[PS]A New Approach to Pore Pressure Predictions: Generation, Expulsion and Retention Trio, Case Histories from GOM*

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Abstract

A comprehensive framework and fresh perspective to pore pressure prediction methods and algorithms based on the established geological building blocks is presented. Applying the suggested four subsurface zones is the backbone of this pore pressure prediction approach. Determining the boundary of the four subsurface zones utilizing petrophysical data is crucial for selecting the appropriate method and algorithms for pressure prediction.

This approach divides the previously so-called normally pressured upper section into two zones: namely hydrostatic and hydrodynamic. Consequently, data in the hydrodynamic section is used to establish the compaction trend and not the entire section above the top of geopressure. The section below the top of geopressure is divided into transition and geo-pressured zones. This method is to mathematically calculate the compaction trend, rather than graphically displaying it for calibration purposes. Moreover, it eliminates the confusion of extrapolating the effective stress predictive values above the top of geopressure. Algorithm supported by empirical data is introduced to calculate the sand beds vs. formation and mud pressures to evade the deep water's shallow water flow (SWF) and sinking wells' head (SWH).

Entrapment represents the main cause of overpressure buildup. Fluid pressure inflation due to stress, aqua-thermal and dewatering processes is the genesis and not the outcome. Therefore, the effective seal is the main cause of creating excess pressure. Investigating possible breach due to subsurface structural failure is a key objective for pore pressure prediction.

The subsurface hydro-geological zoning greatly affects the velocity, resistivity and density profiles. Seismic velocity to pore pressure transformation modeling foresees the trio process from generation to expulsion to entrapment before drilling the prospect. The newly introduced subsurface partitions, trio concept, algorithms and predictive modeling incorporated with the geological setting are supported by case histories from the Gulf of Mexico

A New Approach to Pore Pressure Predictions: Generation, Expulsion and Retention Trio, Case Histories from GOM

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ABSTRACT

A comprehensive framework and fresh perspective to pore pressure prediction methods and algorithms based on the established geological building blocks is presented. Applying the suggested four subsurface zones is the backbone of this pore pressure prediction approach. Determining the boundary of the four subsurface zones utilizing seismic data is crucial for selecting the appropriate method and algorithms for pressure prediction.

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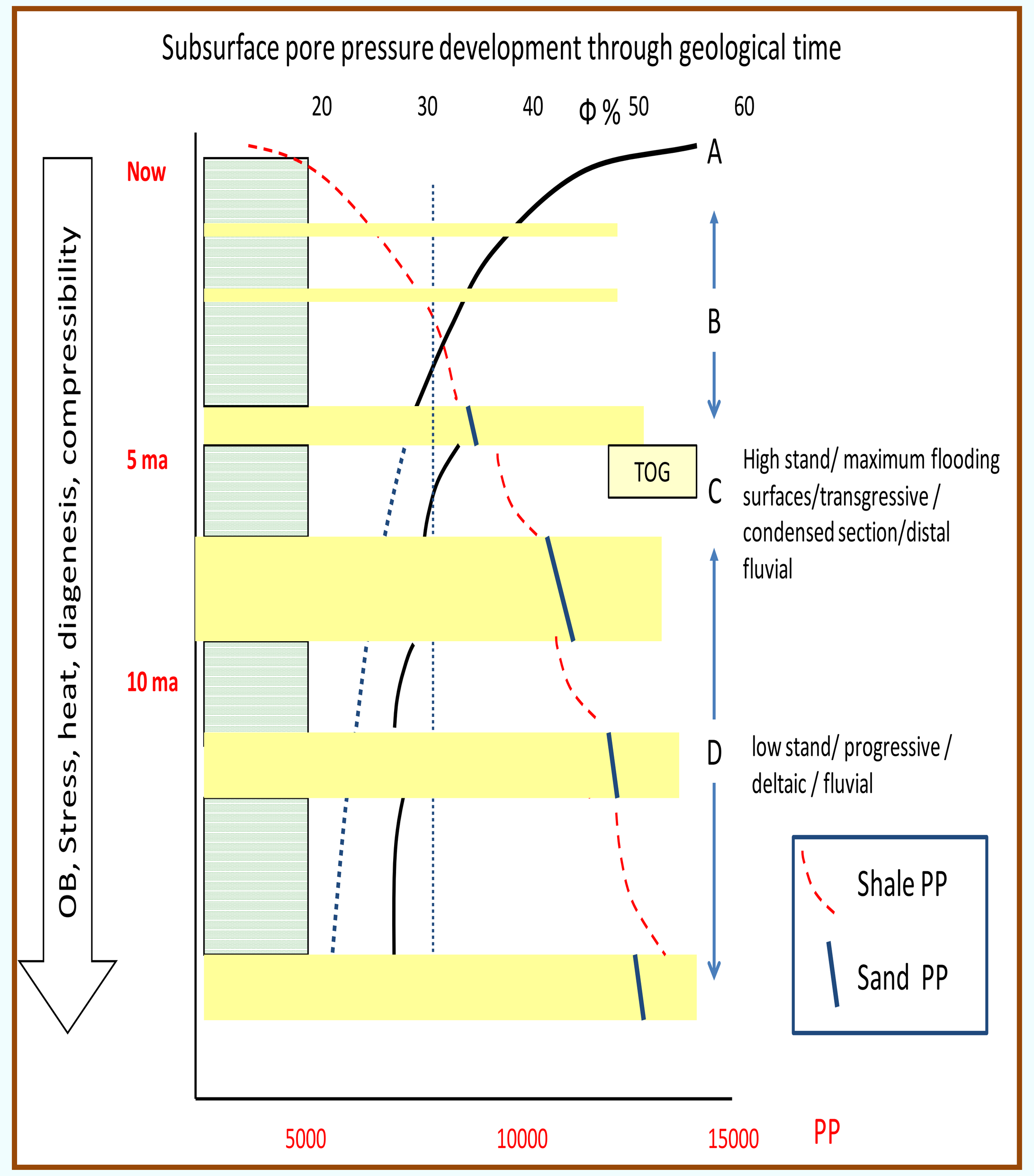
In this paper, entrapment represents the main cause of overpressure buildup. Fluid pressure inflation due to stress, aqua-thermal and dewatering processes is the genesis and not the outcome. The effective seal is the main mechanism for creating excess pressure. Investigating possible breach of the seal due to subsurface structural failure is a key objective for pore pressure prediction.

