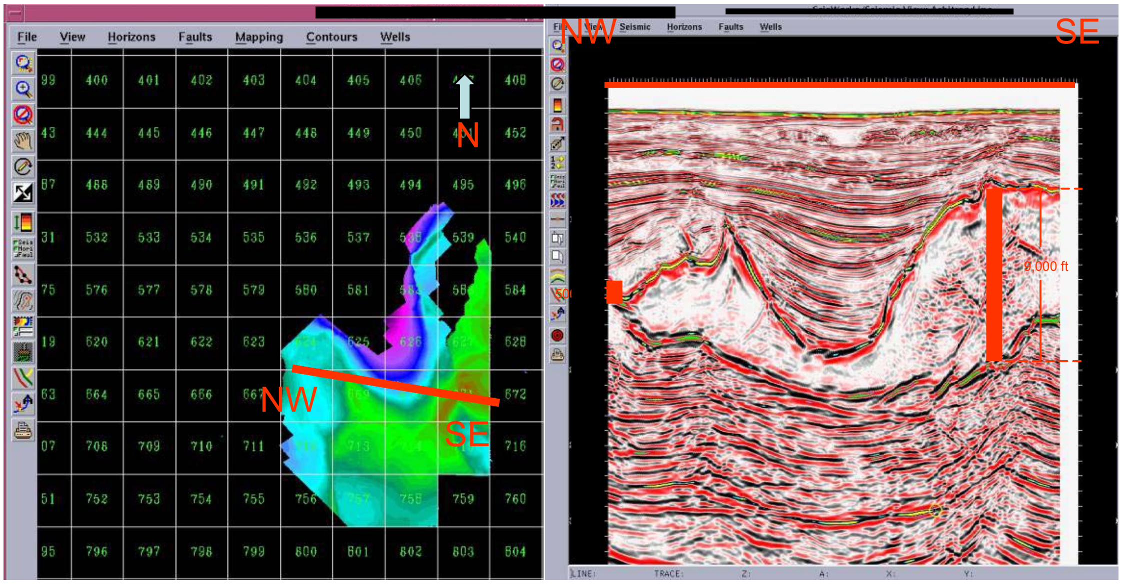
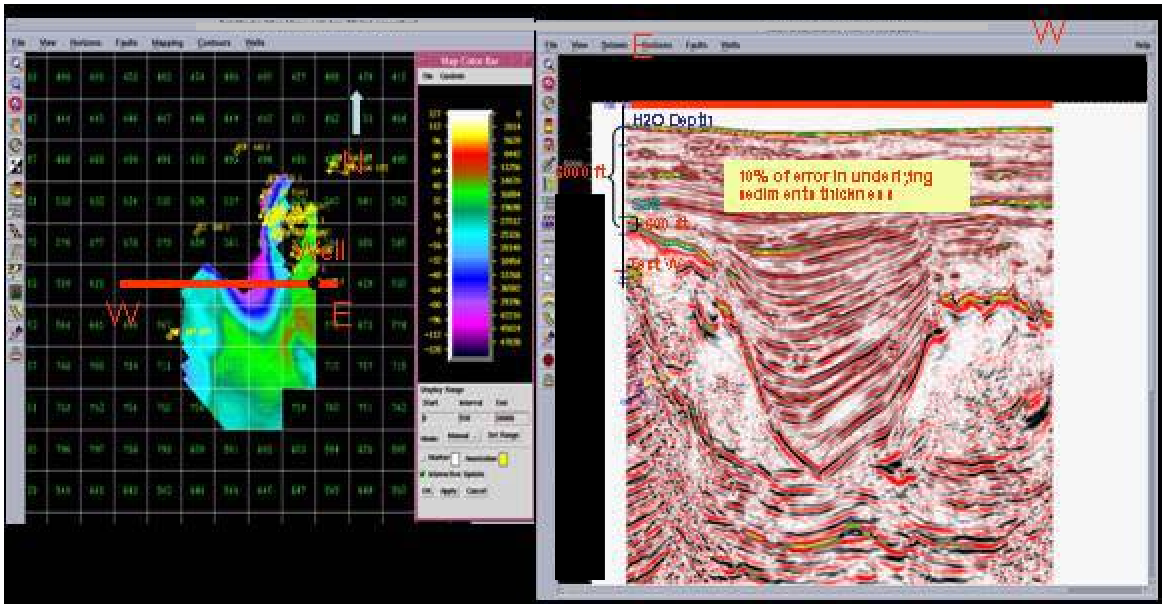


Figure 11. Maximum and minimum salt thickness.



