Implementation of an Exploration Workflow to Characterize a Low Poro-Perm Gas-Bearing Prospect Using Rock Physics Depth-Trends to Assist AVO Classification*

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Abstract

An Oil and Gas company is not able to sustain over the time without creating value through its life cycle. In the last decades PetroSA has been using sophisticated seismic and geological survey techniques to determine whether viable oil and gas reservoirs may exist and identify potential well locations for exploration drilling by performing independent play fairway analysis to evaluate the potential of the Syn-Rift II Valanginian Upper Shallow Marine (USM) formation. The prospect of interest is defined as a gas-bearing Upper Shallow Marine (USM) sands and is one of the most attractive prospects documented in the Bredasdorp Basin, south coast South Africa in term of geological risk and potential volumes. One of main risks are associated to reservoir presence and quality. A single well was drilled in the area of interest but planned to target a shallow reservoir. On the other hand, few wells that targeted the same formation at a similar depth level are located far away from the interest structure. This paper describes a methodology which attends to de-risk this prospect in the USM by calculating the AVO response as a function of litho-pore fluid facies by using rock physics depth-trend. Data from analogue wells and/or nearby areas are used to determine the distribution of Vp, Vs and density for each likely facie defined and empirical porosity-depth trend models are computed to calibrate such data to the given depth of interest. The different facies defined above are then combined to each other to cover all the realistic interface scenarios on the geological setting of interest. The interfaces AVO responses are computed using an approximation to the AVO Zoeppritz equation (Shuey), and AVO pdfs are then calculated from each interface scatter plot to predict the most likely litho-pore fluid facies from seismic (I,G) attributes. The top of reservoir interface resulted classified as an AVO “Class I” characterized by a high zero-offset amplitude. The AVO response showed a good separation between litho-facies (sand-shale), but more subtle between fluid cases (sand-gas, sand-water) in the AVO attributes (I,G) domain. On the other hand, the main driver for an efficient AVO classification in this low poro-perm reservoir is controlled by the porosity, so an overlapping between interface clusters in the A-B domain was noticed.

Selected Reference

Avseth, P., H. Flesche, and A.-J. Van Wijngaarden, 2003, AVO classification of lithology and pore fluids constrained by rock physics depth trends: The Leading Edge, v. 22/10, p. 1004-1011.

International Conference & Exhibition

Implementation of an exploration workflow to characterize a low poro-perm gas-bearing prospect using rock physics depth-trends to assist AVO classification

Jorge Adrian
Gervasio Robles

Agenda

- ✓ Background & goals
- ✓ Problem & proposed solution
- ✓ Observations & Conclusions
- ✓ Acknowledges

Background:

- ❑ The E-AT prospect is defined as gas-bearing sands, deposited during a synrift stage as prograding deltas/upper shore-face facies in a high-stand systems tract.
- ❑ The prospect is defined as a 3 way structural closure (east, west, and south) and by an erosional pinch-out combined with a normal fault to the north.
- ❑ Reservoir quality is controlled by compaction, but over-pressure leads by a rapid subsidence is expecting to preserve reservoir quality poro-perm.
- ❑ The location of the potential source rock (SR) is assumed to overlie the target, down dip from it (migration via onlap).

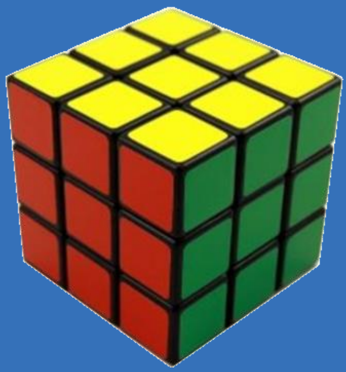
Problem:

E-AT represents one of most encouraging prospects based on field size distribution of the basin. However, some key risks and uncertainties still remain which could impact the chances of success (COS).

The scope of this study intends to mitigate the risks associated to reservoir quality and hydrocarbon presence.