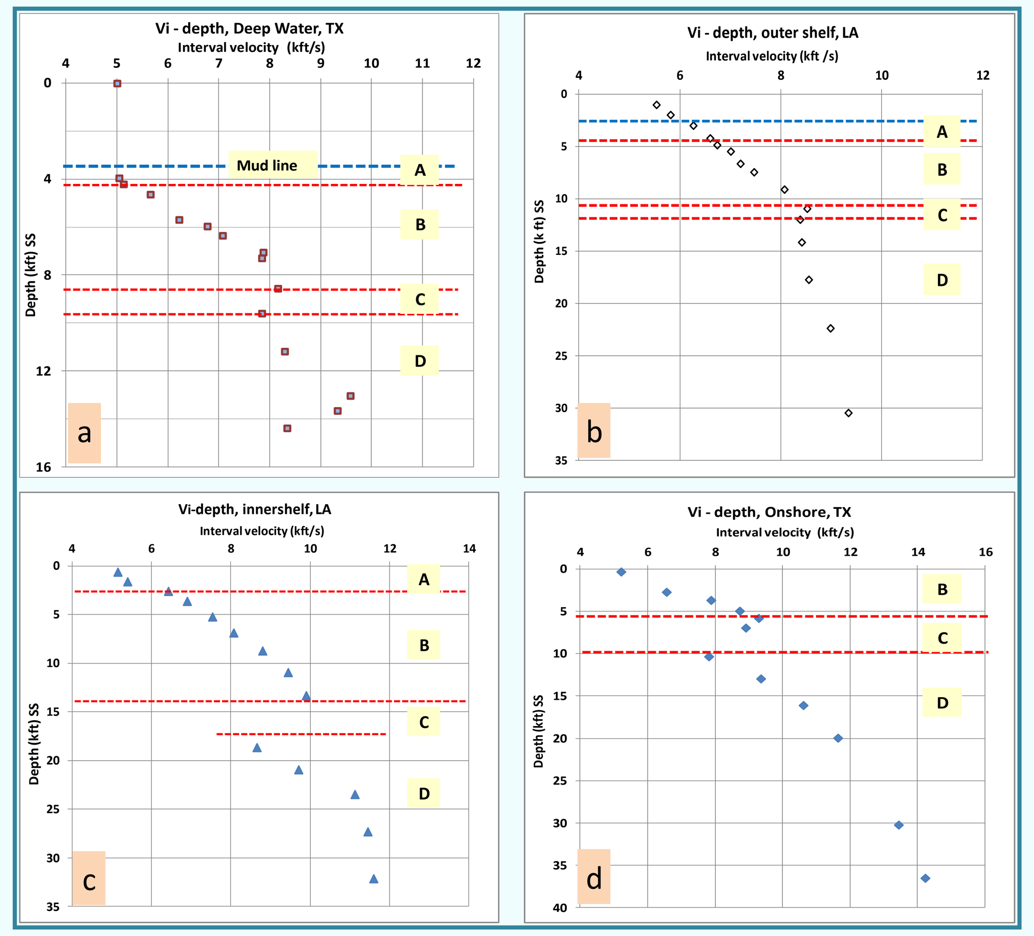
The subsurface hydro-geological zoning greatly impacts the velocity, resistivity and density profiles. Seismic velocity to pore pressure transformation modeling foresees the trio process from generation to expulsion to entrapment before drilling the prospect. The newly introduced subsurface partitions, trio concept, algorithms and predictive modeling incorporated with the geological setting are supported by case histories from the Gulf of Mexico.