10% of error in underlying sediments thickness

[redacted]

Figure 12. Error related with sediments thickness.

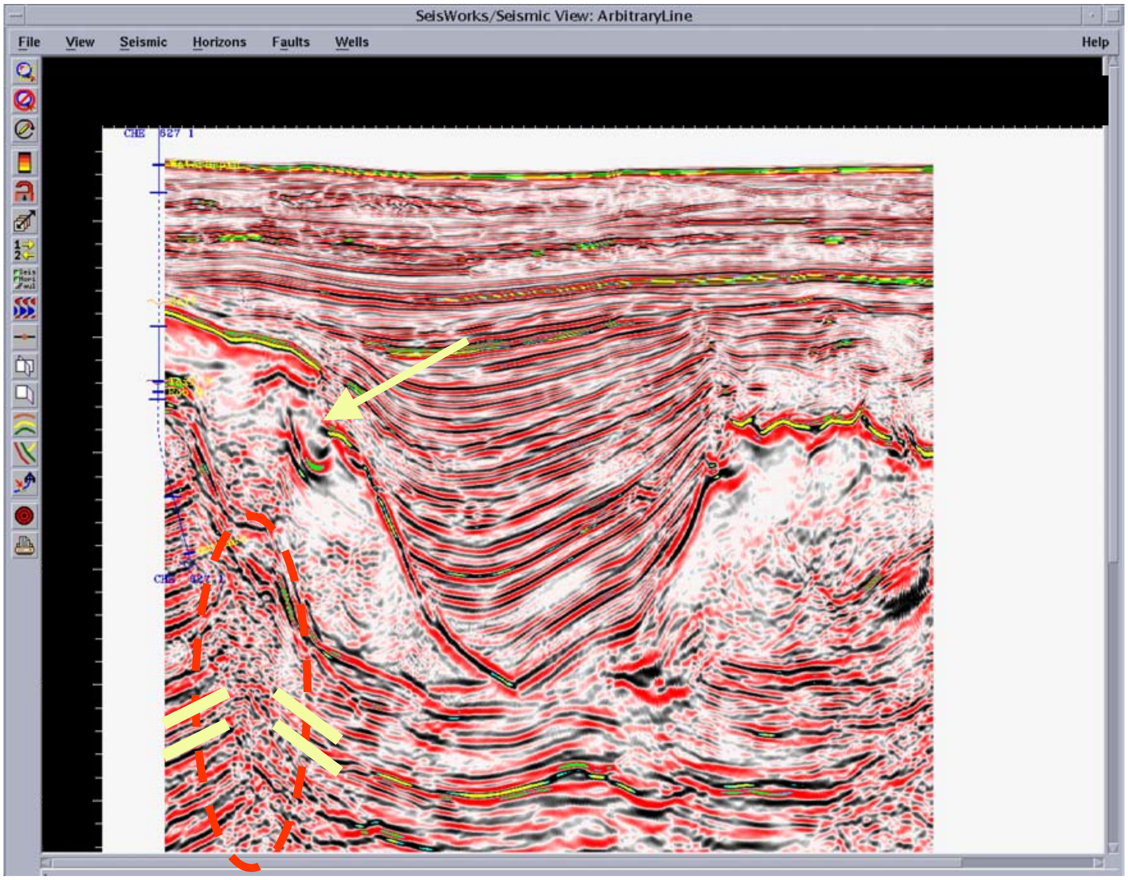


Figure 13. Observation of salt overhang and salt weld. We observed that where the salt overhang is happening it seems to appear as if bellow the structure there is a salt weld. If we observe how the layers deeps (on yellow) it is exactly the result of a fluid rising upward from a deepest source. It occurs where the overhang happens.

The salt structure seems to be moving through out the middle to upper Miocene. Proceeding from the Oligocene. This is deduced from the subsalt and underlying salt paleos.

3.2.Subsalt Horizon Interpretation and Discussion.

