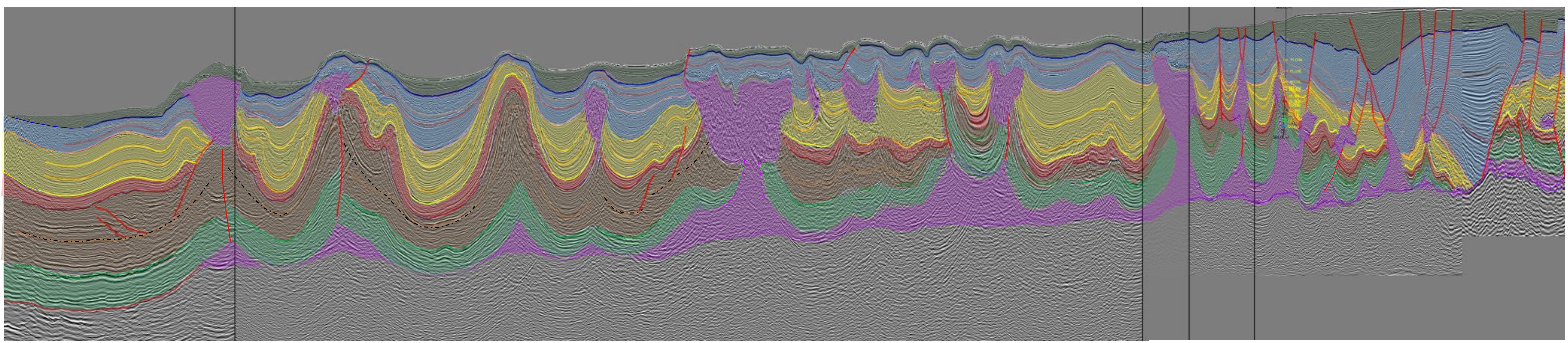
GULF OF MEXICO – DEEP WATER – SOUTH SECTOR

SALINE BASIN

PETROLEUM GEOLOGICAL SYNTHESIS



December 2015

GULF OF MEXICO – DEEP WATER – SOUTH SECTOR

Introduction

Article 39 of the Ley de los Órganos Reguladores Coordinados en Materia Energética, provides that Comisión Nacional de Hidrocarburos has the responsibility to ensuring projects are delivered according to the following rules:

- Accelerating the development of knowledge of petroleum potential in the Country.
- Increase the recovery factor and obtaining the maximum volume of crude oil and natural gas in the long-term, economically viable conditions of wells, of fields in process of extraction and abandonments sites.
- The replacement of hydrocarbon reserves, as guarantors of energy security of the Nation and, from the prospective resources, based on the available technology and according to the economic viability projects.
- The use of the most appropriate technology for exploration and extraction of hydrocarbons, according to the productive and economic results.
- Ensure that administrative processes responsible, with respect to the exploration and extraction of hydrocarbons activities, are conducted with adherence to the principles of transparency, honesty, accuracy, legality, objectivity, impartiality, effectiveness, and efficiency.
- Promote the development of the exploration and extraction of hydrocarbons activities for the benefit of the Country.
- Ensure the utilization of associated natural gas in the exploration and extraction of hydrocarbons.

As part of the next bidding rounds for hydrocarbon exploration areas, and in compliance with the above-mentioned functions, Comisión Nacional de Hidrocarburos prepared this document to present a Petroleum Geological Synthesis of the Saline Basin, focusing on its portion located in the Deepwater Gulf of Mexico.

Saline Basin: It is characterized by the presence of different deformation styles related to compressive tectonic events and salt tectonics, whose effects are printed on the sedimentary sequence as a structural front trending south-southeast to north-northwest, mainly developed from the Paleogene to Miocene time. The structural style reflects the strong influence of mass salt intrusions that originated the development of a series of structures in the form of large anticlines cored by salt, fauled blocks with high dip angles, as well as expulsed blocks and extruded salt canopies up to surface levels which may affect, in some cases, the topography of the seafloor.

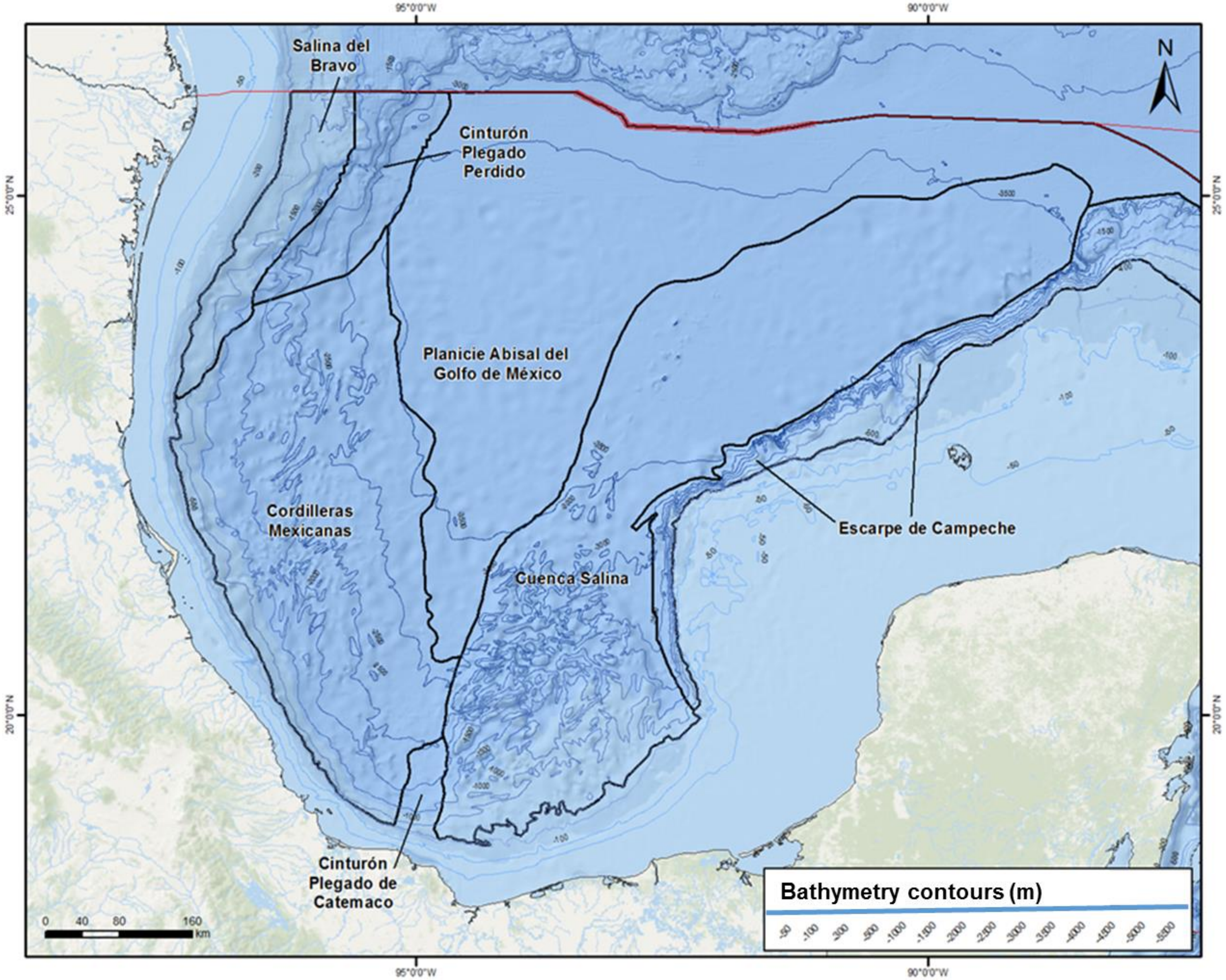
In this area, nine plays with prospective resources are identified and documented. In the Cenozoic, the Pliocene-Pleistocene and Miocene turbiditic sandstones. In the Paleogene the turbiditic sandstones of the Eocene-Oligocene and Paleocene are included. In the Mesozoic the plays known as Upper Cretaceous Breccia, Fractured Cretaceous carbonates and Upper Jurassic, are identified.

In this document, texts, maps, graphs and sections are addressed intended to be thematic elements as general indicative information about the Saline Basin in its Deepwater Gulf of Mexico portion:

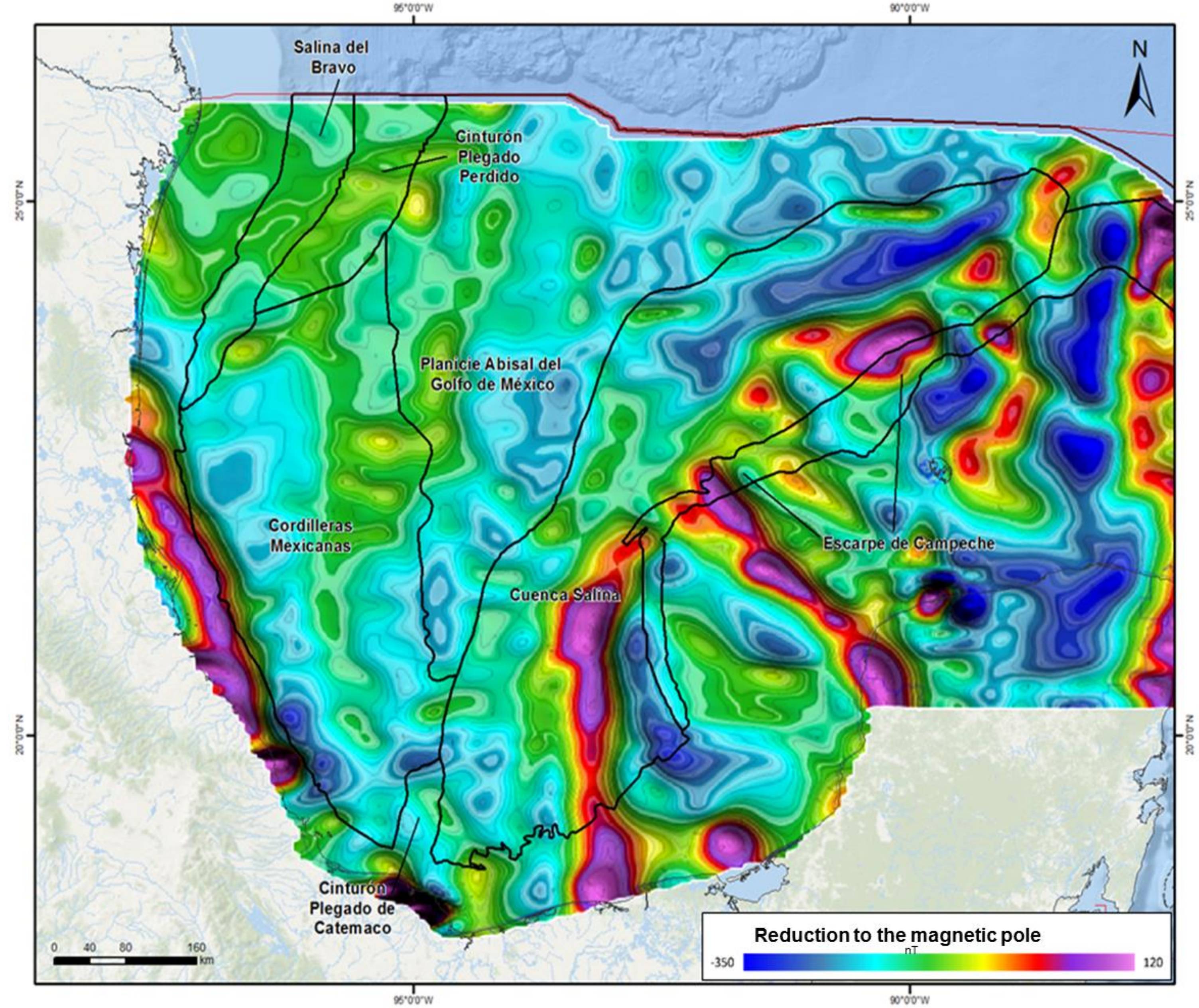
- The regional geological context .
- The stratigraphic framework of the Jurassic to the Pliocene, a description of the sedimentological and distribution of sedimentary facies sequences for petroleum prospectivity purposes.
- The structural framework, chapter where deformation processes of the sedimentary sequence and the resulting oil type traps, are described.
- Petroleum systems, that define the elements and processes of generation, migration and trapping of hydrocarbons accumulations.
- Plays Delimitation.

Regional Settings

Deep Water – Regional Settings – Geological Provinces



Geological provinces Map



Reduction to the magnetic pole Map

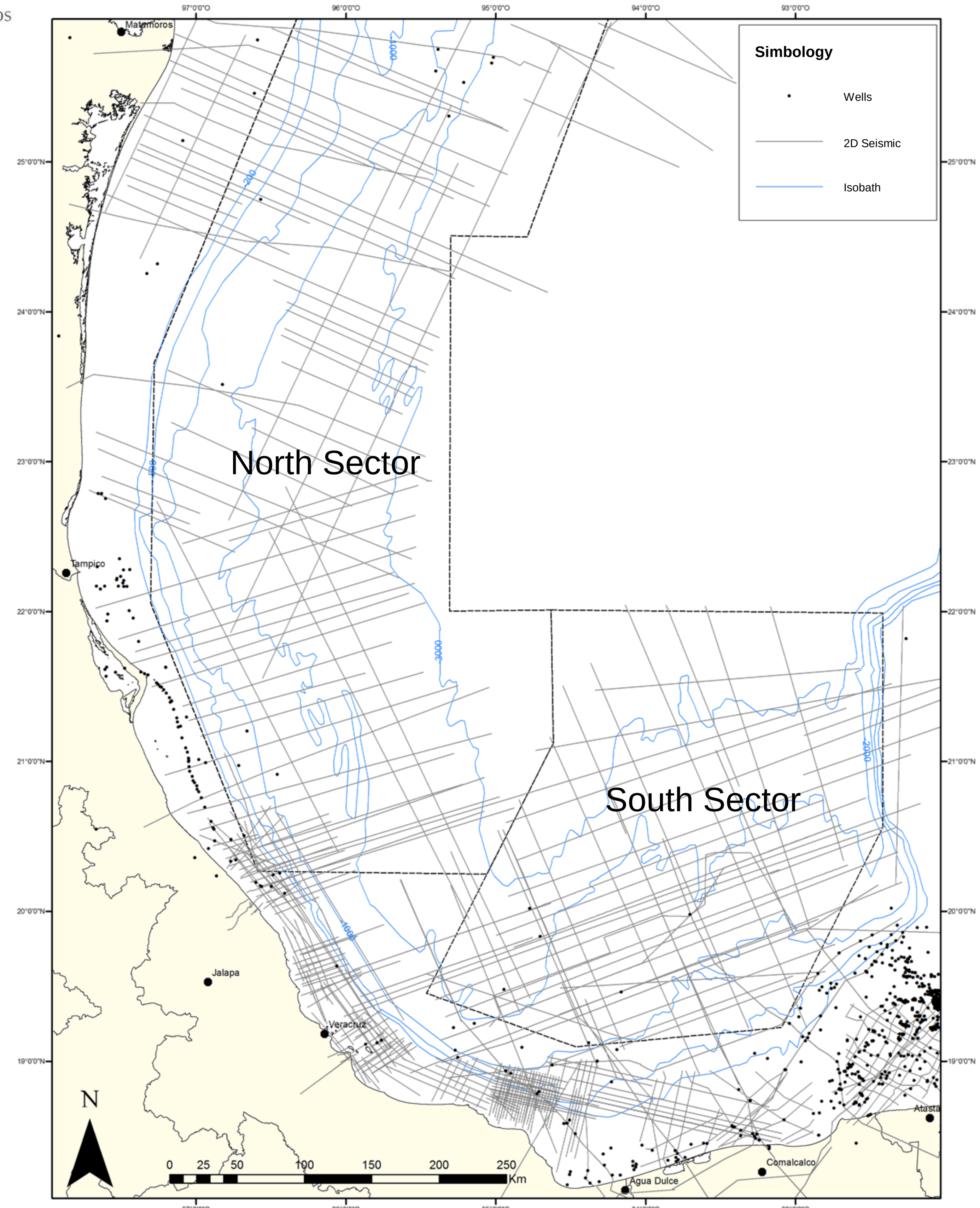
Deep Water area in the Gulf of Mexico extends from the 500 m isobath to 1,500 m depth in the open sea. The term ultra-deep water refers to depths greater than 1,500 m. In the Gulf of Mexico depths more than 3,500 m are registered.

Deep Water Geological provinces in the Gulf of Mexico:

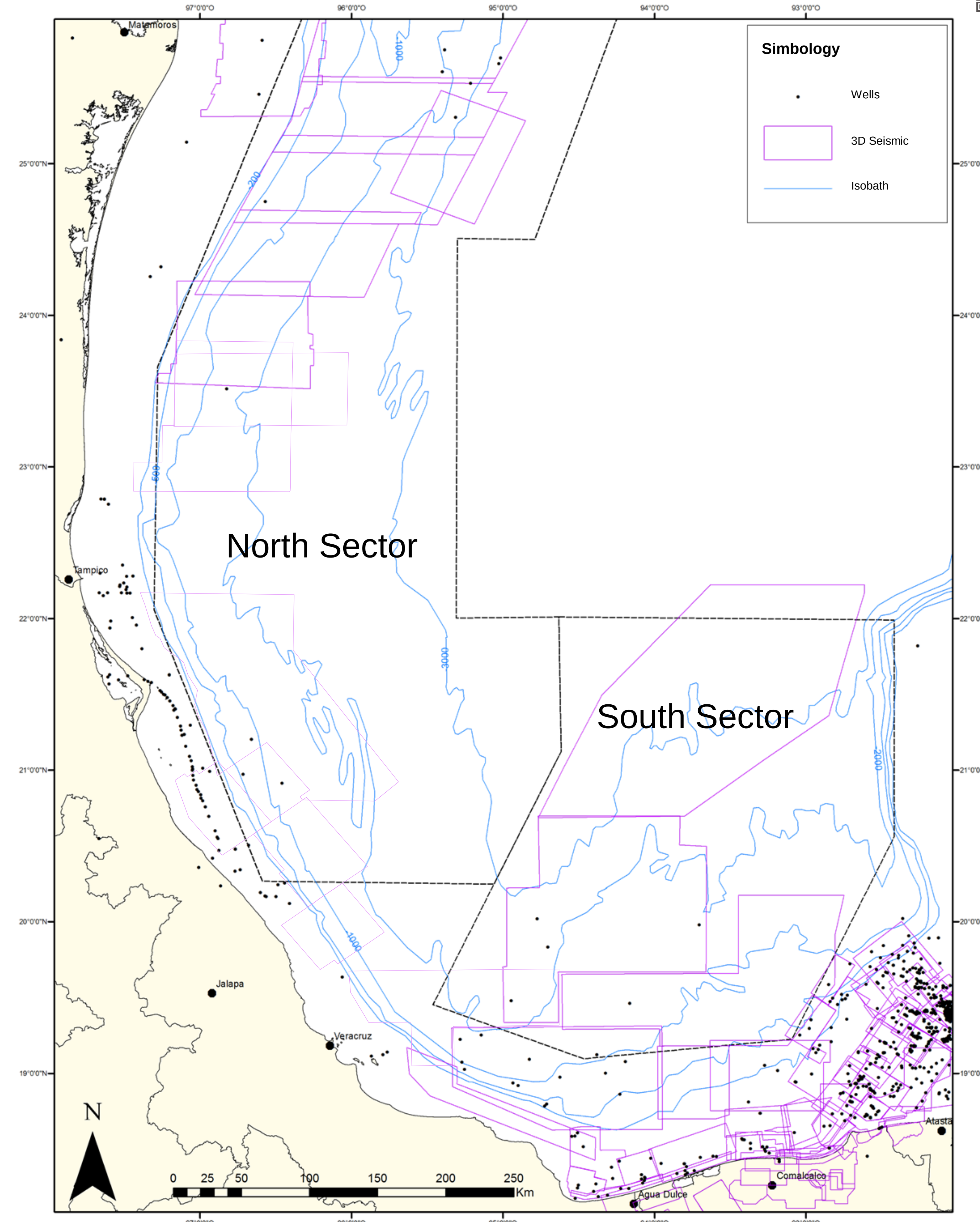
Salina del Bravo – Perdido Fold Belt (Cinturón Plegado Perdido)– Mexican Ridges (Cordilleras Mexicanas) – Catemaco Fold Belt (Cinturón Plegado de Catemaco) – Saline Basin (Cuenca Salina) - Campeche Escarpment (Escarpe de Campeche).

Reduction to north pole of the Gulf of Mexico map, relating the position of the magnetic anomaly with the direct position in subsurface of the basement morphologically positive elements.

Deep water – Regional Settings - 2D and 3D Seismic Map



2D Seismic



3D Seismic

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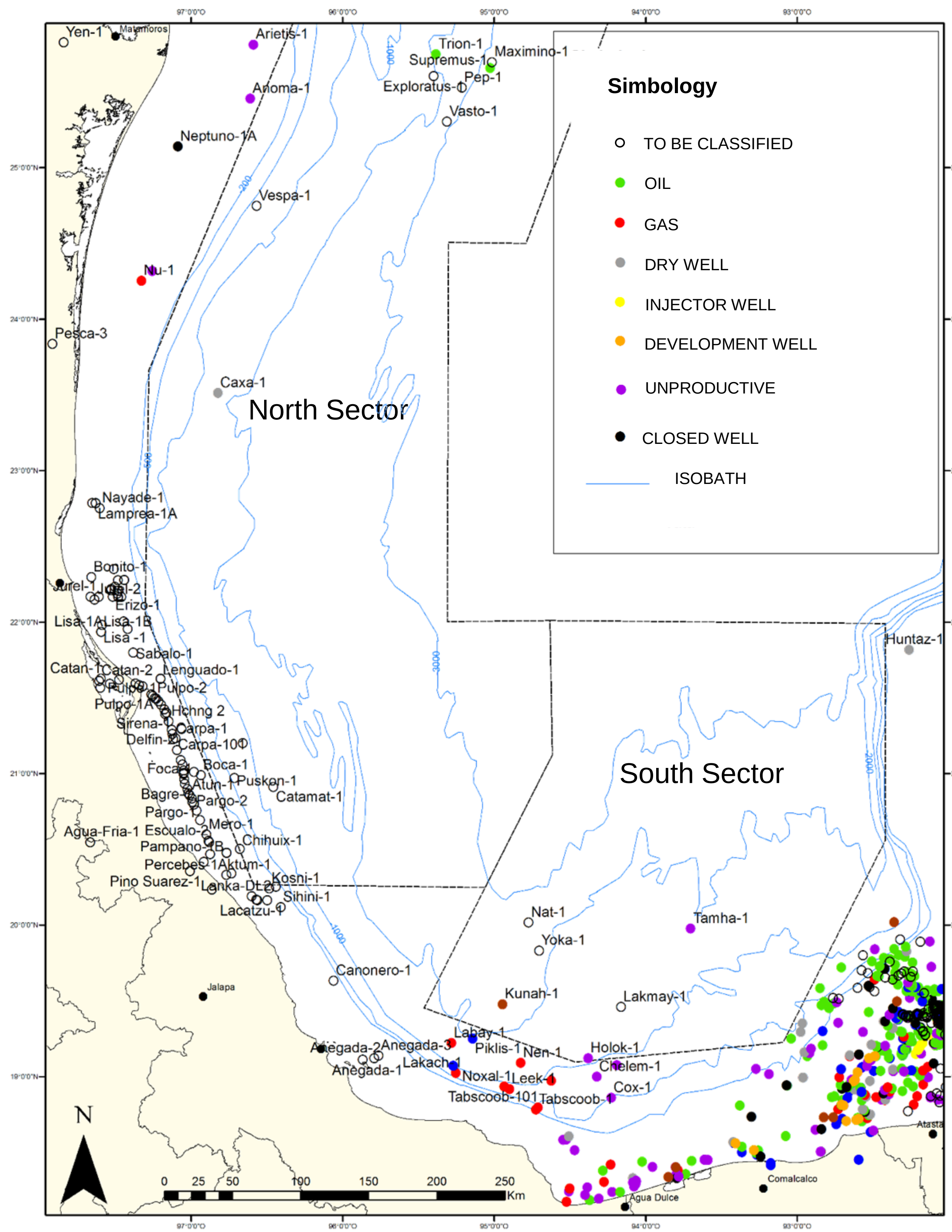
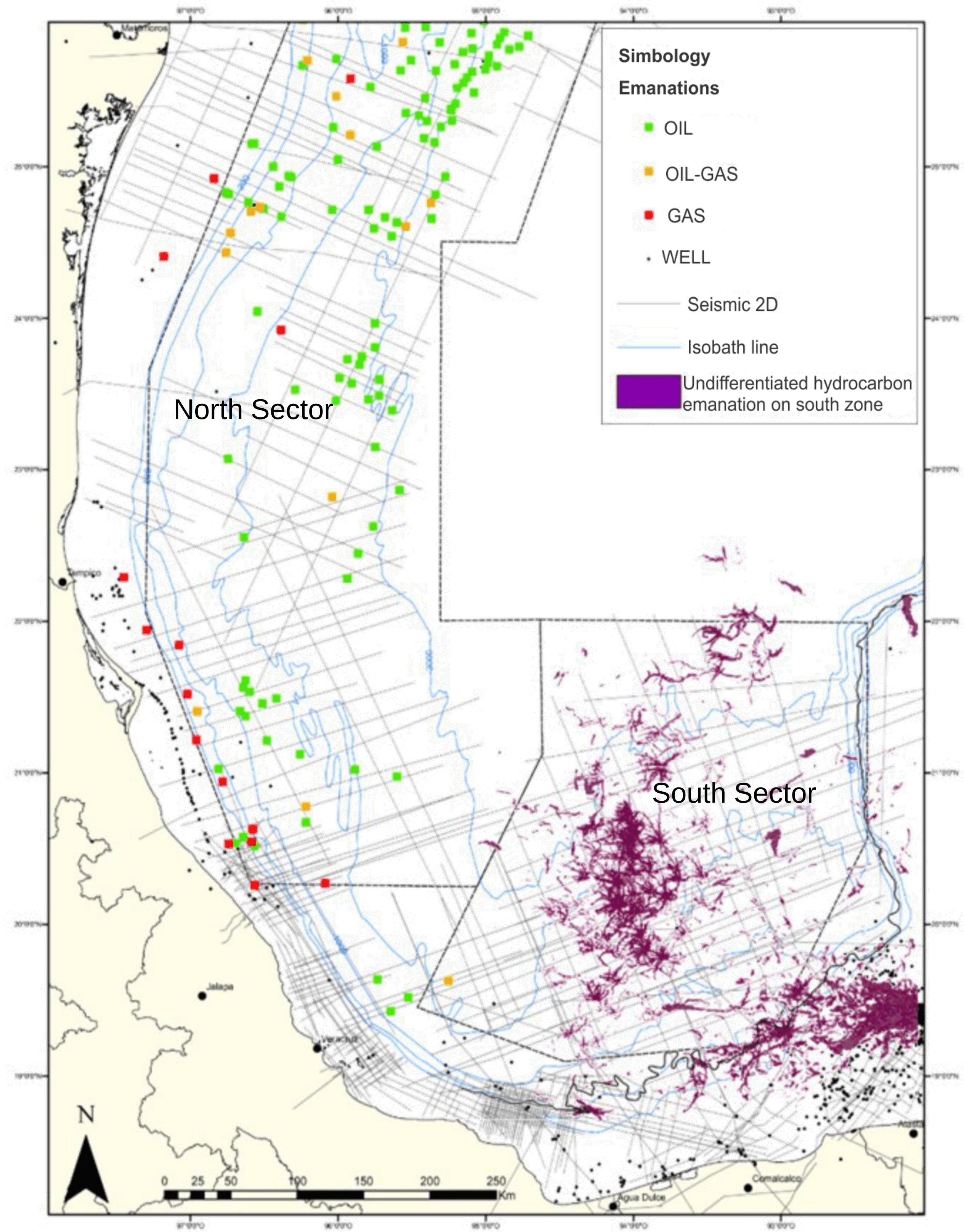
Deep Water - Regional settings - Exploratory Wells and HC Seeps



Wells



Emanations

Discoveries

Recent discoveries in the Perdido Fold Belt confirmed the oil potential of the Tertiary rocks in the North Marine Region. Good quality reservoirs and promising resources in place were found in recently drilled wells (e.g.Trion-1 and Supremus-1), as well as in the known fields located to the north of the border (e.g. Trident-1), indicating the existence of active petroleum systems with significant resources in place.

On the other hand, the new discovery done by Vespa-1 well, found hydrocarbon accumulations ins Miocene sandstones, proving another active petroleum system in the mini-basins sector.

This confirms the existence of active petroleum systems with significant resources in place on a trend of structures extending from the Alaminos Canyon in the United States through the Mexican territory.

On the other hand, new discoveries of the well (Vespa-1) with accumulations in the Miocene sands, prove the existence of additional active petroleum system in the slope of the mini-basin area.

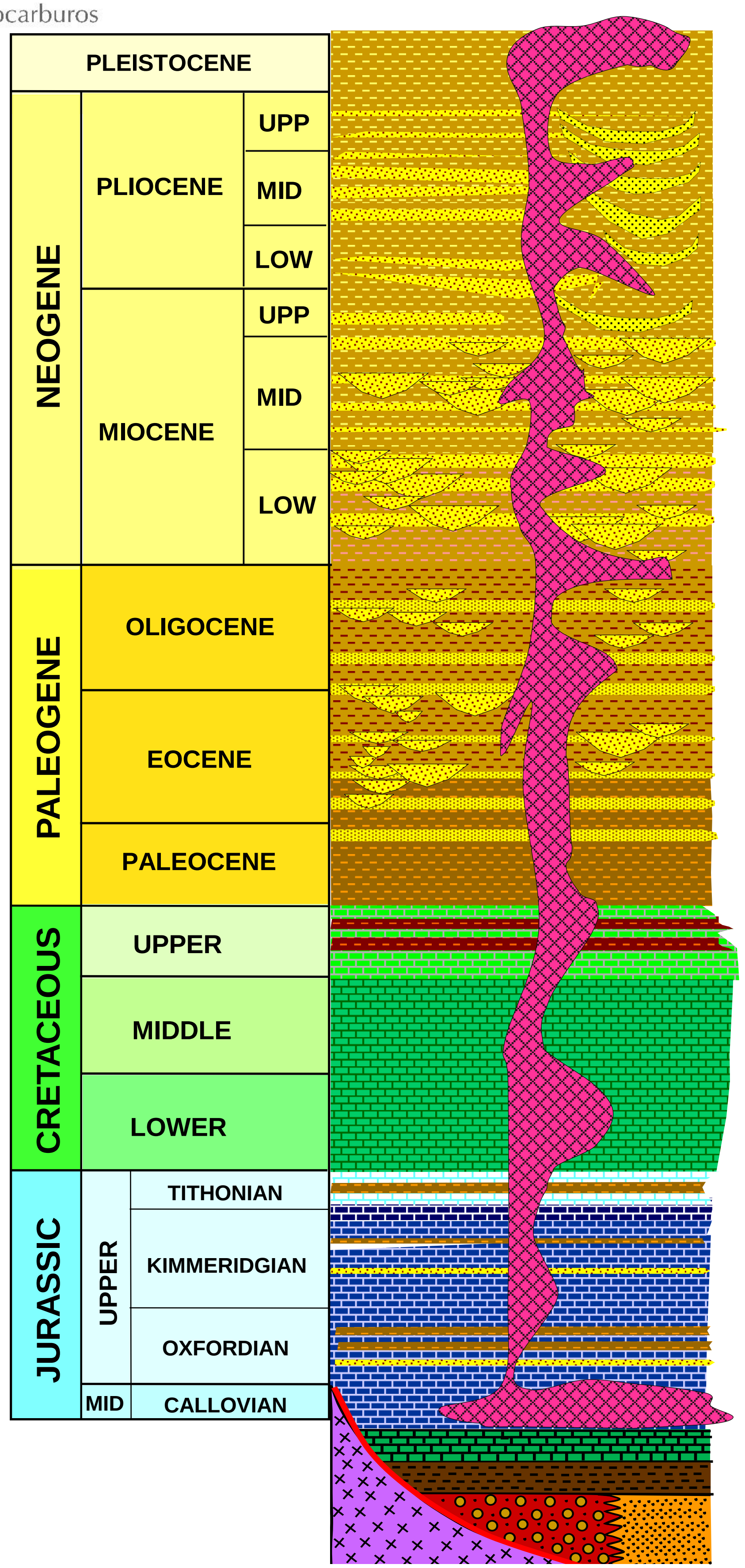
On the other hand, the previous discoveries such as Tamil-1 and Nab-1 wells, located in the eastern part of the Salina Basin, prove the existence of extra-heavy oil in Cretaceous rocks.