SEQUENCE STRATIGRAPHY AND PP DEVELOPMENT



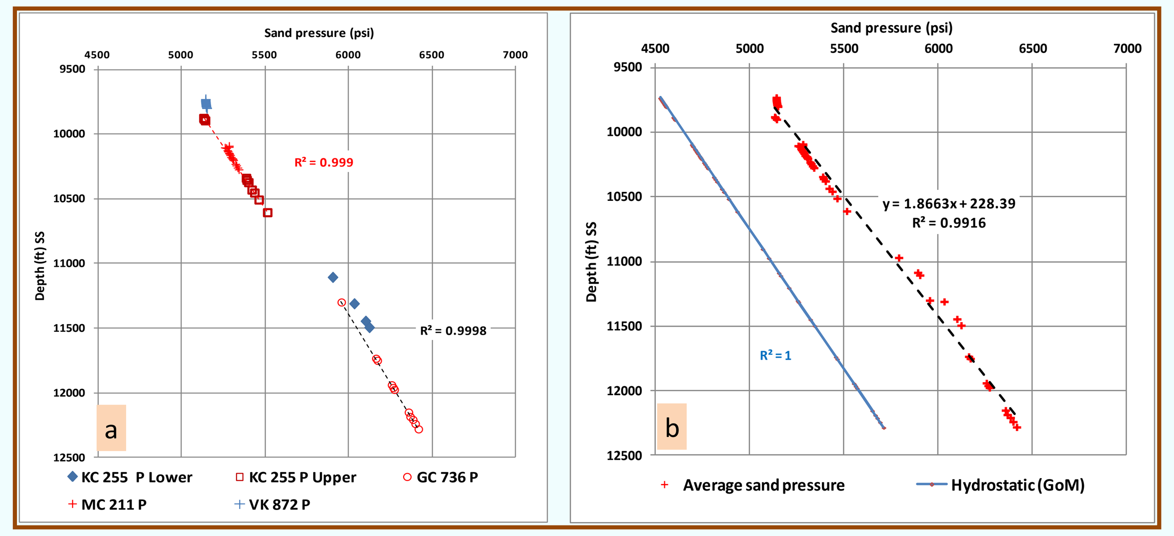
Deposition of Stratigraphic Sequences impacts the pressure profile development. Cyclic maximum flooding surfaces alternating with low stand deposits create subsidence, stress, heat, compartmentalization and the repeating of the compaction process through geological time. Note the different pressure gradient's trend behavior of shale vs. sand.

ASSIGNING THE 4 ZONES BEFORE DRILLING



Velocity changes vs. depth due the presence of the four subsurface zones (A, B, C and D) in different geological settings: (a) deep water, (b) outer shelf, (c) inner shelf (bottom of zone C is selected based on sequence stratigraphy), and (d) onshore (thick Anahuac shale represents zone C).

SAND PRESSURE GRADIENT IN ZONE B



Plot a (left) displays zone B Upper Pleistocene sands pressure–depth relationship in deep water wells. The measured pressure data (RFT) shows a shift in the pressure gradient (slope) from 0.59 to 0.53 psi/ft between the deep and the shallow section respectively. Moreover, the resulting hydraulic head (intercept) is higher in the shallow than the deep section. Plot b (right) shows the average gradient.

PRESSURE GRADIENT CALCULATION IN ZONES C AND D.

