High resolution sequence stratigraphy of the Mexican Gulf of Mexico based on interpretation of well and seismic data

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Summary

Prolific source rocks, an abundance of trap types and stacked reservoirs and seals combine to make the Gulf of Mexico (GOM) a hydrocarbon super-basin. The GOM was the main site of development of sequence stratigraphy and seismic sequence stratigraphy. That work was concentrated in the northern half of the GOM. Less work was published on the southern half of the GOM. We present here a completed stratigraphic model for the Mexican Gulf of Mexico (MGOM) built using interpreted well and seismic data from Middle Jurassic to Quaternary. For 201 key wells we interpreted lithology, sequences to 2nd and 3rd order level and all the chronostratigraphic and lithostratigraphic units. From this information we derived the geological environment of deposition and associated depositional facies. 18 geological and depositional environment (facies) maps were created for key sequences across the MGOM – to provide a composite regional stratigraphic framework that is representative of the sub-basins in the MGOM.

Introduction

Digital wireline logs, scanned image files, drilling information and reports, lithology and biostratigraphic data were sourced for all wells in the study area. The data are processed to provide standardized, regionally consistent, high quality log data and geological interpretations. The geological analyses include formation and sequence (*2nd & 3rd order*) tops, lithology and depositional facies interpretations – all presented in a browser that enables the user to quickly analyze well correlations and to visualize Gross Depositional Environment (GDE) and facies maps.

Theory / Method

Conducting a sequence stratigraphic study of a large structurally complex (O' Reilly et al., 2017) area such as the MGOM required meticulous organization of a large team of specialists. A simplified workflow diagram with all the key stages in the study is shown in Figure 1.

The project began with the review of all previous relevant work (with a particular emphasis on biostratigraphic and petrophysical reports) and the selection of a set of wells that would ultimately be whittled down to the 201 key wells that are considered representative of the stratigraphic evolution of the MGOM. Logs were edited where required to provide

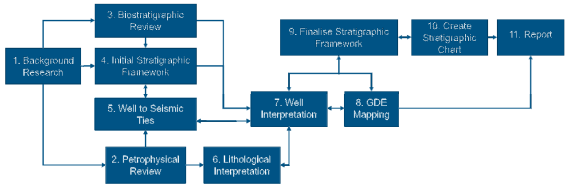

Figure 1: Sequence stratigraphic interpretation workflow

the highest possible quality dataset for the interpretation. For the Mexico project, parent and sidetrack wells were merged to provide the fullest extent of the well system. This initial scoping work (stages 1 to 3) was used to build our initial stratigraphic framework (stage 4).

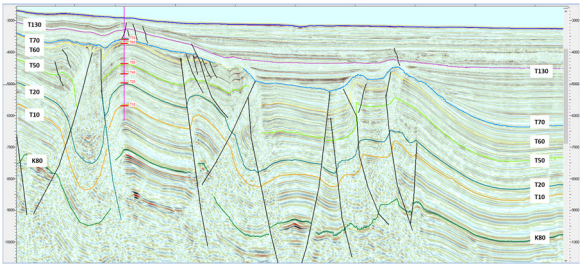

Figure 2: The Gigante seismic interpretation was upgraded to account for the greater number of wells available to this study.

Synthetic seismograms were made for well to seismic ties (stage 5). The 11 horizons (basement to Top Miocene; also salt horizons) of the Gigante seismic depth interpretation (done with 20 wells: O'Reilly et al., 2017) were reviewed in the light of the 201 wells available to this study. Where necessary, the Gigante interpretation was upgraded to provide a robust intra-well correlation framework. A new Top Pliocene horizon (important in the southern MGOM) was also interpreted (Figure 2). Interpretation of Pliocene well formation tops highlighted the importance of using both well and seismic data to ensure regional consistency within and between basins. Some wells had poor top-hole sections, which considerably lowered correlation confidence between wells. Interpretation by the operator based on published well reports was inconsistent on both seismic and well sections (Figure 3). The use of seismic allows us to fine-tune the formation tops, allowing for better correlation.

Sequence stratigraphy of the Mexican GOM

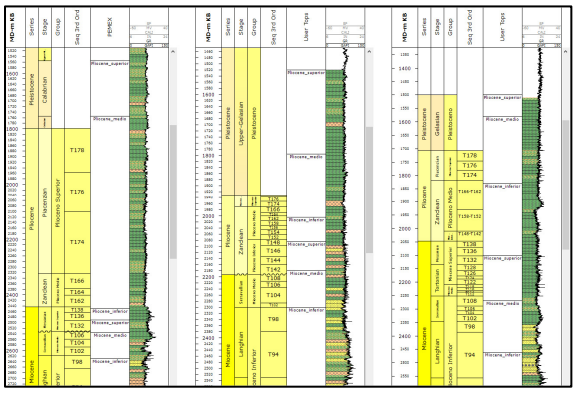

Figure 3: Poor hole conditions and differences in stratigraphic / faunal classifications result in well correlation errors that can be rectified by extensive seismic interpretation.

Detailed analyses of the well lithology began (stage 6). An important part of this was assessing the mineral modifiers (e.g. glauconite, kaolinite, pyrite, bitumen, etc) and cements (quartz, calcite, dolomite, etc) that can be important to understanding reservoir and seal quality and the input control on the depositional environment. All data available for each well was used such as cutting descriptions, mudlog, sidewall core descriptions, core images & descriptions and end of well reports.