Emanations

There are numerous evidences of oil and gas emanations on the seafloor, proving the presence of active petroleum systems in deepwater. Most of these emissions are located mainly in the Perdido Fold Belt, in the Subsalt Belt front, in the mini-basin area related to salt diapirism, and in the distal compression system front with detachment level within the Eocene shales. In the South sector, emanations are mainly located at the central part, in the Saline Basin, related to the salt tectonics.

Stratigraphic and Sedimentological Framework

Stratigraphic and Sedimentological Framework – Deep Water South Sector



Progradation
Turbiditic Sandstone deposits
Turbiditic deposits submarine channels and fans
Increased presence of shale
Marls, basin carbonates and breccias **Basin carbonates**
Source Rock **Carbonates and Terrigenous**
Salt (Callovian) **Red beds** **Basement**

Neogene: The terrigenous sediments filled the basin and are represented by interbedded sandstones; mainly turbidites and shales. There is no conclusive evidence about important erosion in this area.

Paleogene: At the beginning of the Cenozoic age, a change in the basin tectonic regime from passive margin to a foreland basin setting causes a marked change in the sedimentation, represented by the lithological contrast between Cretaceous carbonate sedimentation and the thicker terrigenous Cenozoic column.

Cretaceous: The development of a passive margin setting during the Cretaceous time is represented by basinal carbonates in most part of the area, and slope related carbonates at the eastern side, with benthic clays and chert interbedded horizons.

By the end of the Cretaceous time, a decrease in the sea level caused the deposition of calcareous debris flows and turbidites at the continental slope margin, on the eastern flank, represented by dolomites, shaly limestone and dolomitized breccias.

Tithonian: During the Tithonian time, the maximum marine transgression occurred, related to the Late Jurassic anoxic events registered worldwide. A mixture of fine terrigenous and laminated organic-rich carbonates, without bioturbation, were deposited.

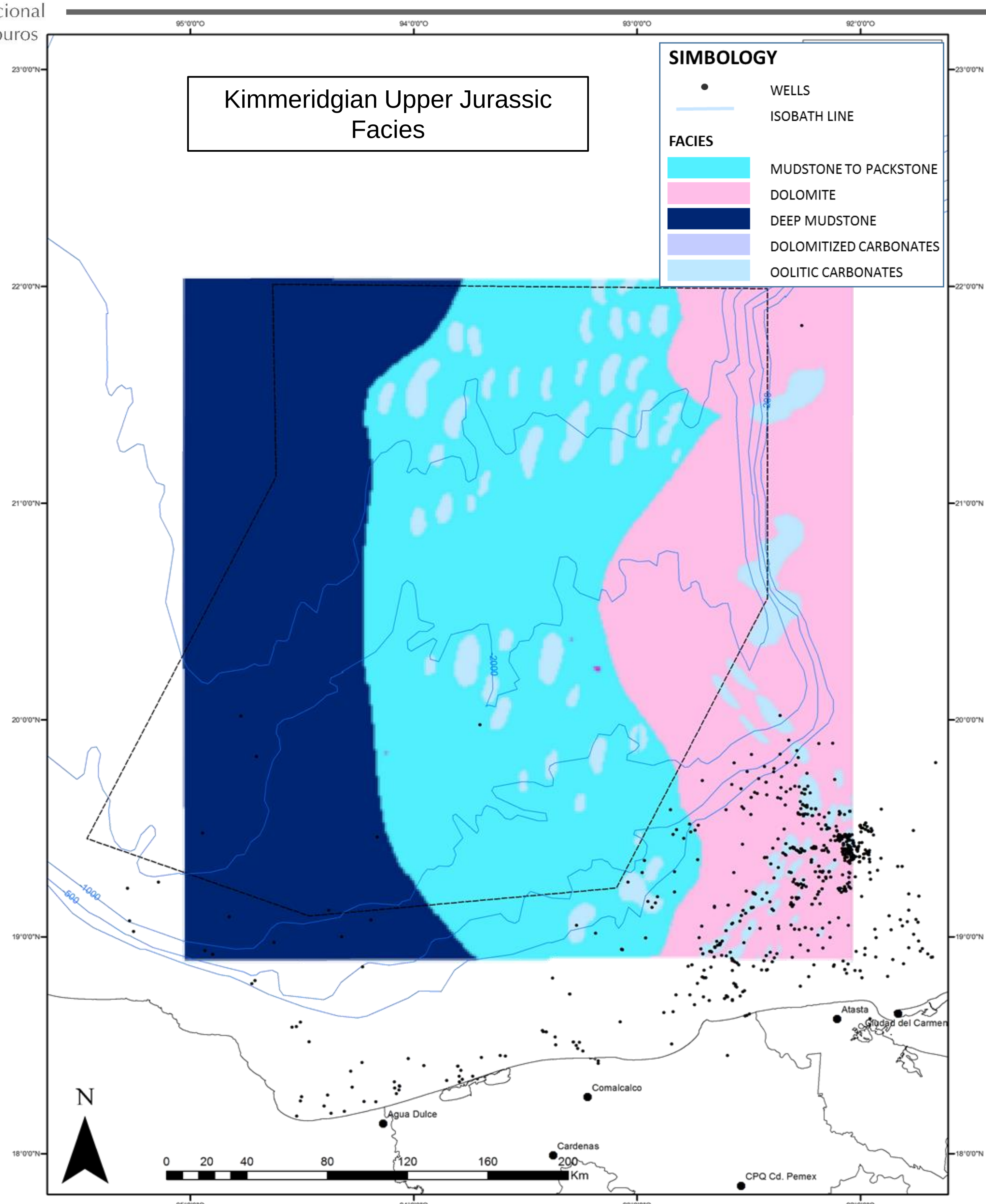
Kimmeridgian: The same marine conditions continued during the Kimmeridgian time. These deposits are represented by significant thicknesses of carbonate and terrigenous rocks in some parts of the basin, changing gradually to partially dolomitized oolitic banks carbonates.

Oxfordian: The sediments of this age consist in shallow marine clastics, evaporites and organic-rich carbonates, whose distribution has not been specified.

Upper Middle Jurassic : It is characterized by the deposition of salt layers associated to the Gulf of Mexico opening processes. During the Callovian and at the beginning of the Oxfordian time, marine conditions were gradually extended across the basin.

Paleozoic: This sequence represents the "economic basement", constituted by Middle Paleozoic continental sedimentary rocks (red beds) derived from the erosion of older crystalline and metamorphic basement rocks, similar to the crystalline rocks reported in Chiapas.

Stratigraphic and Sedimentological Framework - Jurassic Sedimentology



Middle Jurassic
It is mainly characterized by salt layers deposition related to the Gulf of Mexico opening. During the Callovian and early Oxfordian time, marine conditions were gradually extended across the basin.

Upper Jurassic
Is characterized by period of marine transgression from the Oxfordian to Tithonian.

Oxfordian is represented by coastal plain, fluvial and dunes environments at the east, changing transitionally to inner and middle floodplain environments to at west during the Lower Oxfordian.

Upper Oxfordian is represented by a middle to outer ramp platform environments, with oolitic banks development forming well defined bands.

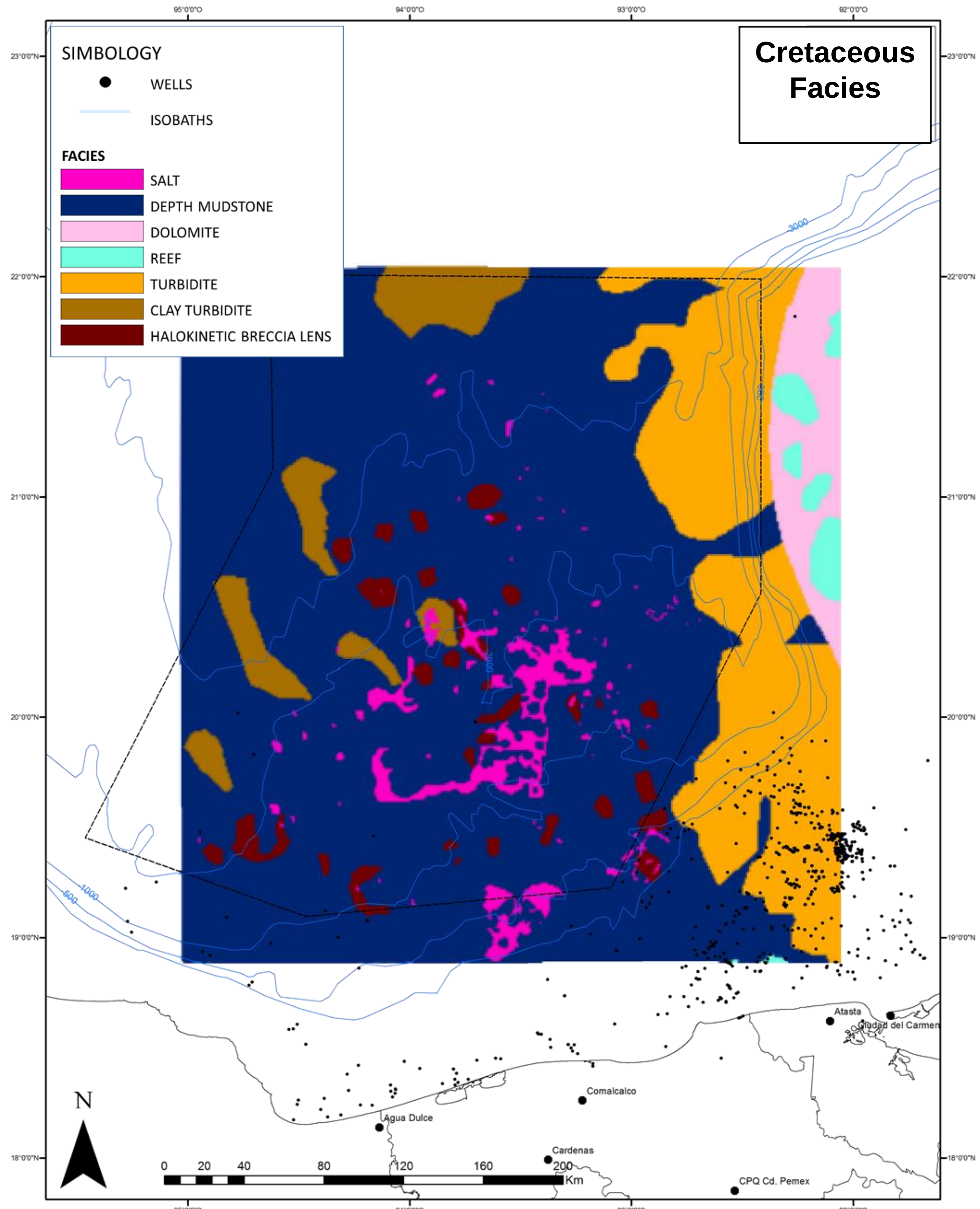
In general, Oxfordian sediments consist of shallow marine clastics, evaporites and organic-rich carbonates whose distribution has not been well specified.

Kimmeridgian time is characterized by rocks deposited in inner to middle marine ramp platform environments during the Lower Kimmeridgian time, changing transitionally during the Upper Kimmeridgian outer marine ramp environments. Geological models suggest the presence of oolitic banks facies, which are considered an extension of those identified in the shallow water Southeast marine Basins.

During the **Tithonian** the maximum marine transgression occurred, related to Late Jurassic anoxic events registered worldwide. A mixture of fine-grained terrigenous and organic-rich laminated carbonates, were deposited.

The main **reservoir rocks** are represented by Lower Oxfordian sandstone systems at East, carbonate rocks (packstones-grainstones) and the Upper Jurassic re-deposited oolites from Upper Jurassic Oxfordian to Kimmeridgian.

Stratigraphic and Sedimentological Framework - Cretaceous Sedimentology



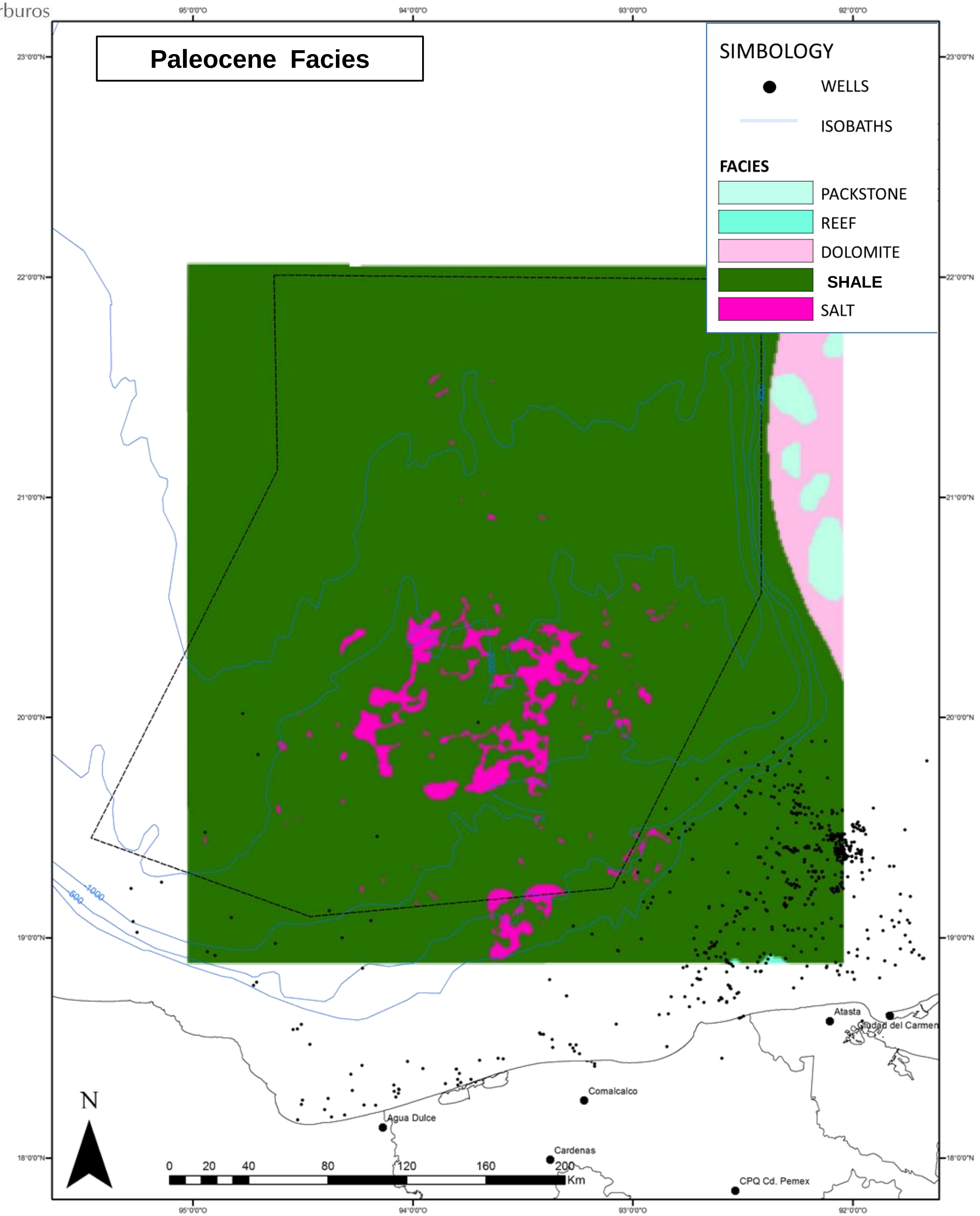
Cretaceous

During Cretaceous time open sea basin conditions were developed, sometimes oxic, where shaley carbonates interbedded with calcareous debris flows were deposited. Halokinetic lense-shaped clastic breccias were deposited as well, composed by carbonate fragments removed from the salt-cored anticlines at their flanks in basin environments, together with calcarenitic turbidite flows coming mainly from the Yucatan Platform.

At the Eastern portion, slope dolomitized breccia facies are identified, related to a destabilization of the Yucatan Platform slope, corresponding to the continuity of Sonda de Campeche deposits.

The Cretaceous main reservoir rocks in deepwater are comformed by slope and basin-floor breccias located at the edge of the Yucatan Platform, changing transitionally westward to basinal fractured carbonates, where halokinetic breccias and related local debris flows can be found.

Stratigraphic and Sedimentological Framework - Paleocene Sedimentology



Paleocene

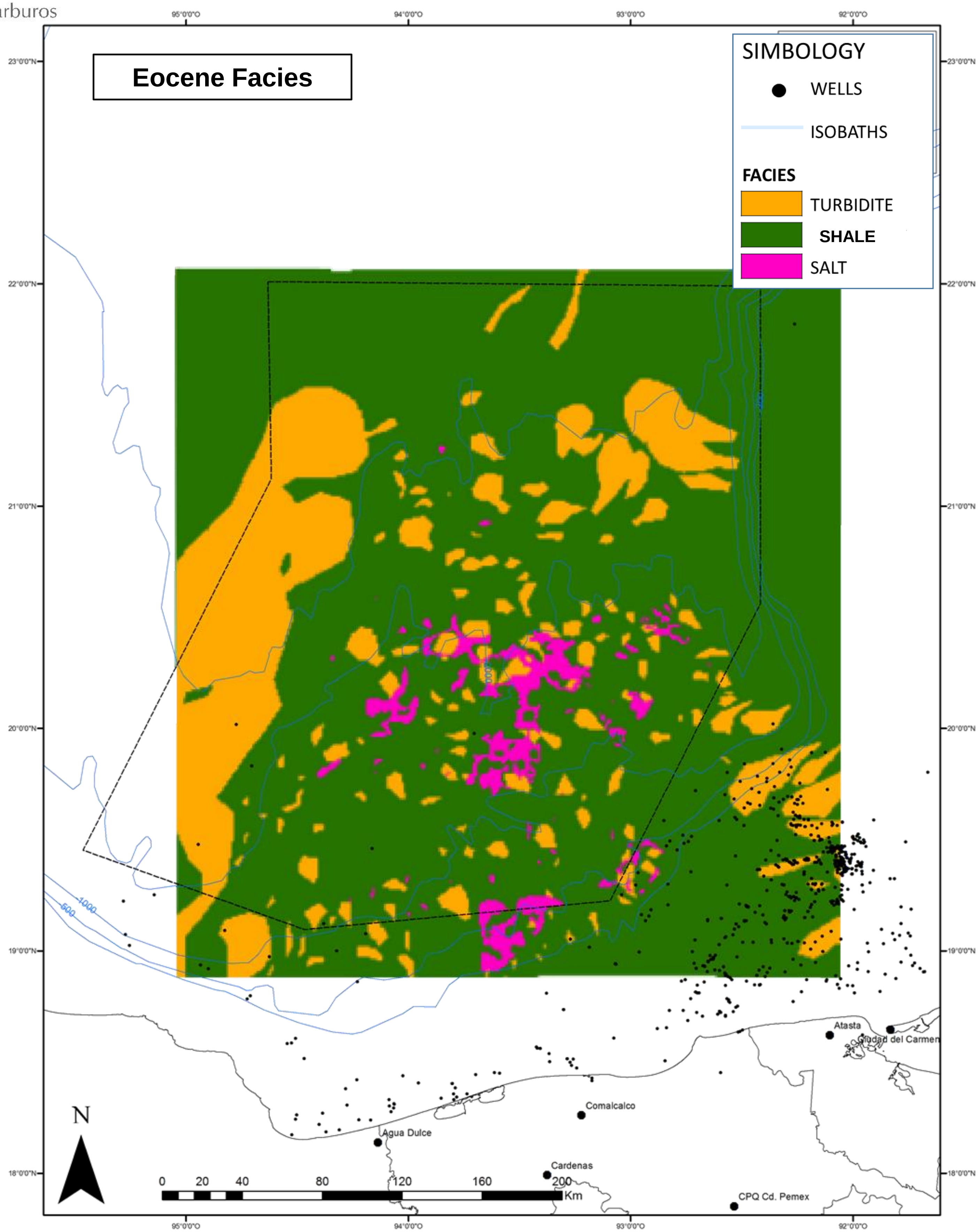
The Paleocene time is represented by bathyal environments, showing a sedimentological composition dominated mostly by shales interbedded with some channel sandstones. The source of the sedimentation came from Southwest.

The presence of some carbonate rocks at Northeast, could be due to the re-worked debris flows, through some distal gravity flows from the Yucatan Platform.

The shale dominant Paleocene rocks, act mainly as a seal for the Cretaceous reservoir rocks, having a wide regional distribution and great thickness.

As reservoir rocks, slope and basin sandstone deposits distributed through submarine channels within the area could be interesting.

Stratigraphic and Sedimentological Framework - Eocene Sedimentology

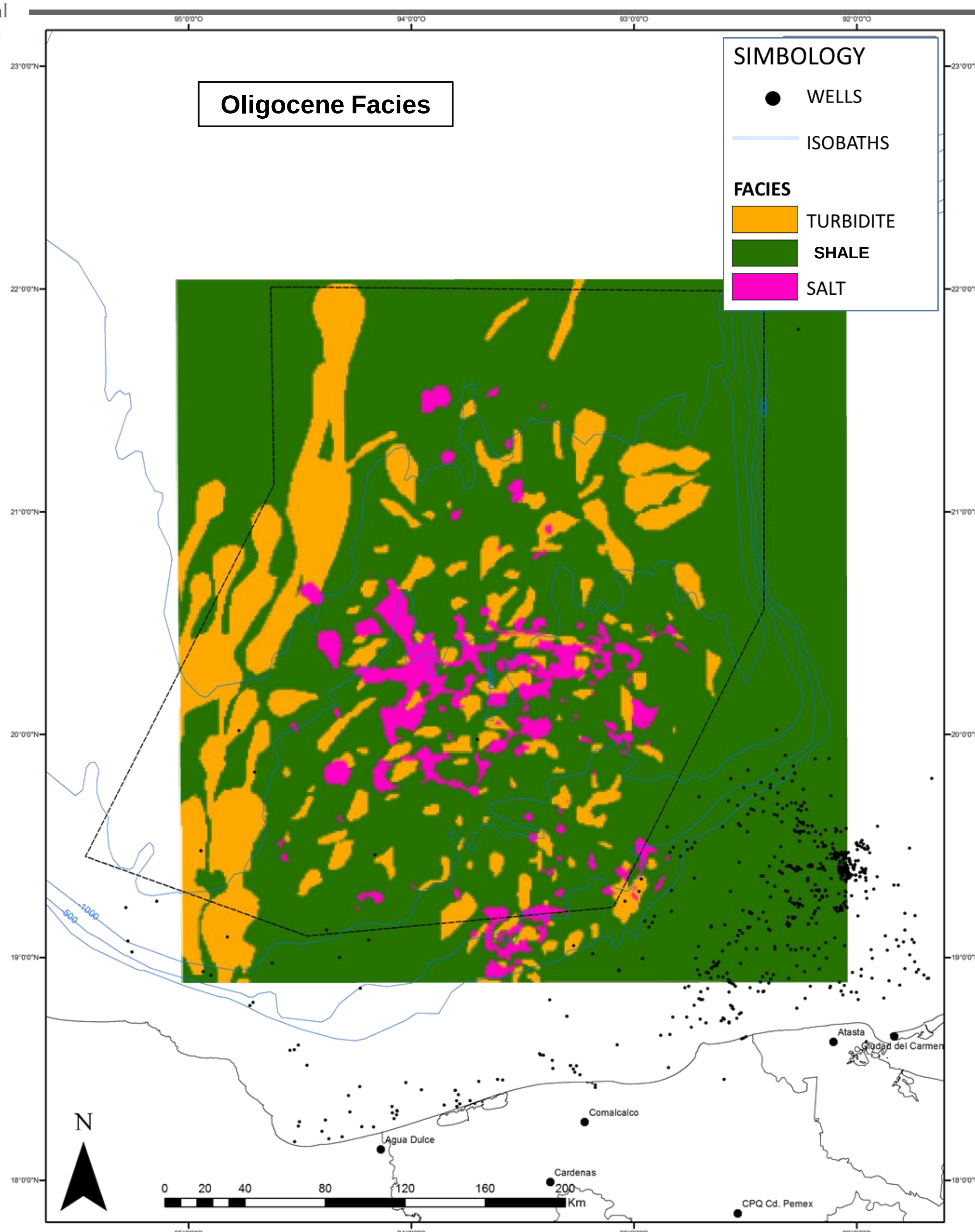


Eocene

Lower and Middle Eocene is represented by shale-dominated bathyal environments and some siliciclastic turbiditic systems, with a South – Southwest proveneance. At north of the area, deposits culminate in huge lobes related to amalgamated channeled fans. Some carbonate-dominated channel and fan complexes exist to the East, originated by the erosion of the Yucatan Platform and probably developed in slope environments.

During the **Upper Eocene** the dominance of bathyal environments and the presence of siliciclastic turbiditic systems continues; at the Eastern side, sandstone fan complexes with proximal and distal amalgamated channels continue spreading to the deepest parts of the basin to finally form confined channel systems and fans toward the central part of the area. The Eastern portion, may present channel systems and carbonate-dominated fans with associated mud flows.

The **reservoi**r **rocks** in the Deepwater South Sector are represented mainly by basin-floor fans and slope sandstone facies, which are expected to be more abundant and thicker to the North. On the other hand, the Eastern portion may contain calcarenites at the proximity of the carbonate platform.



Oligocene

Taking into account the specific study area in the Deepwater South Sector, most of the area corresponds to shale-dominated basin-floor facies; to the Eastern portion, a calcareous influence it is observed due the proximity to the carbonate platform.

The Oligocene is characterized by the presence of turbiditic systems in amalgamated channel and overbank facies with a SW - NE trend, as a continuity of the Eocene depositional systems and culminating as basin-floor fans at North, where salt influence is lower.

The Oligocene **reservoir rocks** are sandstones and shales related to channel and fan facies.

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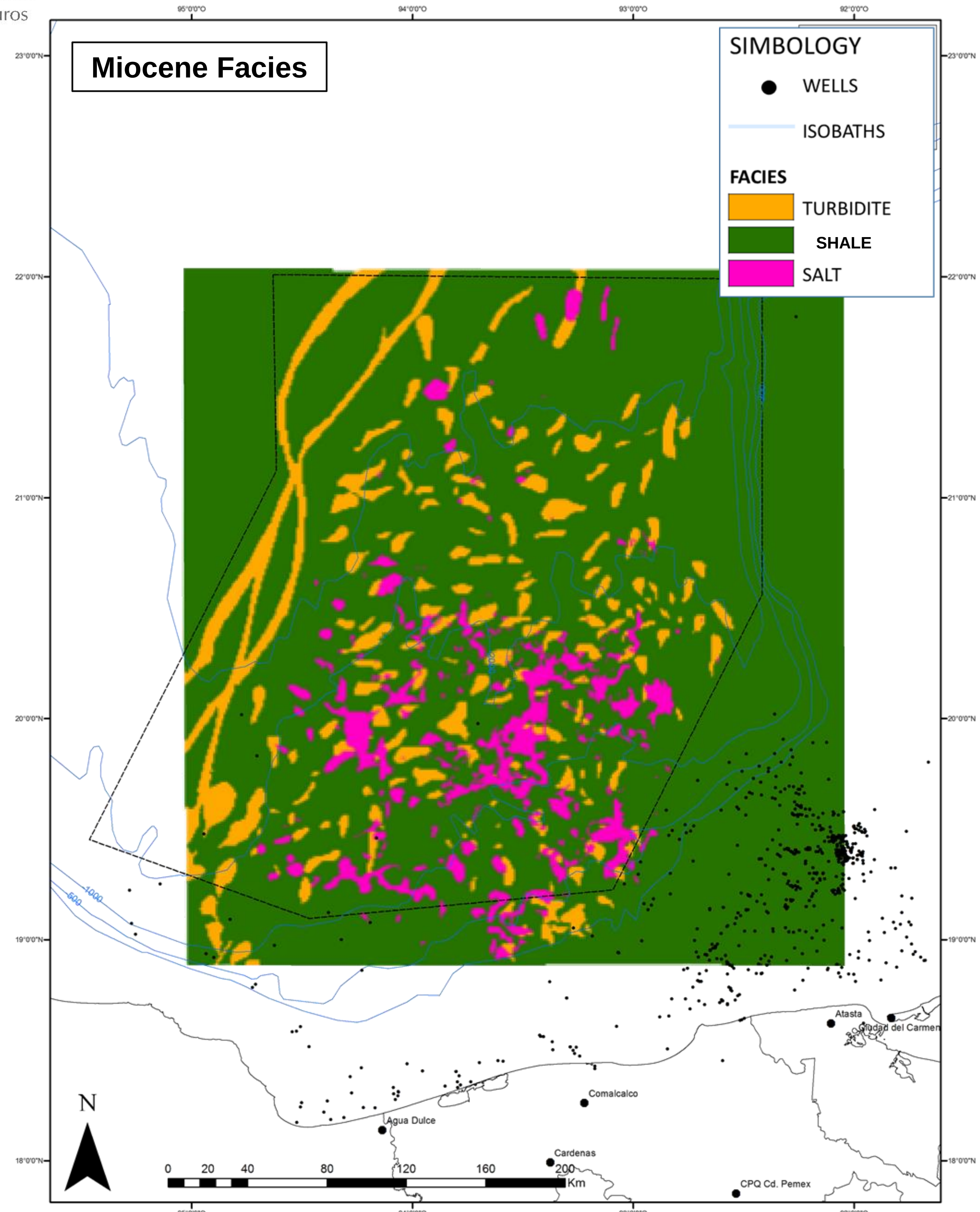
Stratigraphic and Sedimentological Framework - Miocene Sedimentology



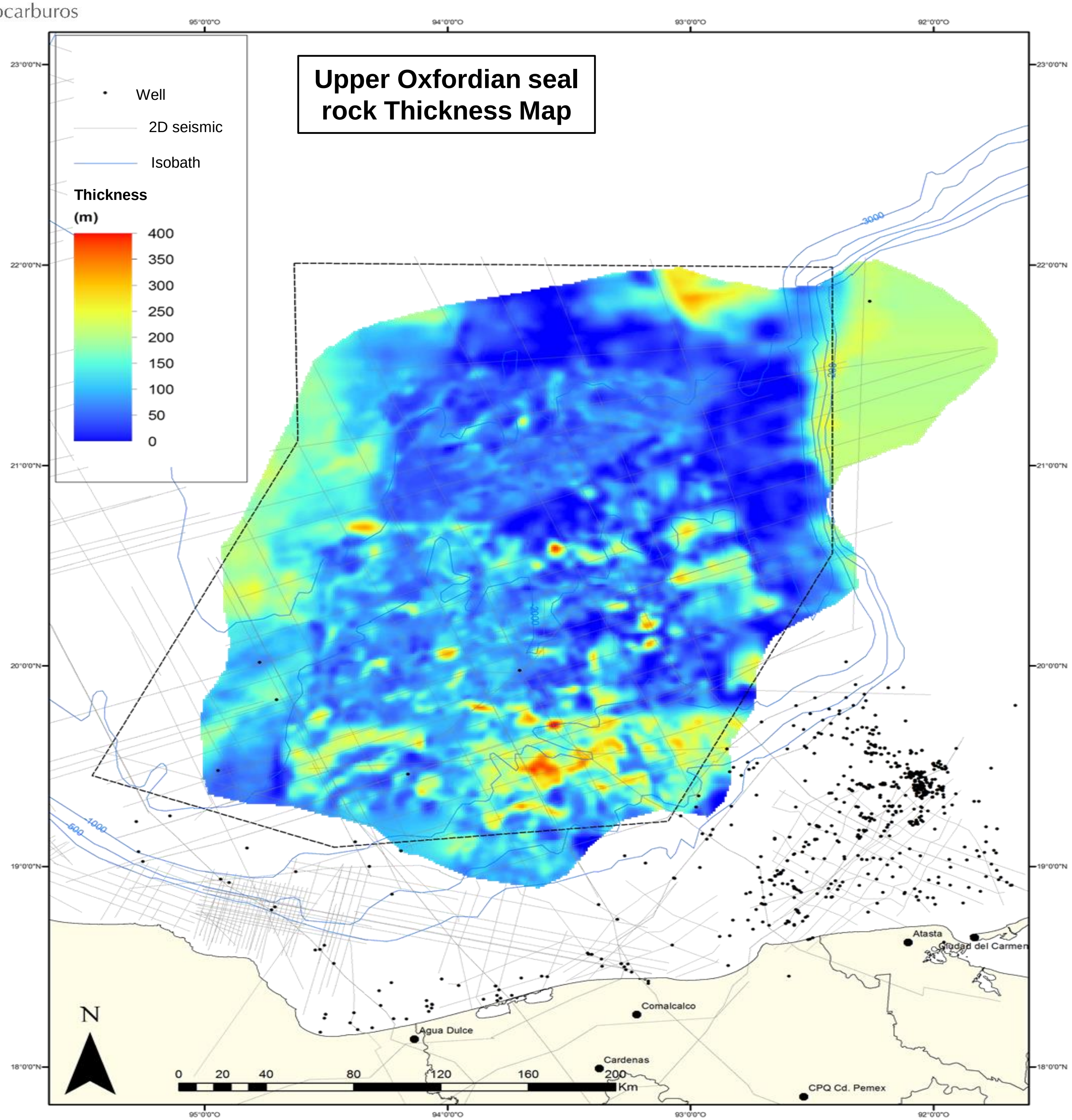
Miocene

From the Miocene, salt barriers plays an important role in the sedimentation distribution. Deepwater environments, channel lobes and fans at basinal conditions prevails. In the Southern portion, minibasins are confined by the salt movement. Sediment input came from the South and Southeast and provenance may vary locally within the Saline Province. On the other hand, at West and along the Saline and Catemaco Fold Belt borderline, the sediment influx mainly bypass directly to the Gulf's Abyssal Plain.