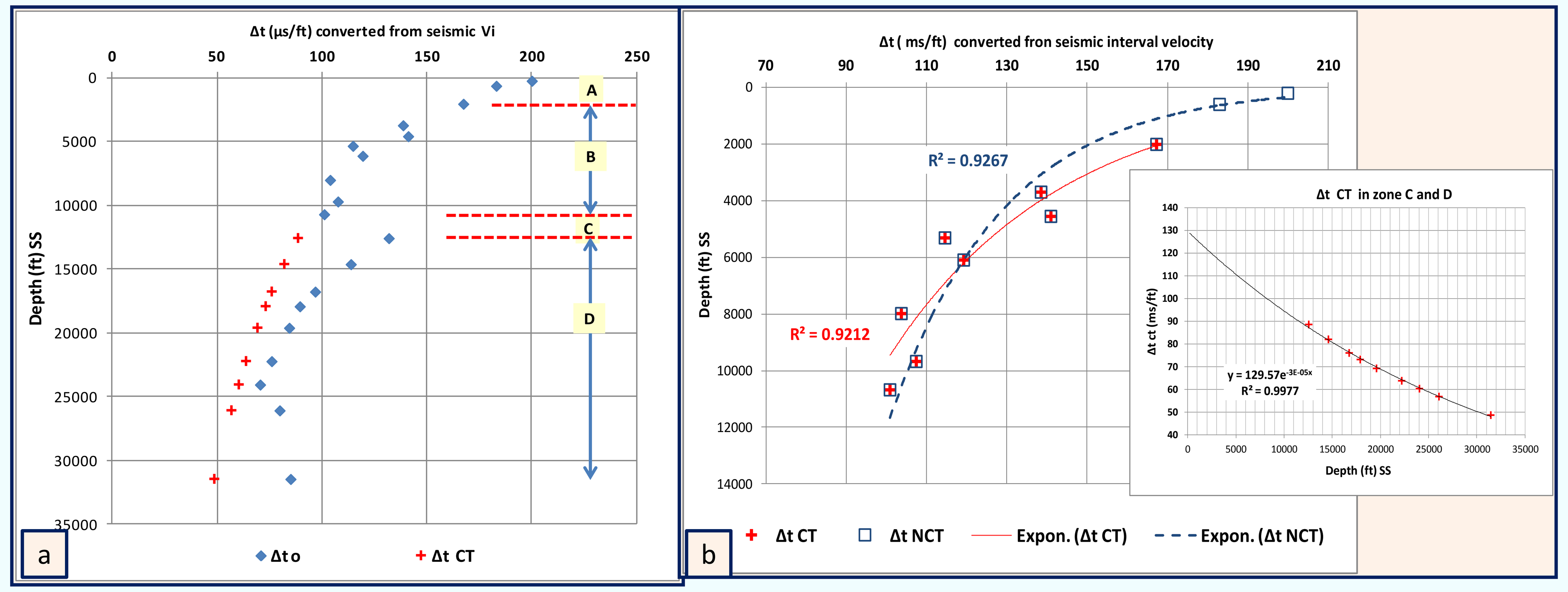
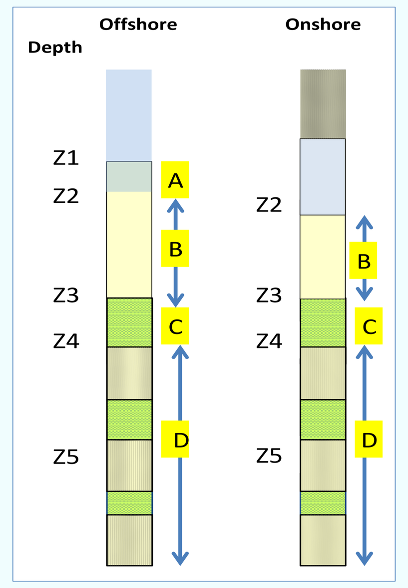
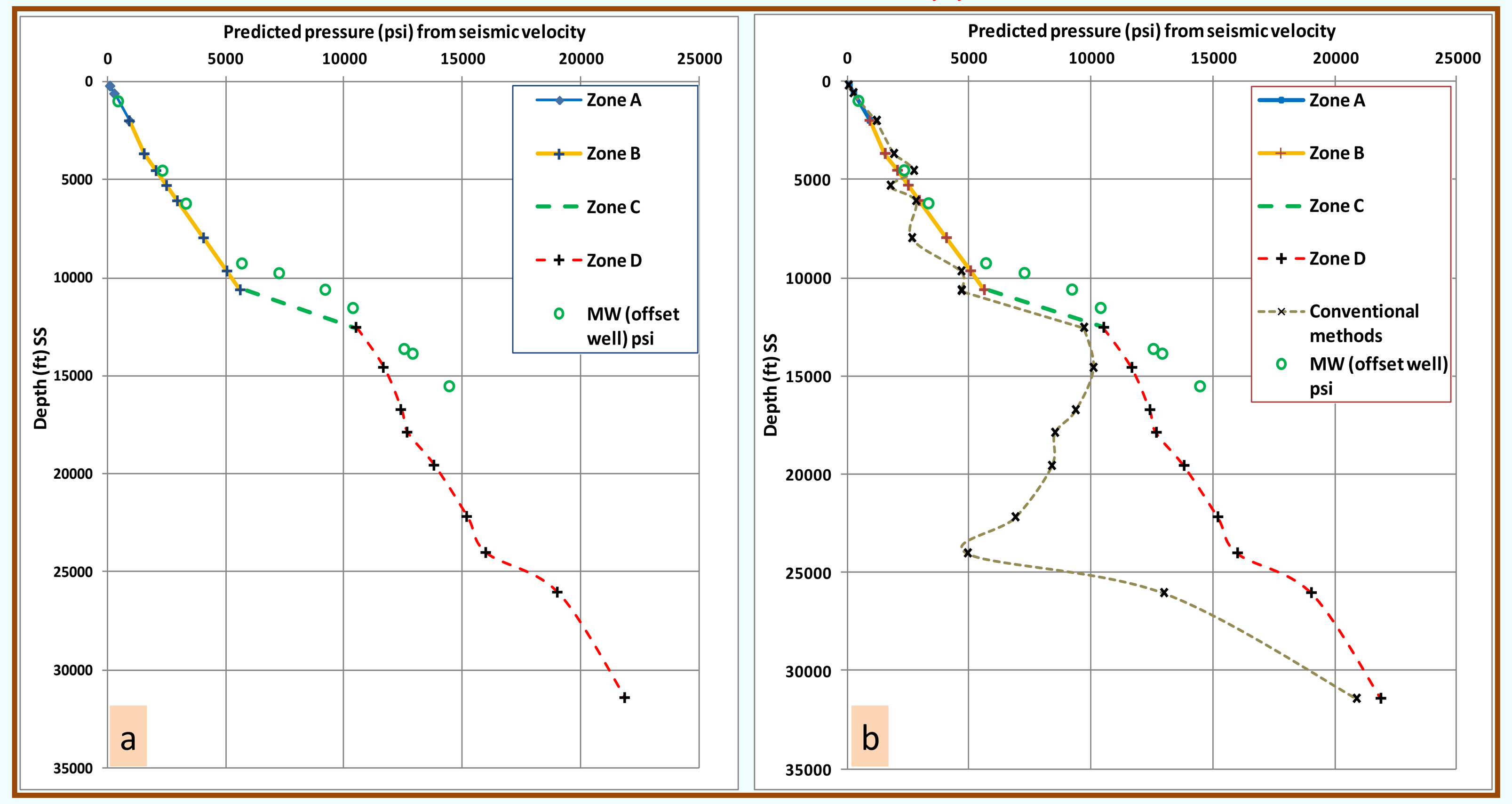


Figure (a) Δt (converted from interval seismic velocity) vs. depth. The blue series represent the entire observed data set (Δto) and red series shows the extrapolated values of ΔtCT as if the compaction trend in zone B did not change slope across zone C and D. Figure (b) shows the discrepancy between conducting the calculations based on the data extracted from the compaction of zone B (red series) vs. data extracted from the so called normal compaction trend (blue series) which includes A and B zones. The inserted ΔtCT plot (on right) shows the method of extrapolating ΔtCT below the top of geopressure (zones C and D).



