

PS The Delineation of Pre-Salt License Blocks in the Deep Offshore Campeche-Yucatan Basin*

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Abstract

The emergence of pre-salt exploration in the past 30 years has resulted in a significant addition to world oil reserves since the first pre-salt discovery offshore Angola in 1983. Among the most successful deep water pre-salt exploration plays is the Campos Basin offshore Brazil, where a milestone achievement of 800,000 bpd production level was achieved just 8 years after the first pre-salt well was drilled in 2006. The Yucatan Basin offshore Mexico represents one of the last significant pre-salt exploration provinces yet to see any significant exploration activity. In this paper we illustrate evidence of an extensive pre-salt layer using newly acquired long-offset 2D seismic data. We distinguish between sub-salt and pre-salt prospects in the Yucatan Basin by illustrating images of pre-salt horst and graben rift structures and pre- and syn-rift deposits, which have been proven as potential source and reservoir rocks elsewhere. Sub-salt plays are also in evidence in the northeastern Campeche Basin, and are well documented in the northern Gulf of Mexico as an exploration analog. The success of pre-stack depth migration for the purpose of improving sub- and pre-salt imaging has been well documented, and the prolific discoveries offshore the US Gulf of Mexico, Brazil and Angola speak to the importance of this imaging tool. However a more fundamental tool necessary for improved imaging is and has always been fold of coverage. The pre-salt section in the Yucatan Basin is in water depths exceeding 3,500 m with a thick sedimentary section; consequently, a 15-second record length is necessary to image the sediments and structures beneath the salt. Normally this would require low fold acquisition geometry to accommodate the extra time between shots, which we resolve using continuous recording acquisition technology and source de-blending to achieve a high fold geometry with a record length sufficient to image the deep pre-salt section. Foremost among the requirements for successful pre-salt exploration is an accurate delineation of block definitions prior to a commercial license round. We demonstrate that clear images of the pre-salt section can be obtained using a high-fold, long record length acquisition geometry with detailed pre-stack depth migration. A dense grid of properly imaged 2D seismic is shown to be necessary and sufficient to provide a basis for block definition and bid round evaluation in the early stages of pre-salt exploration in the Yucatan Basin.

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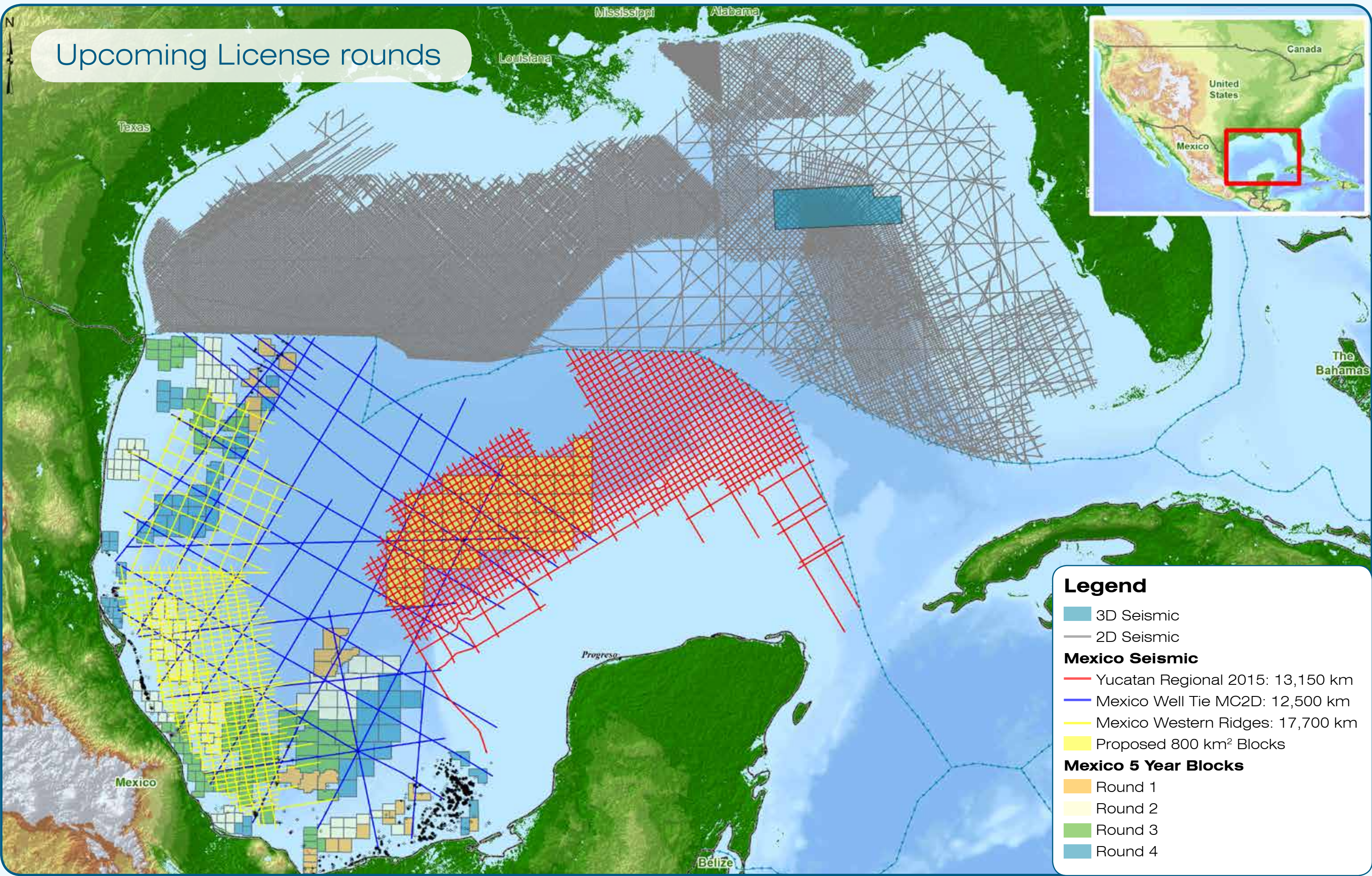
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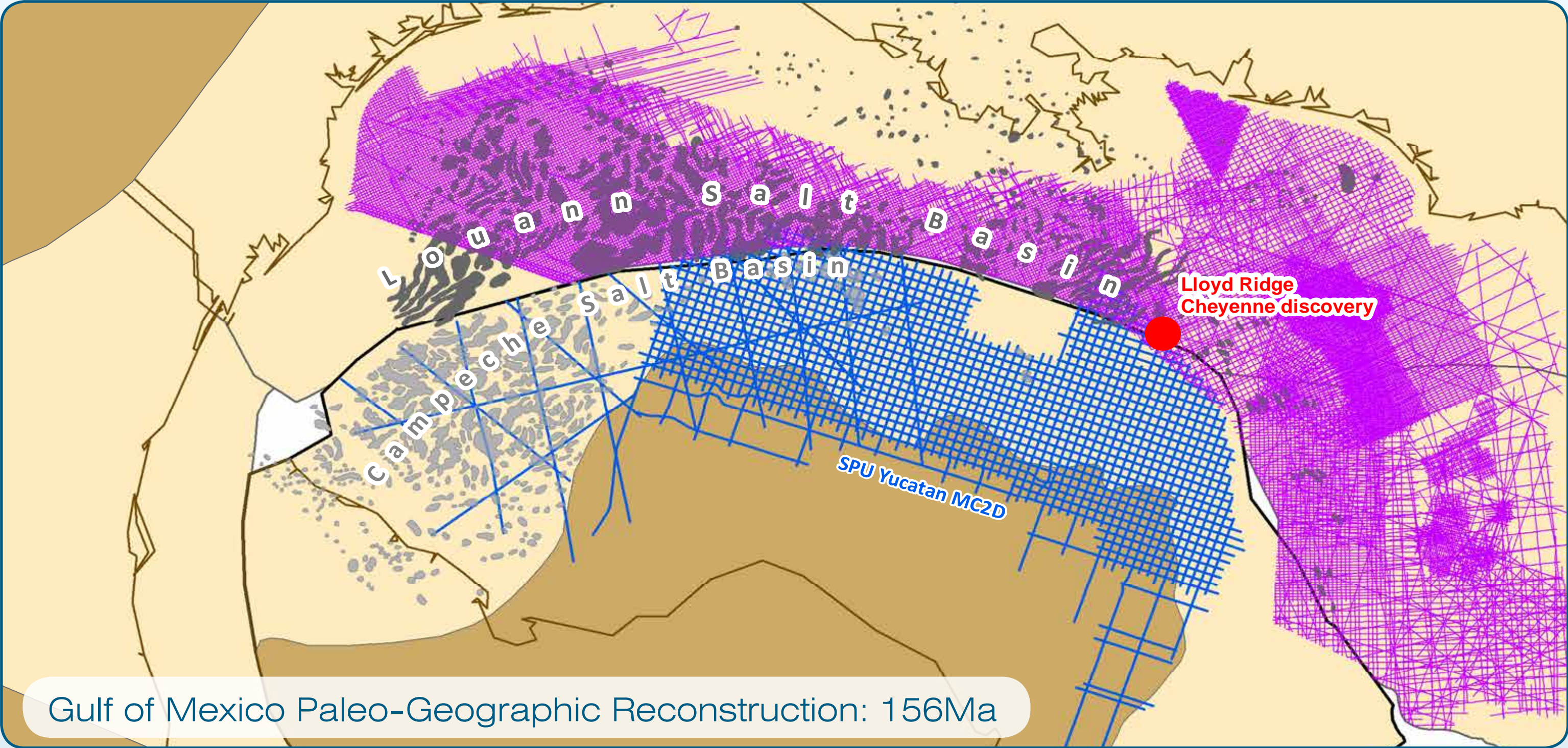
The Delineation of Pre-Salt License Blocks in the Deep Offshore Campeche-Yucatan Basin - Mike Saunders, Laurie Geiger, Karyna Rodriguez, Phil Hargreaves - Spectrum Geo