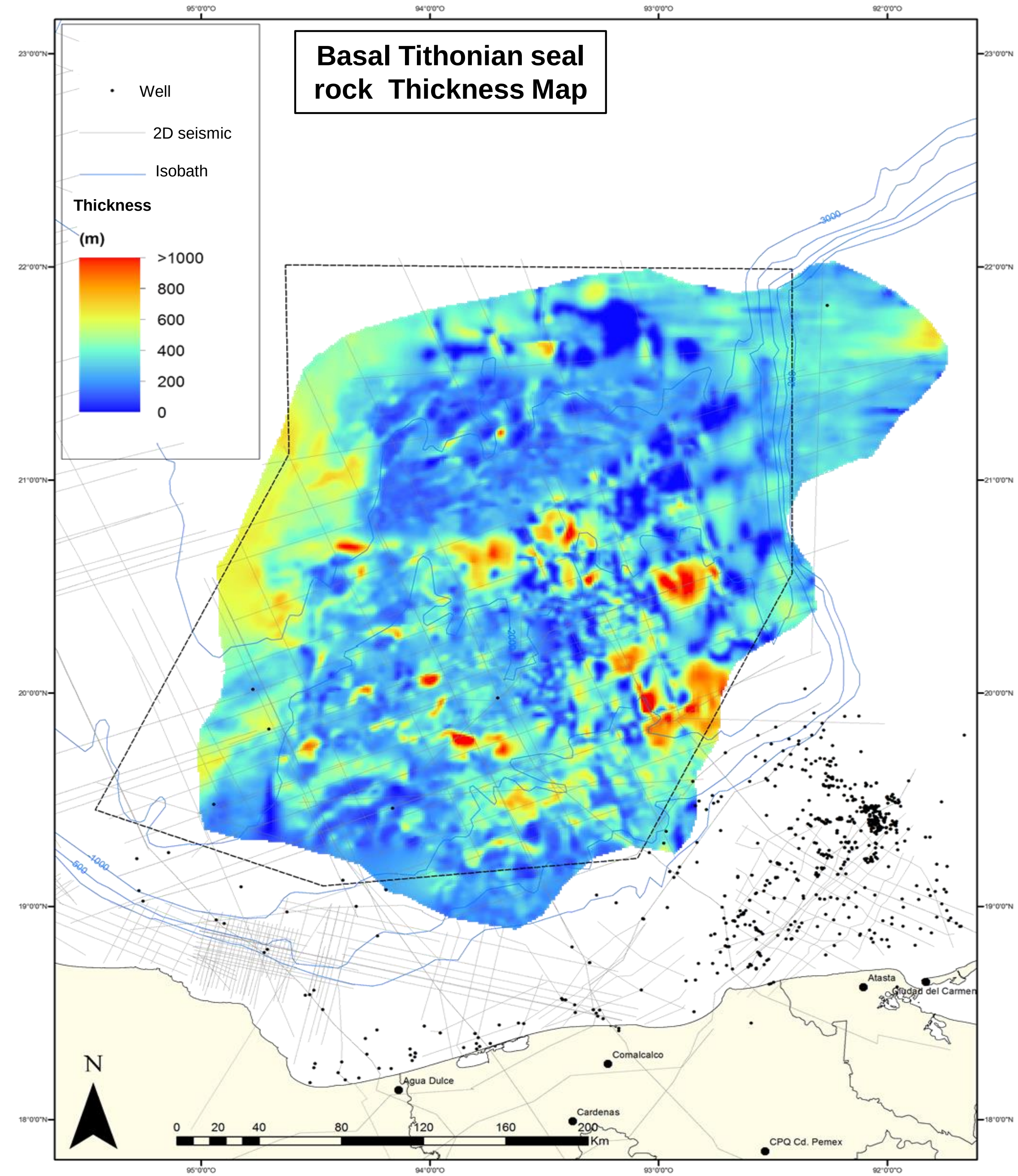
Miocene is the most prolific stratigraphic level in the area, up today, with production mainly in the Catemaco Fold Belt.

The **reservoir rocks** in the Deepwater South Sector are turbiditic sandstones with variable thickness, with a Southwestern volcanic source influence, combined with a mainly quartz-feldspatic contribution from the South.

Stratigraphic and Sedimentological Framework - Regional Seal (1)

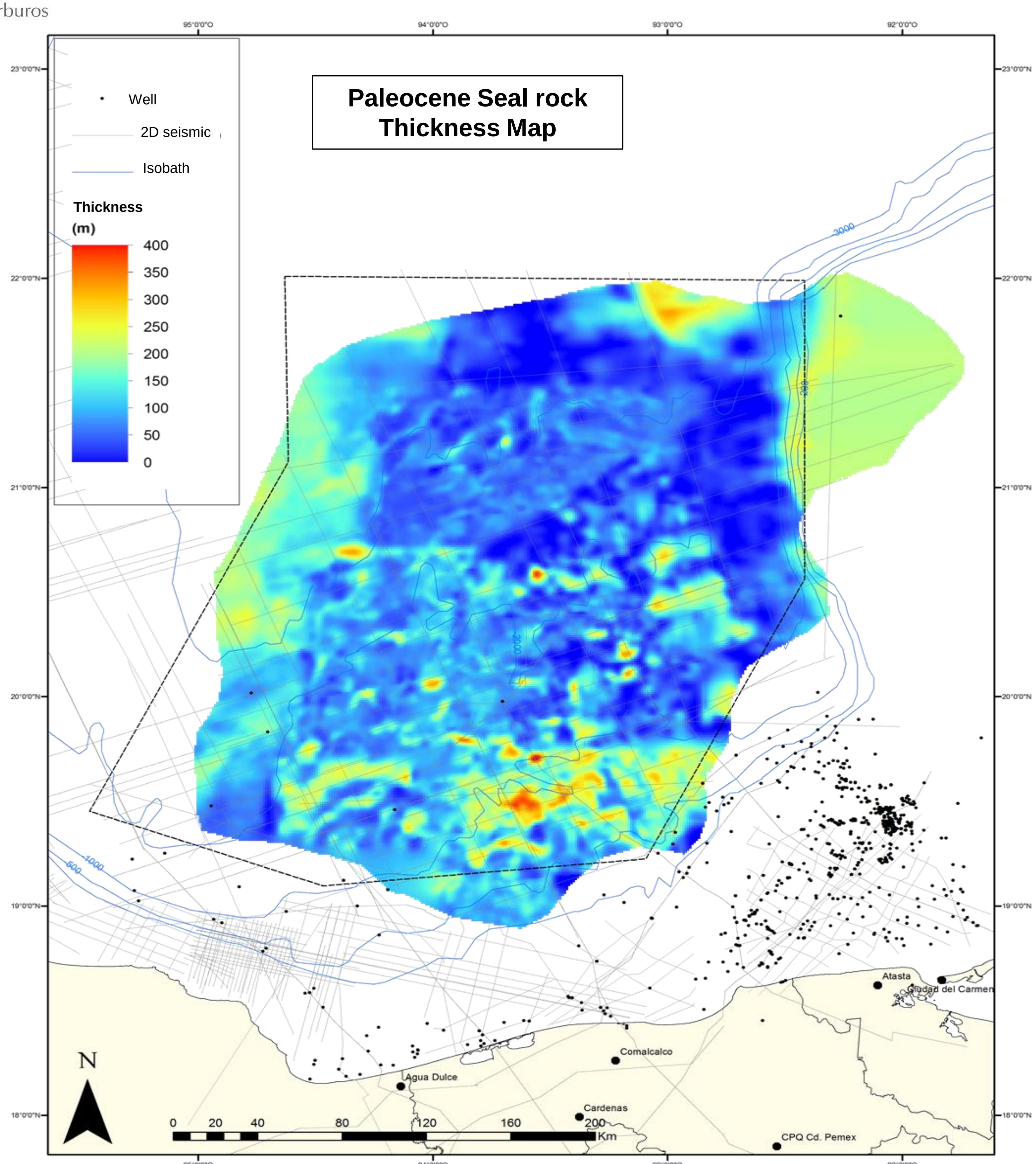


The source rock of the Upper Oxfordian works simultaneously as upper seal for the Middle Oxfordian reservoir rock.



The upper seal for Kimmeridgian reservoir rocks consists of shaly limestone at basal Tithonian levels

Stratigraphic and Sedimentological Framework - Regional Seal (2)



Upper Seal rock for Cretaceous reservoir rocks

In this area, Paleocene has characteristics of being very clay-rich shales and thicker, so it works as a good regional seal rock for Cretaceous reservoir rocks .

Upper seal rocks of Tertiary reservoir rocks

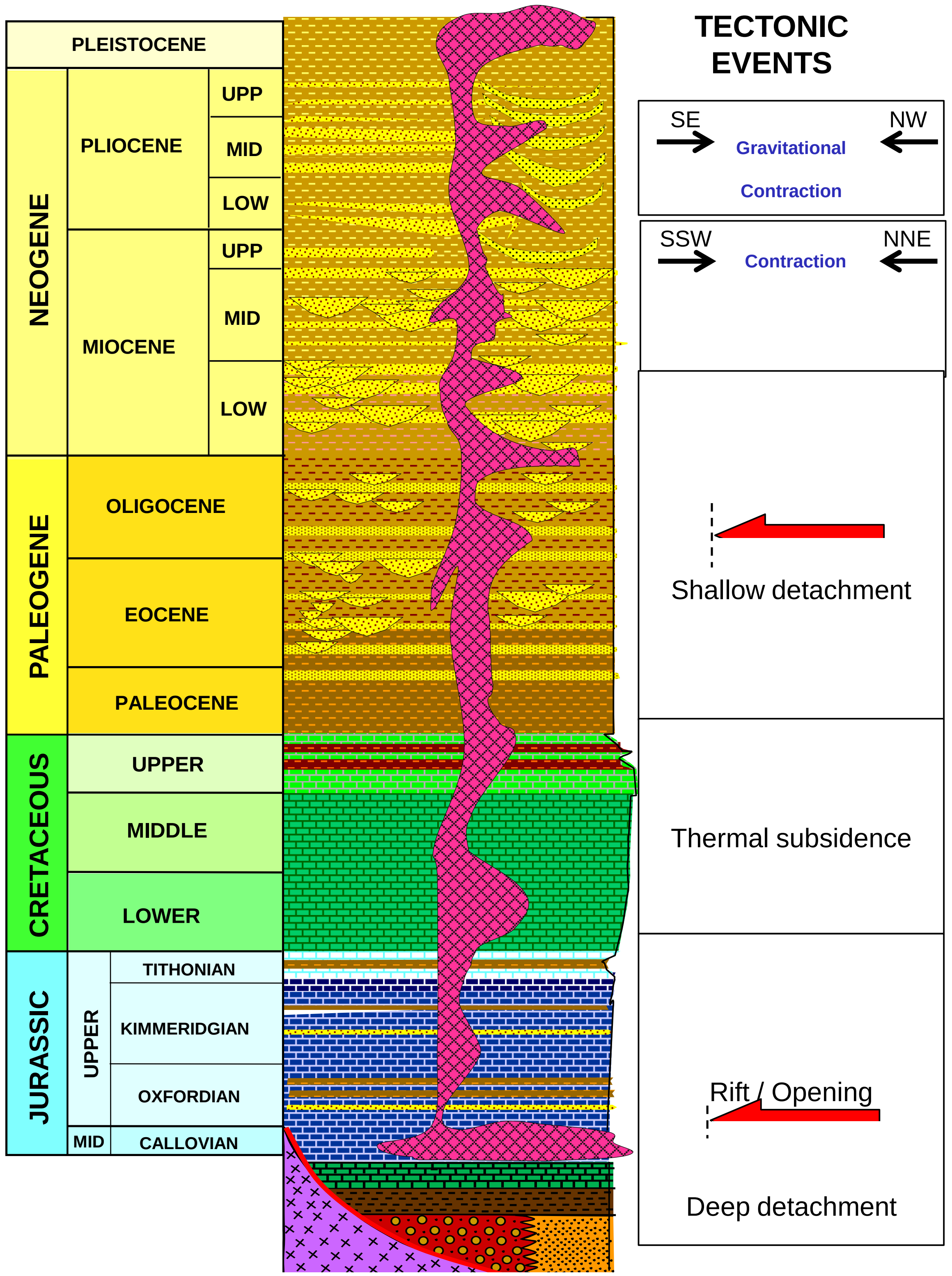
In Upper Paleogene (Eocene and Oligocene) and Neogene, thinner regional seal rocks exist due to interbedding sandstones and shales related to siliciclastic turbiditic systems.

These seal rocks can be interrupted by faults of variable displacement (tens to hundreds of meters of vertical displacement).

At the top of the stratigraphic column (Upper Pliocene and Pleistocene), seal rock quality is uncertain, due to its shallower position and inferred by the presence of hydrocarbon seeps on the seafloor.

Tectonic and Structural Framework

Tectonic Framework – Structural (1)



Upper Miocene - Lower Pliocene

Increasing of gravitational tectonics related to thesedimentary load and salt movement. Mini-basins generation.

Development of salt canopies and tongues. Closure of diapiric structures, creating salt weld faults (Lower Pliocene).

Middle - Upper Miocene

Correspond to a couple of compressional events: Laramide and Chiapanecan Orogenies. Development of prominent salt-cored anticlines. Beginning of salt bodies intrusion due to halotectonic effects. Thrust fault detachments above the salt layers creating “pop up” structures.

Cretaceous - Middle Miocene

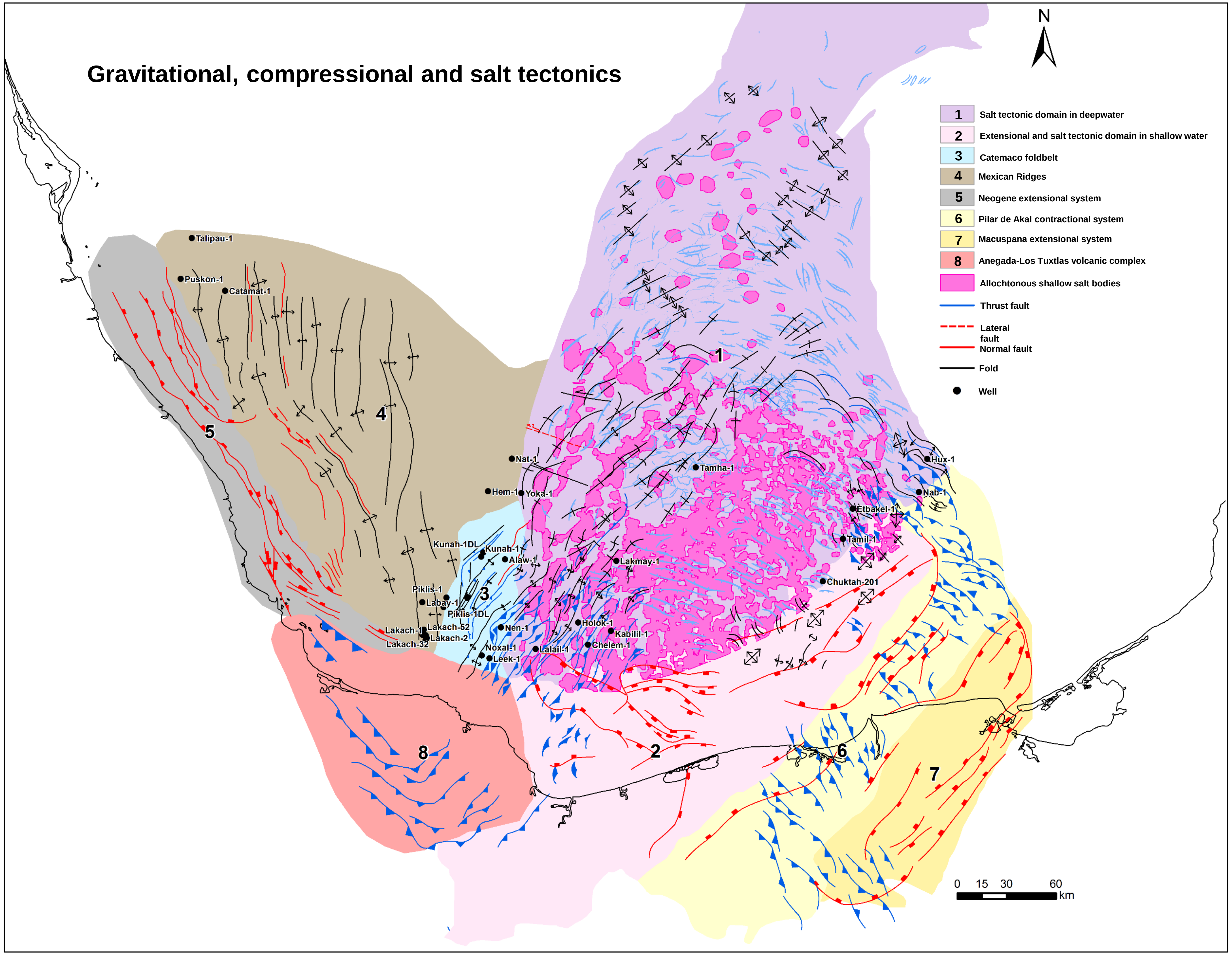
Thermal subsidence period, passive margin settings with subtle structuring of the geological units.

Early salt movement by flotation, differential charging and gravitational sliding generating pads and salt domes structures (halokinesis).

Jurassic

Corresponds to the Gulf of Mexico opening processes.
Horst and graben systems infilled by red beds and Callovian salt layers.
Weak drapping structuring related to the salt units and differential subsidence.
First halokinetic movements.
Upper Jurassic units sedimentation, with lateral and thickness variations in the paleo-structural highs.

Tectonic Framework – Structural (2)



The deepwater zone corresponding to the South Sector is result of different tectonic events from the Middle Jurassic to Recent time.

Late Miocene - Recent

Gravitational tectonics, large sediment input to the basin and mobilization of autochtonous and allochtonous salt volumes; extension-contraction combined systems.

Middle Miocene - Recent

Tectonic processes related to the Chiapanecan compressional event, re-deformation of previous structures.

Eocene - Early Miocene

Continuation of the Gulf of Mexico evolution, lithostatic load related subsidence and by evacuation of salt bodies, influence of both Laramide and Chiapanecan Orogenies.

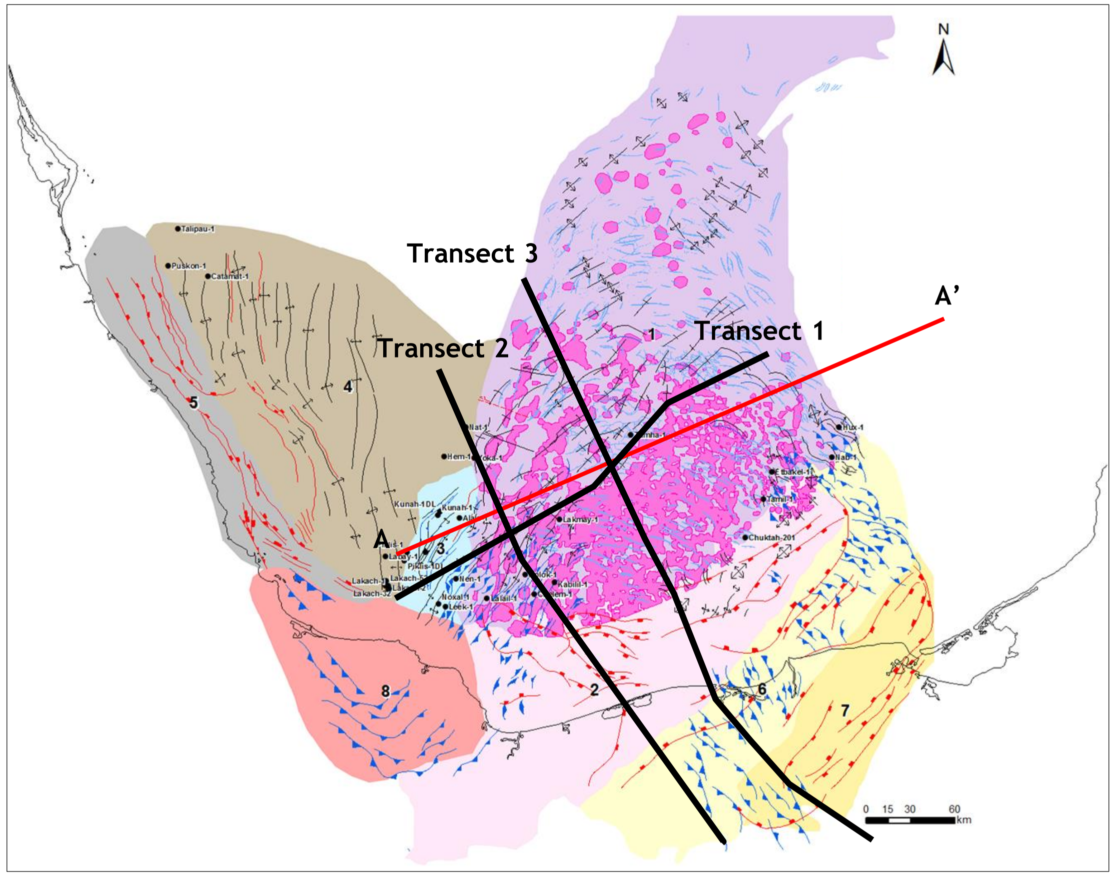
Late Jurassic - Cretaceous

Continuation of the evolution of the Gulf of Mexico, development of a extensional-gravitational system, formation of early salt related structures.

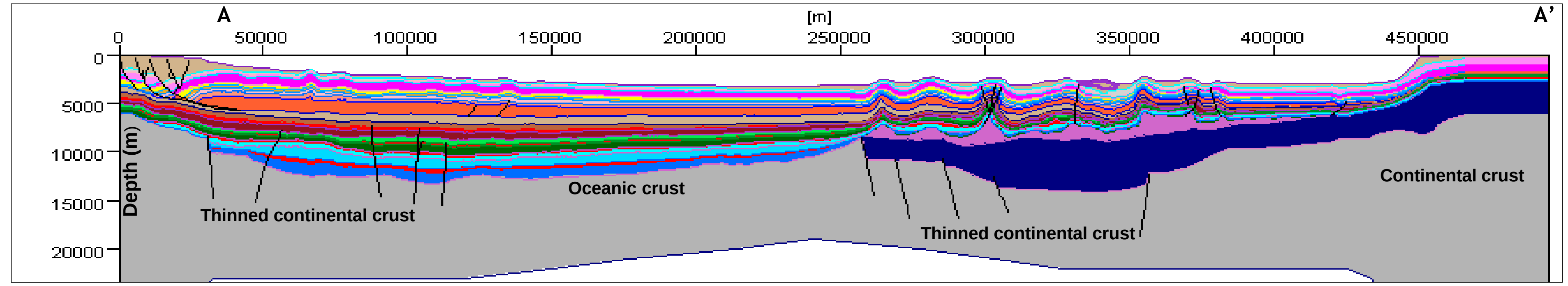
Middle Jurassic

Beginning of the Gulf of Mexico opening evolution, tectonic subsidence, horst-graben and half-graben structures development, formation of the rift basin, deposit of thick layers of salt.

Tectonic Framework – Structural (3)



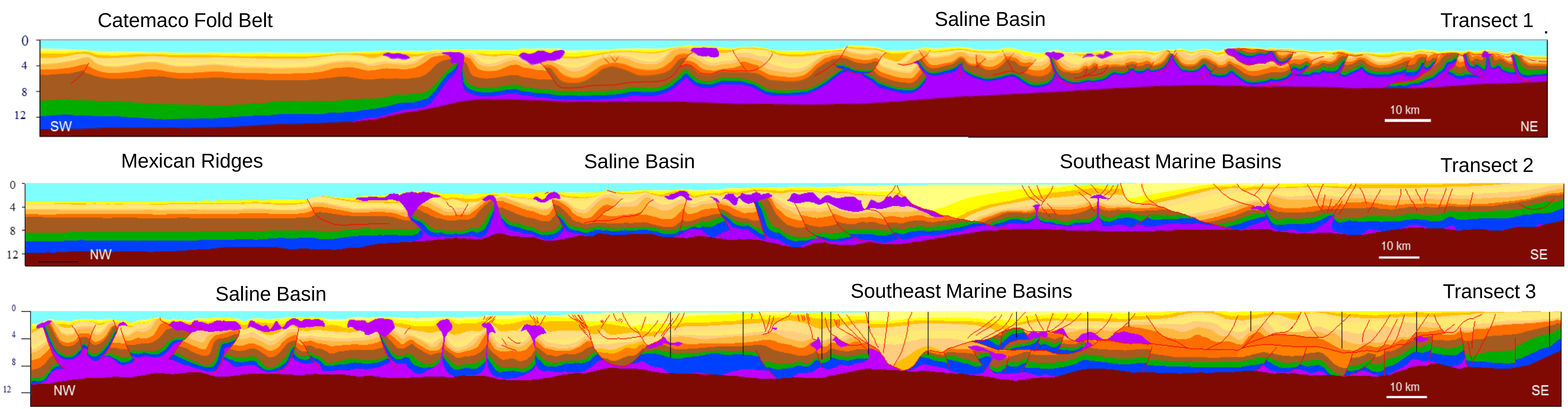
Crust type distribution



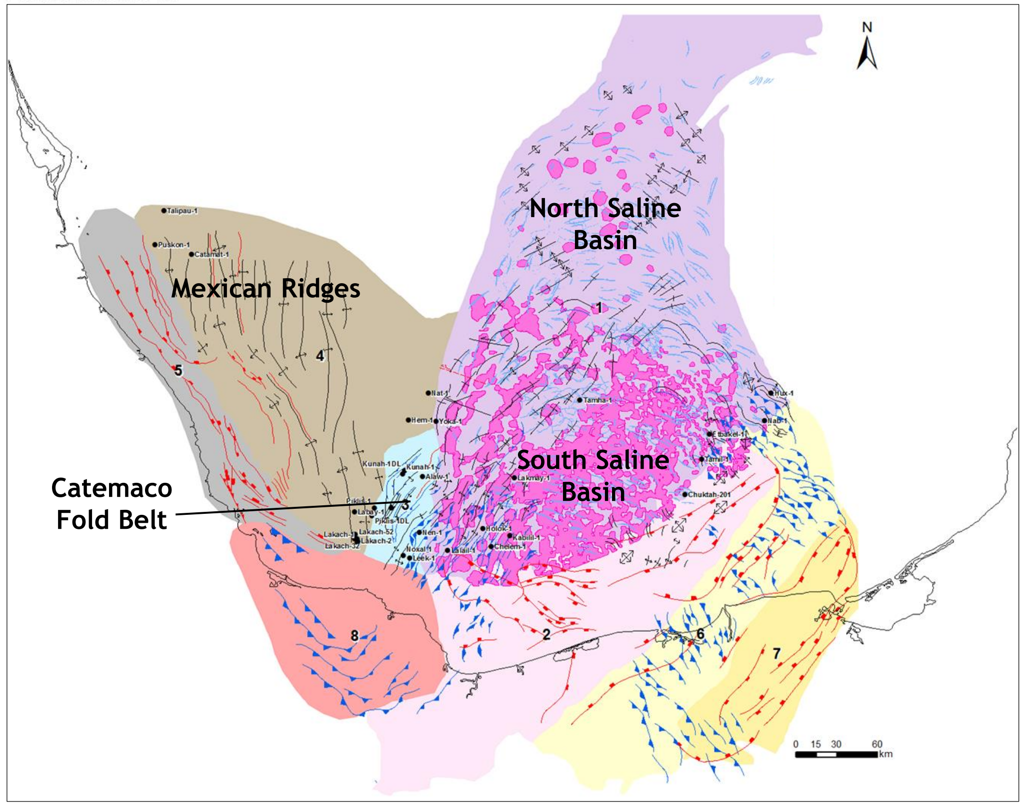
Mesozoic
- **Rifting**
- **Salt deposits**
- **Oceanic crust formation and drifting processes**

Cenozoic
- **Laramide and Chiapnecan tectonic events interaction**
- **Linked structural systems (Extension – compression)**

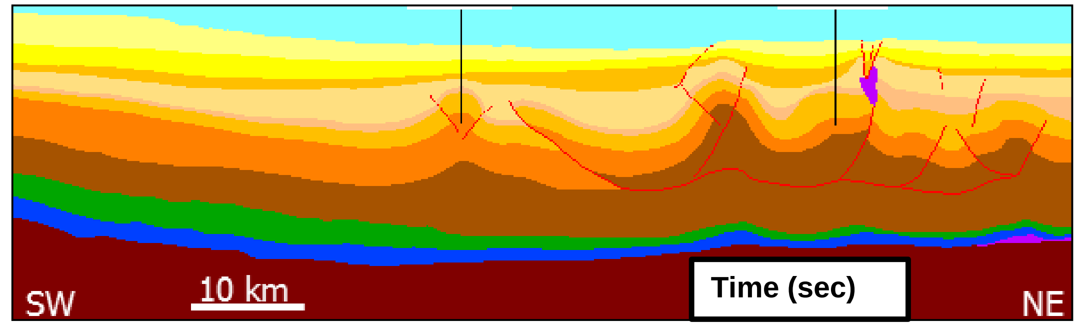
1-3 Transects depicts the reservoir rock sequences continuity from the Southeast Marine Basins towards the Catemaco Fold Belt, Mexican Ridges and Deepwater Saline Basin, where a high prospective potential is expected.



Tectonic and Structural Framework – Structural styles



Catemaco Fold Belt

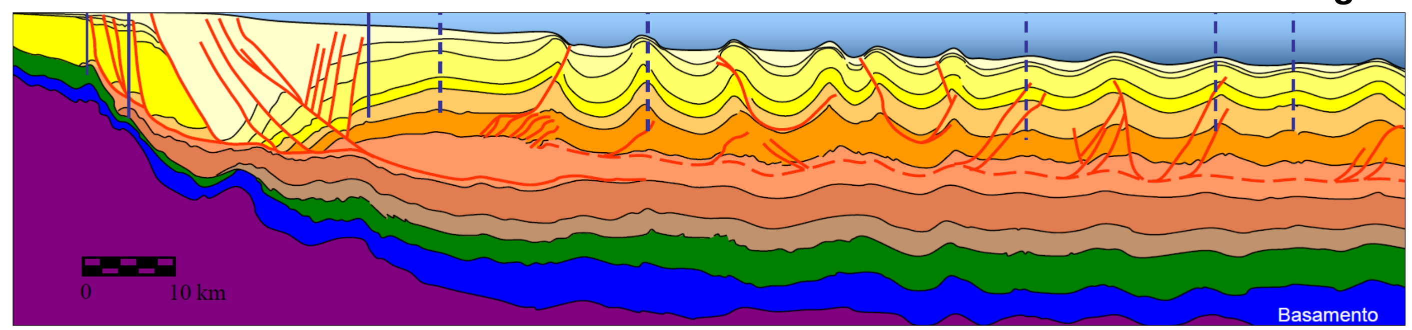


Structural domain: Contraction

Structural styles:

- Asymmetrical anticlines with a Northwest trending.
- Structural and combined structural-stratigraphic traps.
- Anticlines, thrust faults and fault-bend folds with a Paleocene and Eocene detachment level.

Mexican Ridges

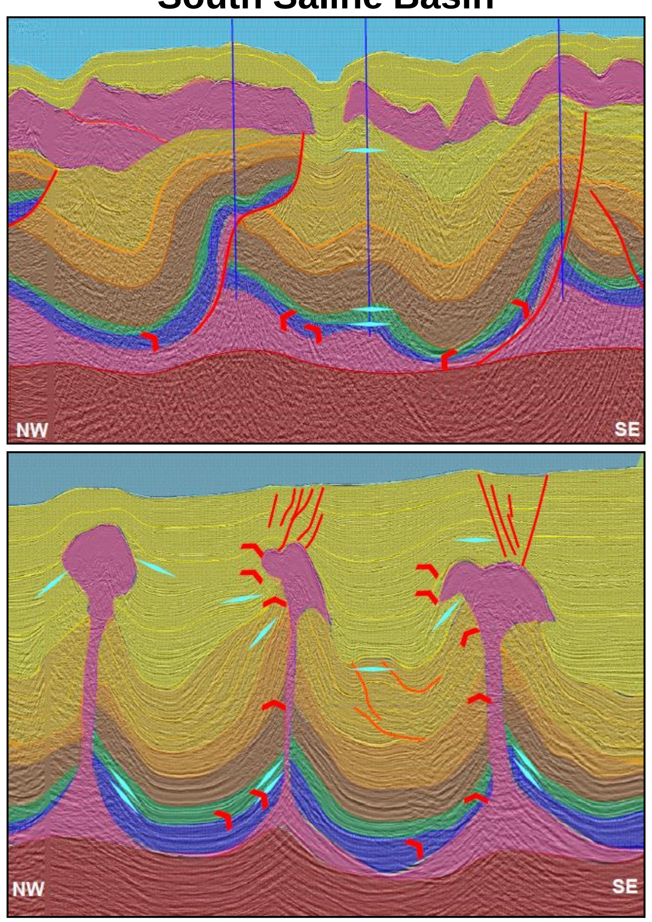


Structural domain:
Gravitational tectonics. Combined extensional–contractional systems.