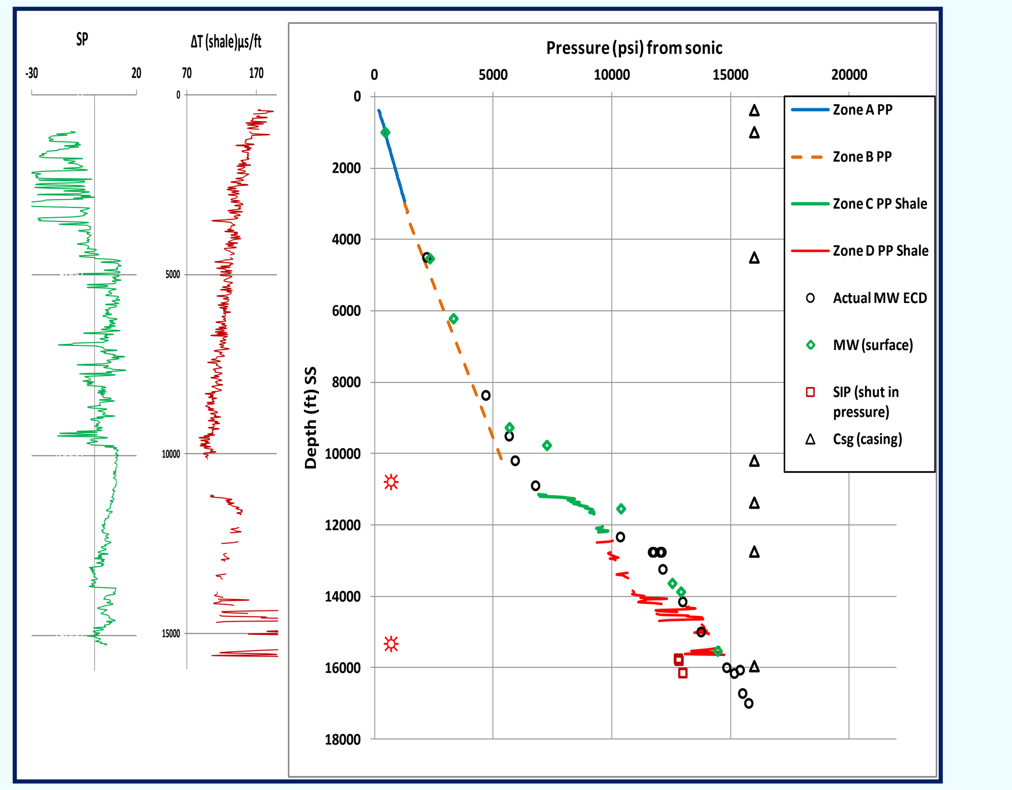
Depth calculation graph shows the discrepancy between onshore and offshore subsurface regarding the four zones distribution.

SEISMIC - PORE PRESSURE TRANSFORMATION MODEL IN ZONES A,B, C AND D.



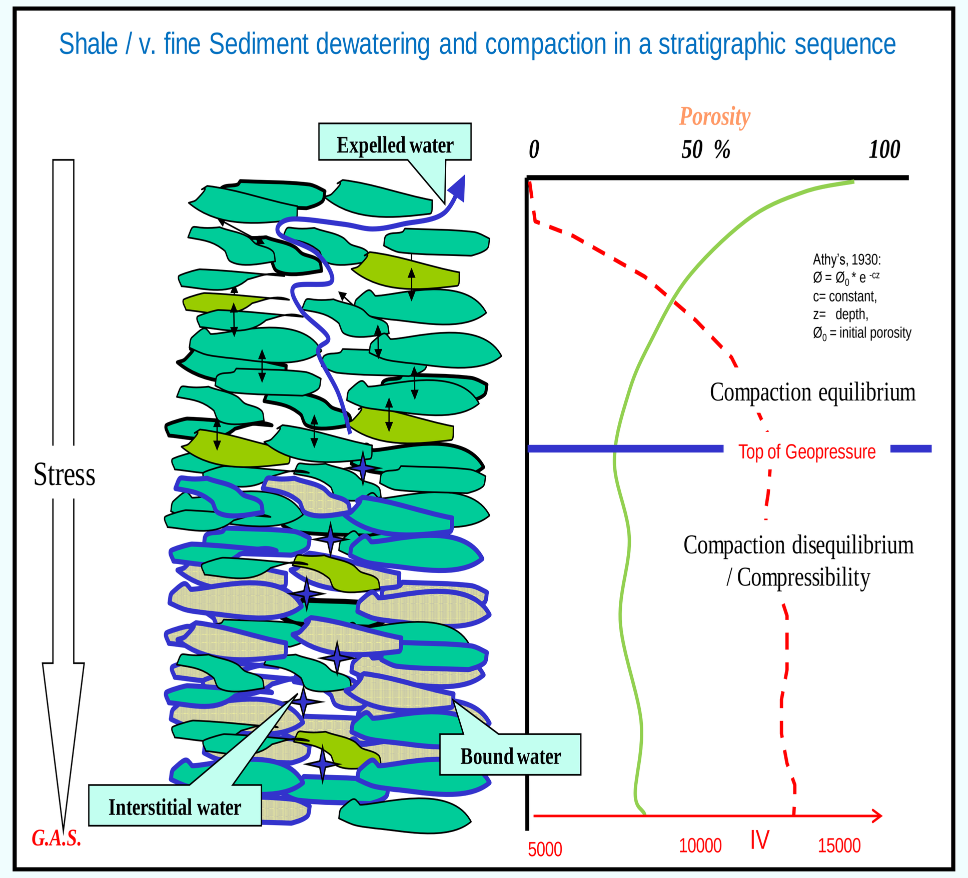
The before drilling predictive pressure model for the four zones is shown on the left plot (a). A comparison between the conventional and the newly proposed method is displayed on the right plot (b). Open green circle represents the mud weight that was used to drill a nearby offset well and also calibrates the pre-drill model. Note the ≈5000 psi pressure ramp at zone C.