Database

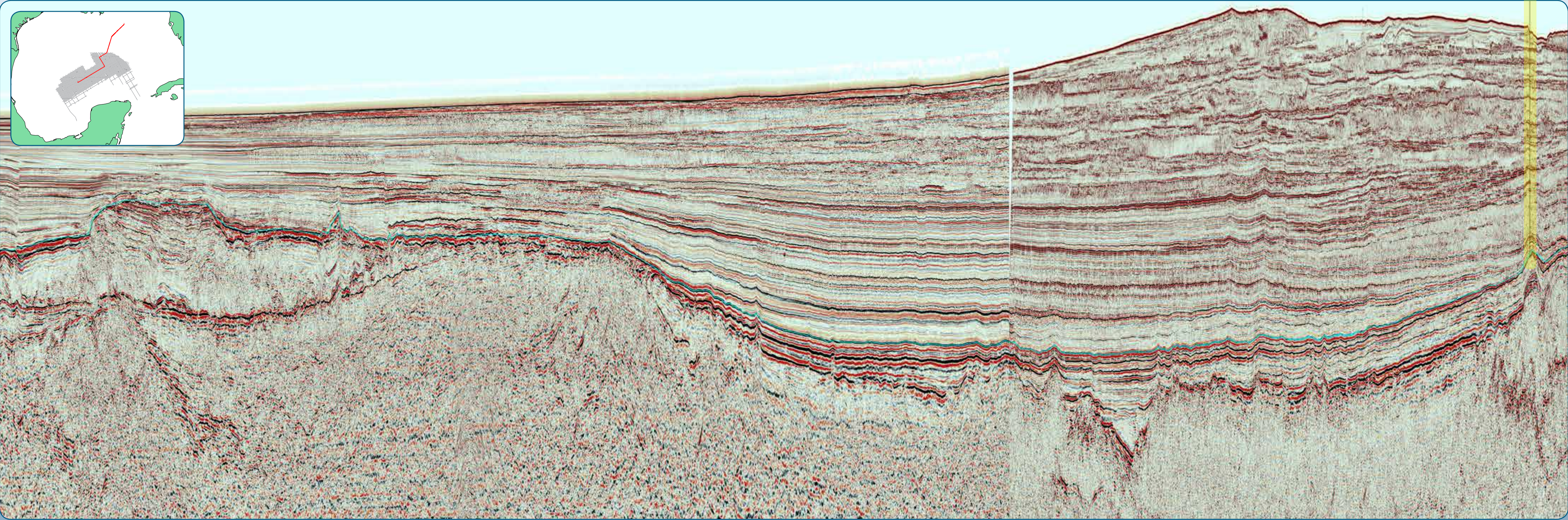
The modern long-offset 2D seismic data used in this study encompasses all the major hydrocarbon provinces offshore Mexico, including areas on offer for Mexico's upcoming licensing rounds. The 2015 acquisition and ongoing broadband seismic data processing are part of a cooperative agreement among Spectrum, PGS and Schlumberger. Some of the latest data examples are shown here, and the final products for the entire project are expected by Q1 2017. Shown on the map are the Western Ridges survey comprising 17,700 km (yellow), the Well Tie survey comprising 12,500 km (blue) and the Yucatan survey comprising 31,150 km in a 10 km x 10 km grid (red). A sea surface slicks study was performed over the Campeche Basin and outboard of the Campeche Escarpment. This survey ties to the Eastern US Gulf of Mexico Deep Focus and Big Wave seismic programs.

The yellow blocks located on the western half of the Yucatan survey will be proposed for licensing as this area has many interesting plays and prospects, including a gravity slump in the central part of the survey. Additionally, there is potential for traps around the numerous salt diapirs in the deepwater where the Sigsbee salt has migrated into the shallow section.