Structural styles:

- Asymmetric anticlines with a East trend.
- Detachment folds at the Eocene level.

South Saline Basin



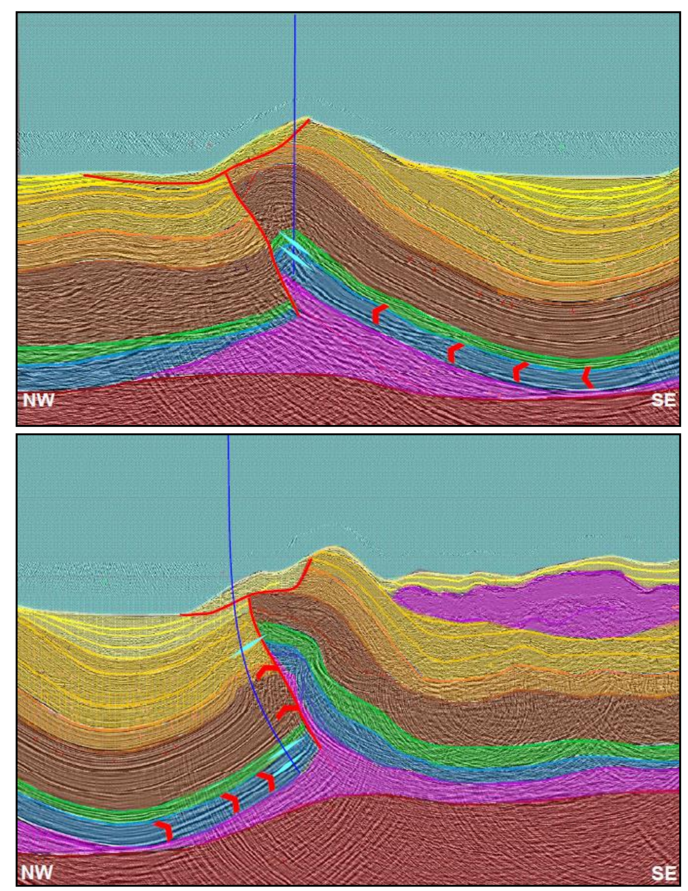
Structural domain:

- Contractional–Extensional and salt tectonics.

Structural styles

- Subsaline folds affected by thrust faults.
- Salt cored anticlines.
- Mini-basins development.
- Salt canopies and diapirism.
- Salt welds and salt walls.
- Shallow allochthonous salt bodies.
- Higher deformation than North Saline Basin

North Saline Basin



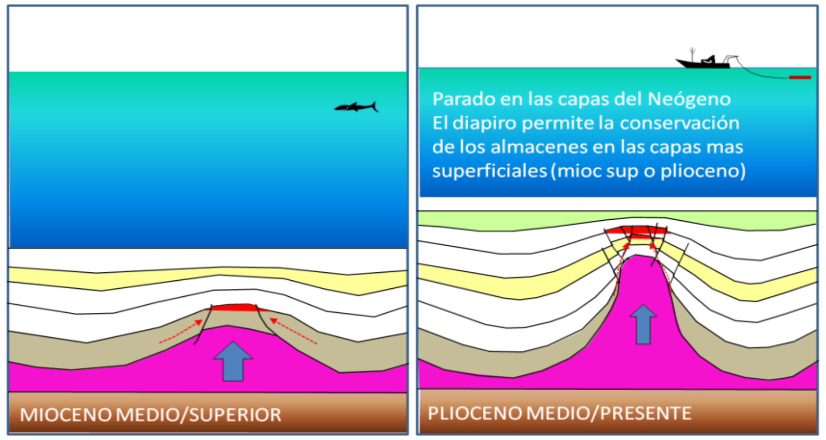
Structural domain:

- Contractional – Extensional and salt tectonics.

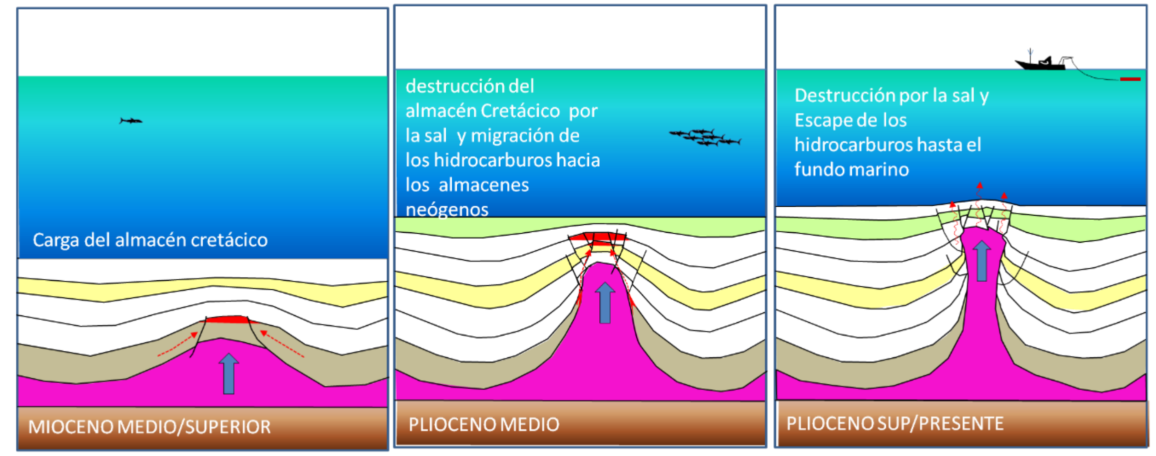
Structural styles

- Salt cored thrust-faulted folds.
- Monoclines against salt bodies.
- Rotated blocks
- Fault-bend folds.
- Shallow salt canopies and diapirism.
- Salt welds and salt walls.
- Lower degree of deformation than the Southern Saline Basin.

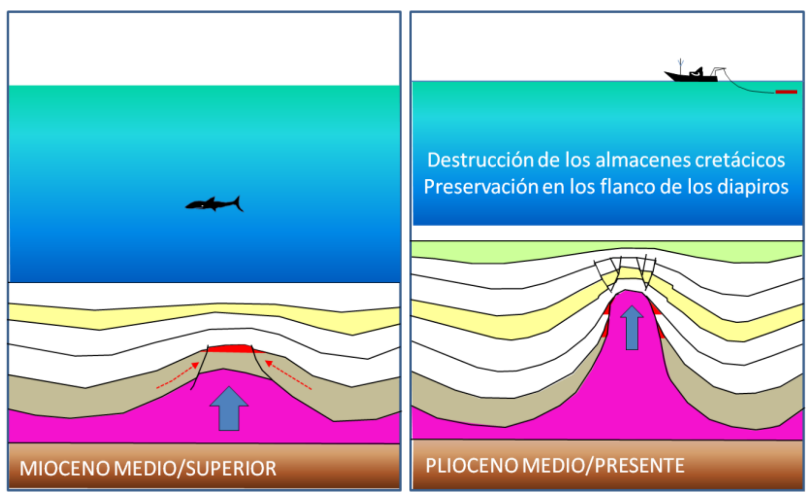
Tectonic and Structural Framework - Typology of the traps associated with salt



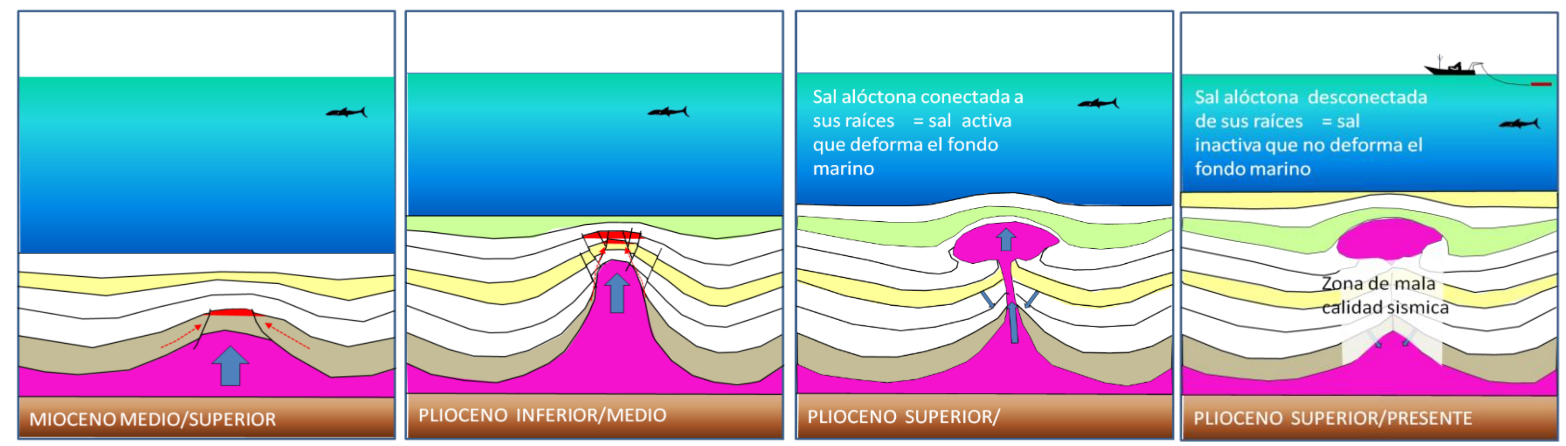
Scenario 1:
Traps that were above the salt-cored structure during the Miocene diapirism activity are destroyed, but hydrocarbon migration goes to early and shallower reservoir rocks.



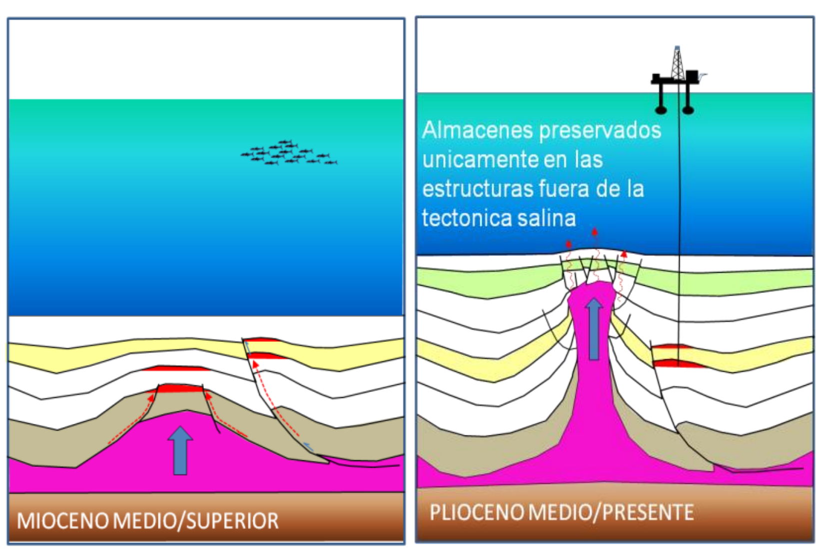
Scenario 4:
Traps that were above the salt-cored structure during a strong Miocene-Pliocene diapirism activity are totally destroyed. Only small traps located at the saline intrusion sides could be preserved.



Scenario 2:
Traps that were above the salt-cored structure during the Miocene diapirism activity are destroyed, but hydrocarbons have been preserved in small traps located on the flanks of salt-cored structures. There are no accumulations at the top of the diapiric structure.



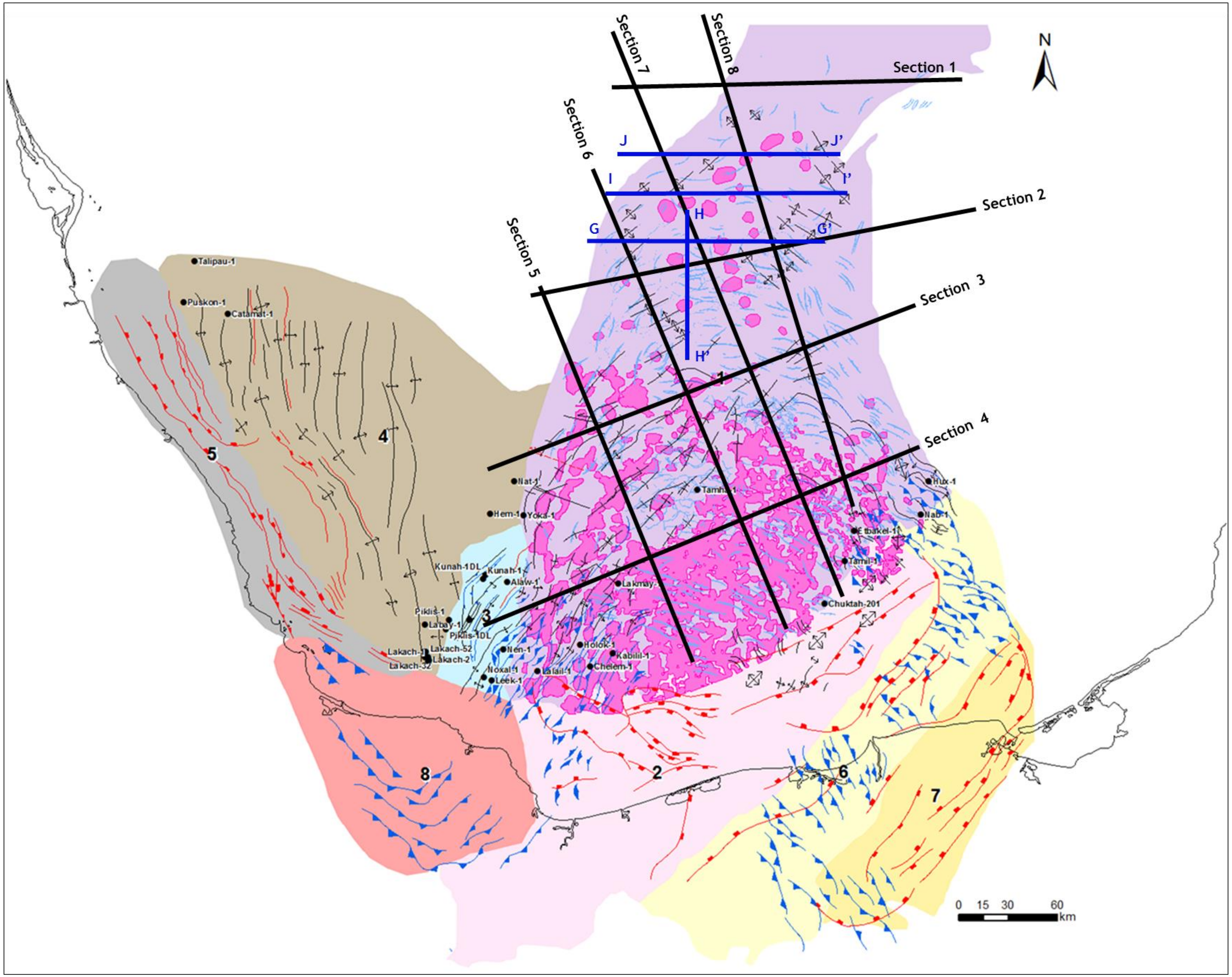
Scenario 5:
Traps that were above the salt-cored structure during a strong Miocene-Pliocene diapirism activity are totally destroyed.
A portion of the salt body is disconnected from the autochthonous source and do not continue to feed enough to reach the seafloor level. Shadow seismic imaging effects appears by the salt body shape, making difficult the seismic interpretation below the salt intrusion.



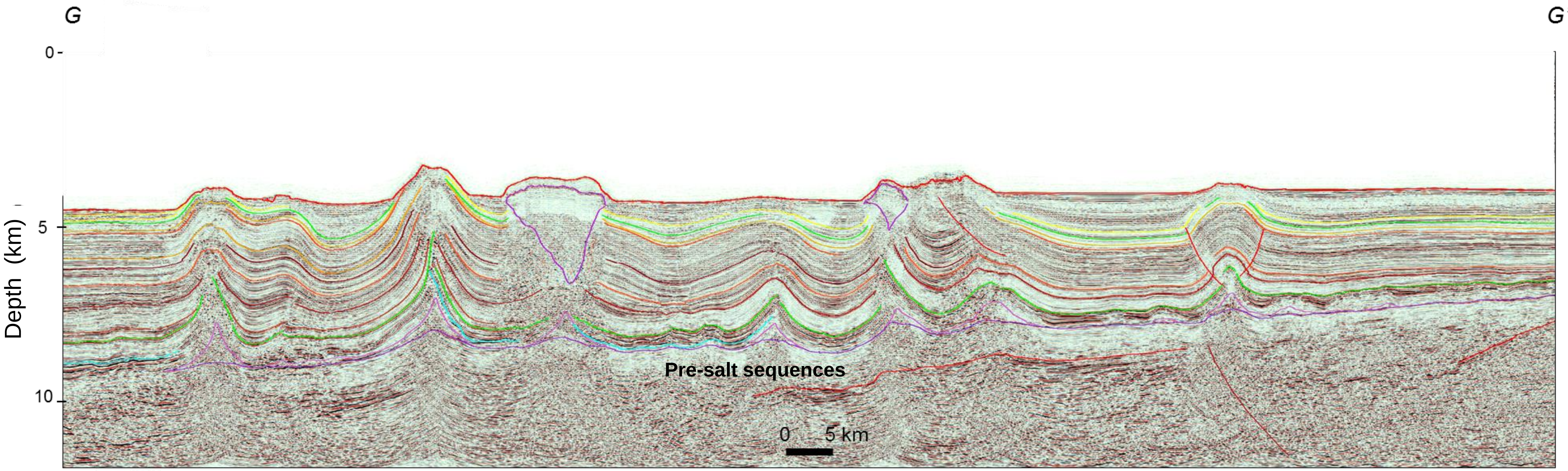
Scenario 3:
Traps that were above the salt-cored structure during the Miocene diapirism activity are destroyed, but hydrocarbons migrated to early and shallower reservoir rocks in a first stage. Later, the salt intrusion became larger, almost reaching the sea bottom, so this secondary trap was broken, while the first one is preserved.

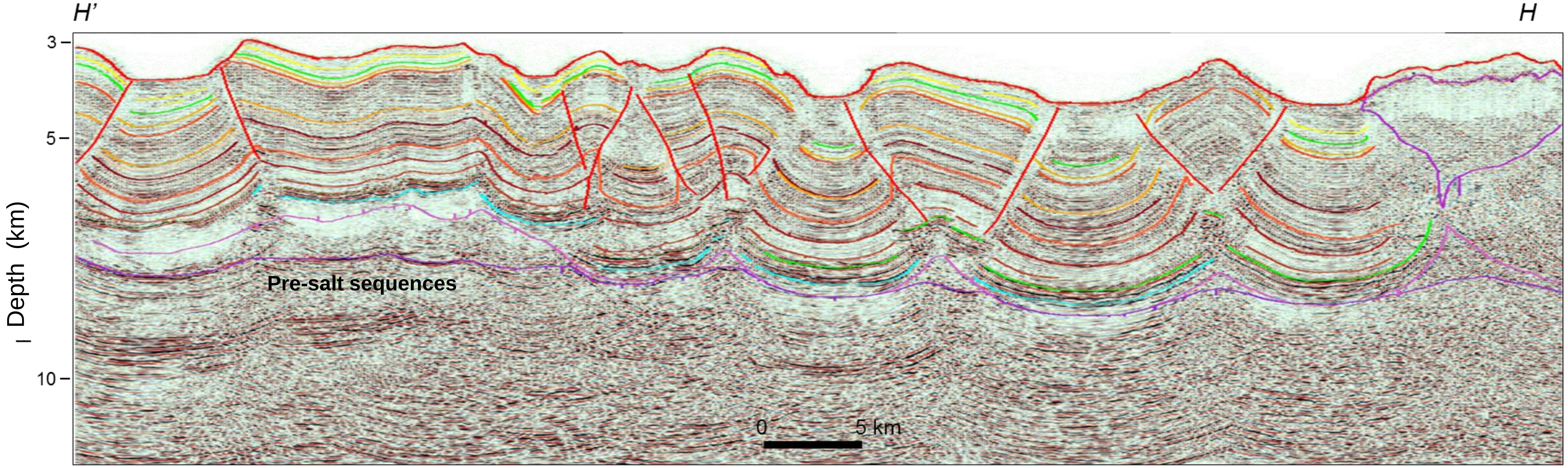
Scenarios - Traps / Diapiric Activity

Tectonic and Structural Framework – Location of Seismic Sections



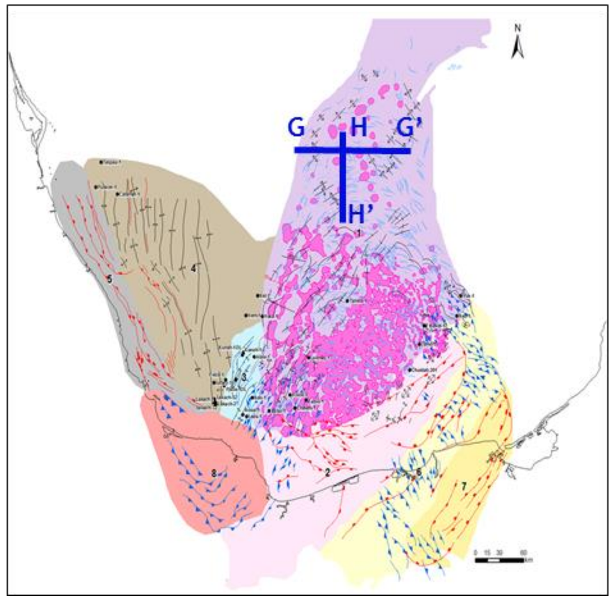
Tectonic and Structural Framework – Regional Seismic Sections (1)



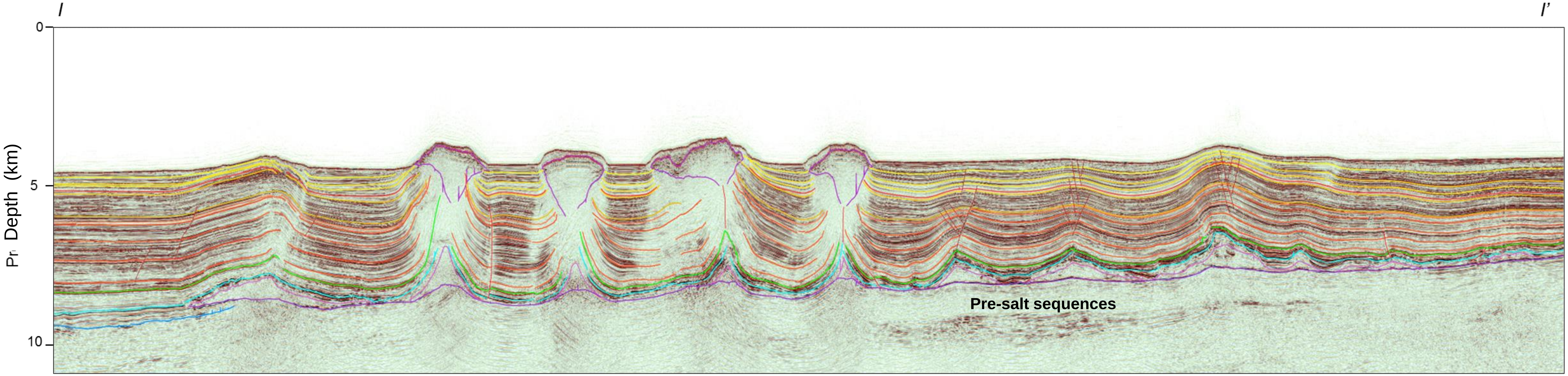


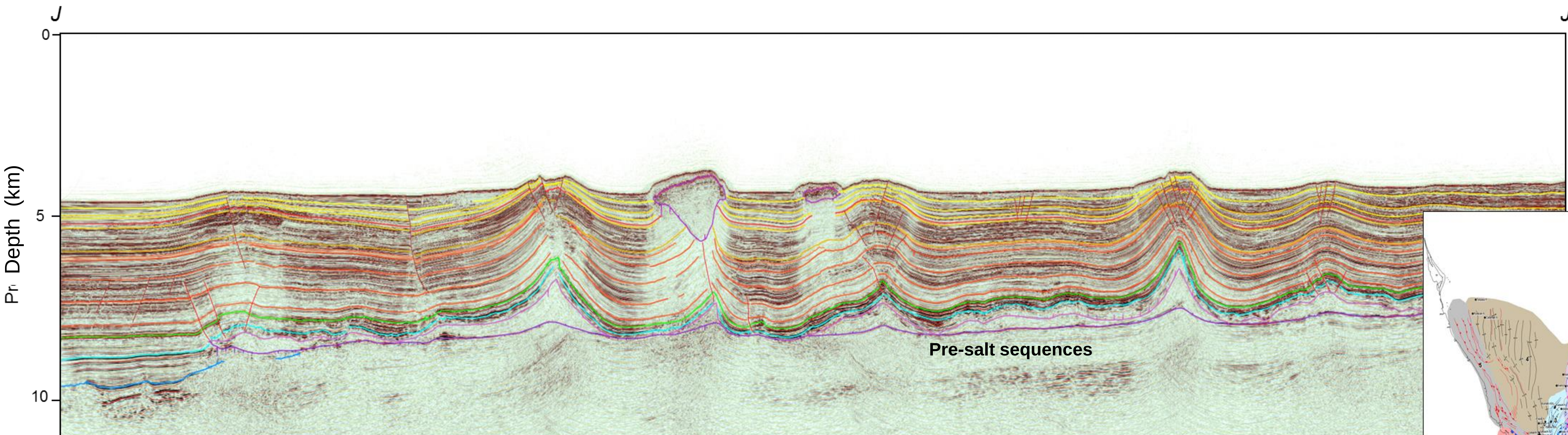
Structures

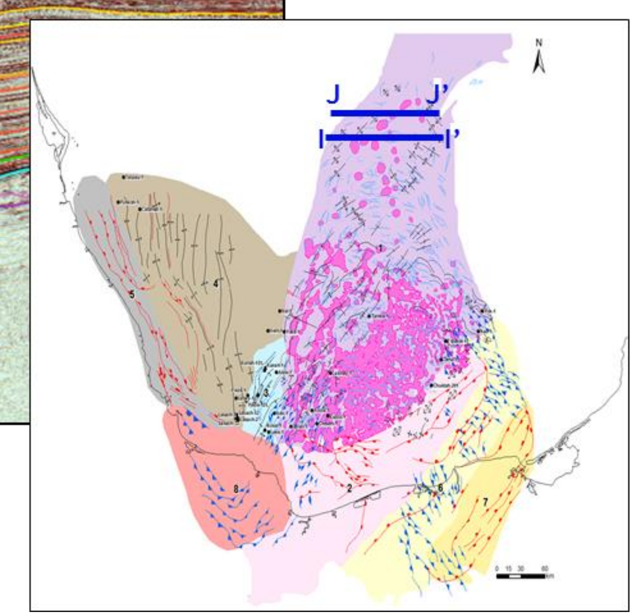
- Salt cored anticlines affected by thrust faults
- Shallow allochthonous salt bodies.



Tectonic and Structural Framework – Regional Seismic Sections (2)



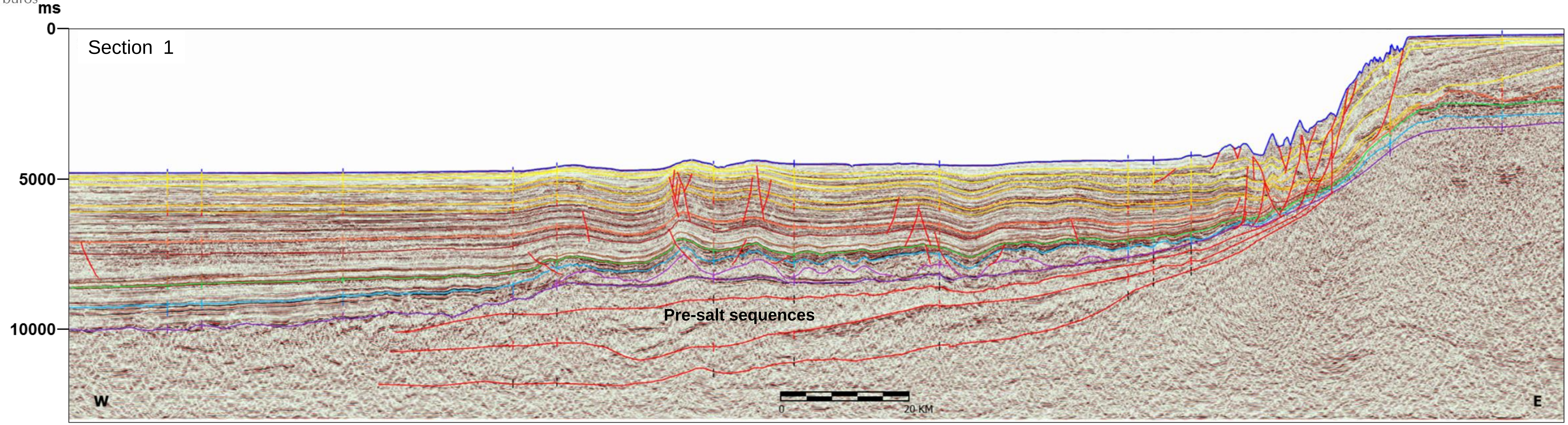


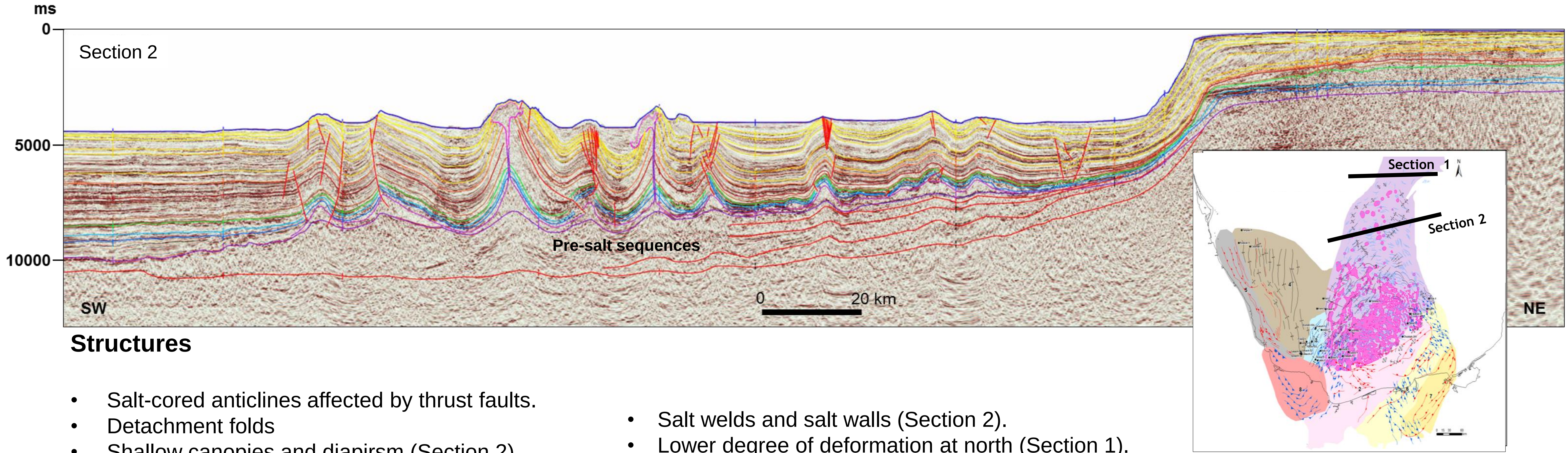


Structures

- Large and thight salt-cored anticlines affected by thrust faults.
- Shallow allochthonous salt bodies.