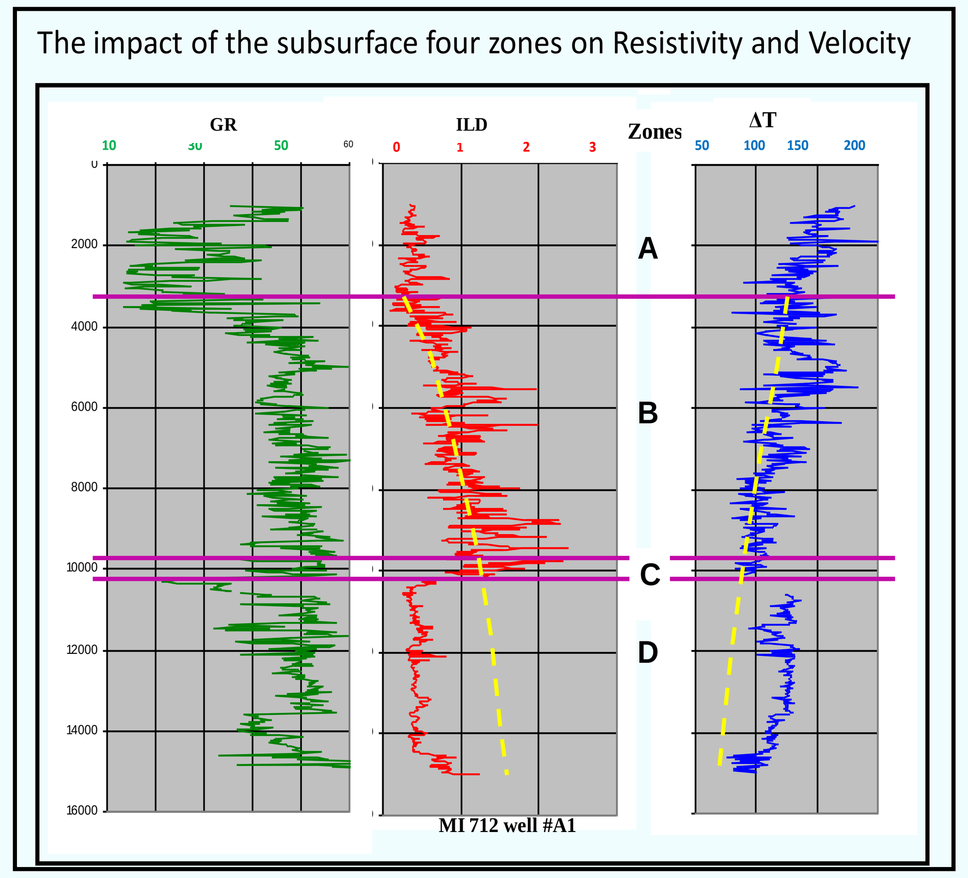
RT MODEL CALIBRATION – TRIO FULFILLMENT



Calibration criterion during drilling MWD - pore pressure of the before drilling seismic-pressure model is shown. Zones A pp (blue) and Zone B PP (orange) are calculated (equations 2 and 9). Zones C PP shale (green) / D PP shale (red), MW, SIP and Csg are predicted shale pore pressure from sonic (LAS), mud weight (surface and equivalent circulating density), shut in pressure and casing seats respectively.