Looking for subsalt closures. That could represent a subsalt trap of hydrocarbons; an amplitude anomaly consistent in different directions of the seismic data towards a salt body was noticed. It could later be recognize two possibilities that this amplitude anomaly (AA) could be or of reservoir quality (Figure 15) or the salt bottom reflected (Figure 16).

3.3. Hypothesis

Previous analysis pointed, it could be observed in the data a subsalt amplitude anomaly consistent in various directions and that seems to consist of a subsalt closure (see figure 14).

As during the Middle to Miocene is when the primary mechanism to activate the salt is the differential loading[2], it was during the Upper Miocene when the structures are compressed and shortened triggering rejuvenation of diapirs and turtle structures. In the entire structure it happens that there is an early stage of diapirism. This can be noticed in general by the asymmetric shape of the structure and a thick section of prediapiric sediments on top of the salt. On this base I suggest to study the possibility showed on figure 14.

During Oligocene-Early Miocene, there was a sediment starvation period, the structures were symmetric because of the lack of triggered mechanisms, in this way what seems to be a dome structure resulted in the Oligocene. During Middle Miocene, deep water deposition created differential loading triggering the salt rising. During Late Miocene, there is the activation of gravity spreading and piercing, causing the entrapment of early Miocene sediments against the inclined sigmoid like salt body showed on figure 14. If this is truth an evaluation of any amplitude anomaly sustained across an structural prospective area should bring clue to future subsalt prospecting analysis.

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[2] See Appendix I. Schematic Profiles showing the structutural Evolution of the Mississippi Canyon (MC) Minibasin and MC fold belt. Adapted from Ricardo Combellas et al paper.

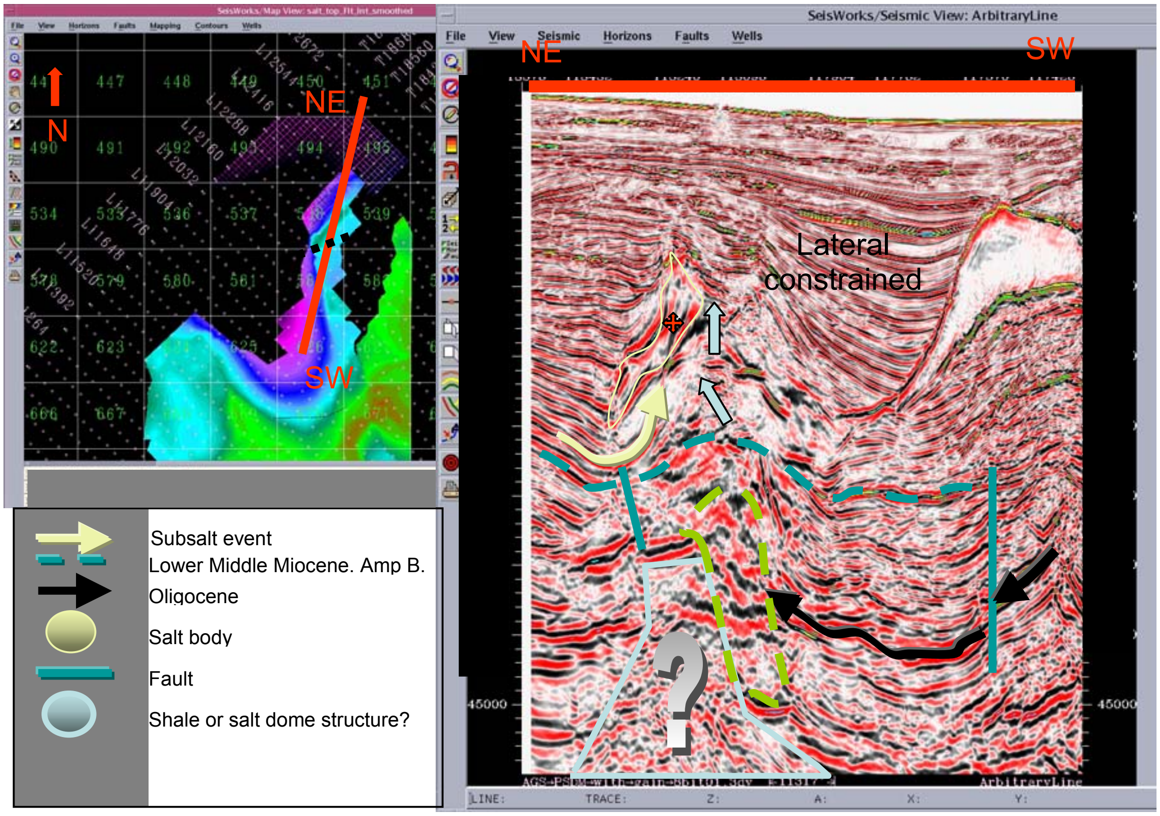

Figure 14. Hypothesis.