Tectonic and Structural Framework – Regional Seismic Sections (3)

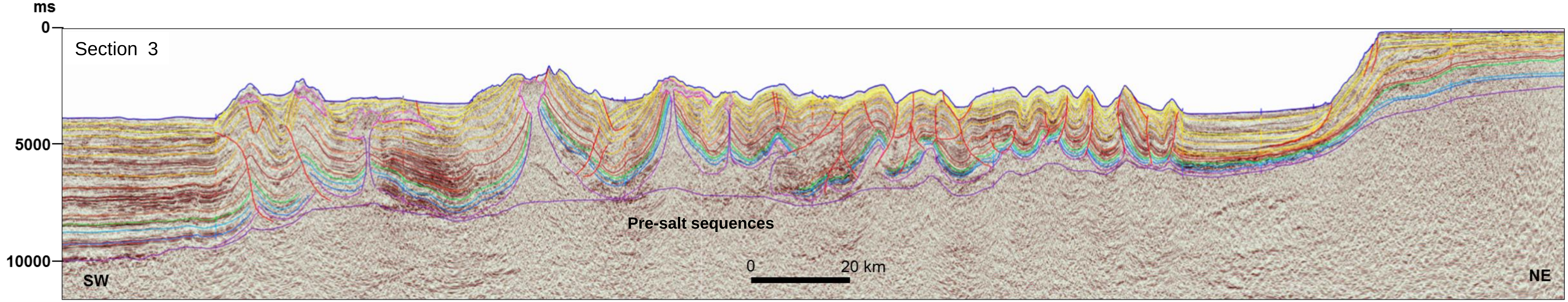


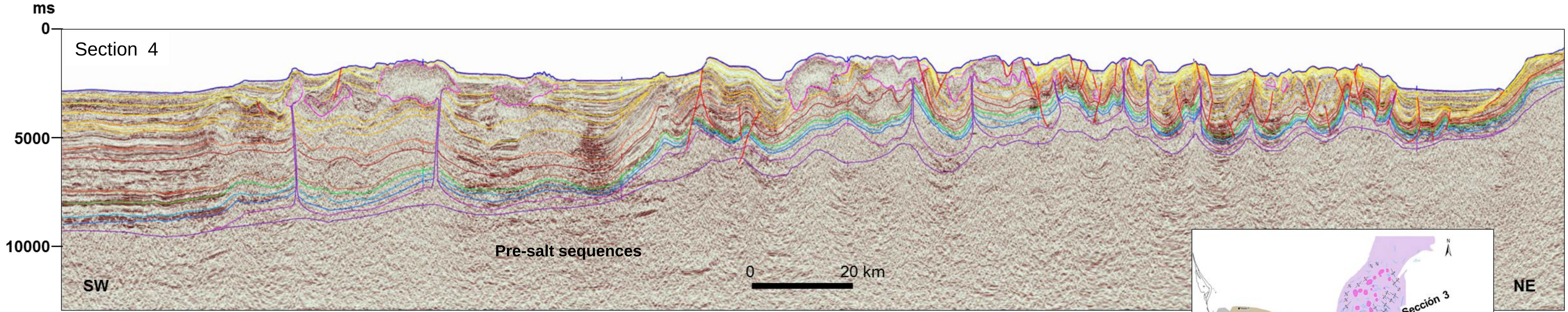


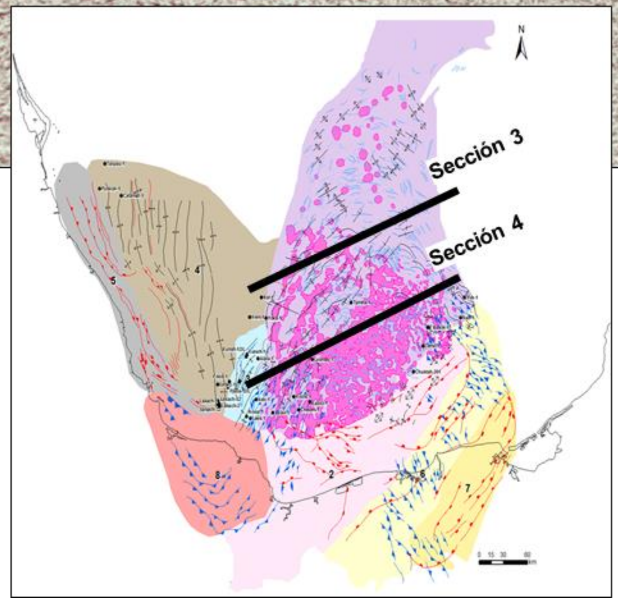
Structures

- Salt-cored anticlines affected by thrust faults.
- Detachment folds
- Shallow canopies and diapirsm (Section 2).
- Salt welds and salt walls (Section 2).
- Lower degree of deformation at north (Section 1).

Tectonic and Structural Framework Regional Seismic Sections (4)



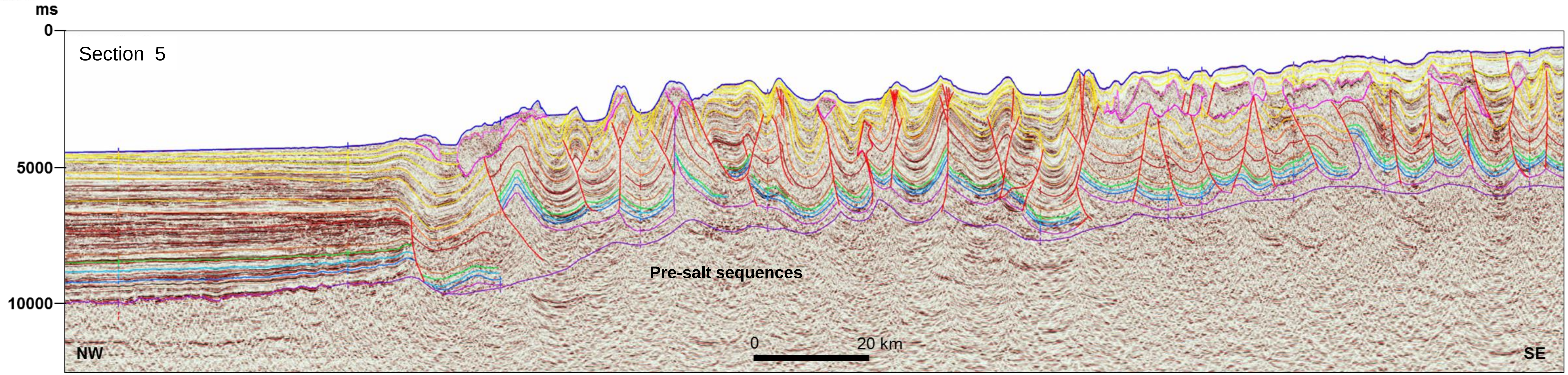


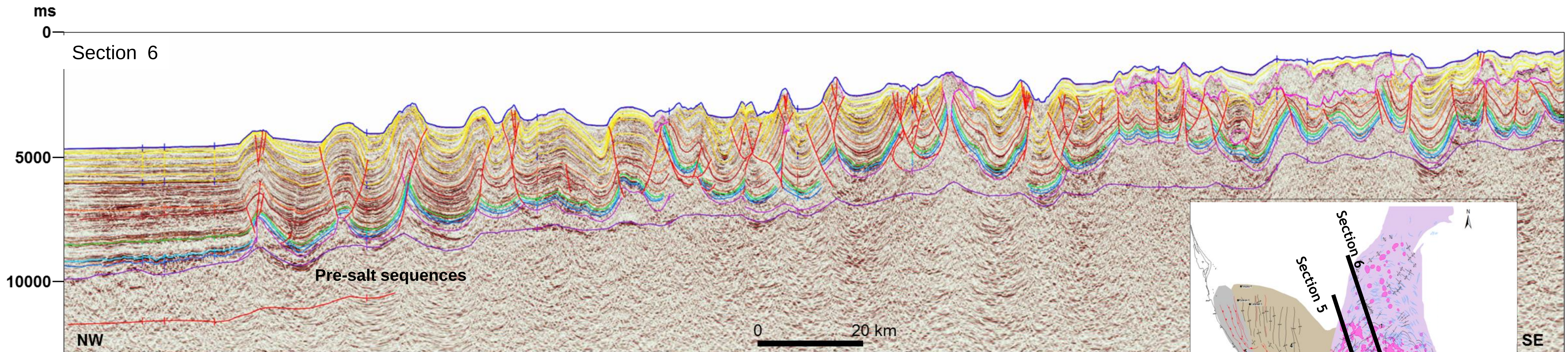


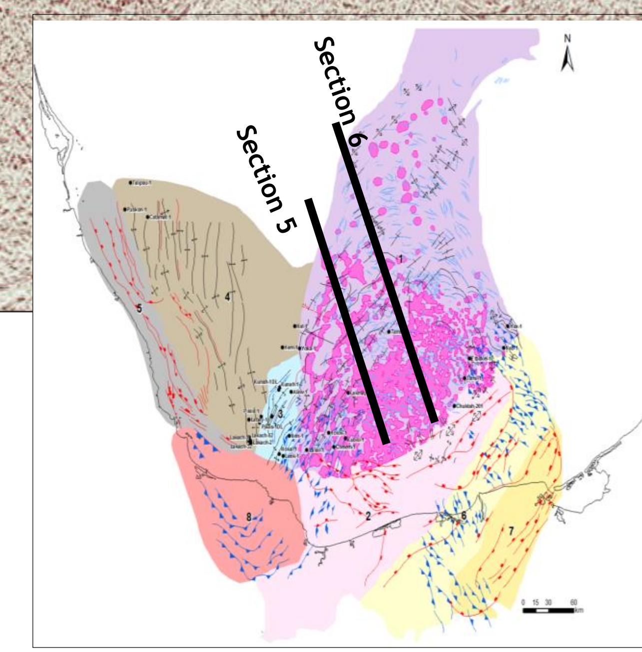
Structures

- Salt-cored anticlines affected by thrust faults.
- Fault-bend folds.
- Subsaline folds.
- Shallow salt canopies and diapirsm.
- Salt welds and salt walls.
- Intense deformation by salt tectonics activity.

Tectonic and Structural Framework – Regional Seismic Sections (5)



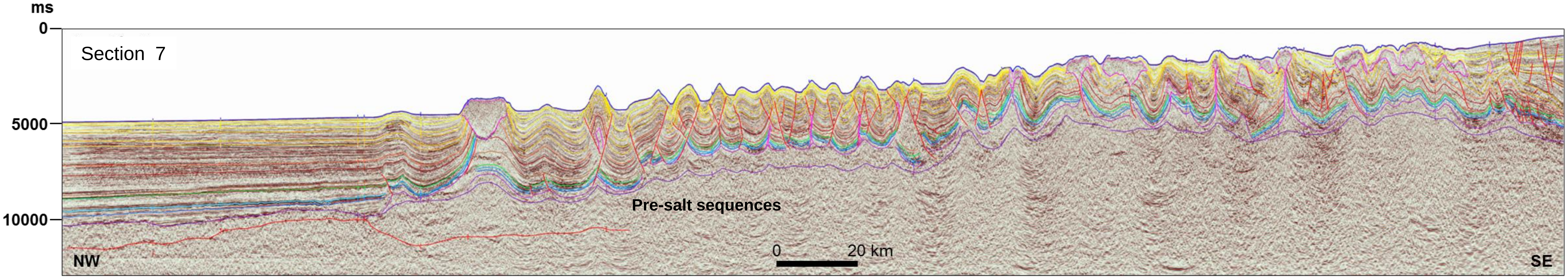


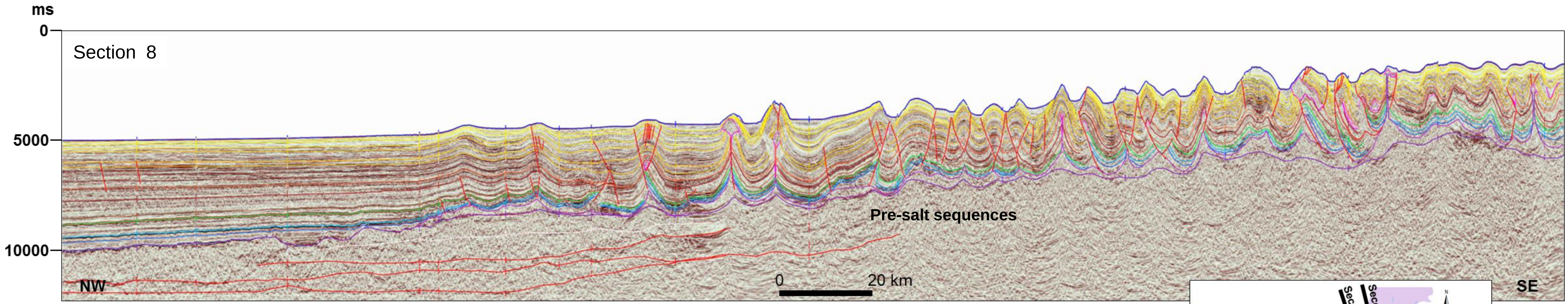


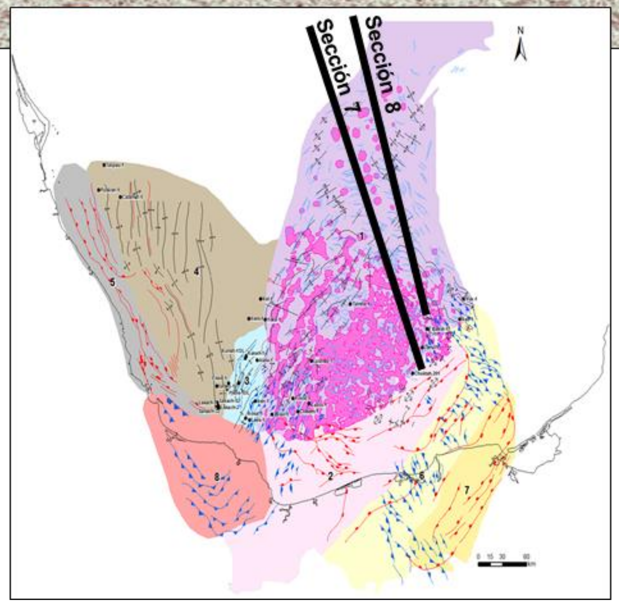
Structures

- Salt-cored anticlines affected by thrust faults.
- Fault-bend folds.
- Subsaline folds.
- Shallow salt canopies and diapirsm.
- Mini-basins development
- Salt welds and salt walls.
- Intense deformation by salt tectonics activity.

Tectonic and Structural Framework – Regional Seismic Sections (6)



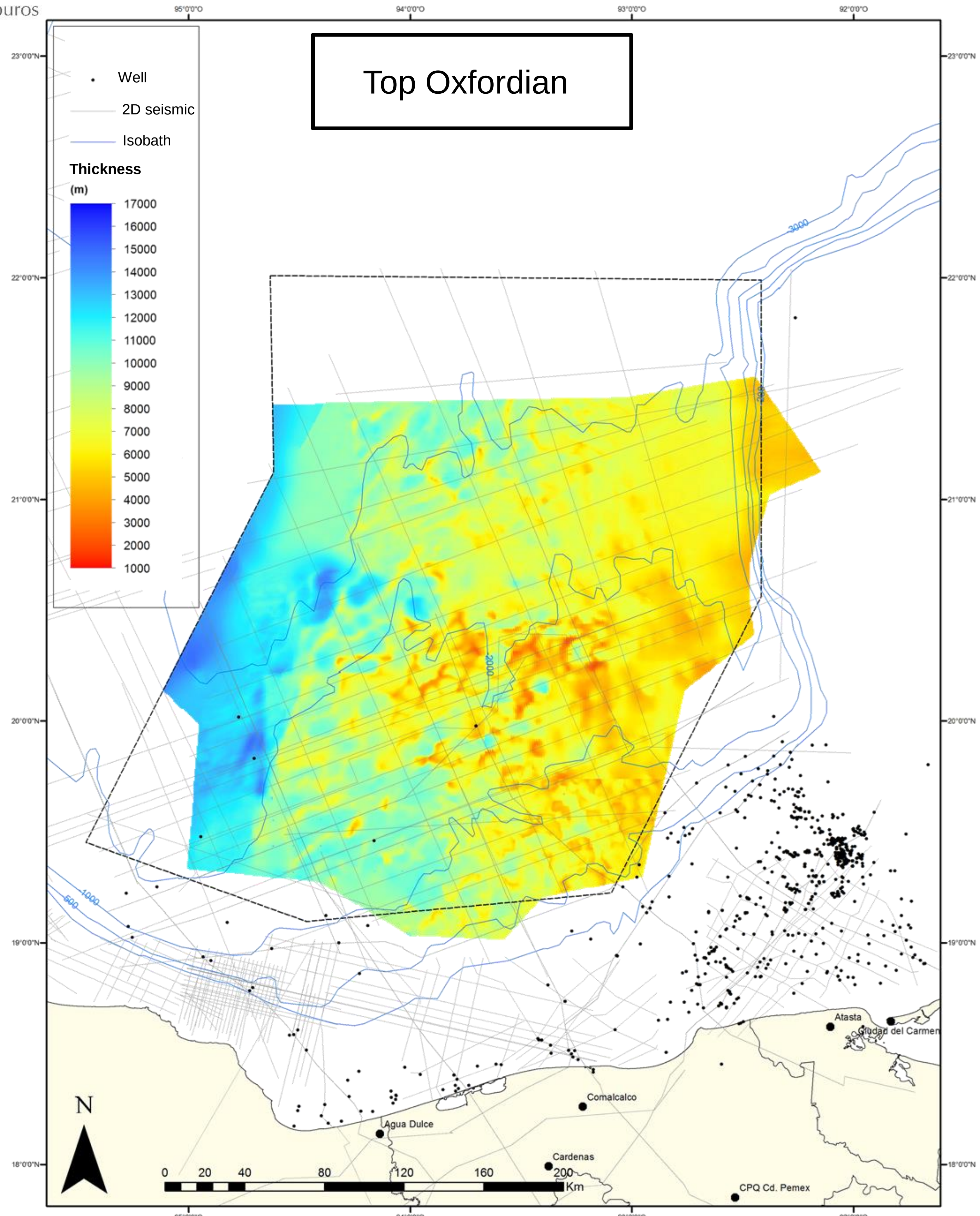


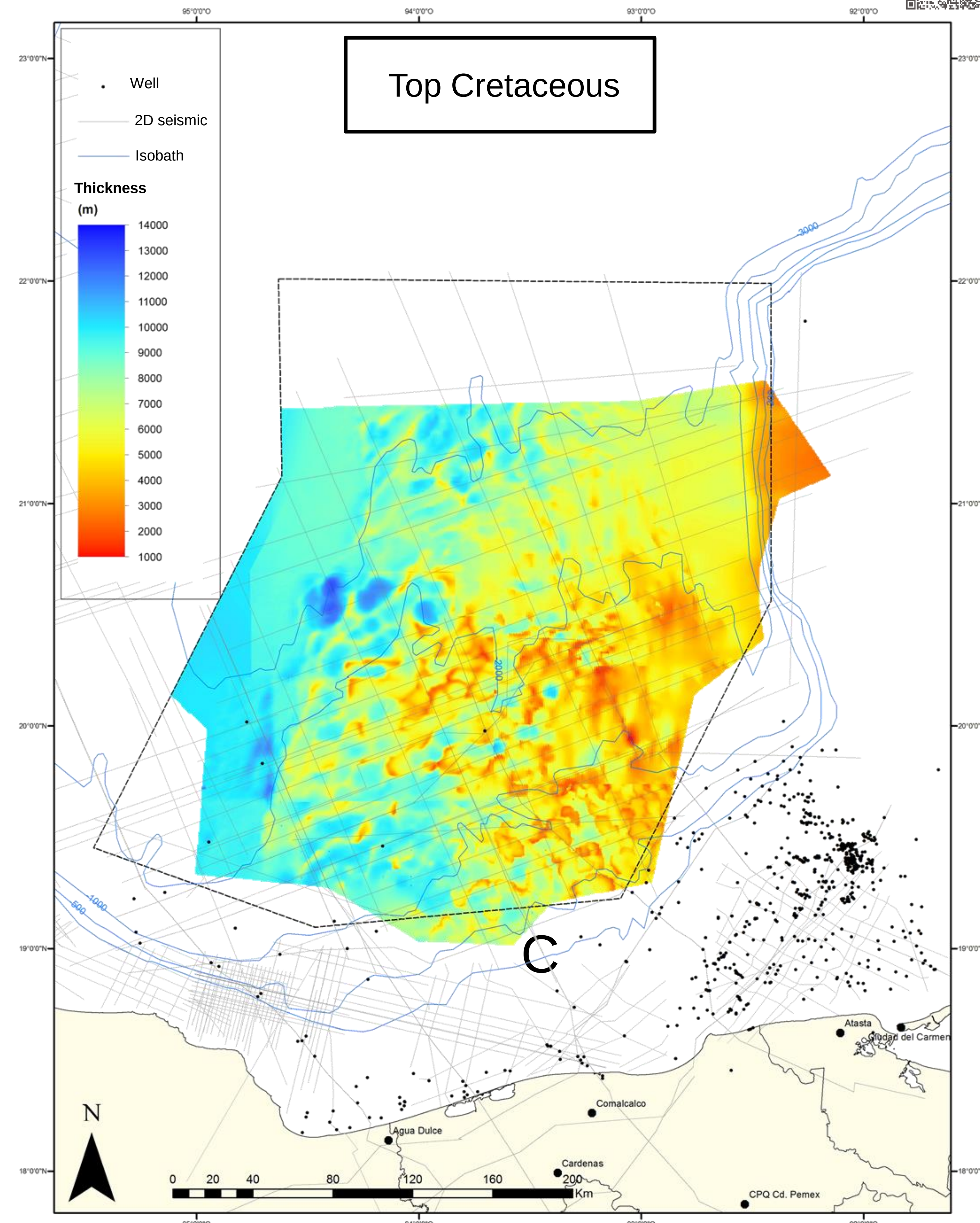


Structures

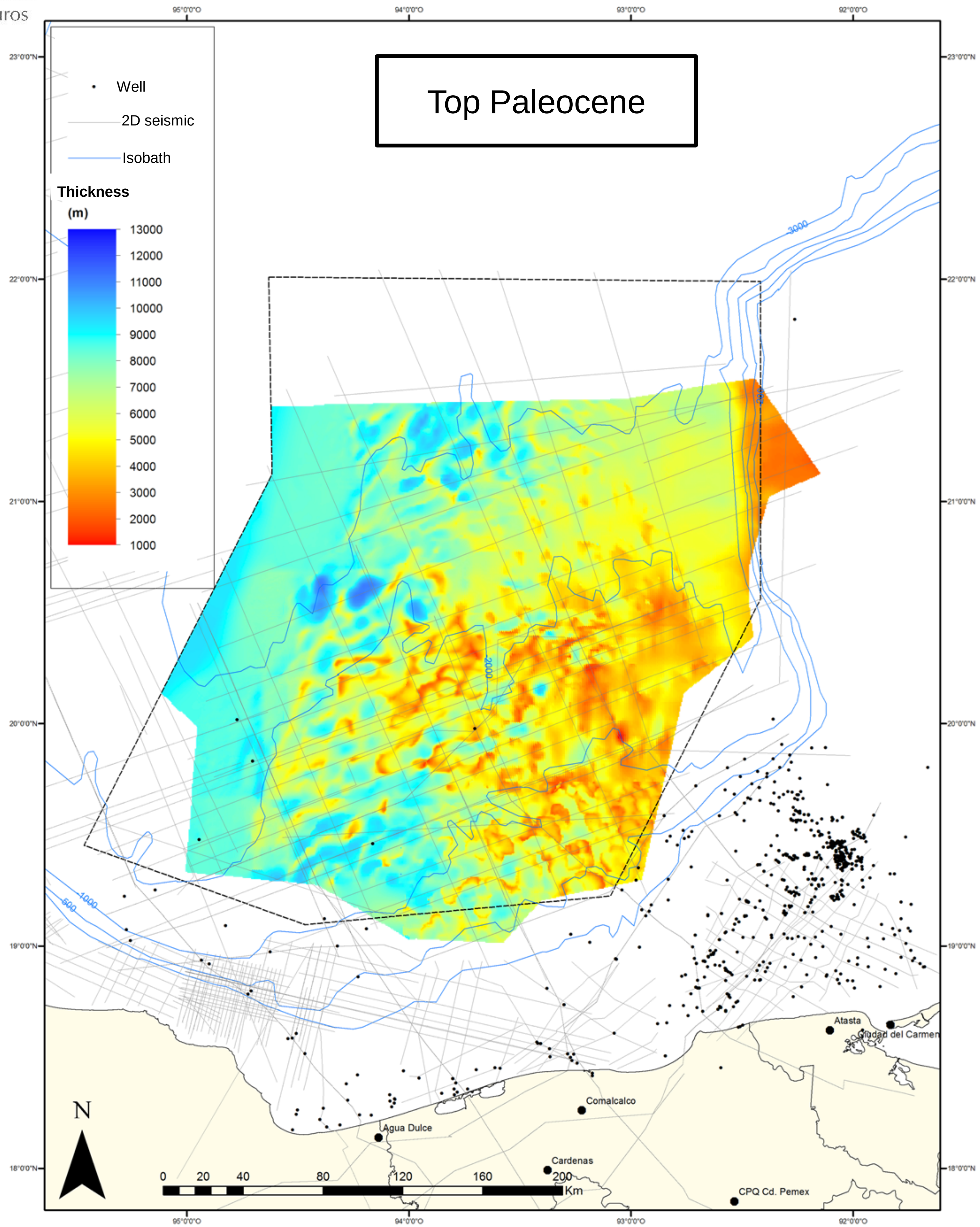
- Salt-cored anticlines affected by thrust faults.
- Fault-bend folds.
- Subsaline folds.
- Shallow salt canopies and diapirsm.
- Mini-basins development
- Salt welds and salt walls.
- Intense deformation by salt tectonics activity.

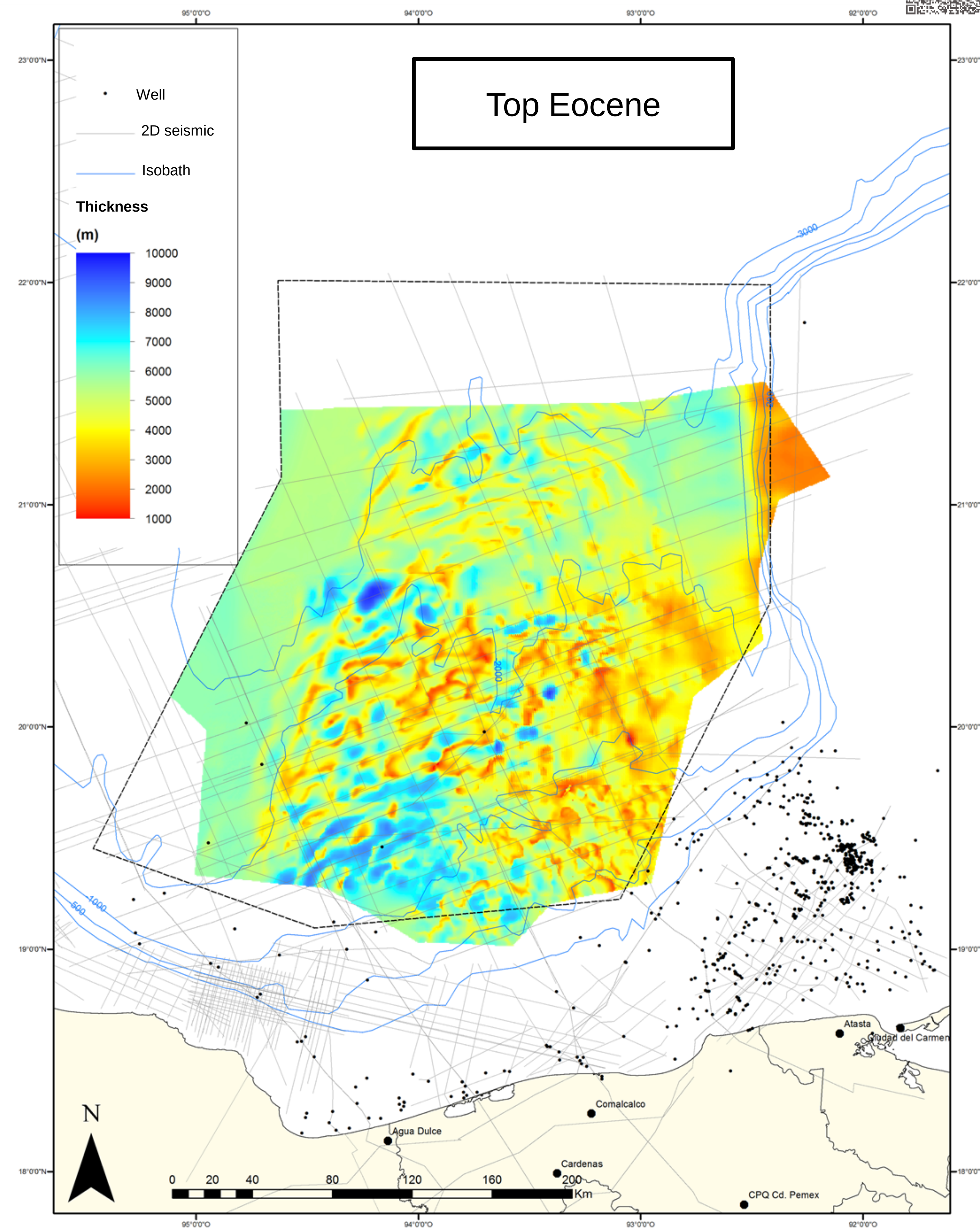
Structural and Tectonic Framework – Structural Maps (1)



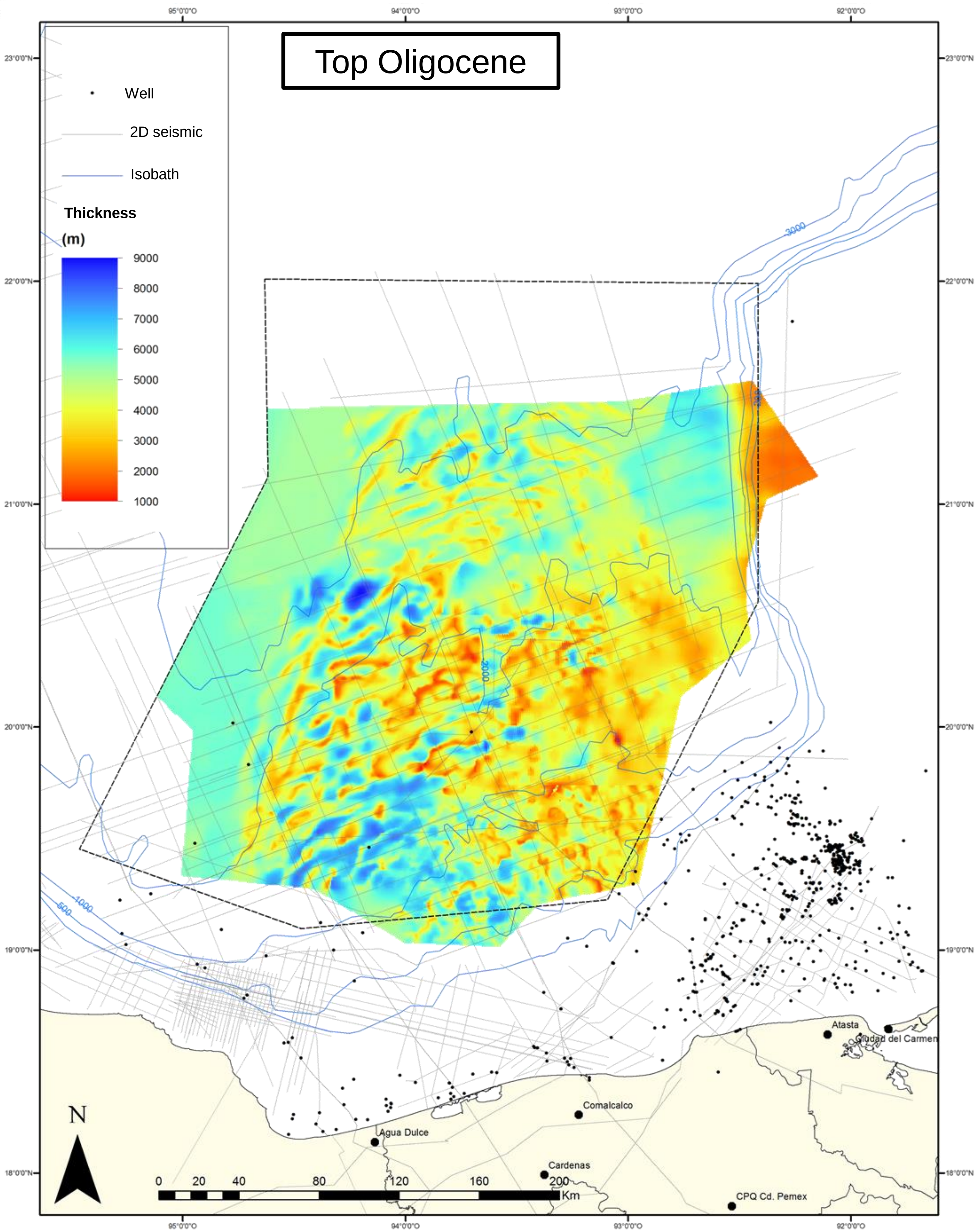


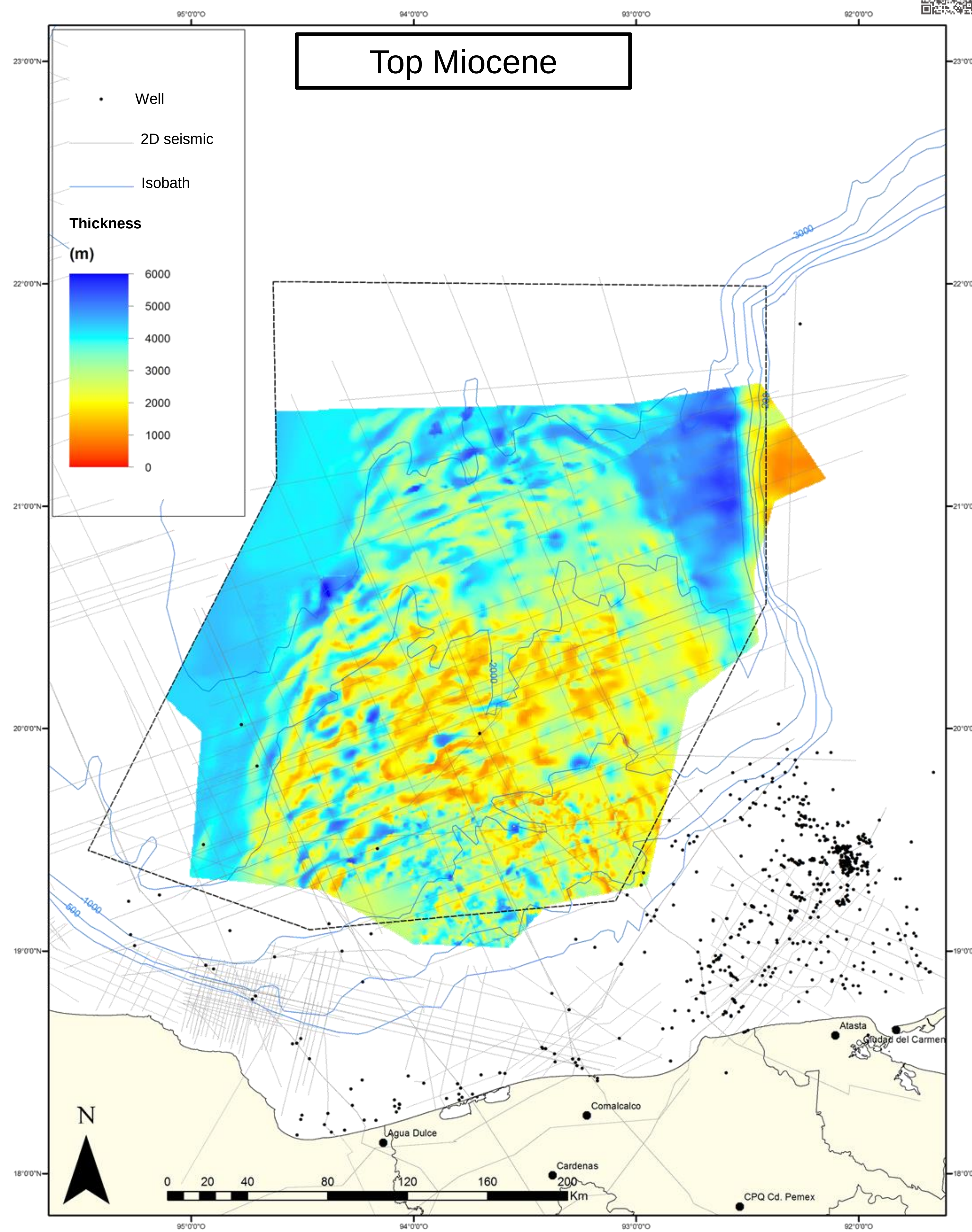
Structural and Tectonic Framework – Structural Maps (2)