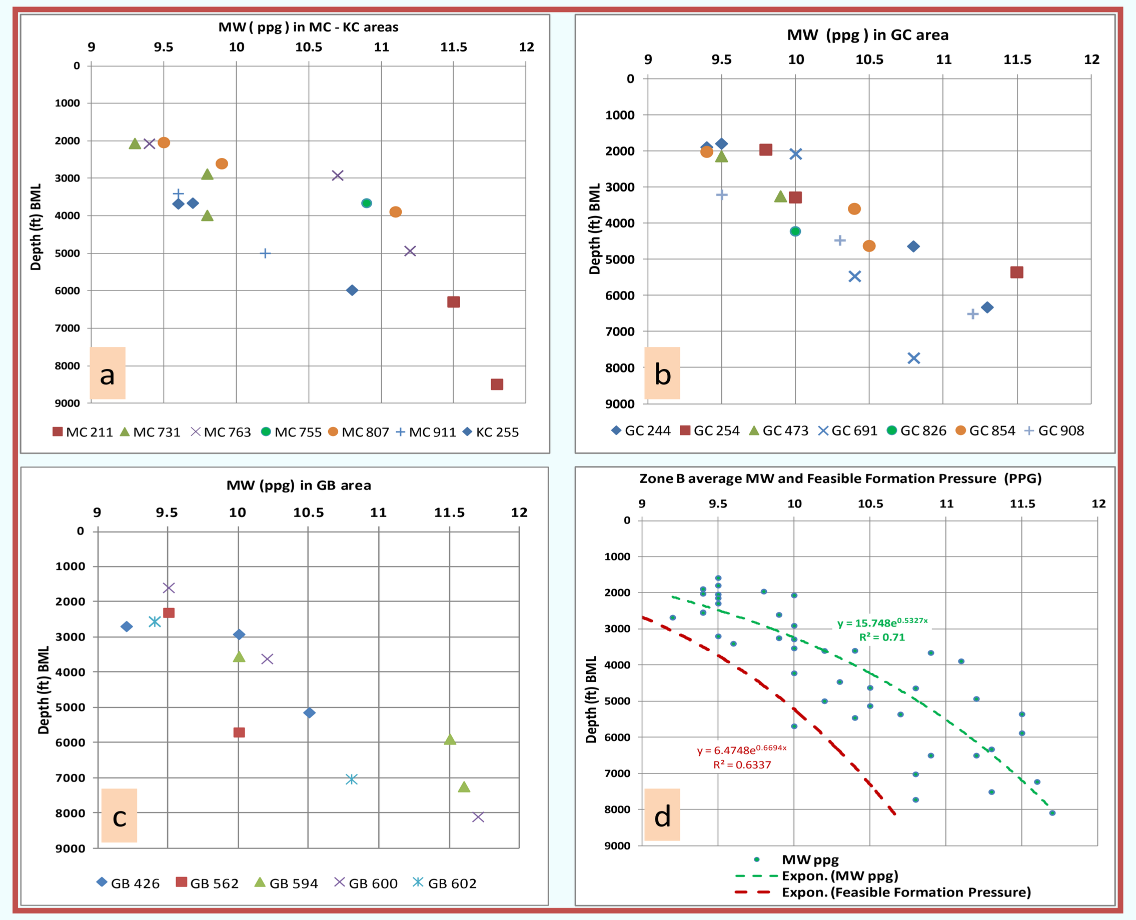
GEOLOGY - HYDROLOGY – GEOPRESSURE - PETRPHYSICAL PROPERTIES WITHIN THE SUBSURFACE 4 ZONES



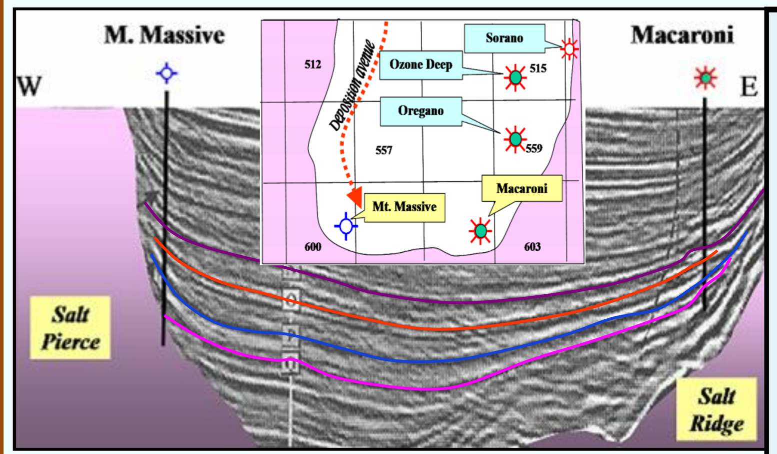


The relationship between porosity, burial depth and fluid pressure is shown on the left panel. The four zones - A, B, C and D are exhibited on the right panel. The Compaction Trend (yellow dashed curve) represents the extrapolated porosity and pressure values as if retention of fluids has not taken place. On the right panel, the impact of the four subsurface pressure zones on the resistivity and sonic logs is shown.