I want to point something prior to the analysis of these two possibilities.

1. As seen in the well chevron 627 # 1. The salt base corresponds with top Middle Miocene (Tex. X). Therefore the salt is moving through upper lower - middle Miocene. (See figures 5)
2. The subsalt event mapped is in between the lower middle Miocene (Amp B) and Middle upper Miocene (chris K). (See figure 5).

Examining figure 11. Salt is displacing in NW direction. As we said before, there is a clear area where differential loading is the mechanism that activates salt movement in that direction. If the displacement of salt activated by this mechanism is in its latest stage, or in other words if all the salt has already been displaced. What is remaining is a thin layer as a thin tail of a sigmoid structure. Another important point is that after mapping a horizon represented by Amp B, I can see that my AA subsalt event is a few feet above this Amp B horizon, leading me to the possibility of being in the lower Miocene. If the salt is moving through the Middle Miocene to upper Miocene, then is possible that this AA subsalt event is not salt, which support theory number 1 on figure 15.

In the next figures 17 and 18 the maps obtained from the seismic are presented.

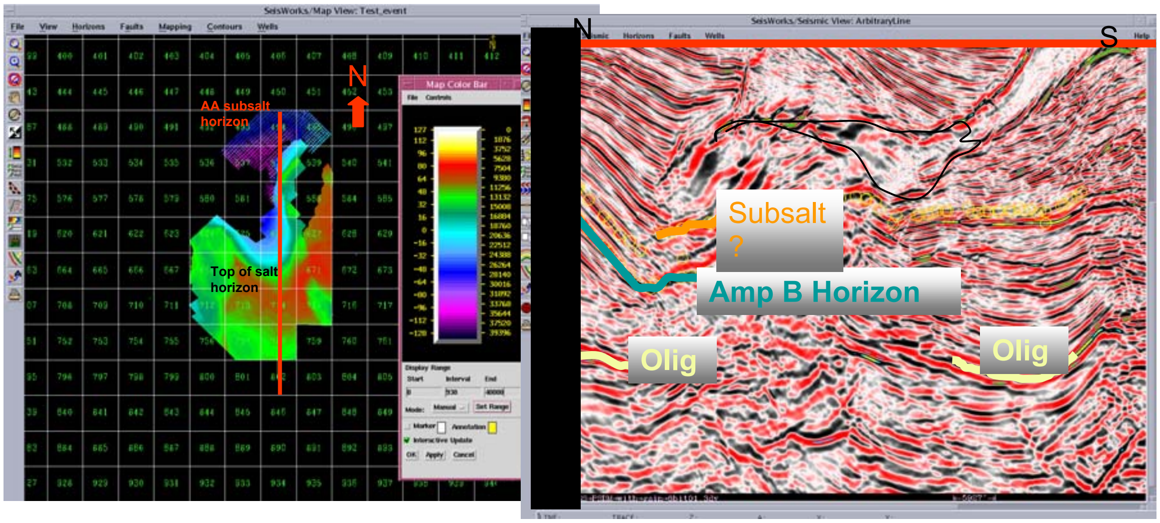

Figure 15. Theory #1.