Reconstruction

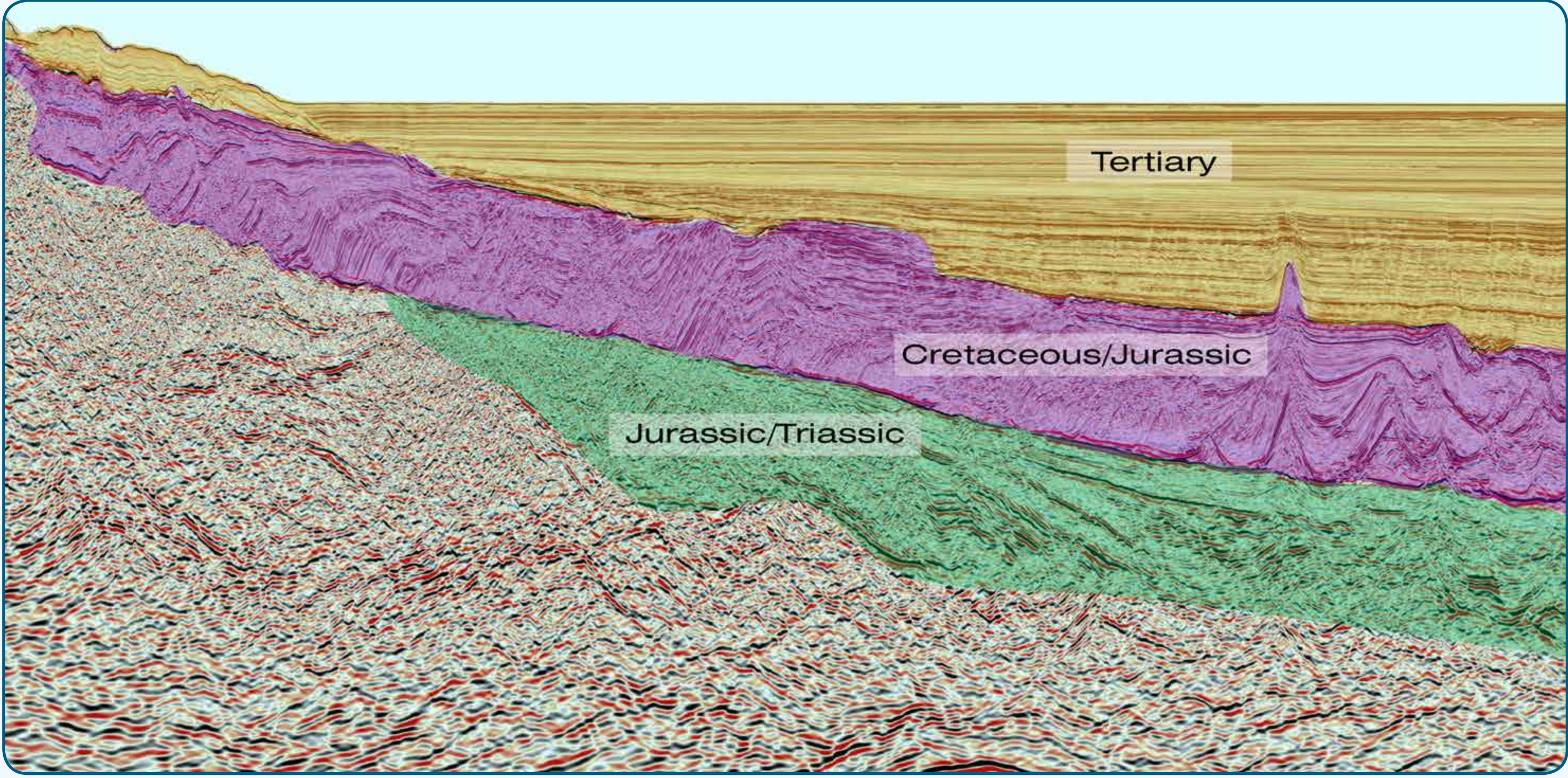
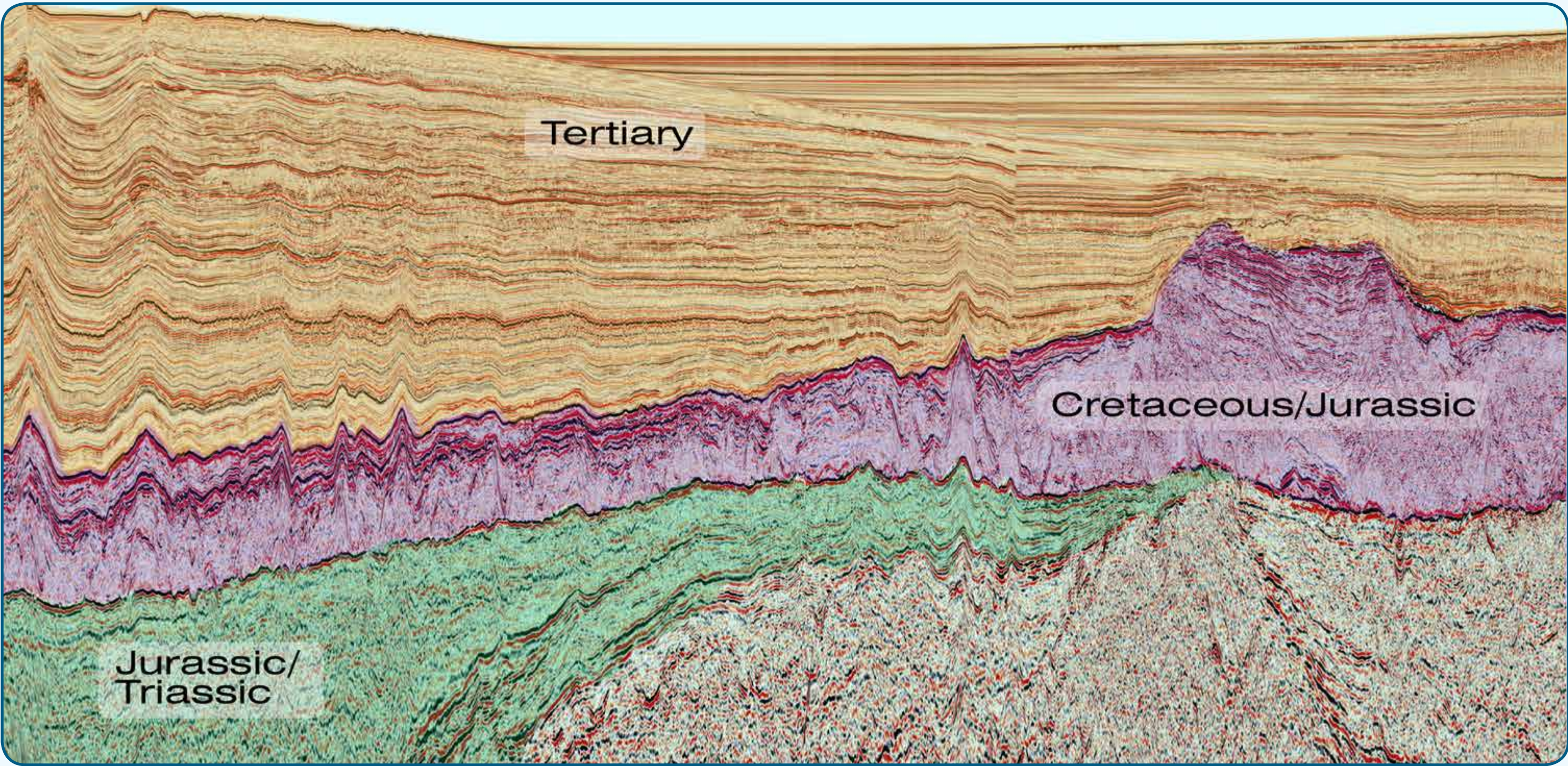
Various tectonic models have been proposed for the Gulf of Mexico (GoM), however their accuracy has been limited by the lack of magnetic spreading anomalies and unevenly distributed geophysical data. This has resulted in uncertainties in opening kinematics and maps of the COB. However, gravity and magnetic constraints provided by recent data have offered support for a plate reconstruction model published by Luan C. Nguyen at the University of Houston. This study aimed to determine and examine the COB of the entire GOM using recent potential field and all available seismic and well data. Another main objective was to reconstruct the Yucatan block to its pre-drift position. By applying different filters to the residual gravity anomaly map, distinct patterns of ridge transform segments were identified, revealing an extinct spreading ridge. The pole of rotation on the western side of Cuba, derived from the geometry of the ridge transform segments, together with using the edge of the Campeche salt basin as the COB, have been employed to determine the COB of the northern GOM. This model has been used in G-Plates to obtain the plate reconstruction model at the time of deposition of the Loann salt and Campeche salt basins, 152 to 156 MA.



Well Calibration

Available well top data from the Lloyd Ridge -1 well has been tied into 2D seismic data available on the eastern GOM. Using the reconstruction at 156 MA, a candidate conjugate seismic line has been identified on the Campeche dataset. Key well tops, including the Top of the Wilcox and Hayn formations, have been correlated from the eastern GOM into the Campeche basin and have been used to constrain the ages on the main seismic sequences. The Campeche data has been divided into three main seismic sequences of Jurassic/Triassic, Cretaceous/Jurassic and Tertiary ages.