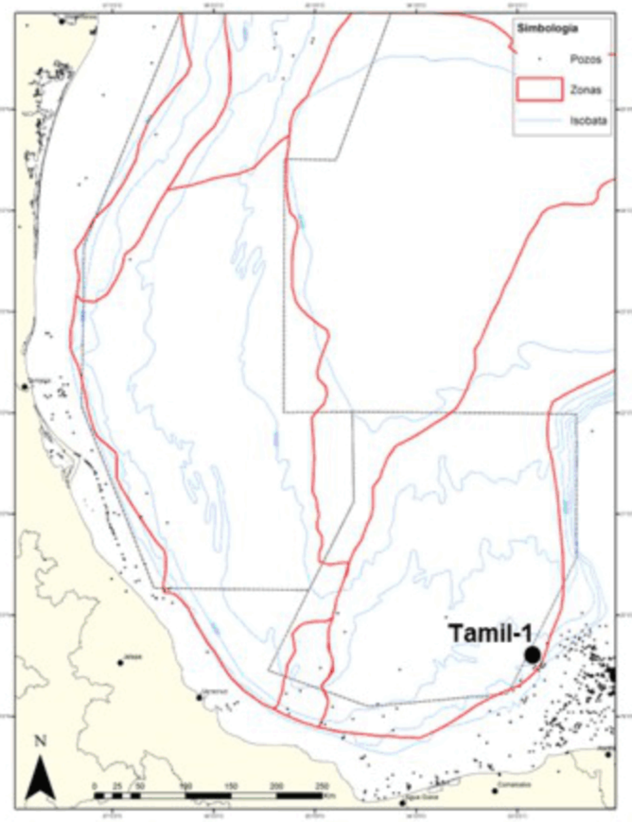
Structural and Tectonic Framework – Structural Maps (3)

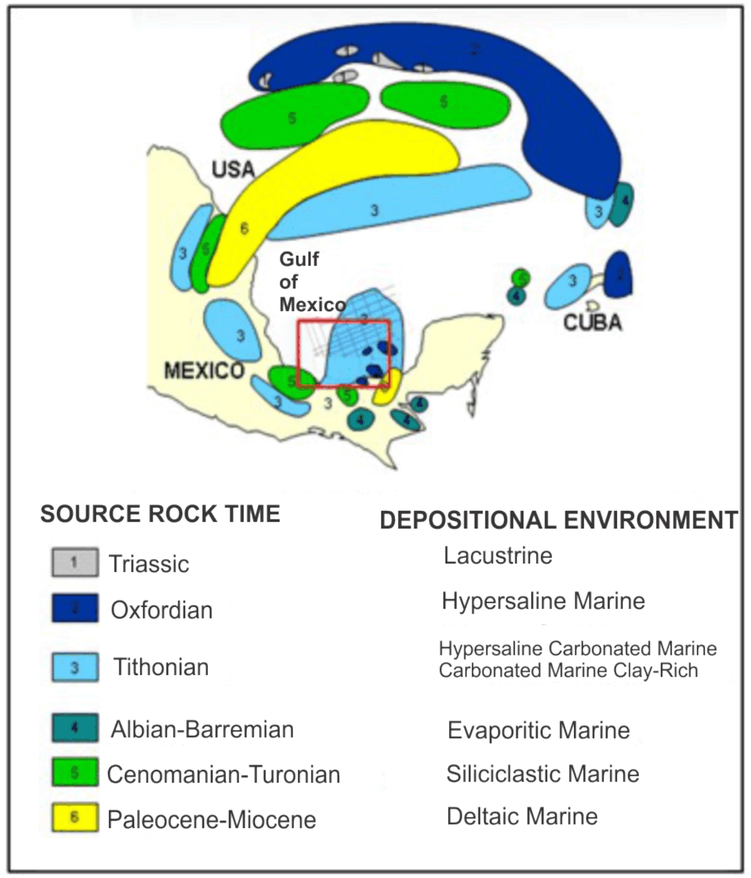


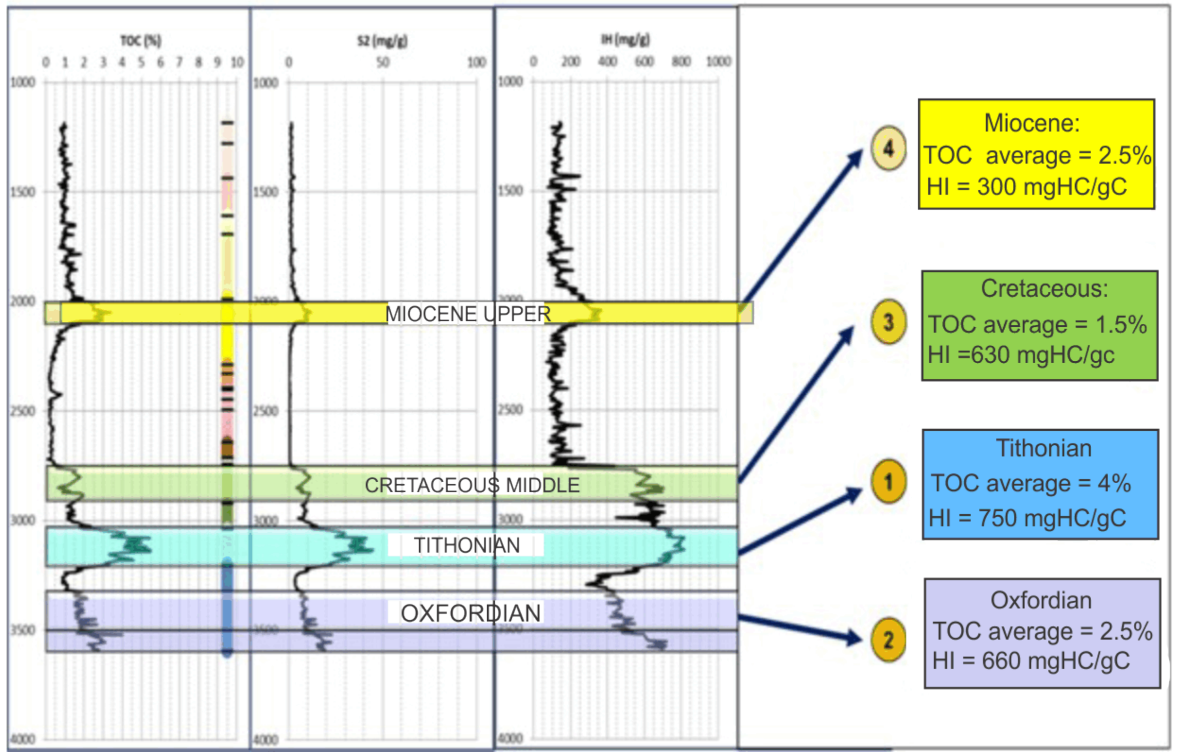


Petroleum Systems

Petroleum Systems – Source Rocks – Type and Quality







Four source rocks of different quality are recognized.

Only Tithonian and Oxfordian source rocks have the potential to be considered as the main source rocks

Cretaceous

Cretaceous rocks have relatively very rich organic matter intervals and probably within the the Kimmeridgian as well, however, there is not precise data about the real potential. Maximum estimated potential is about 2.5 T/m². There are samples with TOC values about 1% (in some areas up to 3-4%) dispersed in Miocene/Pliocene shales with mixed organic matter (types II/III) but its contribution to Cenozoic accumulations is unproven.
According to geochemical interpretations, it has been established that the accumulations observed in the Cenozoic Rocks have a Jurassic origin.

<u>Features of Cretaceous source rocks</u>
Net Thickness: 20-200 m
Organic content: ~2.5 %
Organic Matter: Type II (HI~500-600)

Tithonian

Tithonian rocks are the main source of hydrocarbons of Mesozoic basins of the Southeast Marine Basins and probably in the Deepwater South sector. They are widely distributed, ranging in thickness between 100-400 m.

From the sedimentological point of view, lithofacies are associated with deepwater carbonate environments ranging from external platform to deep basinal environments. In some areas, two horizons can be distinguished from the Tithonian rocks: A secondary thick horizon of low quality and a main thinner horizon of the highest source rock quality. Maximum estimated potential is about 3-4 T/m².

<u>Features of Tithonian source rocks</u>
Net thickness: 20-200 m
Organic content : ~4%
Organic Matter: Type II to II S (HI ~ 500-700)
The regional Upper Jurassic source rock of marine origin (Type II) is proved in the area and is the source rock that fed the discovered accumulations of light and medium oil (by chemical analysis of the oil).

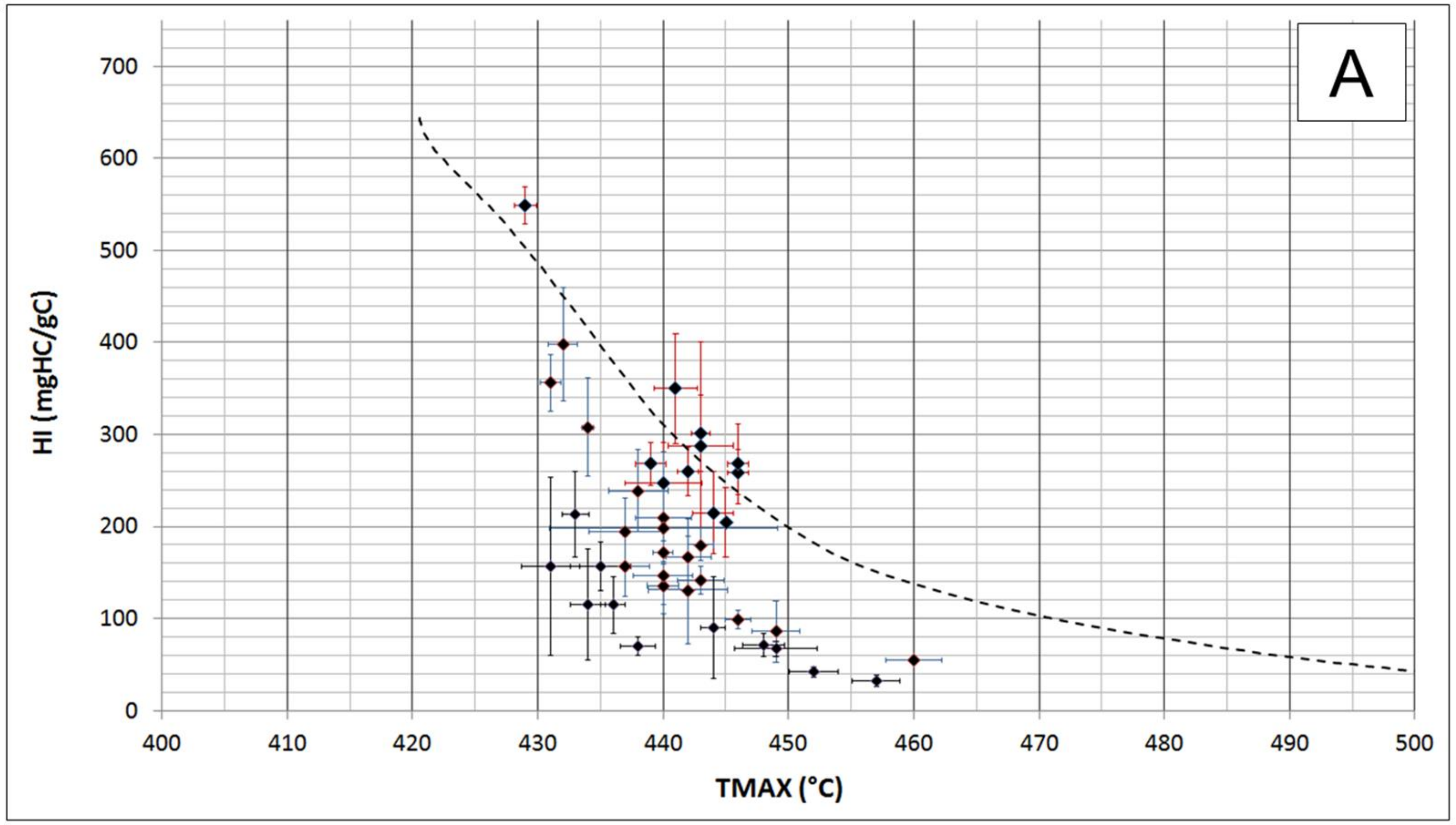
Oxfordian

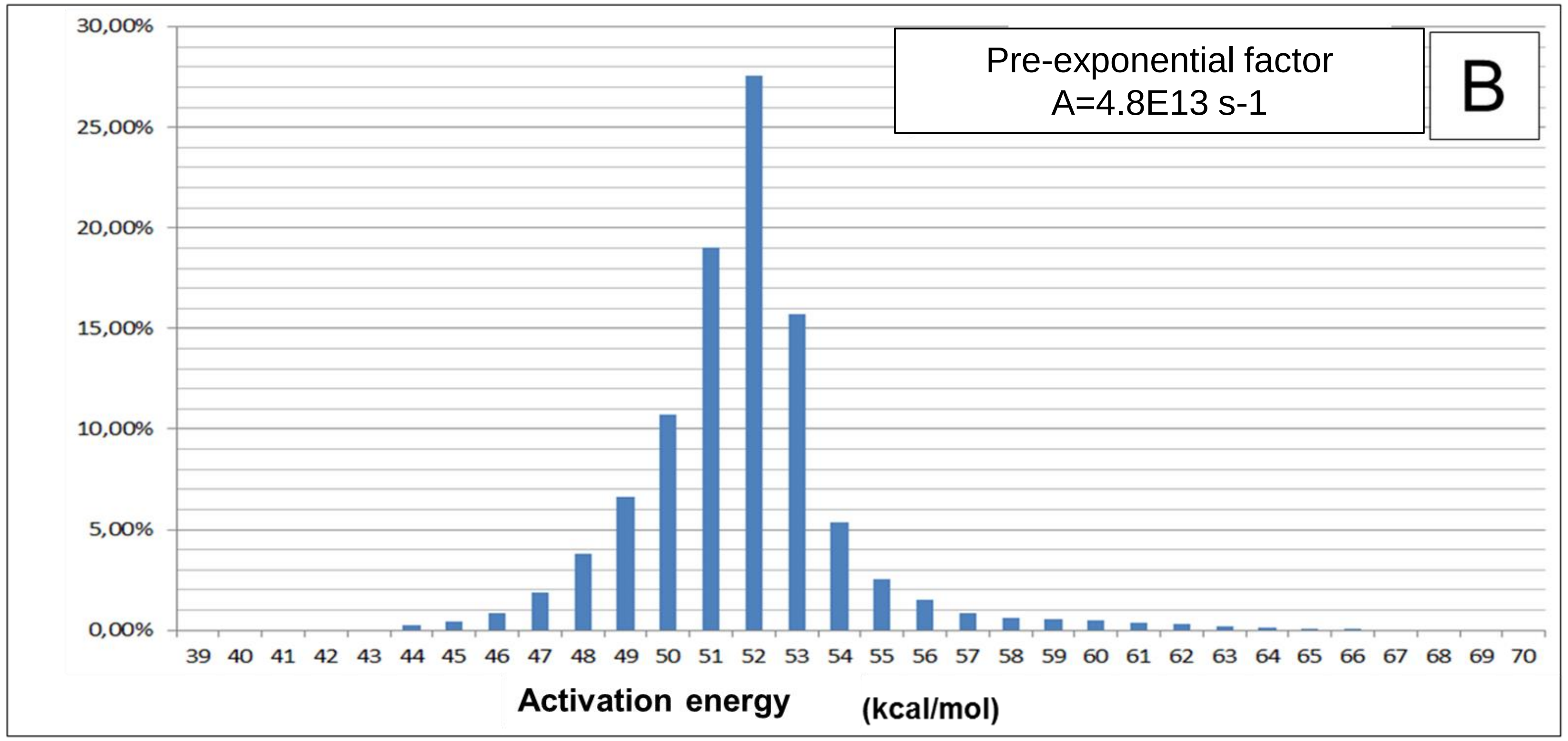
The Oxfordian oil generator subsystem could be considered as secondary in the Southeast Marine Basins. Maximum estimated potential is about 3 T/m².

<u>Features of Oxfordian source rocks</u>
Net thickness : 20 to 200 meters
Organic content: ~3%
Organic Matter: Type II (HI~500-700)

The Oxfordian oil generator system is considered as a closed system, since the accumulations in the Lower Oxfordian sandstones come only from the hydrocarbons expulsion from the Oxfordian source rock, and not migrate to Kimmeridgian or Cretaceous levels.

Petroleum Systems – Generating Rocks – Initial Potential

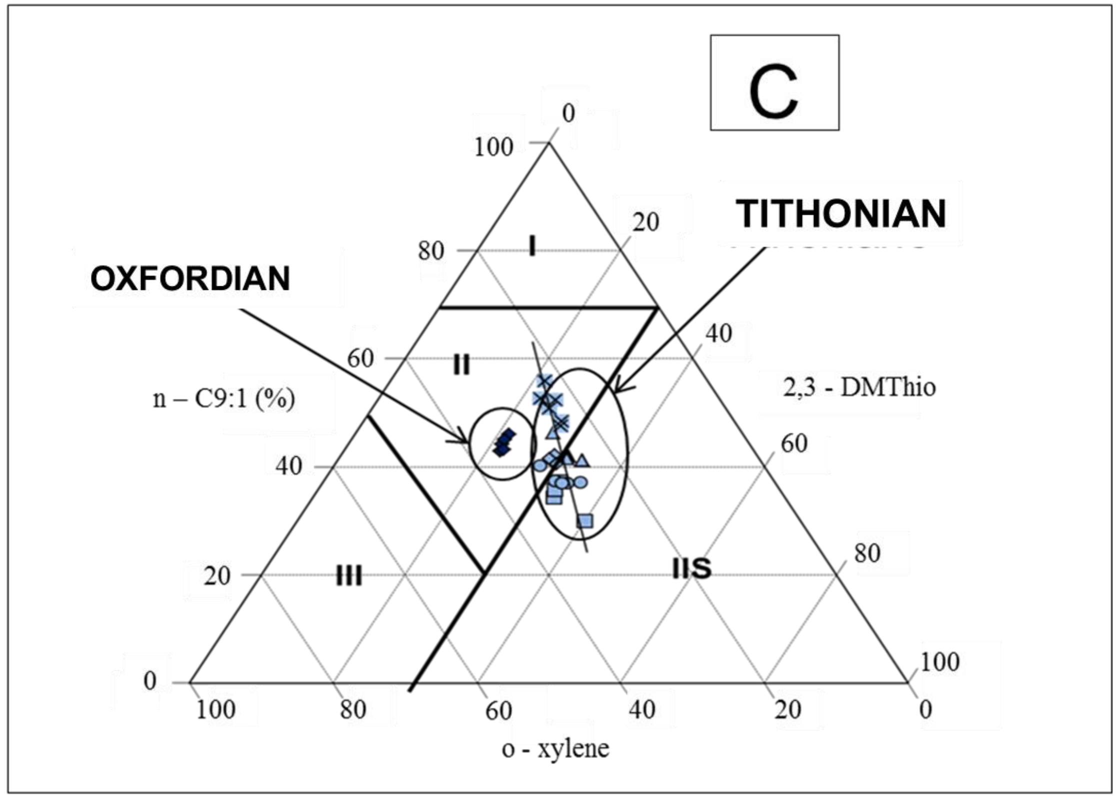




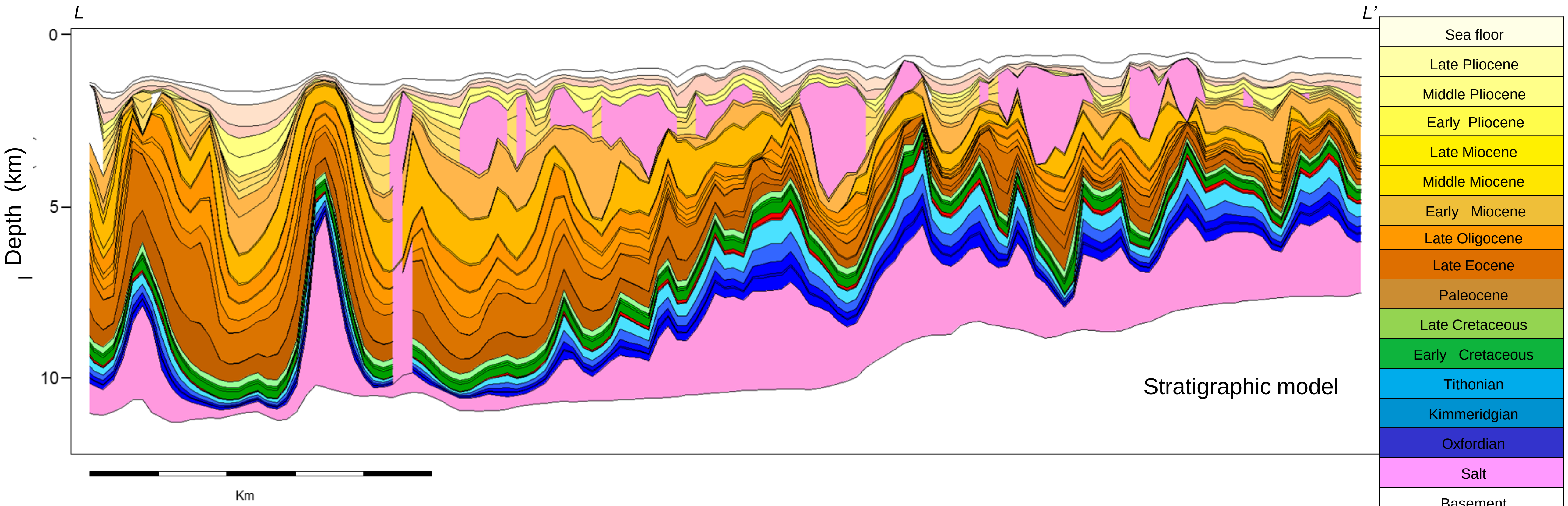
The initial potential in the area is determined based from over 1,500 pyrolysis data, with a detailed analysis. In the eastern part of the shallow water zone the Tithonian rocks have an average initial potential between 4.0 to 5.0 T/m², with significant lateral and vertical variations of the initial TOC and HI. Lateral and vertical variations of initial average HI from 250 mgHC/gR to 600 mgHC/gR were found.

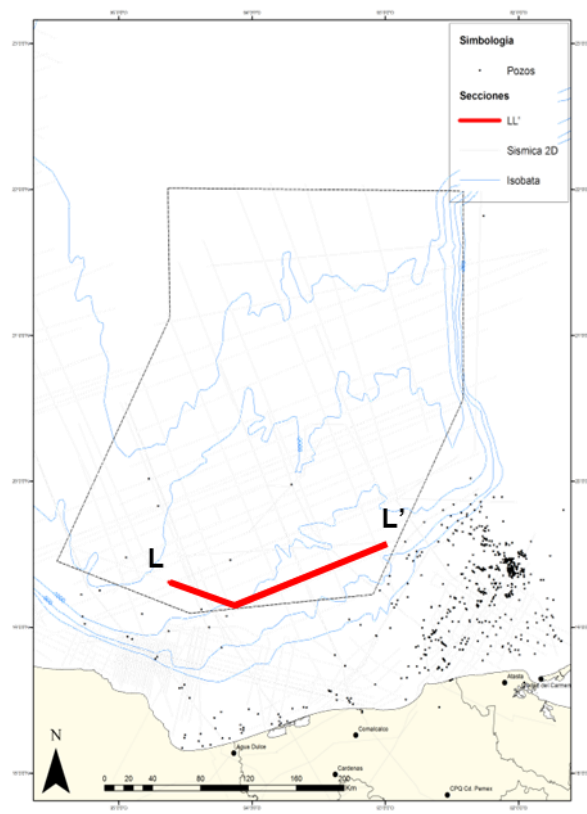
Experiments with kinetical parameters were performed for the Tithonian, Cretaceous and Oxfordian rocks on some mature and immature samples. **Figure A** represents the diagram of the HI average in function of Tmax average per well on the Tithonian and the kinetic evolution curve. **Figure B**. The Titonian rocks in the marine area is characterized by Tmax values greater than 430°C and a maturity value beyond 0.6% VRo.

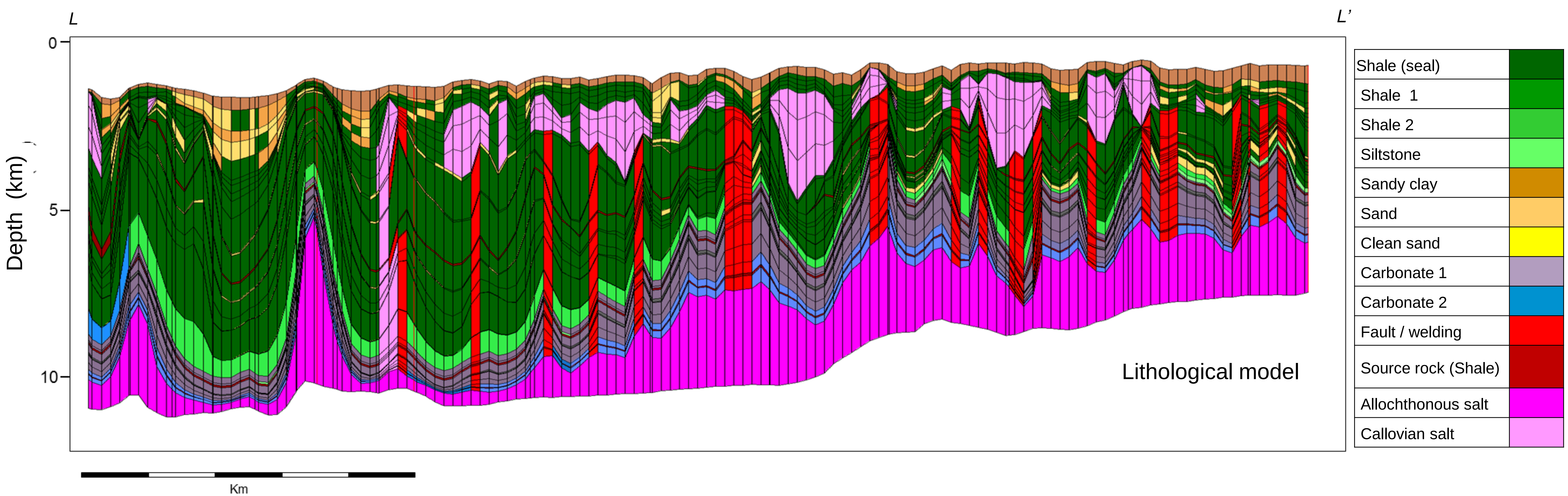
The abundance anaylisis of n-non-1-ene, 2.3 dimethylthiophene and o-xylol in several samples confirms that the Tithonian level present lateral variations of Type II to IIS. In comparison, the Oxfordian seems clearly be Type II, **Figure C**.