The results of the work covered by stages 1 to 6 were then integrated as we proceeded to the well interpretation (stage 7), which includes chronostratigraphy, lithostratigraphy sequence interpretation, environment and facies. There is much iterative to-and-fro between stages 7 and 10 as results in one area may result in revision of work in another area. A stratigraphic chart was created (stage 10) that summarizes our understanding of the tectono-stratigraphic evolution of the MGOM. An excerpt from this chart is shown in Figure 4a. The formations, lithology and events that shaped each basin are represented on this stratigraphic chart.

Using industrial and academic biostratigraphic data, well reports and wireline log characteristics, 27 second order sequences were identified. These second order sequences were then further refined to 90 third order sequences. Biozonations are used to support the sequence stratigraphic interpretation. Figure 4a shows the various nannofossil and foram zones referenced. Comparison of our interpretation with the PEMEX interpretation (Figure 4b) shows that we have increased the refinement of the MGOM stratigraphic

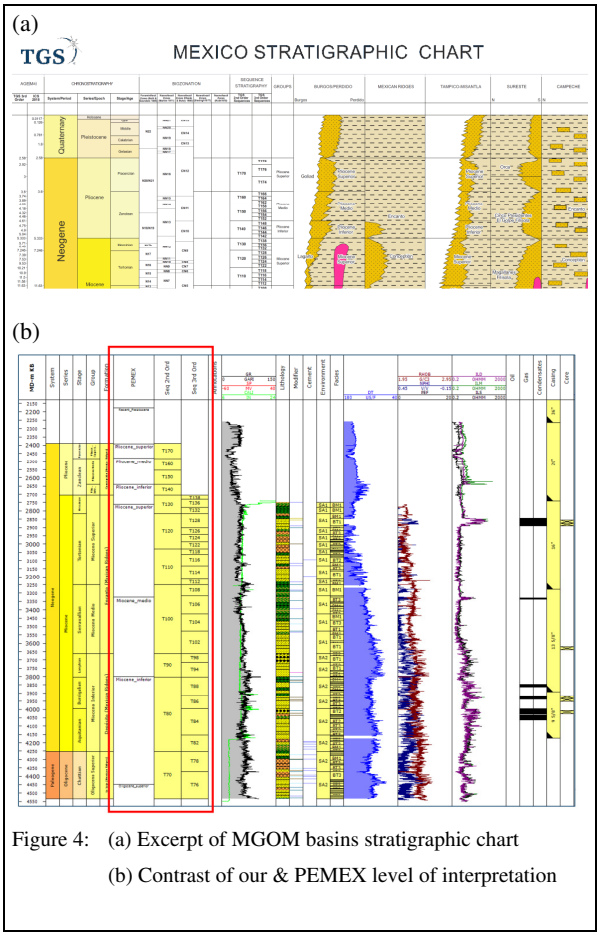

Figure 4: (a) Excerpt of MGOM basins stratigraphic chart
(b) Contrast of our & PEMEX level of interpretation

interpretation and, therefore, of basin understanding. This in turn will support a much finer resolution and delineation of potential play fairway facies.

From the well and seismic interpretations, 18 GDE maps were created covering the most prospective & important intervals from Pliocene to Upper Jurassic. As we interpreted sequences down to a 2nd and 3rd order level, we have been able to correlate depositional facies and their associated environments across the region.

As an example of the way in which we can now track the lateral and down-dip evolution of depositional facies and environments, consider the Lower Pliocene (T140) sequence in Cuencas del Sureste. We can see that between wells there are large thickness variations due to withdrawal of allochthonous salt canopies forming a mini-basin architecture. We also see (Figure 5) a progressive change in

environment from left (well A, east) to right (well C, west) in the basin:

- Offshore transition (D6) Storm dominated silty sand sheet: which are poorly sorted and form lower quality reservoir sands in well A
- Well B has prodelta / upper slope shelf turbidites (with moderate quality reservoir sands): a product of reworking of shelf sands & muds
- Upper slope amalgamated channel / lobe turbidites: high sand/mud ratio, clean, good quality reservoir sands in Well C

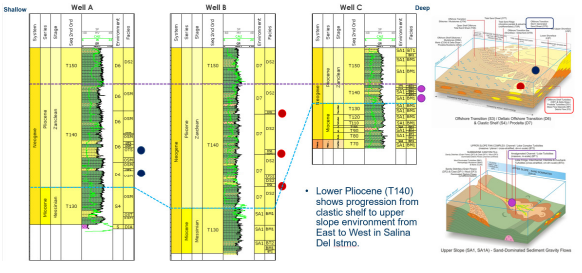

Figure 5: Shallow to deep Cenozoic facies transitions

Conclusions

We have completed a detailed sequence stratigraphic interpretation of 201 wells in the MGOM, to a much higher level of detail than was previously published.

Integration with 2D seismic data has provided high resolution depositional environment and facies maps from Middle Jurassic to Quaternary throughout the MGOM.

This study enables highly accurate and confident correlation of interpreted 2nd and 3rd order sequences across the entire extent of the MGOM.

The deep-water MGOM is under-explored, by comparison with the US GOM. Further exploration and prospect delineation of the outboard areas will rely on detailed play fairway analysis to constrain the characteristics of the various risk elements (source, reservoir, seal, charge & trap). Our unique and comprehensive sequence stratigraphic framework, in particular the GDE maps, will be a key component of any Play Fairway Analysis of the under-explored deep-water MGOM

Acknowledgements

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