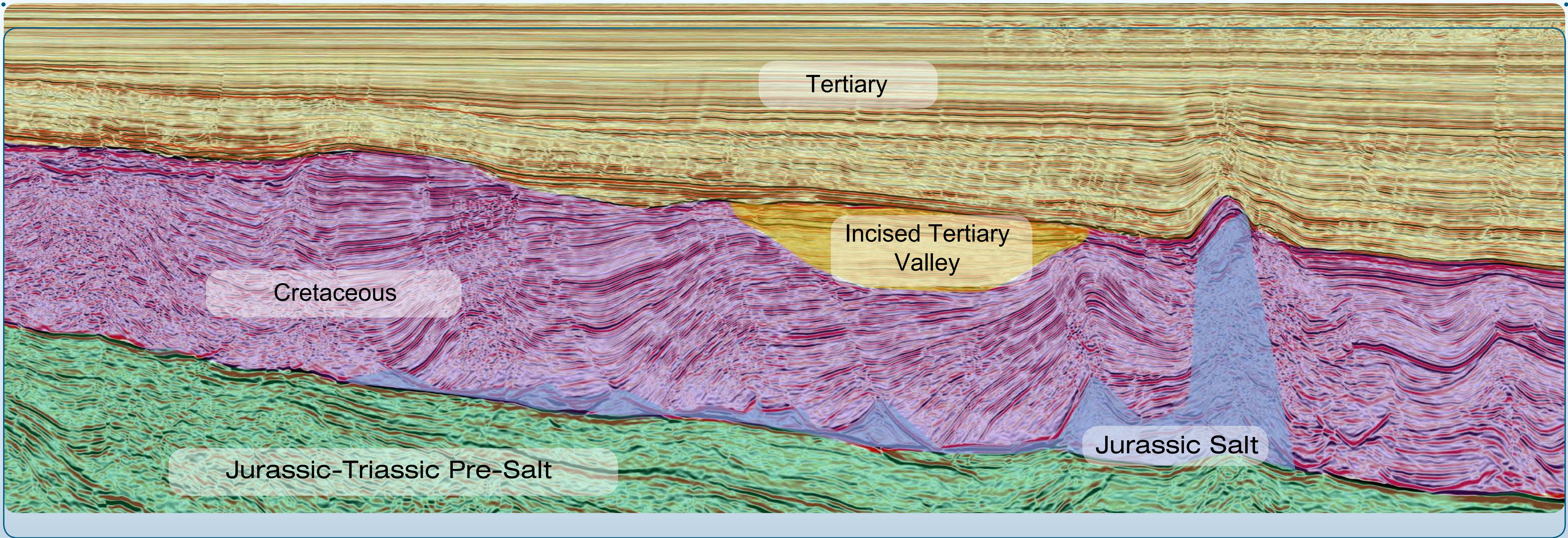
Post-salt Norphlet Interpretation



Mapped sequences

Three main seismic sequences have been identified based on the seismic character revealed by the PSTM 2D seismic data. The base of the Jurassic/Triassic sequence is not always a sharp seismic boundary but can be identified by more chaotic reflectivity below and a series of parallel reflectors and tilted fault blocks above. The base of the Cretaceous/Jurassic sequence is a very abrupt, sharp and clear boundary. It is characterized by a high amplitude reflector probably resulting from the acoustic impedance contrast between the salt and the clastic sequences below. This sharp boundary also acts as a detachment surface for a series of gravity slides revealed in the Cretaceous/Jurassic sequence.

In previous seismic datasets this sequence appeared to be predominantly made up of salt. Downdip of the gravity slump on the western side of the Campeche basin, laterally equivalent large salt diapirs, known as the Sigsbee knolls, are located towards the edge of the basin. The base of the Tertiary marks the top of this gravity slump sequence, and is characterized by another sharp, high amplitude reflector present throughout the dataset.

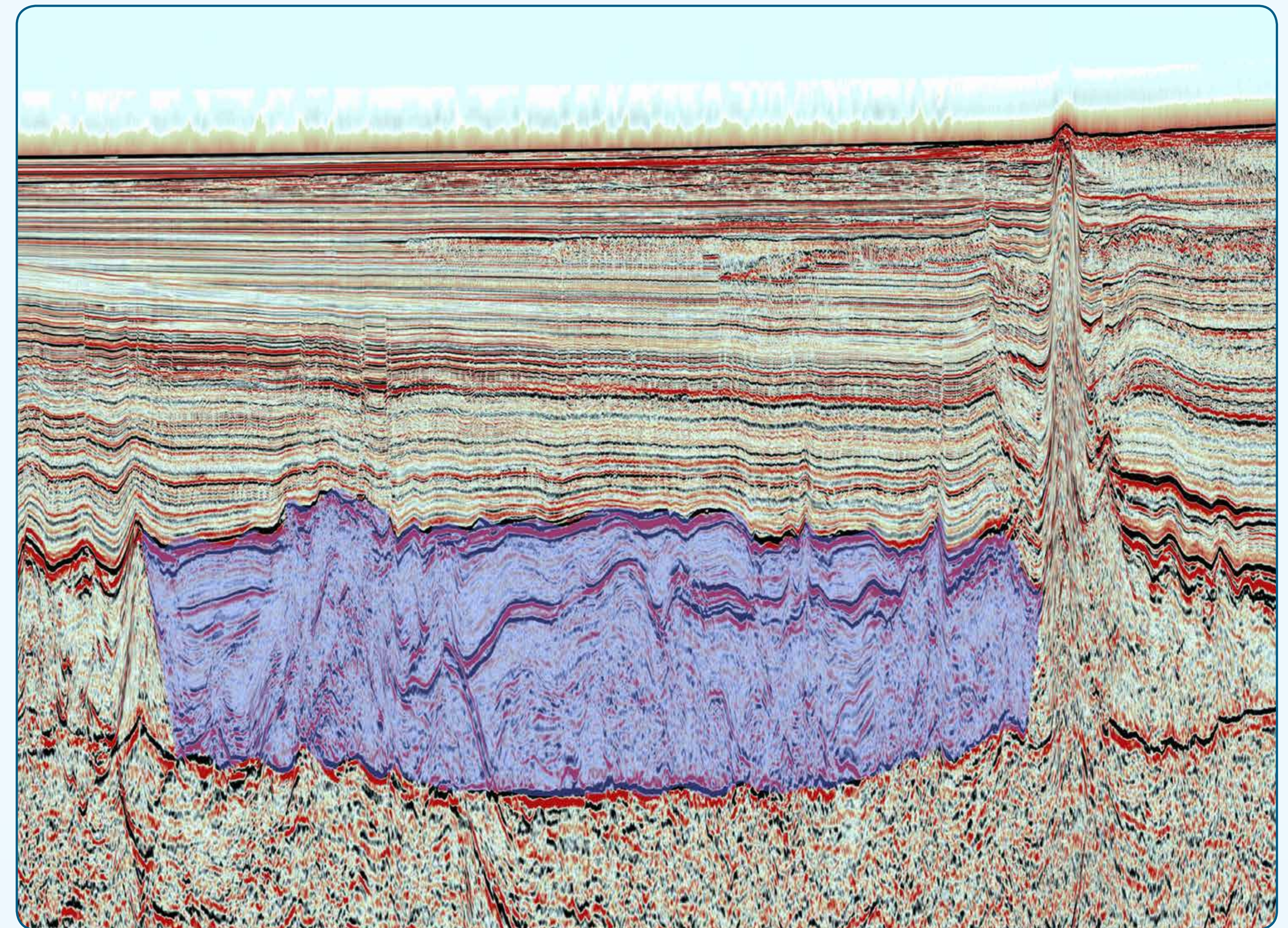
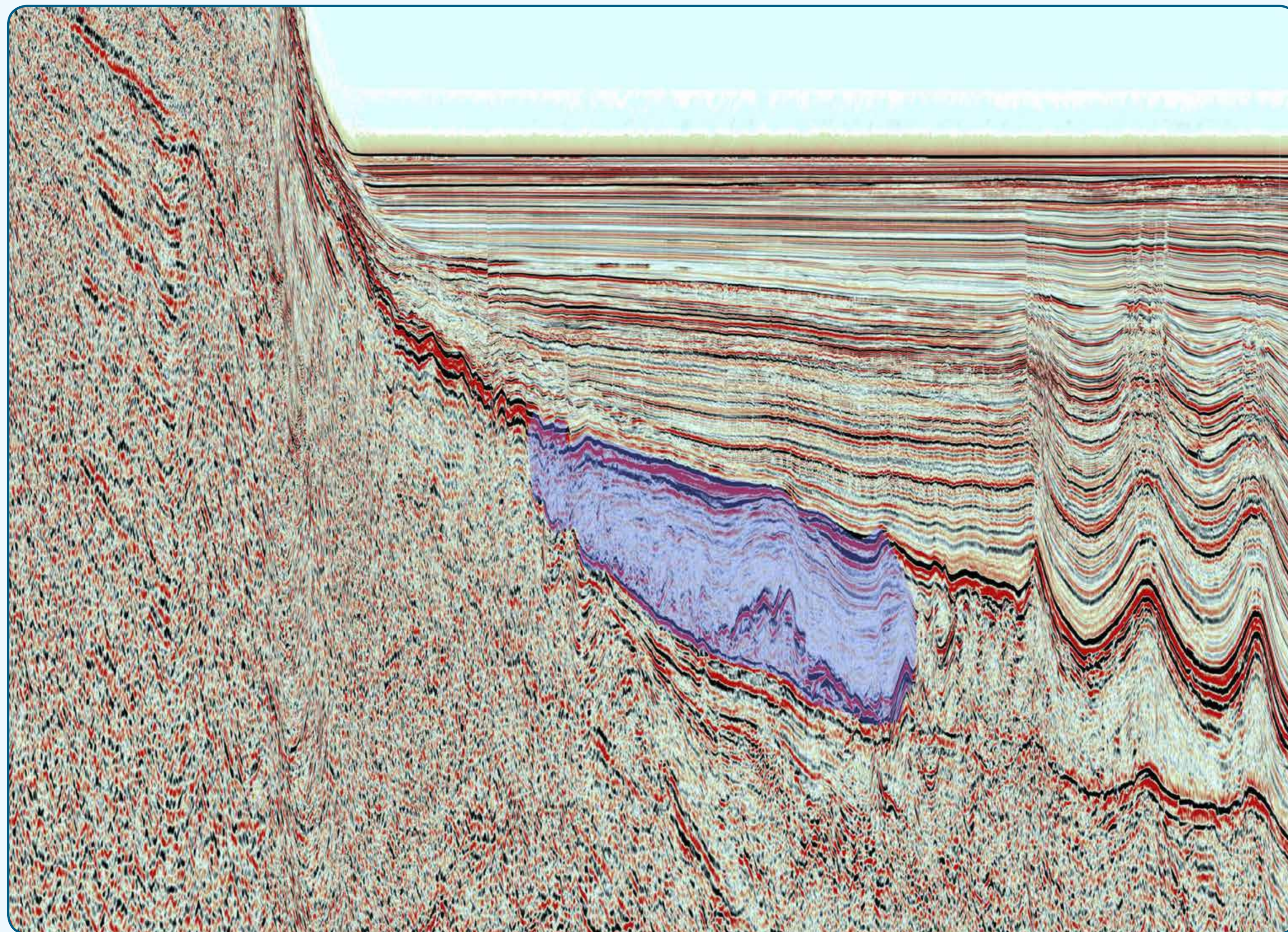