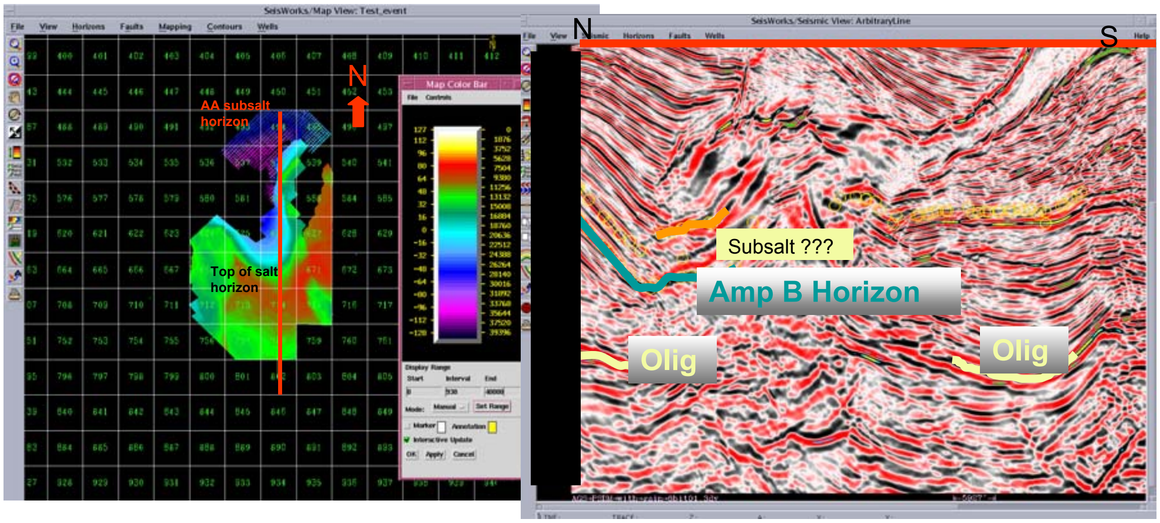

Figure 16. theory #2.

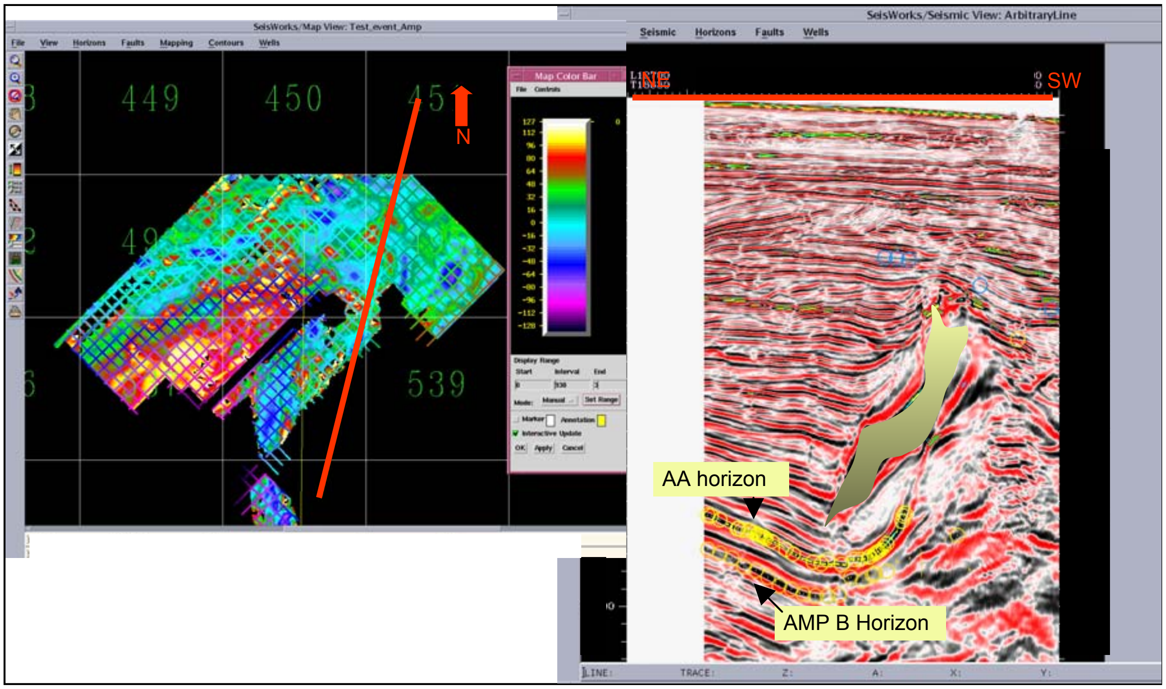

Figure 17. Amplitude extraction of the subsalt horizon following theory #1.