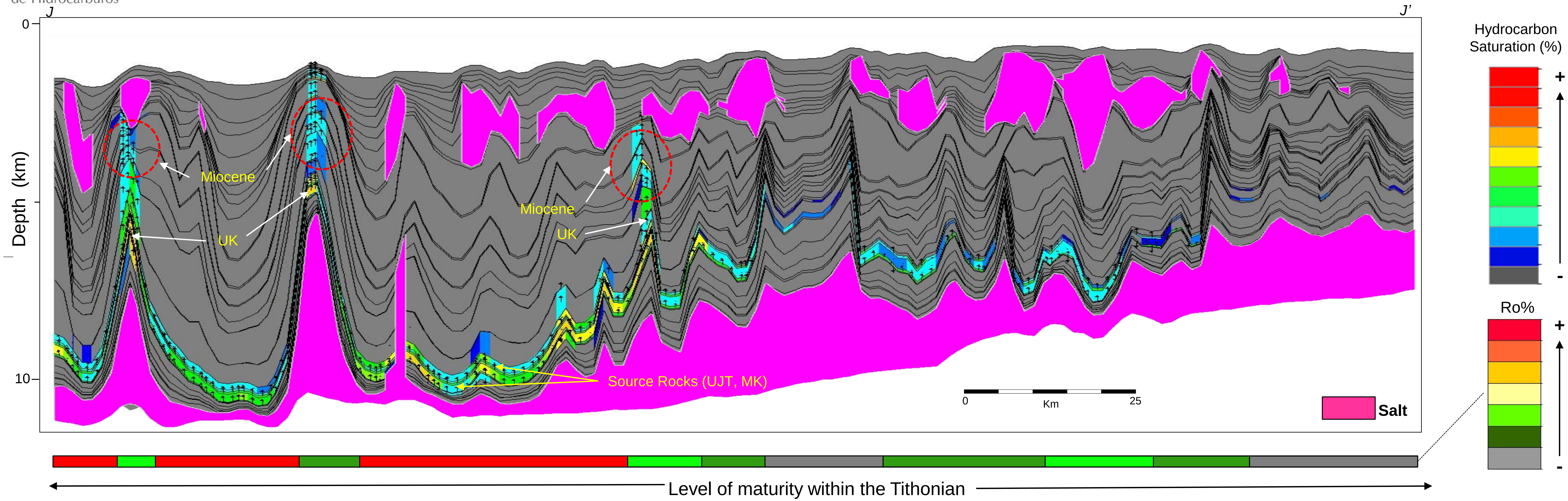
Petroleum Systems – Geological Model

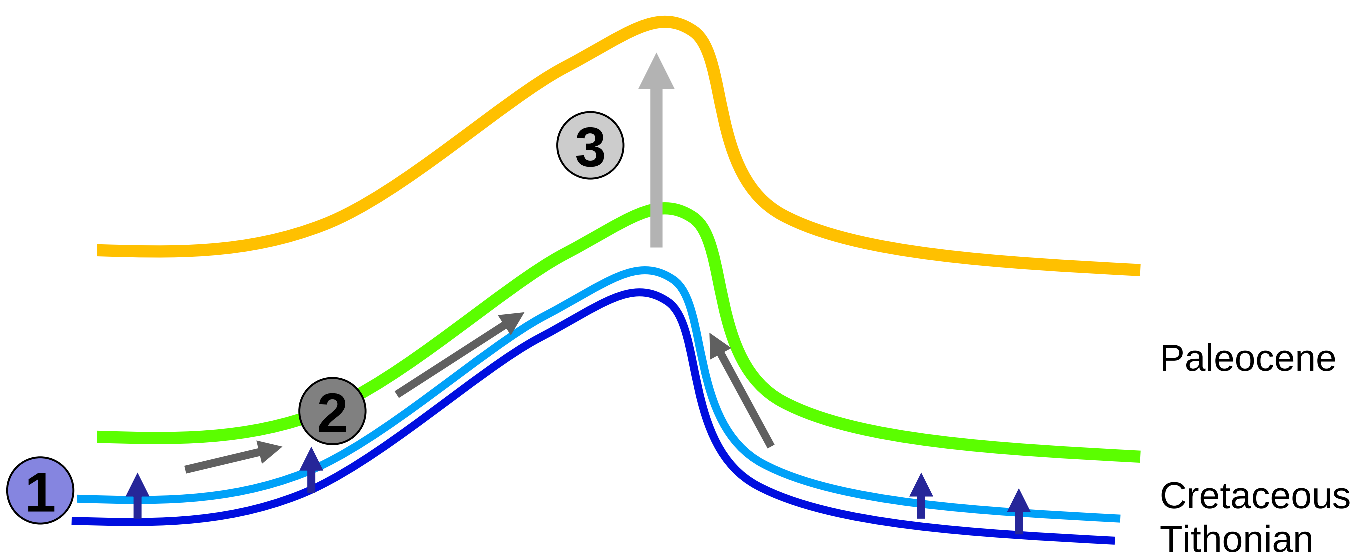






Petroleum Systems – HC migration model



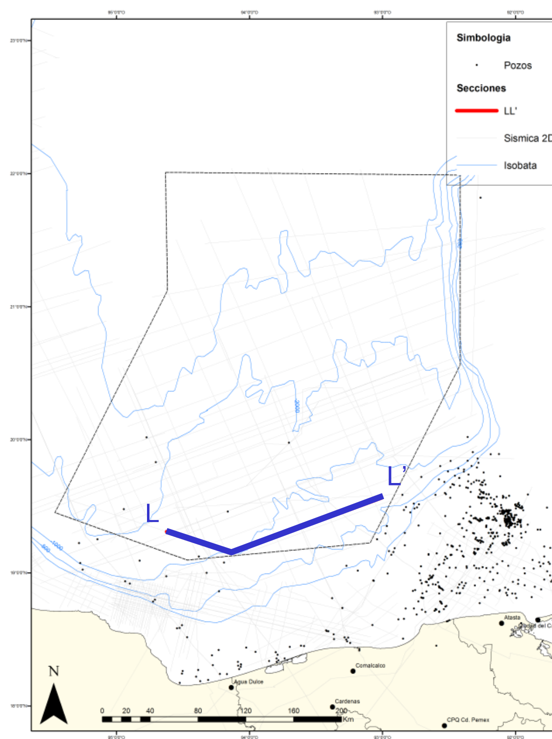


HC migration model

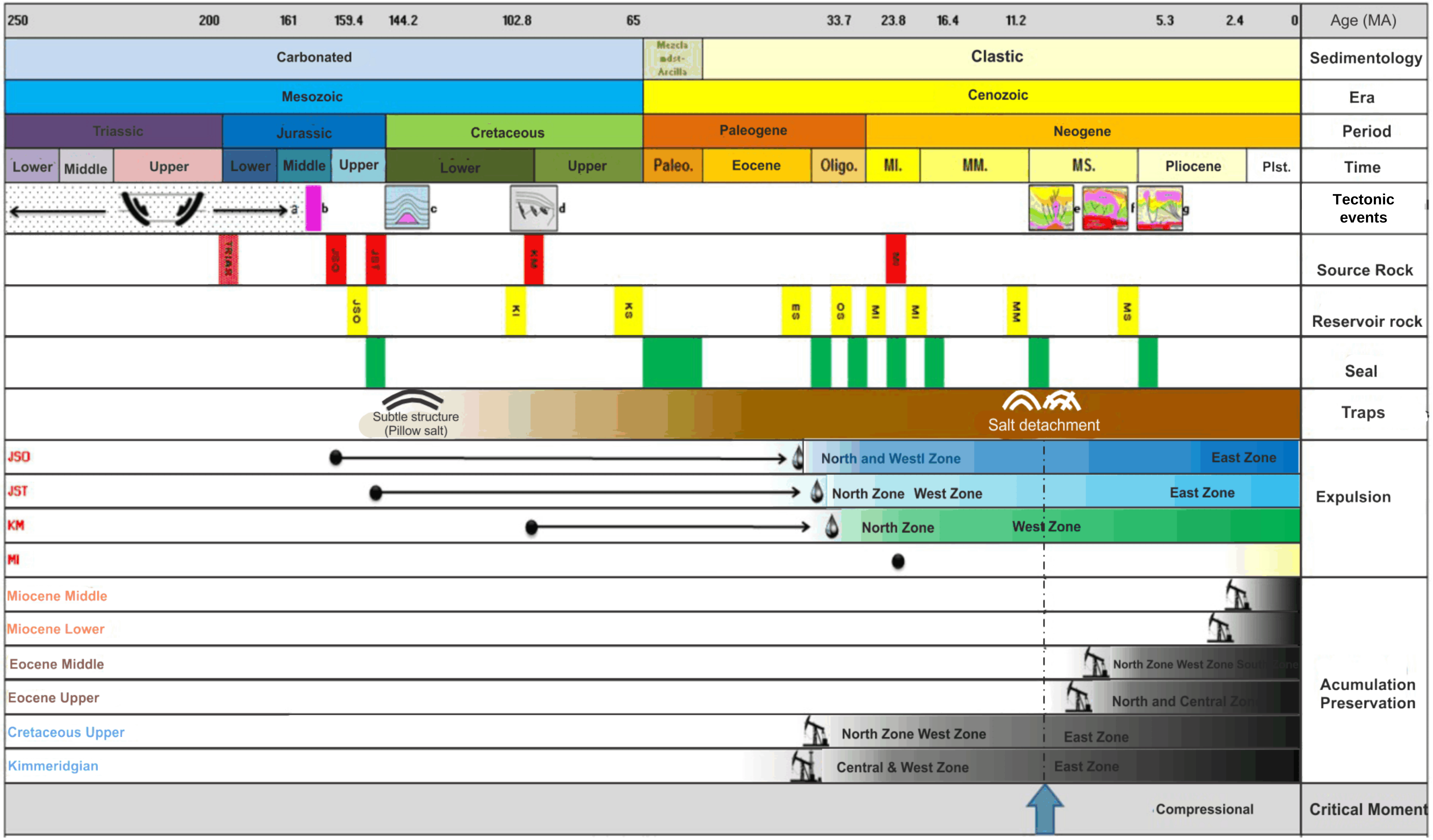
1. HC expulsion of the Tithonian and Cretaceous rocks (primary migration)
2. Lateral migration in Cretaceous rocks to the top of the structures
3. Leakage in Paleocene rocks when an important HC column accumulate, allowed by the fluids density: at least 40 % of gas = > RGA > 300 m3 / m3 , API < 35/40 eq. VRO > 1.1%

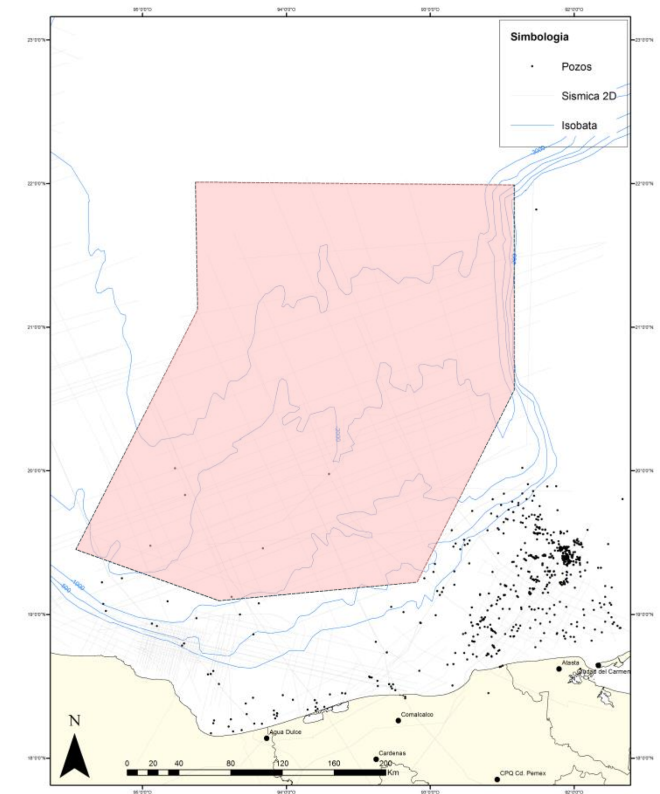
Notes

- Because low permeability of Cretaceous rocks, the migration velocity is slow.
- Migration system in Cenozoic rocks indicates that accumulation of extra light oil / condensate / gas is more favorable.



Petroleum Systems – Synchrony Diagram





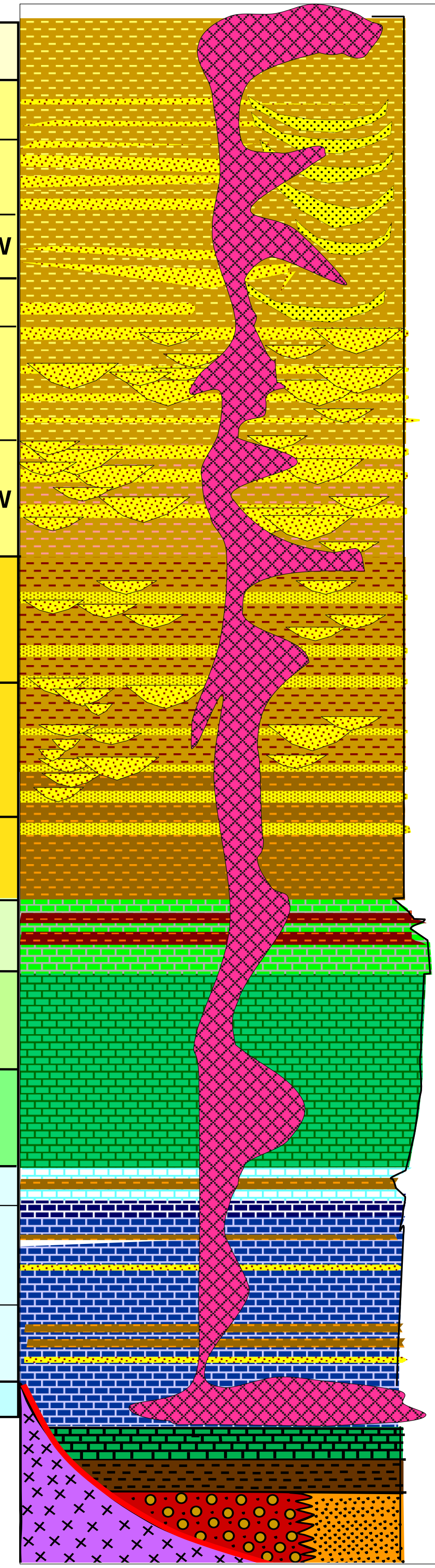
Regional Tectonics-geological events

a. Rifting period.
b. Evaporite deposition (Callovian).
c. Early salt domes
d. Passive margin.
e. Compressional tectonic Chiapanecan event and diapiric salt intrusion.
f. Development of salt canopies.
g. Diapiric salt closures, salt welds.

Plays Delimitation

Plays Delimitation

Period	Epoch / Stage	Identified plays	Play	Main Lithology and depositional features
	PLEISTOCENE			
NEOGENE	PLIOCENE (UPP, MID, LOW)	Low prospective potential play, some fields at southeast of the area, shared as a continuity of the shallow water zone	Established	Basin floor and slope turbiditic sandstones
NEOGENE	MIOCENE (UPP, MID, LOW)	Established play in Catemaco foldbelt, whith a high prospective potential in Mexican Ridges and in the Saline Basin	Established	Basin floor and slope turbiditic sandstones Submarine channel systems
PALEOGENE	OLIGOCENE	Low prospective potential play in Mexican Ridges and in the Saline Basin	Hypothetical	Turbiditic sandstones (submarine fans and channels
PALEOGENE	EOCENE	Moderate prospective potential play in Mexican Ridges and in the Saline Basin	Hypothetical	Basin floor and slope turbiditic sandstones Submarine channel systems
PALEOGENE	PALEOCENE	Regional seal rock for Cretaceous play		Basin floor shales
CRETACEOUS	UPPER, MIDDLE, LOWER	Established play producing mainly heavy oil in fields discovered in the adjacent shallow water Southeast Marine Basins. Prospective potencial related mainly to medium-heavy oil as an extension to deepwater	Established	Basinal fractured carbonates, calcareus brecchias derived from the slope
JURASSIC	UPPER: TITHONIAN, KIMMERIDGIAN, OXFORDIAN; MID: CALLOVIAN	Main source rocks of the area (Tithonian) Kimmeridgian and Oxfordian plays with producing fields in shallow water zones; prospectivity potential in deepwater	Hypothetical	Source rock – calcareous shales (Tithonian) Oolitic bank deposits Basinal and platform carbonates

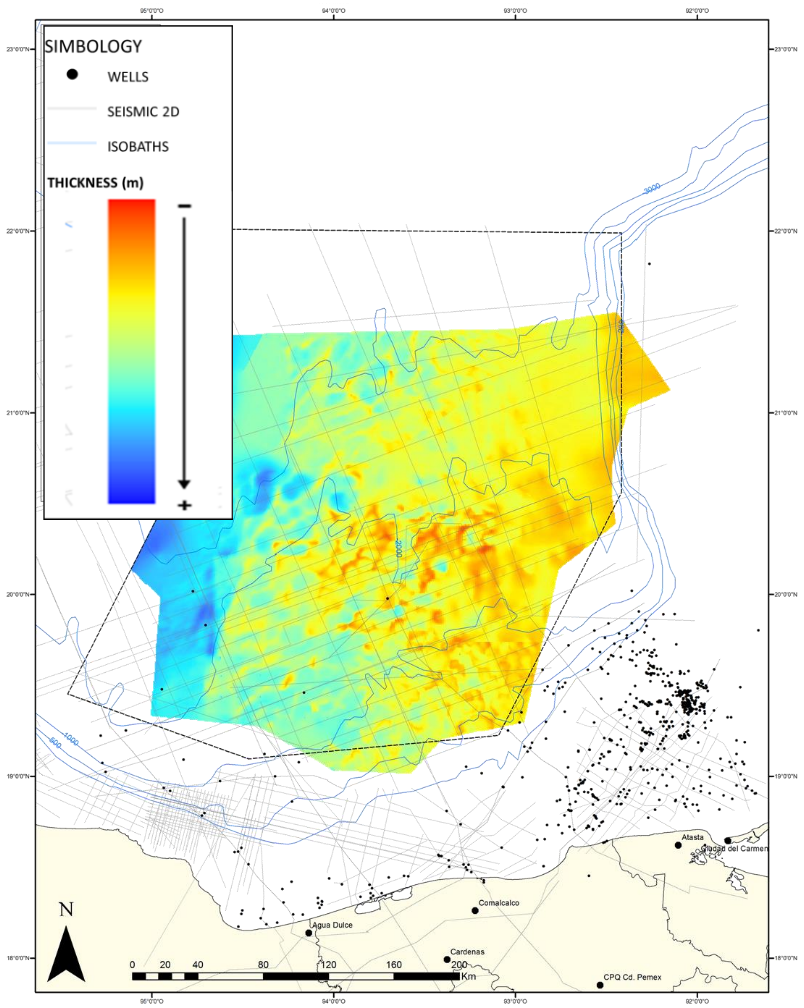


Established play — *Hypothetical play*

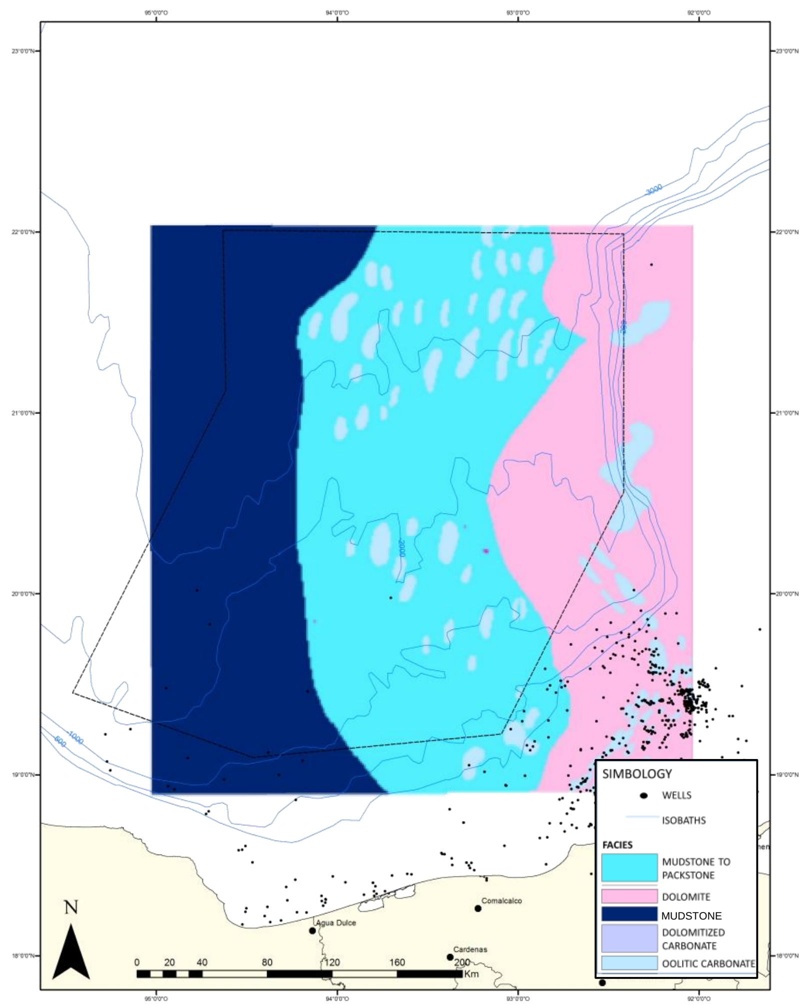
Plays Delimitation - Oxfordian y Kimmeridgian

Comisión Nacional de Hidrocarburos

Structural maps - Oxfordian



Facies maps - Kimmeridgian



Lower Oxfordian Play

Source Rock: Middle Oxfordian argillaceous limestones and calcareous shales.

Reservoir rock: Ramp carbonates and oolitic deposits.

Seal rock: Middle Oxfordian argillaceous limestones and calcareous shales.

Trap Type: Structural and combined. Salt tectonics and active diapirism activity is predominant in this area, most of the traps are associated to Callovian salt movements.

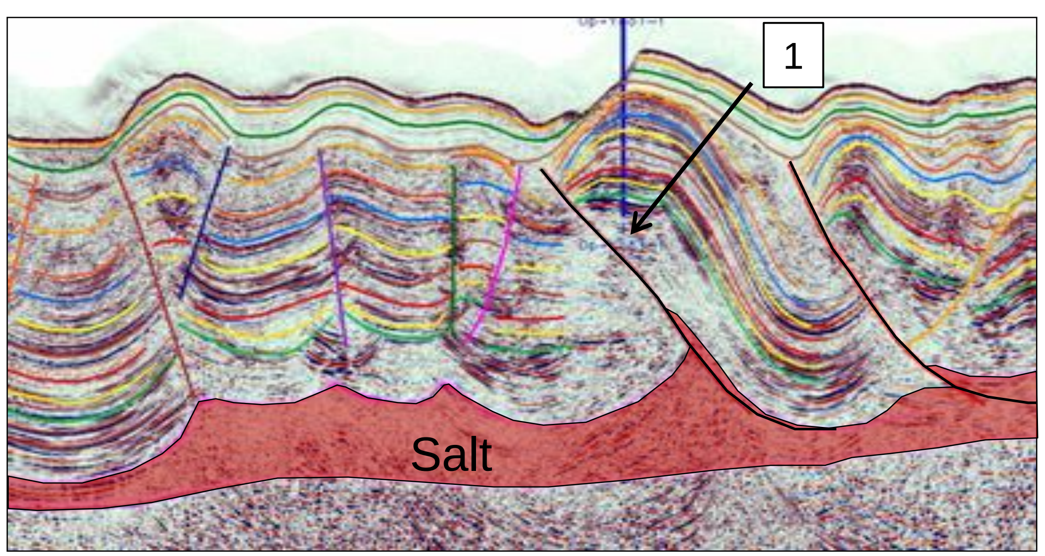
Examples include:

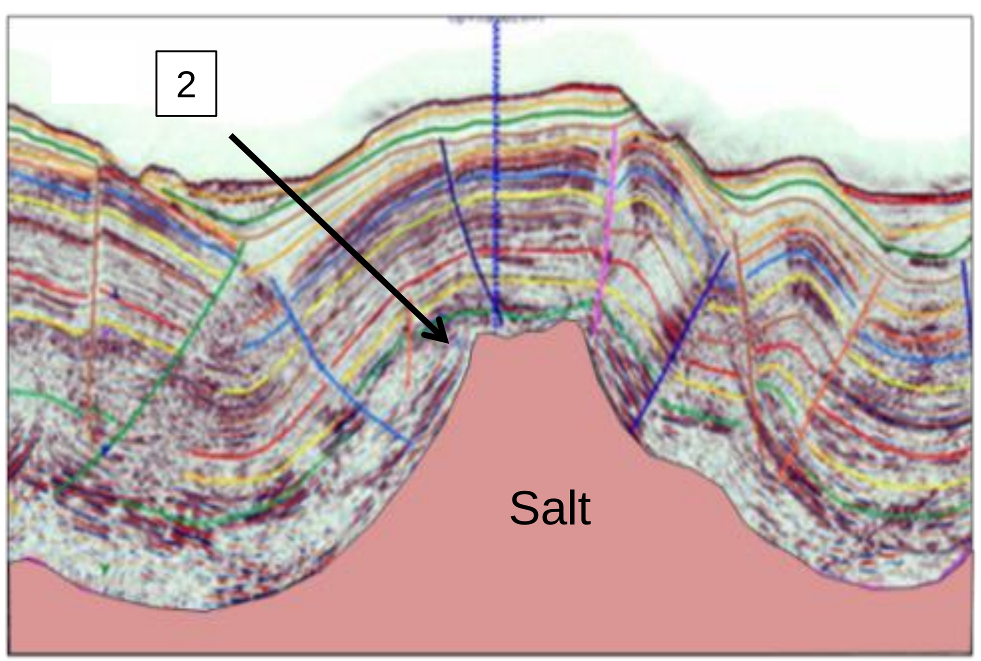
1) Salt cored anticlines and salt detachment folds related to salt tectonics activity.
2) Compressional anticline folds related to the compressional Cenozoic phase, with a detachment level in the Callovian salt deposits or within the Paleogene shales.

The API gravity is variable; higher values to the southwest, just under the mature Oxfordian levels (downward reverse migration). Burial and secondary cracking processes are an important additional factor for the hydrocarbon quality.

Due to depth variations, the secondary cracking processes could play an important role.

Migration efficiency is the highest, because the source rock is just under the reservoir rock (*per descensum* migration by underpressure).





Kimmeridgian Play

Source Rock: Tithonian argillaceous limestones and calcareous shales.
Reservoir Rock: Oolitic bank deposits and basinal and ramp carbonates.
Seal rock: Tithonian shales and shaly limestones.

Trap type: Structural and combined. Formation of these traps have been interpreted that occur at the same time as the Oxfordian trap formation.

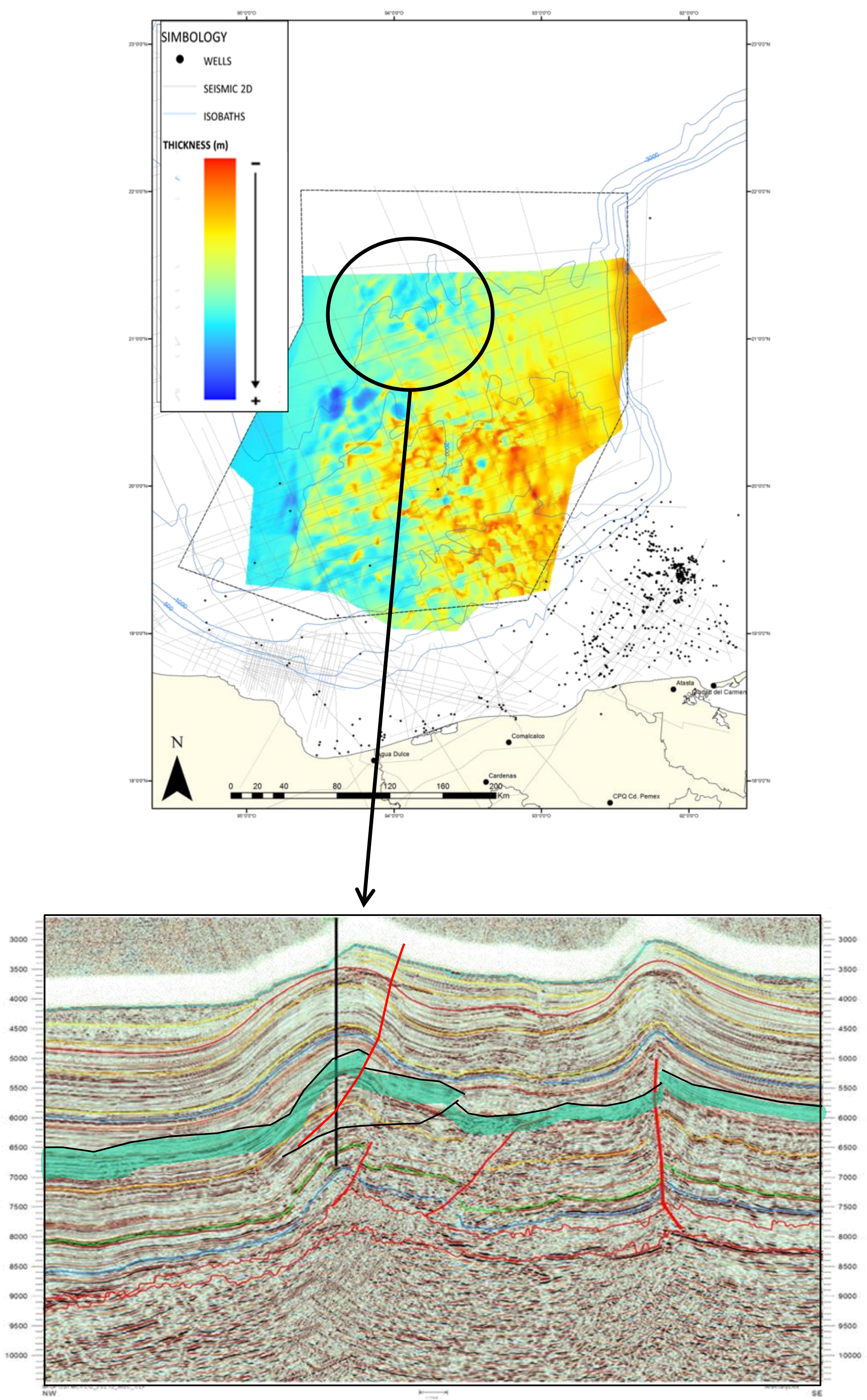
The API gravity is variable, with a similar tendency than the Oxfordian Play.

Due to depth variations, the secondary cracking processes could play an important role.

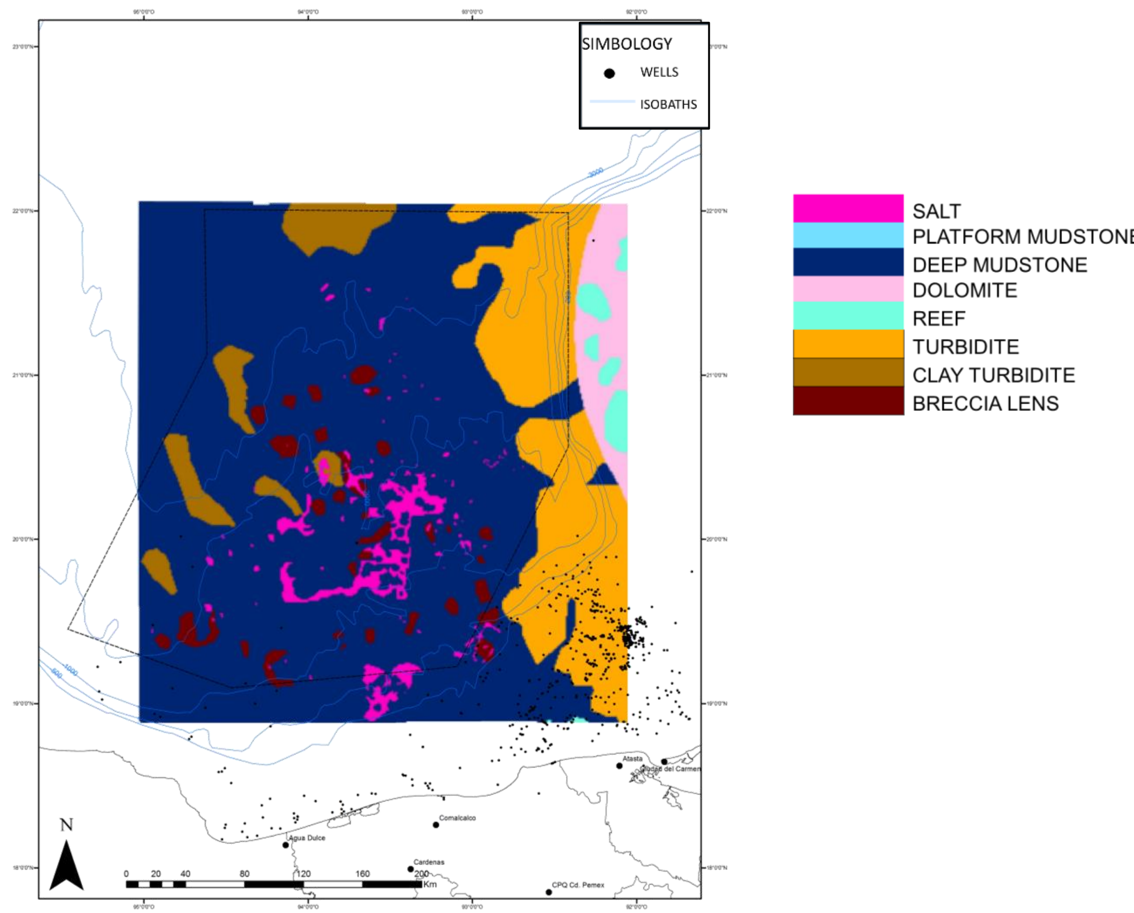
Structural component play an importan role in the trap definition. Migration processes were through faults and in a *per descensum* migration pattern (overpressure). Efficiency migration is better than Cretaceous, since the source and reservoir rocks are very close to each other.

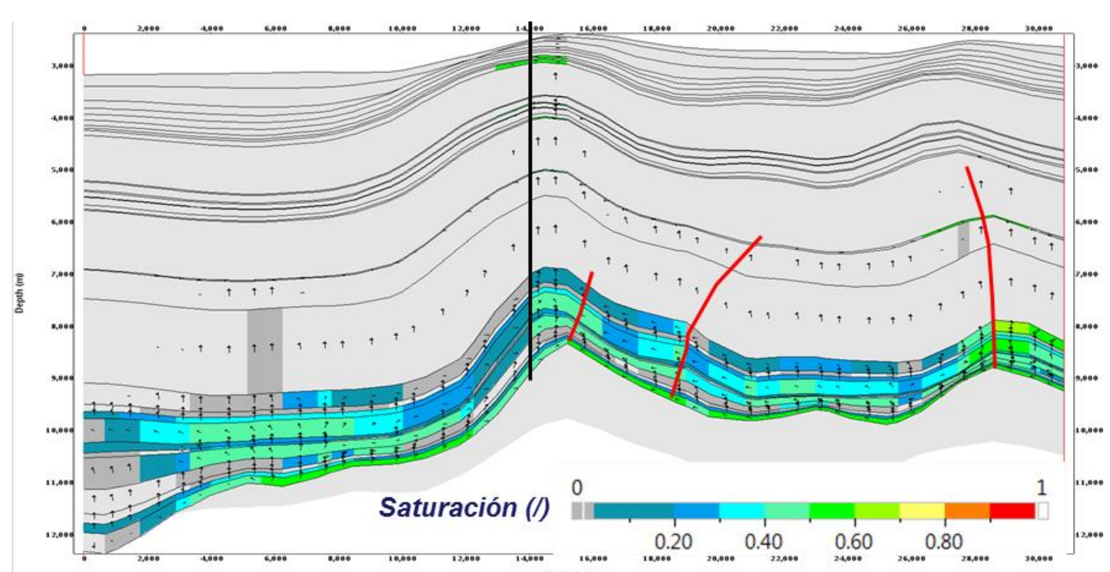
Plays Delimitation - Cretaceous

Structural Map- Top Cretaceous



Facies Map - Cretaceous





Cretaceous Play

Source Rock: Tithonian argillaceous limestones and calcareous shales.