Post Salt Norphlet interpretation

The Jurassic Norphlet Formation is a widespread aeolian sandstone with an aerial extent of several hundred thousand square km, stretching across Louisiana, Mississippi, Alabama and into the deepwater Gulf of Mexico. The first well targeting the deepwater Norphlet play was drilled in 2003 in the De Soto Canyon protraction, which encountered approximately 30 m of oil column within the aeolian sand. The Norphlet section is typically overlain by the Smackover Formation, which acts as both the seal and hydrocarbon source for Norphlet reservoirs.

The interpretation of a raft or gravity slump feature outboard of the Campeche Escarpment is analogous to the northeastern Gulf of Mexico, where the traditional gravity-driven system predicts a downdip contraction where the salt pinches out or inflates by salt drainage. The Upper Jurassic source rock and the aeolian sandstone reservoir of the Norphlet Formation are broken up and compartmentalized, forming structures that could be prospective. It is anticipated that the Norphlet aged rocks would be fluvial and aeolian to the southeast, in the basin outboard of the Campeche Escarpment.

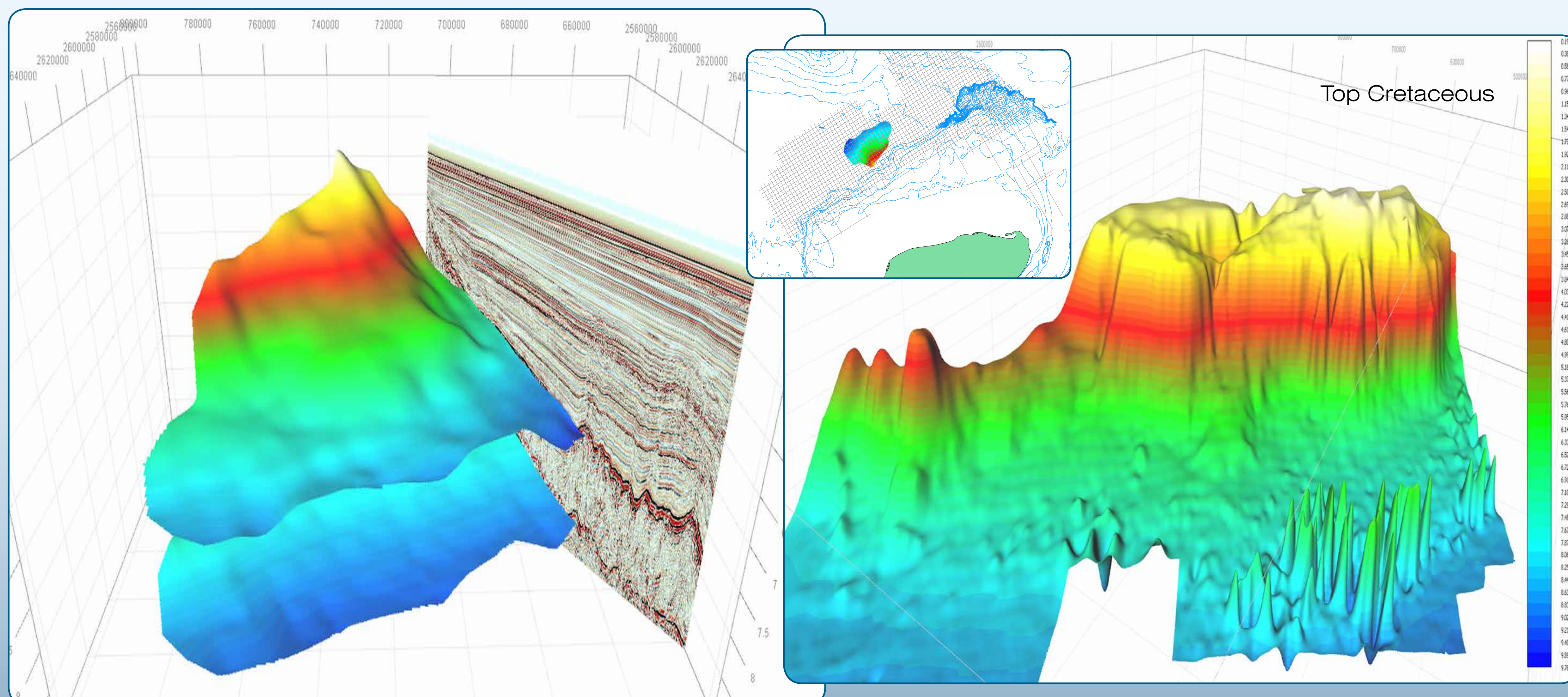
Gravity Slump



Gravity Slumps Seismic Examples

The internal character of the Cretaceous/Jurassic sequence revealed by the latest PSTM data unveiled a series of gravity slides detaching along what has been interpreted as the base of a mostly evacuated salt, with only scattered remnants of salt left throughout the gravity slump. The lateral extent of the gravity slump was identified in both the strike and dip directions and was mapped throughout the entire dataset.

In the strike direction the gravity slump decreases in lateral extent and depth going from the basin towards the shelf. The interpretation of the top and base of the gravity slump feature resembles the shape of a submarine fan when it is displayed in 3 dimensions.