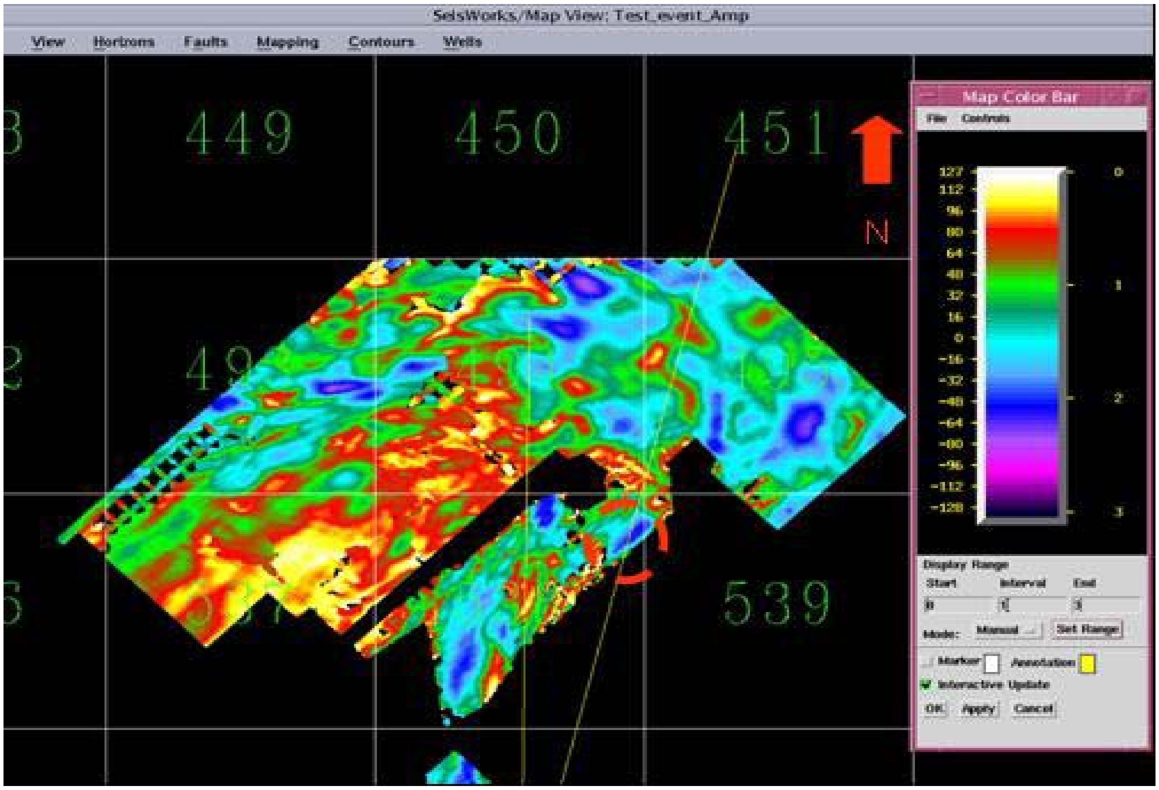

Figure 18. Extraction Amplitude Map of the Subsalt horizon. The encircled area is the location of the amplitude anomaly mapped.

CHAPTER 4: CONCLUSIONS

1. The allochtonous salt structure is displacing NW – SE direction through Middle to Late Miocene. During Middle Miocene the salt mobility was activated by Differential loading and during Late Miocene an active diapirism dominated the structures.

2. It is important to recognize the nature of any salt weld interpretation. Determine the effects of salt thickness and geometry on sub-salt reflections is critical.

3. The velocity utilized to process these data has to be corrected. There is 10% estimated error in overlying sediment thickness.

4. The sub-salt map presented could represent theory #1, noted in the results. This could lead to a feasibility evaluation for further decisions.

5. The salt structure below which there is the sub salt horizon is not connected to the main structure (Black dashed line on figure 17).