Reservoir Rocks: Basinal fractured carbonates; locally calcareous debris flows and halokinetics breccia lenses could be found. There is evidence of the presence of calcareous breccias deposited at the toe of the slope in Eastern sectors.

Seal rock: Regional upper seal rock is composed by Paleocene shales.

Trap Type: Structural type is predominant over stratigraphic and combined. However, there is not an uniform trap type distribution, it depends on the local geological conditions (structural style, lithology).

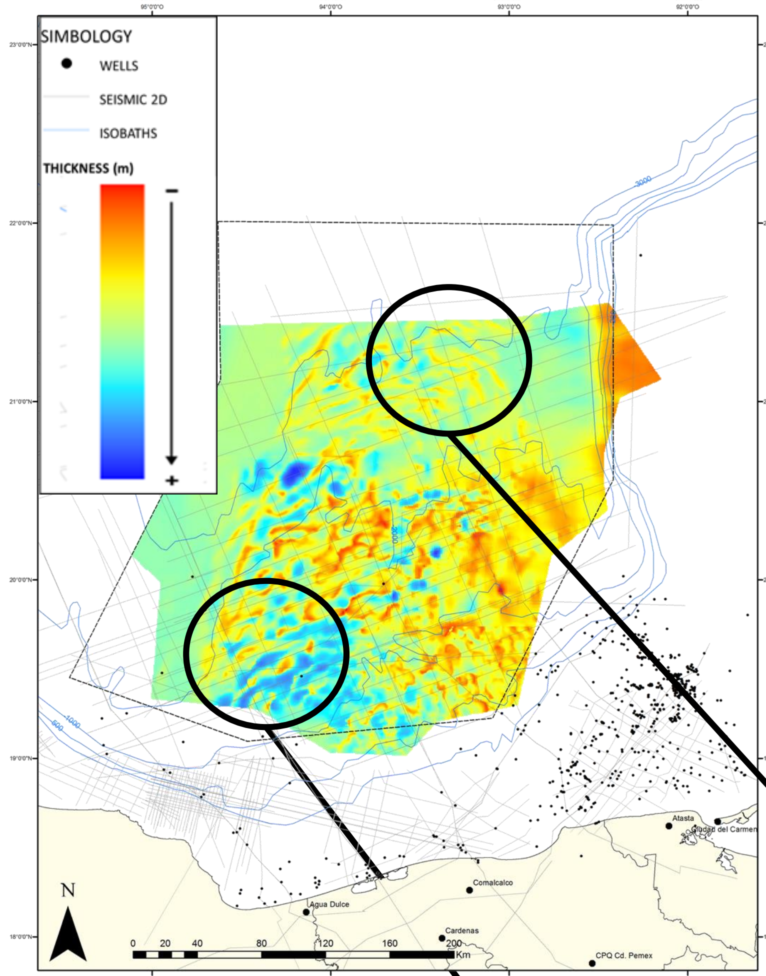
Structures were formed by Callovian salt movements. Examples of these structures are salt cored anticlines, affected by faulting related to the Cenozoic contractional processes, showing a detachment level in the Callovian salt deposits or within the Paleogene shales.

The expected oil API gravity in the area is variable, the expected tendency is to found heavy to light oil in a E-W direction.

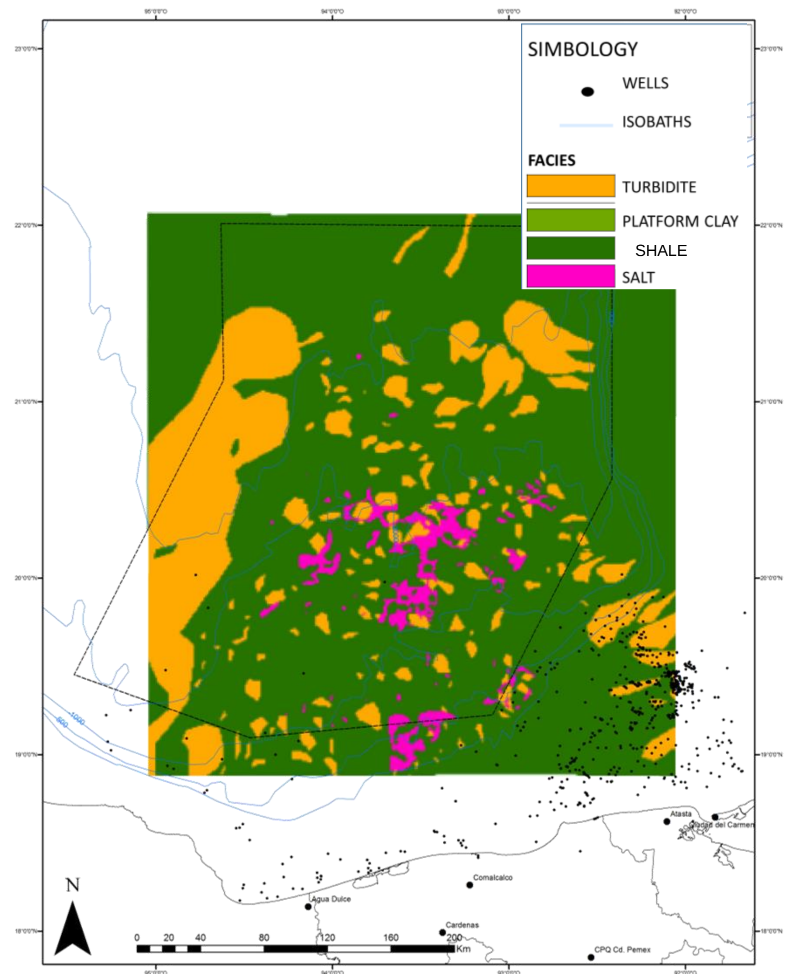
Migration processes occurs vertically through faults, and laterally through Cretaceous rocks. Hydrocarbons are accumulated in fold structures or in pinch out shaped drainage areas. Migration efficiency is generally better than in Cenozoic rocks.

Plays Delimitation - Eocene

Structural Map Eocene



Facies Map Eocene



Eocene Play

Source Rock: Tithonian argillaceous limestones and calcareous shales.

Reservoir Rock: Turbiditic sandstones and calcarenites possibly at the eastern part.

Seal rock: Eocene/Oligocene shales and in some cases by fault closures.

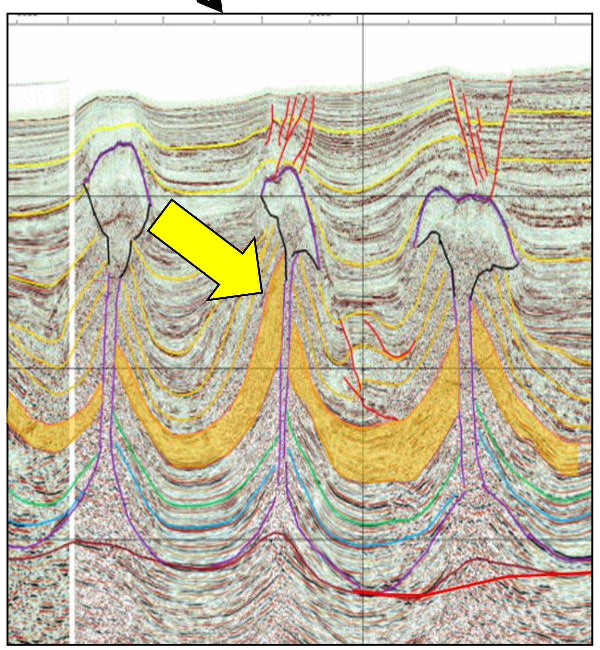
Trap Type: Structural and combined.

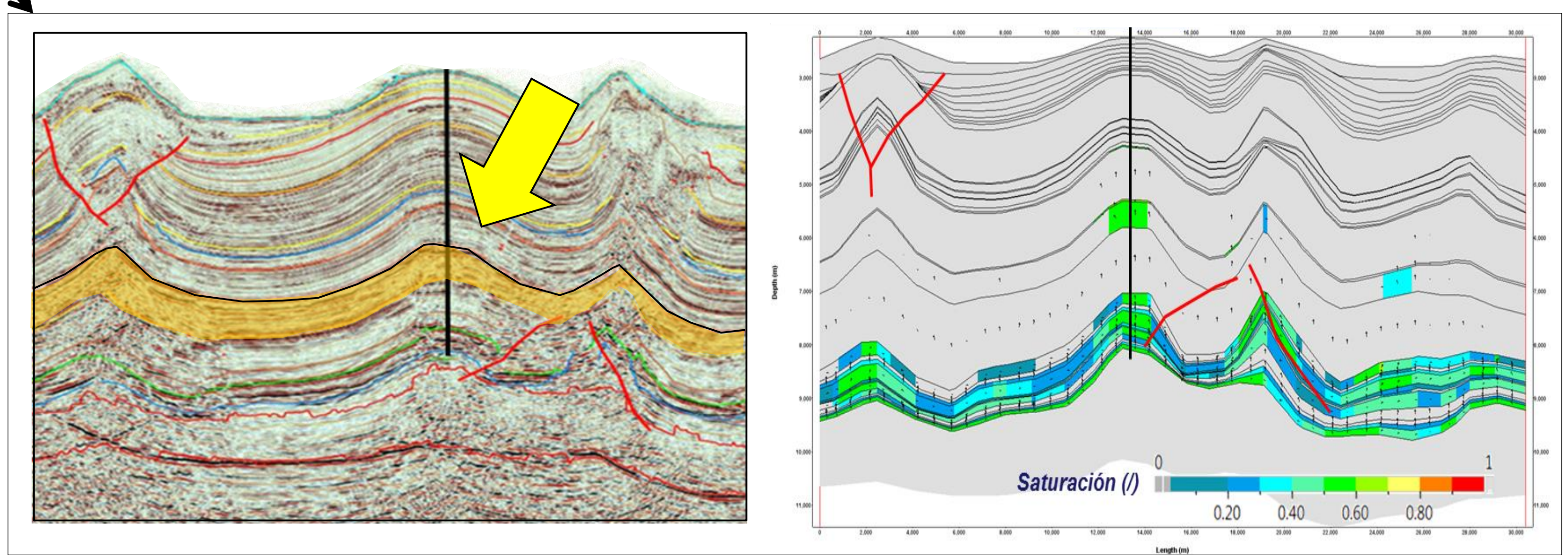
Structures:
Anticlines related to salt tectonics, with a salt detachment level.
Anticlines affected by faults related to the Cenozoic contractional processes, showing a detachment level in the Callovian salt deposits or within the Paleogene shales.

Structures are best preserved at northern area.

Combined:
Mostly related to diapiric flank structures, salt act as a lateral seal and developed during the active salt tectonic phase (deformation/hiatus/erosion of the salt dome and related syntectonic sedimentation, onlaps).

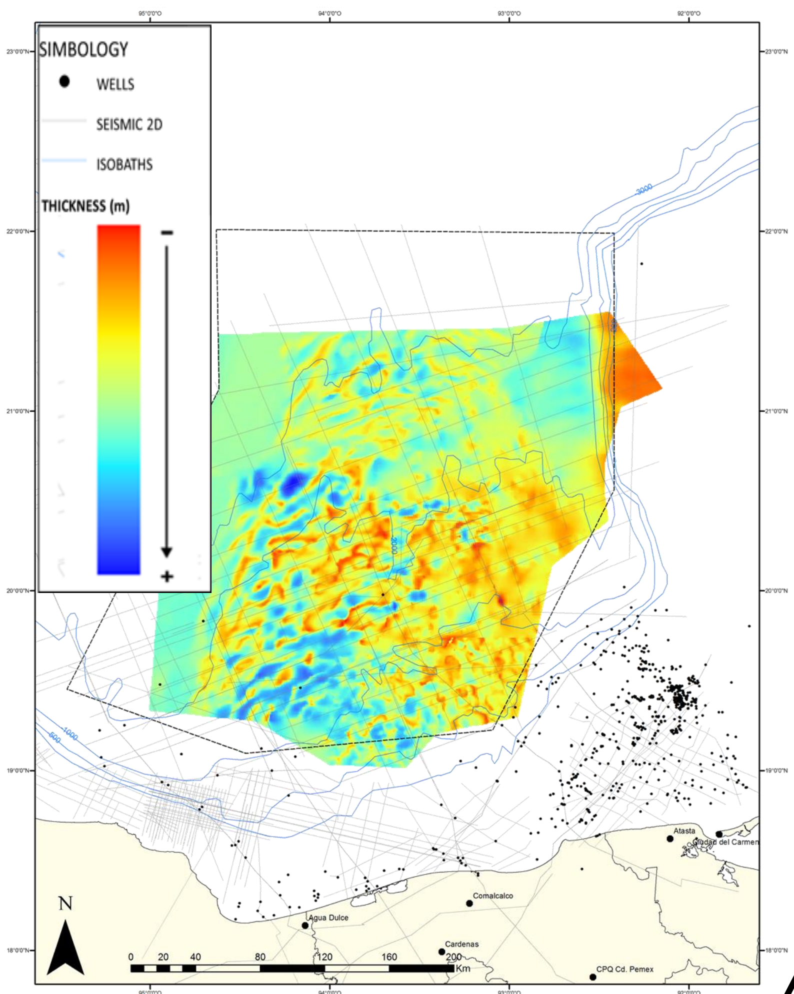
The expected oil API gravity in the area is variable, the expected tendency is to found heavy to light oil in a E-W direction.



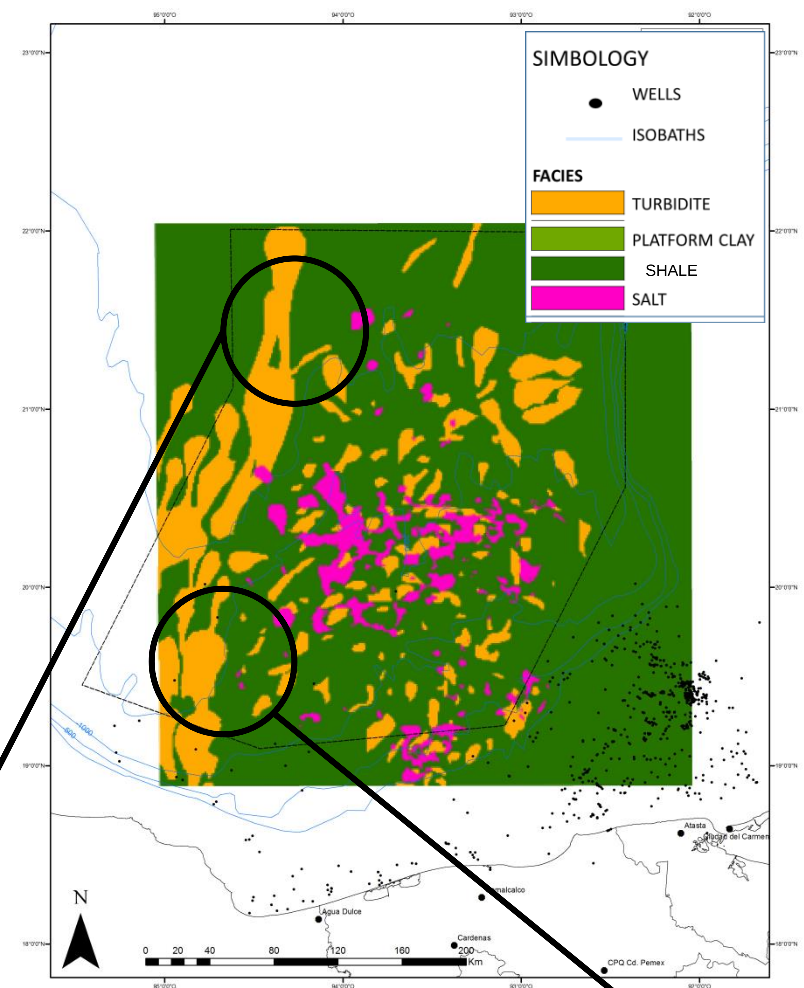


Plays Delimitation - Oligocene

Structural Map Oligocene



Facies Map Oligocene



Oligocene Play

Source Rock: Tithonian argillaceous limestones and calcareous shales.
Reservoir rock: Sandstones.

Seal rock: Local interbedded Oligocene shales, and occasionally by fault closures.

Trap Type: Structural and combined.

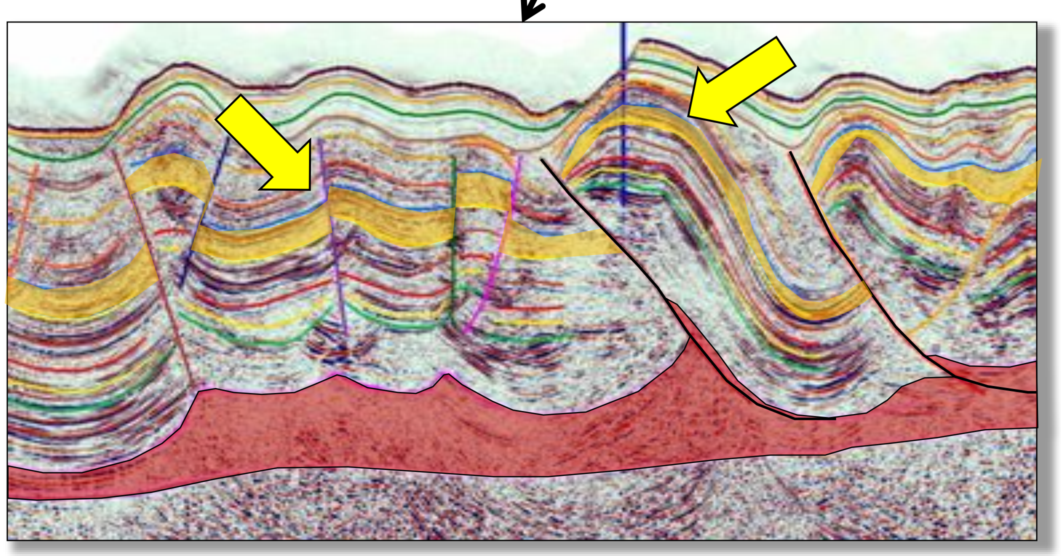
The structural component is important in the trap definition (including faults). For example:

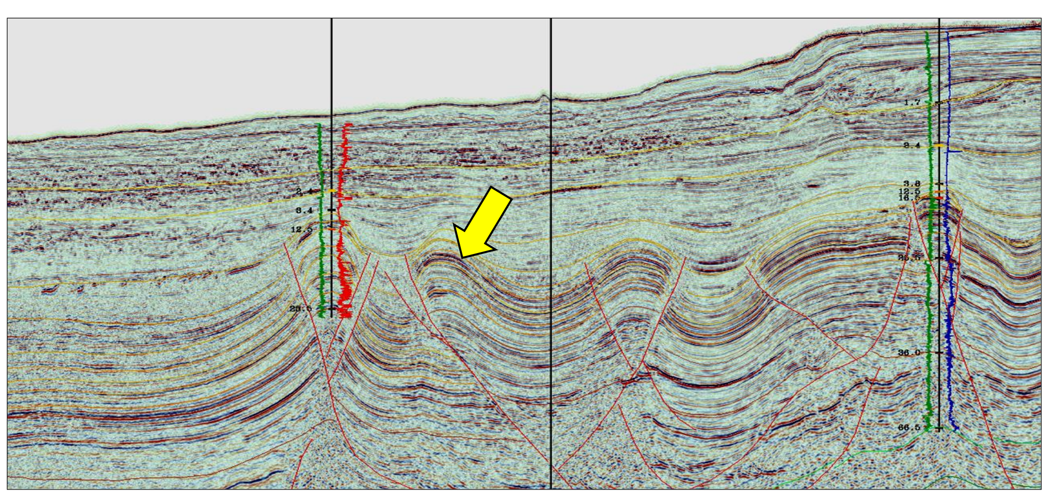
Anticlines affected by faults related to the Cenozoic contractional processes, showing a detachment level in the Callovian salt deposits or within the Paleogene shales.

Anticlinal folds formed during the Miocene compressional phase with Paleogene detachment level, without influence of salt tectonics.

Combined:
Mostly related to diapiric flank structures, salt act as a lateral seal and developed during the active salt tectonic phase (deformation/hiatus/erosion of the salt dome and related syntectonic sedimentation, onlaps).

The expected oil API gravity in the area is variable, the expected tendency is to found heavy to light oil in a E-W direction.

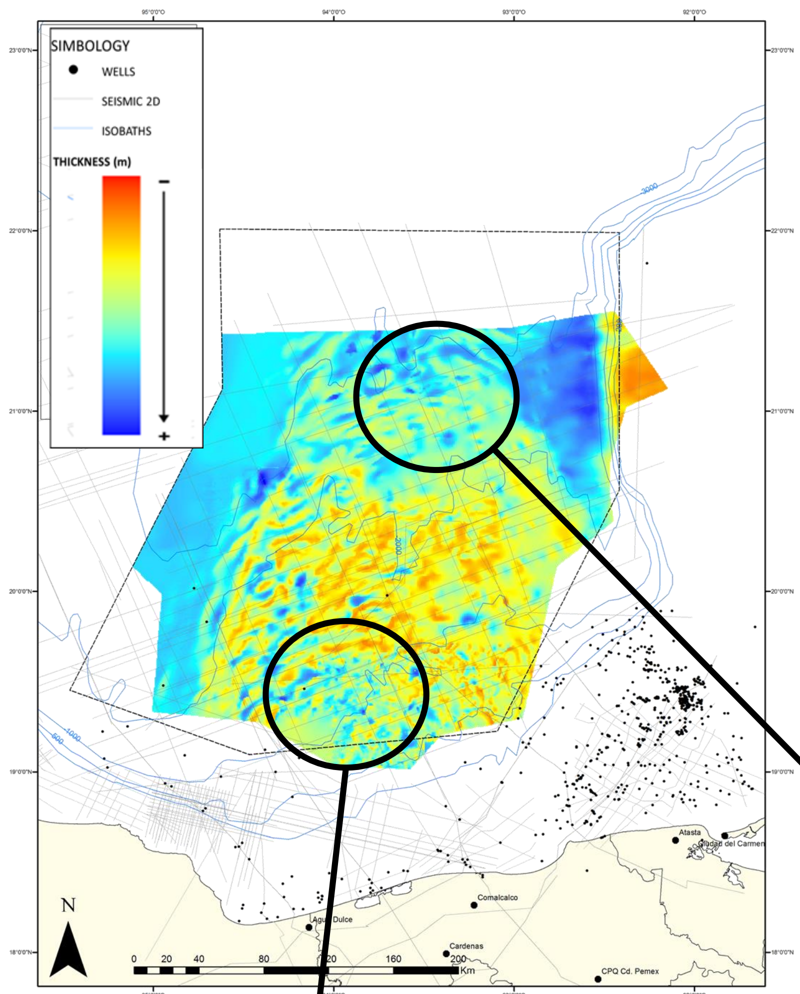




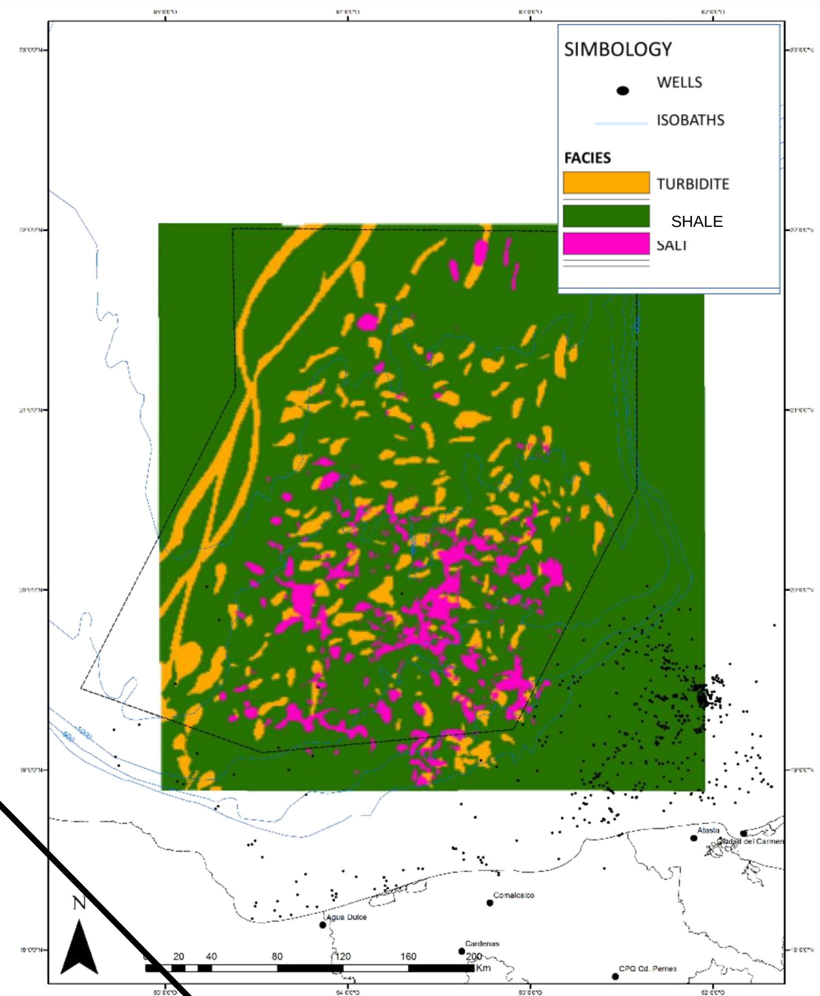
Miocene compressive structure with a Paleocene detachment level, without influence of salt tectonics.

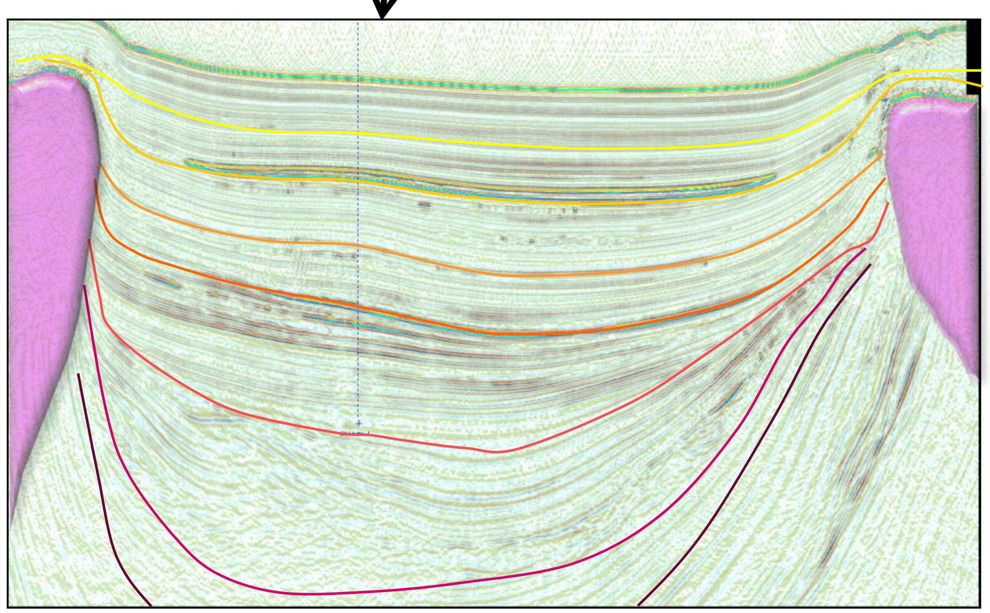
Plays Delimitation - Miocene

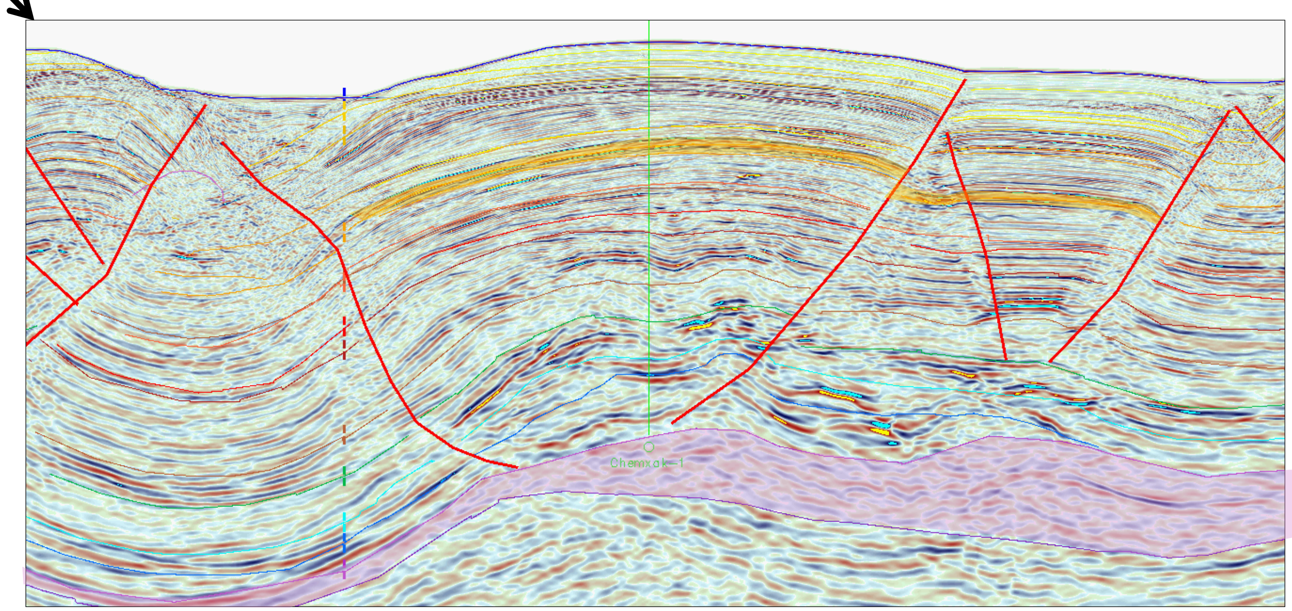
Structural Map Miocene



Facies Map Miocene







Miocene Play

Source Rock: Tithonian argillaceous limestones and calcareous shales.

Reservoir rock: Sandstones.

Seal rock: Upper seal: Local interbedded Miocene shales, lateral facies changes, seal against salt bodies and occasionally by fault closures.

Trap Type: Structural and combined.

The structural component is important in the trap definition, however there are traps with a strong stratigraphic component. For example:

Anticlines affected by faults related to the Cenozoic contractional processes, showing a detachment level in the Callovian salt deposits or within the Paleogene shales.

Anticlinal folds formed during the Miocene compressional phase with Paleogene detachment level, without influence of salt tectonics.

Combined:
In the minibasin structures related to diapiric flank structures, salt act as a lateral seal and developed during the active salt tectonic phase (deformation/hiatus/erosion of the salt dome and related syntectonic sedimentation, onlaps).

The expected oil API gravity in the area is variable, the expected tendency is to found heavy to light oil in a E-W direction. At the SW sector, the expected hydrocarbon is mainly gas, as the recent discoveries done in this play.

Bibliography

I. Análisis de sistemas sedimentarios, sistemas petroleros, plays y prospectos, Área Temoa y Holok - 2009 - PEMEX E&P / Activo Regional Exploración RMSO - Ciudad del Carmen (A)

II. Modelo de sistemas petroleros pseudo 3D y riesgo exploratorio, zonas Han y Temoa Norte - 2010 - PEMEX E&P E&P / Activo Regional Exploración RMSO - Ciudad del Carmen (B)

III. Modelado Sistemas Petroleros y Análisis de Plays, Aguas Profundas Golfo de México, Bloques Han-Sur y Yoka-Ixic - 2012 – PEMEX E&P / Activo Regional Exploración RMSO - Ciudad del Carmen (C)

IV. Modelado Sistemas Petroleros, Análisis de Plays y localizaciones en áreas de Aguas Profundas Golfo de México, Bloque Sayab-Sur - 2013 - PEMEX E&P / Activo Regional Exploración RMSO - Ciudad del Carmen (D)

V. Atlas, evaluación regional, Cuencas del sureste del Golfo de México - Felipe Ortuño. Documento CNH – 2014 (Área regional)