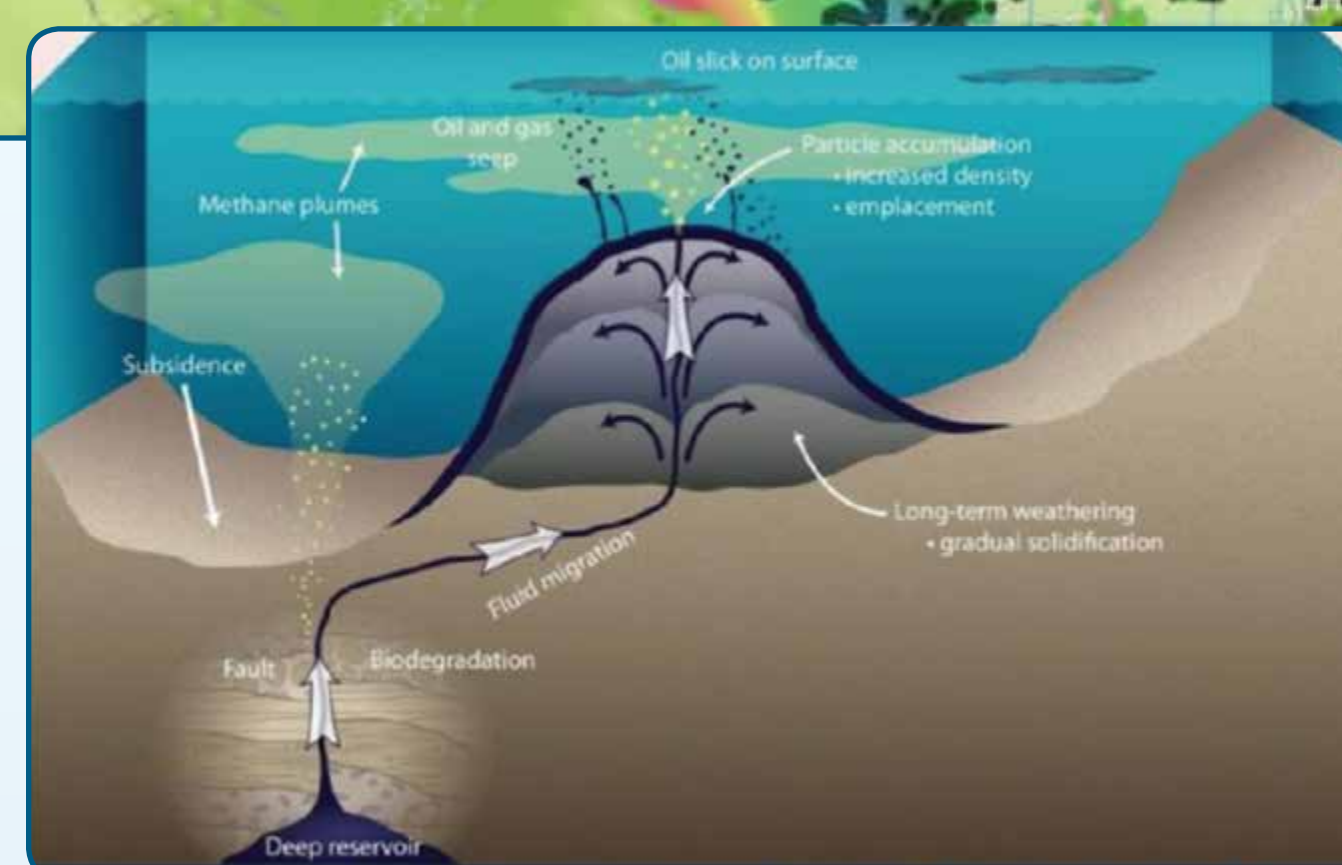
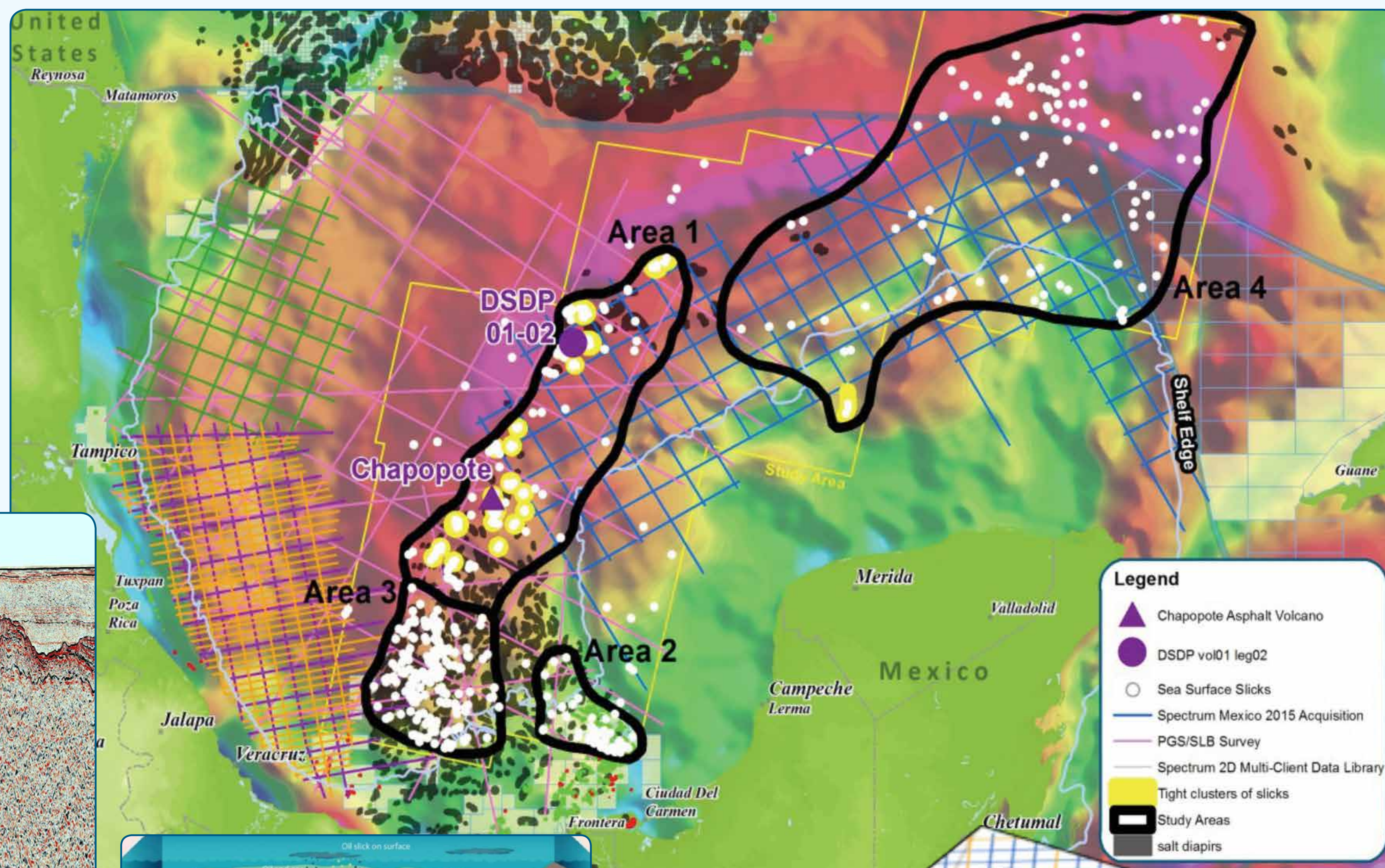
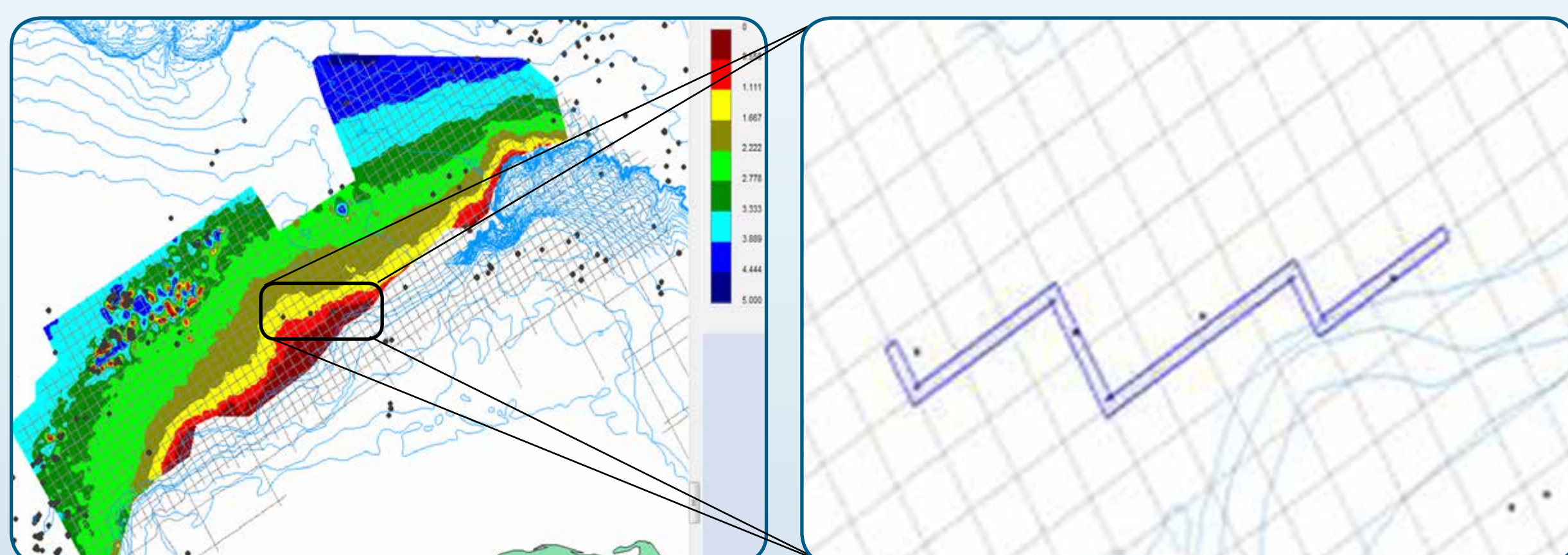
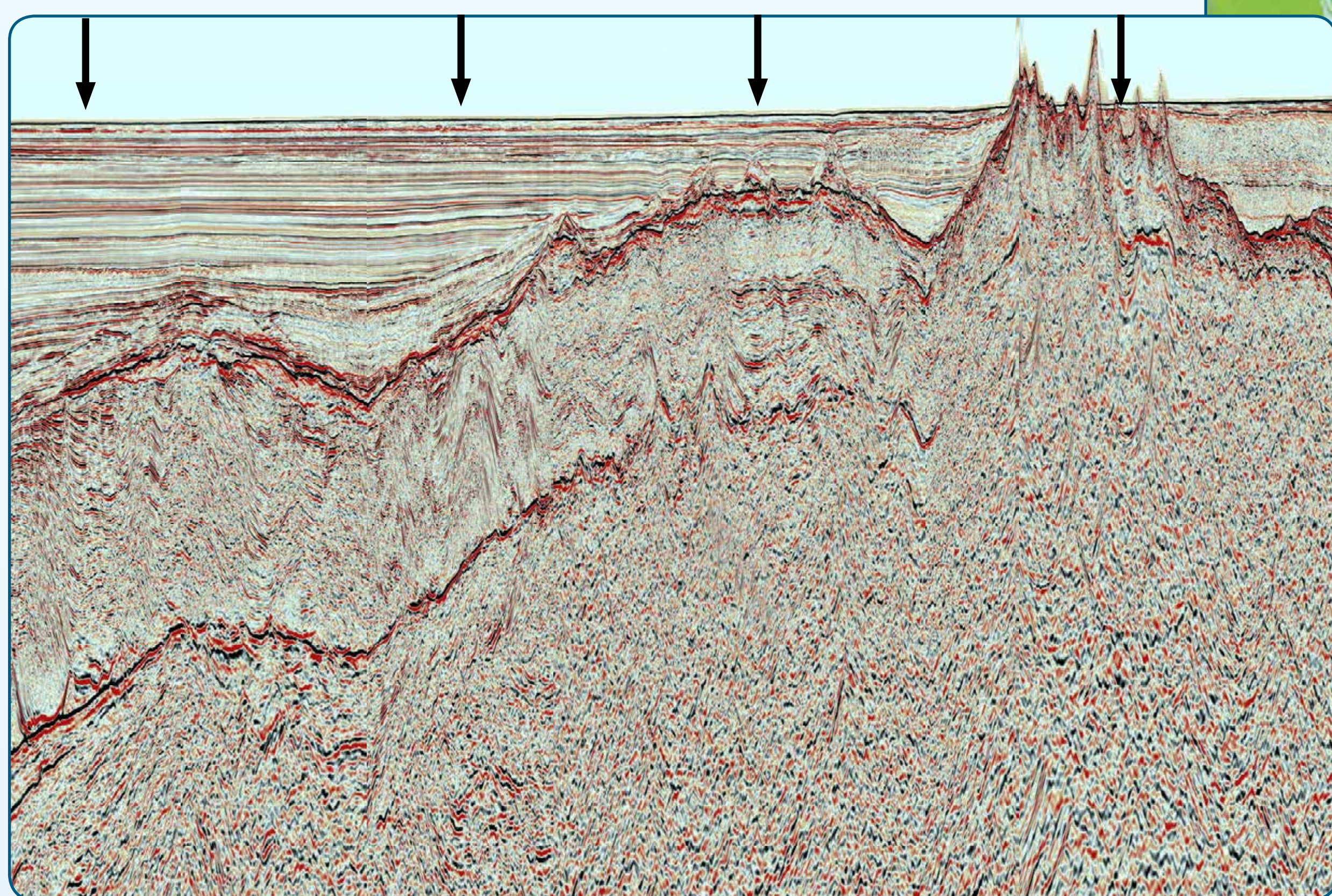