FEASIBLE FORMATION PRESSURE GRADIENT IN ZONE B

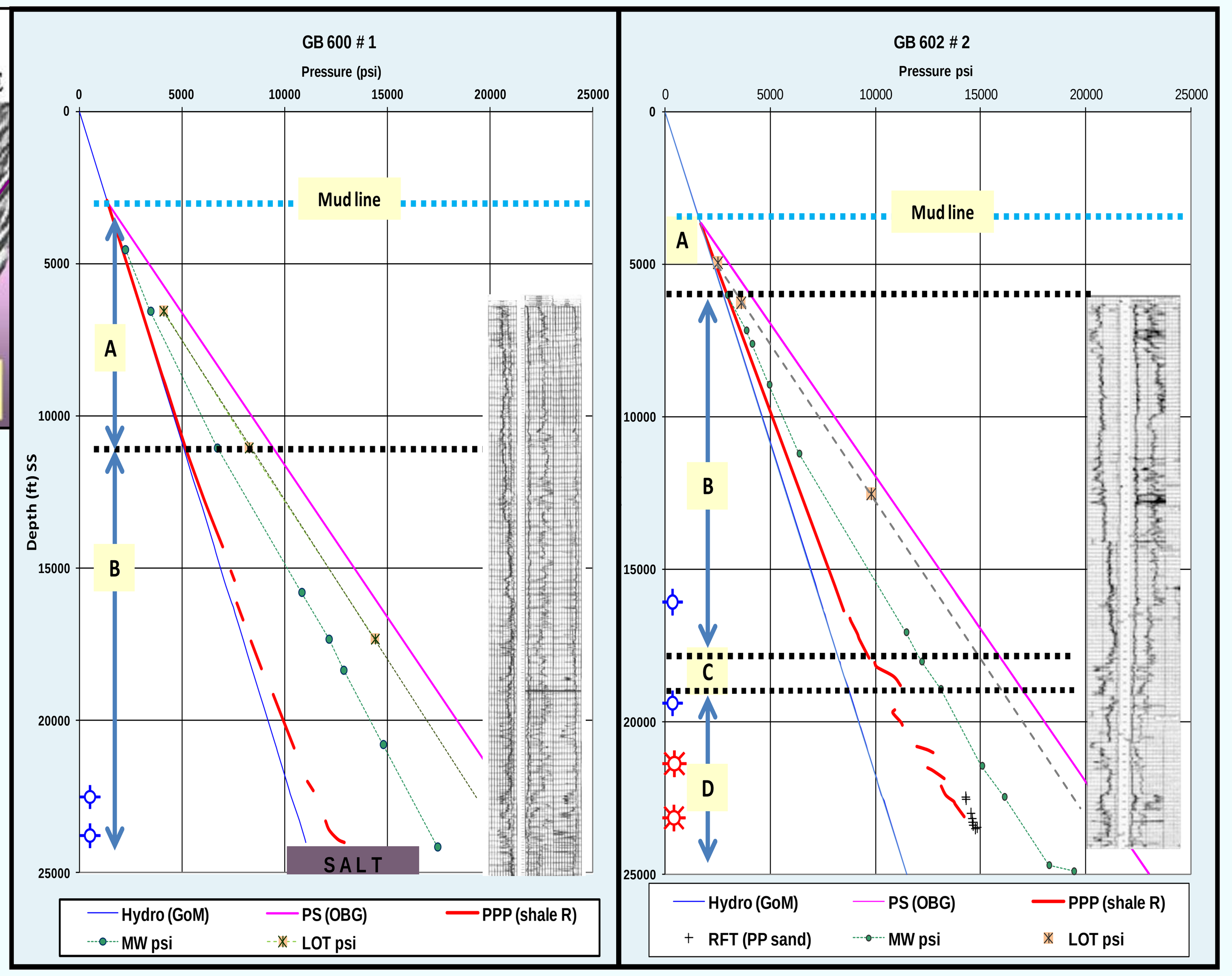


Mud weight (MW) recorded data used to drill several wells in zone B of the GOM deep water. Plots (a), (b) and (c) are MW from Mississippi Canon, Green Canyon, and Garden Banks respectively. Note that the MW increases with depth to combat the increase of the hydrodynamic pressure gradient. A subtle difference can be noticed on the MW-depth distribution charts among the different areas. Plot (d) is the average MW and feasible formation pressure (FFP) calculations of the entire collected data set in ppg.



Top: The geological setting of Auger basin, Gulf of Mexico and the seismic tie between the Macaroni field and Mt. Massive prospect (after Shaker, 2004). Seismic was extracted from the disappointing seismic anomalies seminar by the Houston Geological Society, 2003.

STRUCTURAL FAILURE'S IMPACT ON PPP



Right : Correlation between the geopressure analysis of GB 602 (right) and GB 600 (left). Note the four zones, especially C, are well represented on the right plot whereas, the left plot is missing the C and D zones due to subsurface structural failure. Hydro (GoM), PS (OBG), PPP(shale R), RFT(PP sand), MW psi, LOT psi are hydrostatic, principal stress, predicted pore pressure from resistivity, repeated formation tester, mud weight and leak off test respectively. Note sand ratio is higher in GB 600 #1 (more deposition) compared to GB 602 #2 on log images. Moreover, GB 600#1 drilled with overbalanced mud weight since GB 602 #2 MW was used as a template.

CONCLUSIONS

- The confident seal is the main cause of excess pressure.
- Stress, heat, HC are responsible for in situ pressure only
- Pressure profile is divided into four zones rather than two.
- Compaction Trend (CT) and is not Normal Compaction Trend (NCT).
- PPP uses Zone B data extrapolation only and not zones A and B
- PPP should be done separately in each zone A,B,C and D
- Effective stress theorem applies only below the TOG.
- Examining the geological building blocks especially structural failure prior to PP prediction

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