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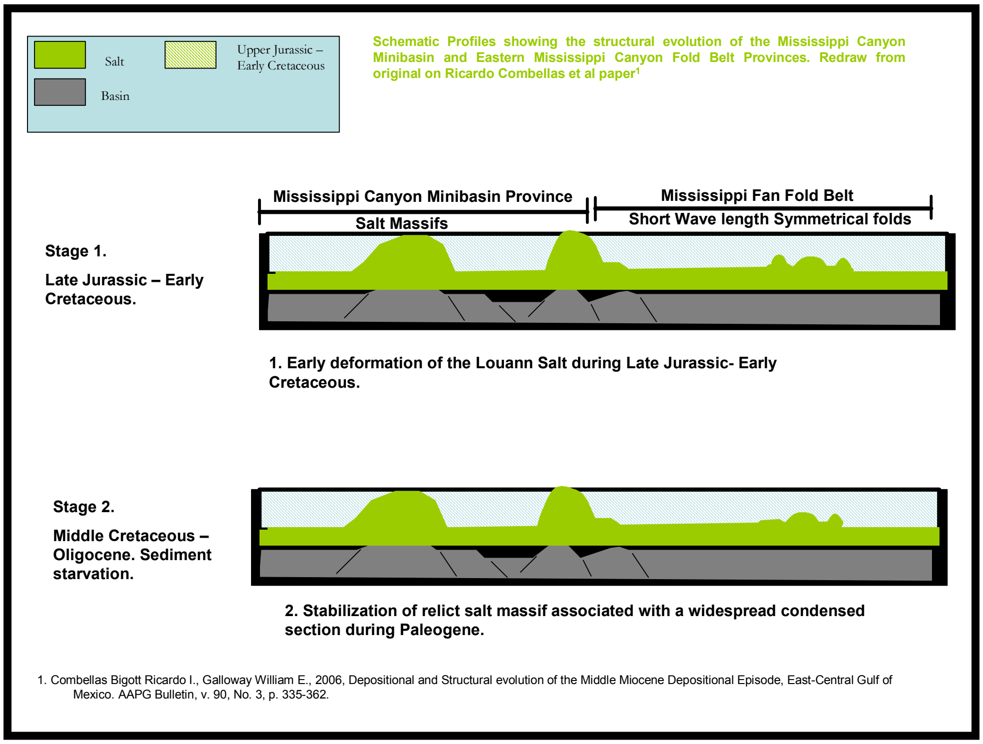
APPENDIX

Appendix I: Schematic profiles showing the structural evolution of the MC Minibasin and Eastern MC Fan Fold Belt[3]



Schematic Profiles showing the structural evolution of the Mississippi Canyon Minibasin and Eastern Mississippi Canyon Fold Belt Provinces. Redraw from original on Ricardo Combellas et al paper[1]

Stage 1.

Late Jurassic – Early Cretaceous.

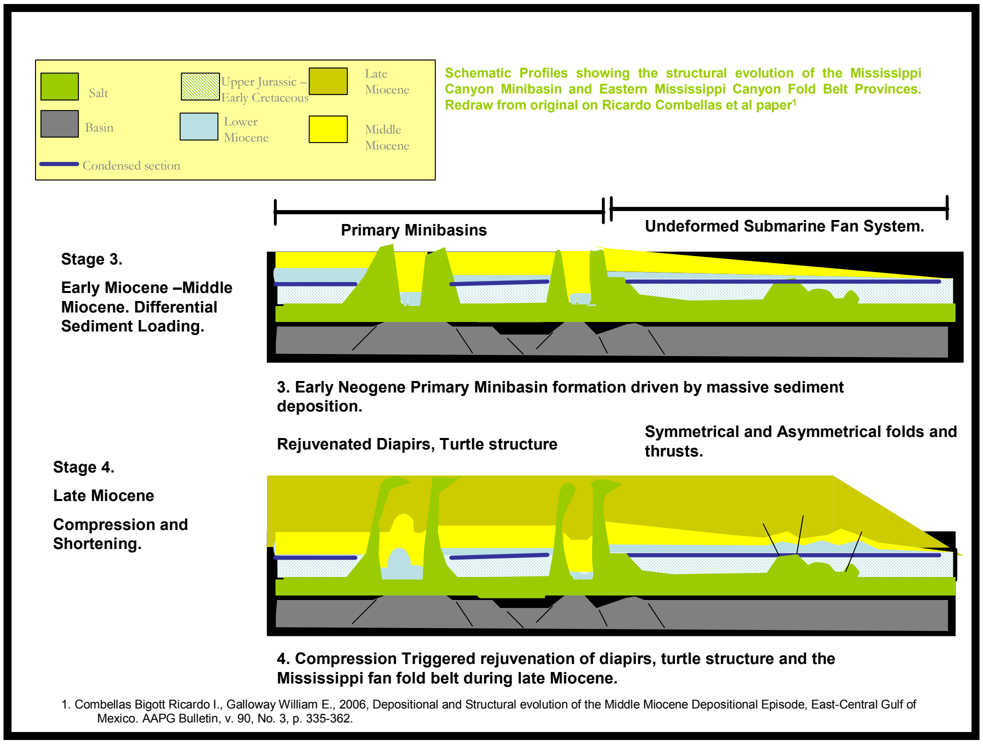
1. Early deformation of the Louann Salt during Late Jurassic- Early Cretaceous.