Gravity Slump Distribution

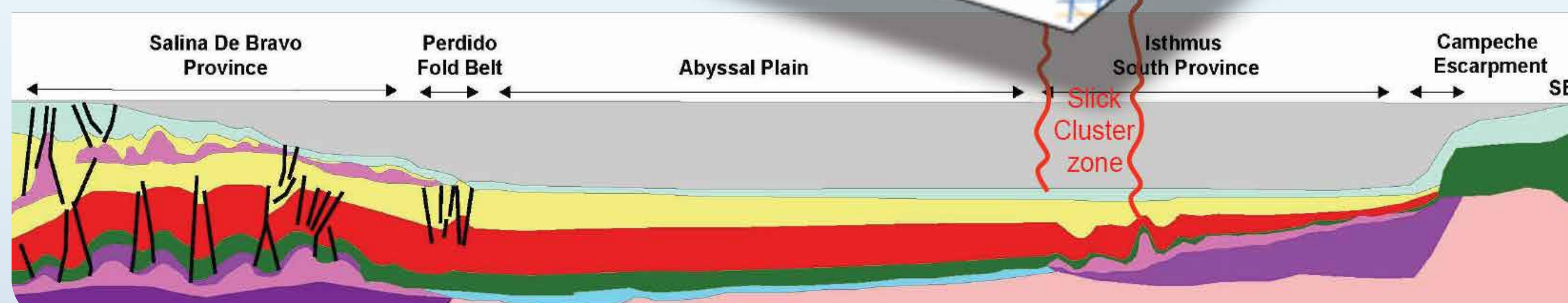
The apex of the submarine fan-like shape of the gravity slump seems to be pointing towards the Chicxulub meteor impact site. This requires further investigation as it may indicate a possible reservoir similar in origin to the prolific Cantarell field. The three dimensional display of the Top Cretaceous relief, at the top of the gravity slump, shows the transition from shelf to basin and the location of the Sigsbee diapires to the northwest of the Campeche Escarpment.

Slicks Study

Manifestations of natural oil seepage in the Cantarell field area



Left: Example based on the Santa Barbara Basin Asphalt Volcanoes after Jack Cook, Woods Hole Oceanographic Institute



Slick Study

Mexico's Cantarell Complex, the world's 10th largest oil field, was discovered after geological investigation of reports from fishermen of oil floating on the sea surface. Today sea surface slicks can be charted over large areas from observations from satellite imagery.

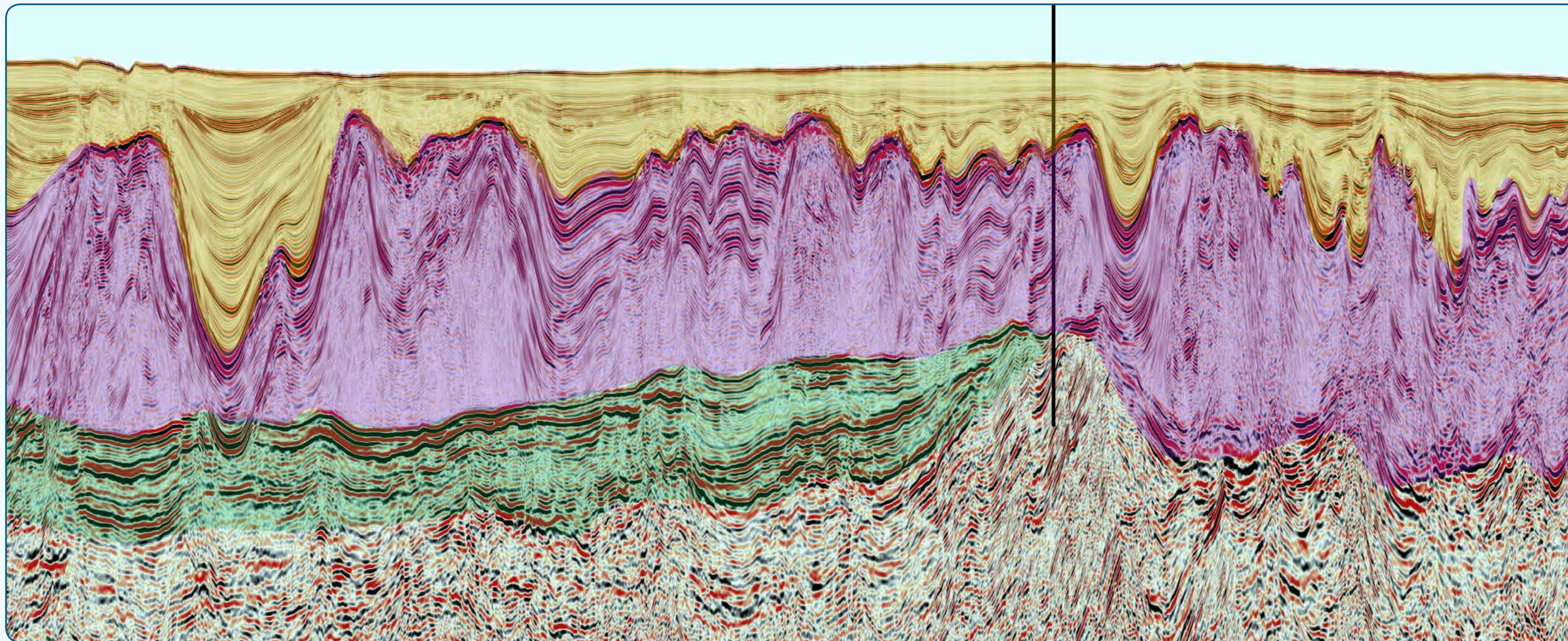
3 Groups of slick trends are identified:

- 1) Slick clusters found in the Cantarell region; the persistent slicks here are known to be connected to the Cantarell Discoveries.
- 2) North Western Isthmus salt province; with a distribution similar to those over Cantarell, these slicks are believed to be naturally occurring oil seeps, and provide strong evidence that this oil play can be extended westwards into the Campeche Basin region.
- 3) North of the Campeche Basin (the Sigsbee Knolls); abundant tight clusters of oil slicks have been interpreted, and it is clear that the seep clusters are closely related to salt diapirism, some of which have been key to the creation of 4-way dip closures responsible for many of the key discoveries offshore in the Gulf of Mexico to date.

Attention is drawn to the Sigsbee Knolls group of slick trends- These indicate that a thermogenic hydrocarbon system is present in the north Campeche basin, is mature for oil, and is generating oil in large volumes. Geochemical sampling from the Chapopote asphalt volcano indicates that at least some of these oils are of Jurassic age (Naehr et. al, 2007).

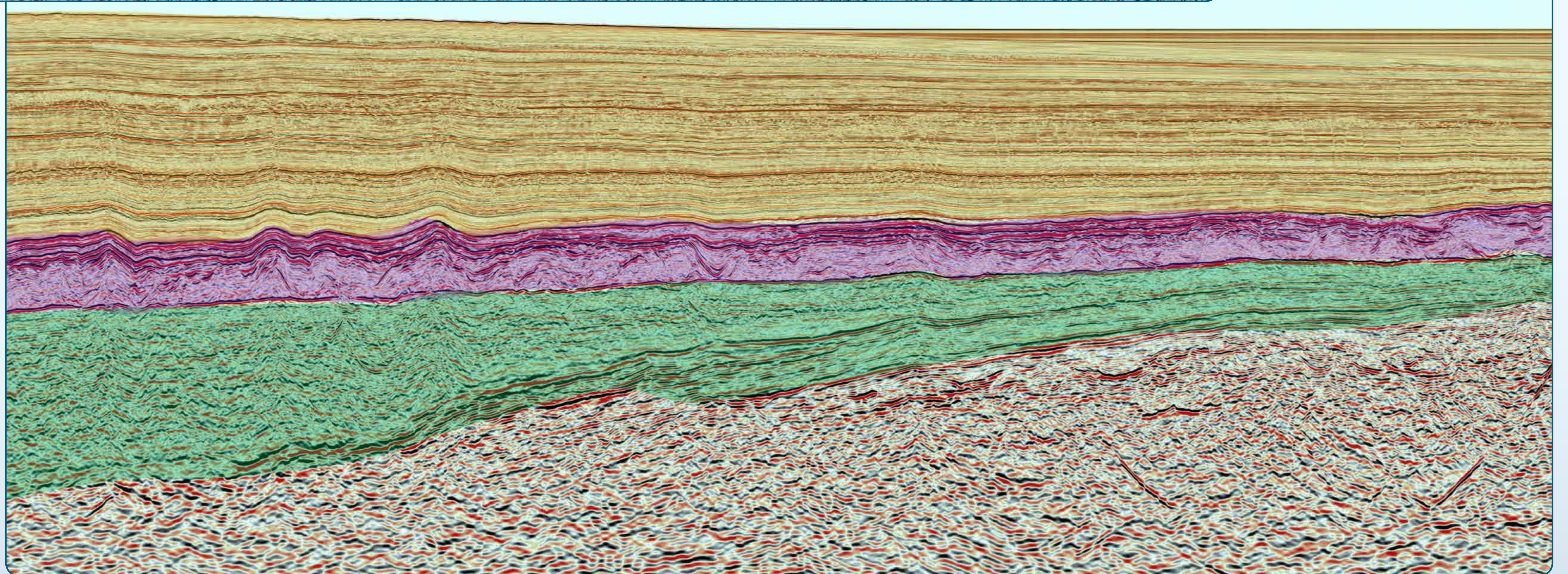
An arbitrary line through a series of seeps not associated with diapirism indicates that oil is also being generated updip of the diapirs, towards the shelf and is finding other routes to the sea surface, such as faults and seal pinch outs.

Summary and Conclusions



PSDM showing 7,000 MMBLS Tupi (Brazil) pre-salt oil field.

Full Integrity PreSTM showing pre-salt interpretation with potential reservoir.



Summary and Conclusions

- A working petroleum system has been identified using oil seeps
- Recent plate reconstruction models indicate the eastern GOM and the Campeche Basin were conjugates during the deposition of the Loann and Campeche salt basins
- Prospective sections have been recognized in Tertiary, Cretaceous and Jurassic sequences
- A possible Norphlet analogue has been revealed and interpreted within a series of gravity slides
- A potentially large pre-salt play is indicated
- Plays are commonly stacked
- More work is needed to examine the eastern part of basin

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