Stage 2.

Middle Cretaceous – Oligocene. Sediment starvation.

2. Stabilization of relict salt massif associated with a widespread condensed section during Paleogene.

1. Combellas Bigott Ricardo I., Galloway William E., 2006, Depositional and Structural evolution of the Middle Miocene Depositional Episode, East-Central Gulf of Mexico. AAPG Bulletin, v. 90, No. 3, p. 335-362.



Schematic Profiles showing the structural evolution of the Mississippi Canyon Minibasin and Eastern Mississippi Canyon Fold Belt Provinces. Redraw from original on Ricardo Combellas et al paper[1]

Stage 3.

Early Miocene –Middle Miocene. Differential Sediment Loading.

3. Early Neogene Primary Minibasin formation driven by massive sediment deposition.

Stage 4.

Late Miocene

Compression and Shortening.

4. Compression Triggered rejuvenation of diapirs, turtle structure and the Mississippi fan fold belt during late Miocene.

1. Combellas Bigott Ricardo I., Galloway William E., 2006, Depositional and Structural evolution of the Middle Miocene Depositional Episode, East-Central Gulf of Mexico. AAPG Bulletin, v. 90, No. 3, p. 335-362.

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[5] Adapted from: Combellas Bigott Ricardo I., Galloway William E., 2006, Depositional and Structural evolution of the Middle Miocene Depositional Episode, East-Central Gulf of Mexico. AAPG Bulletin, v. 90, No. 3, p. 335-362.

Appendix II. Sediment deposition Analysis for Middle Miocene.

The Discoaster B is a top upper Miocene paleo reflected in several wells that are producing from T4B sand. What I realized later Is that I have to look for the same depositional environment that contains sands as productive or better than T4B sands, finally I got to the conclusion of what is exploring and that what I am looking for is the same depositional environments where the structures facilitates me the localization of traps: seal, fluid and possibility of getting there.

During the Middle Miocene a pronounced eastward migration of the ancestral Mississippi river depocenter occurred. Sediments are deposited east of the actual Mississippi delta. (Jesse L. Hunt et al).

Amphistegina shale (Amp B), the ancestral Mississippi river prograded the paleoshoreline. Here a first evidence of Tennessee drainage system into the GOM is noticed. (Jesse L. Hunt et al).

During the appearance of Cibides Optima, there is a cycle of great retreat and erosion of deltas, the Mississippi and Tennessee delta. The thickest deposition were in the eastern Mississippi canyon minibasin province. (Jesse L. Hunt et al).

During Cristelaria I, Regional flooding event. The shore line retreated 16 Km with respect to genetic cycle 2. Here a prominent ancestral Tennessee delta fluvial, delta, delta fed apron system tract developed nourishing the growing radial Mississippi canyon Atwater valley fan system. (Jesse L. Hunt et al).

Tex W, Extend from western to the east of the present Mississippi river delta. The earliest productive Progradational facies are contained are in offshore eastern Louisiana. The only aggradational facies with pay in the central GOM occur off the coast of Mississippi and Alabama. These facies were deposited by the ancestral Mobile River system. No transgressive facies were observed in this chronozone. (Jesse L. Hunt et al).

During upper Miocene the ancestral Mississippi river depocenter began migrating to the west. Deposition extends basinward across the Louisiana OCS, especially during late upper Miocene. Submarine fan facies with associated hydrocarbons extend across Mississippi Canyon area and are observed in Green Canyon and Garden Banks areas. (Jesse L. Hunt et al).

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