Solution:

A 10-steps workflow that uses rock physics depth-trends to predict elastic properties at target depth to assist in the AVO classification of lithology and pore fluids in a low poro-perm reservoir.



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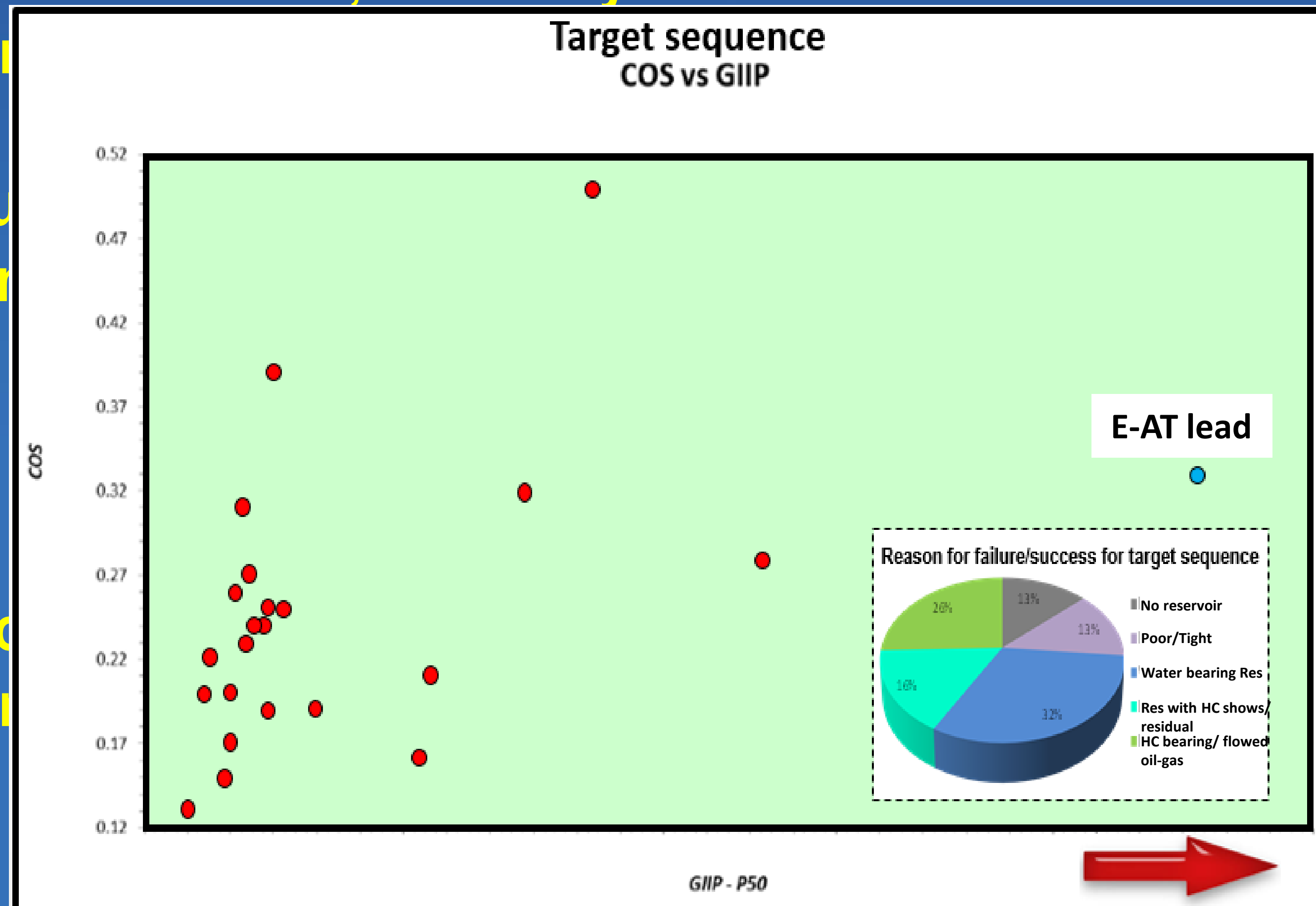
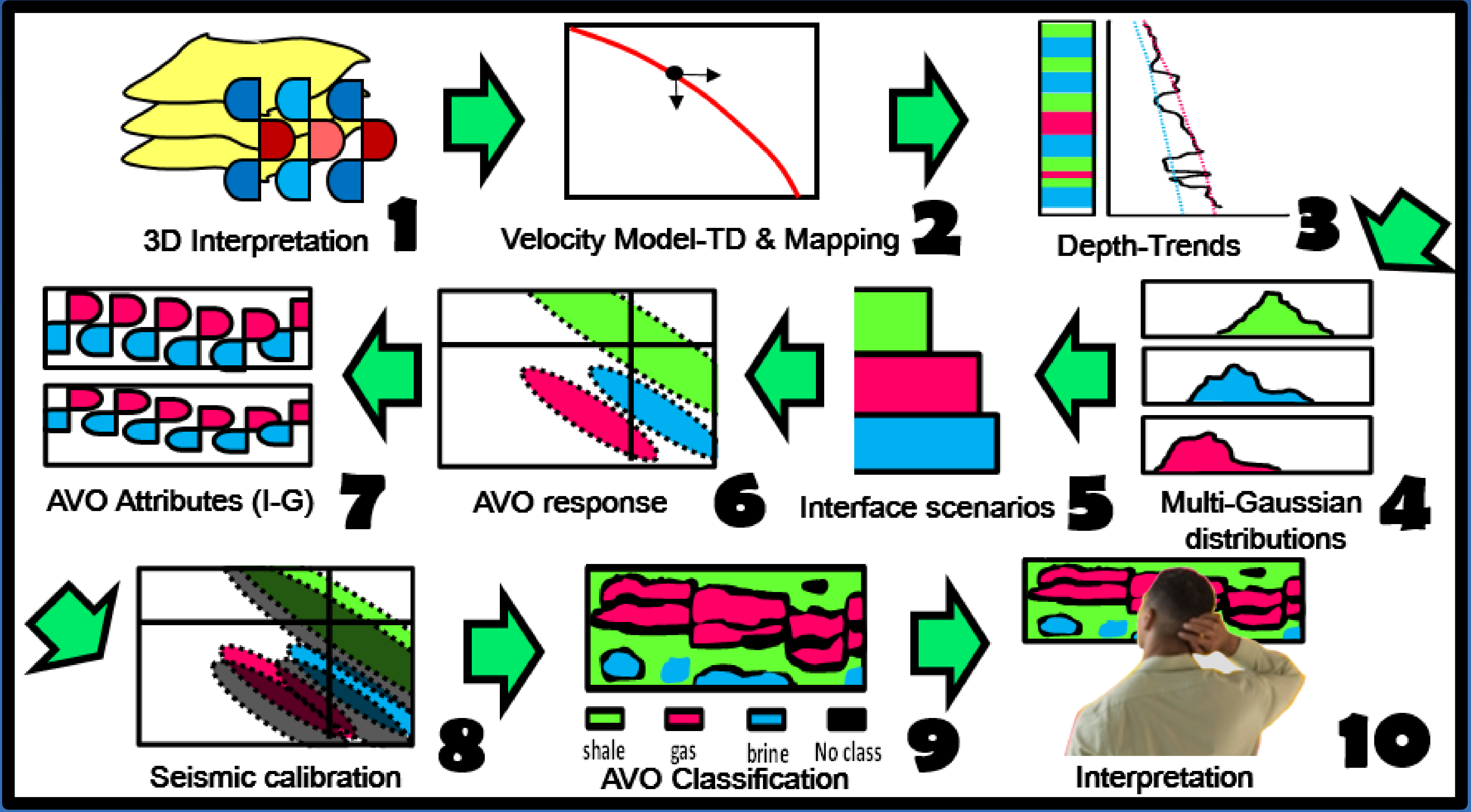
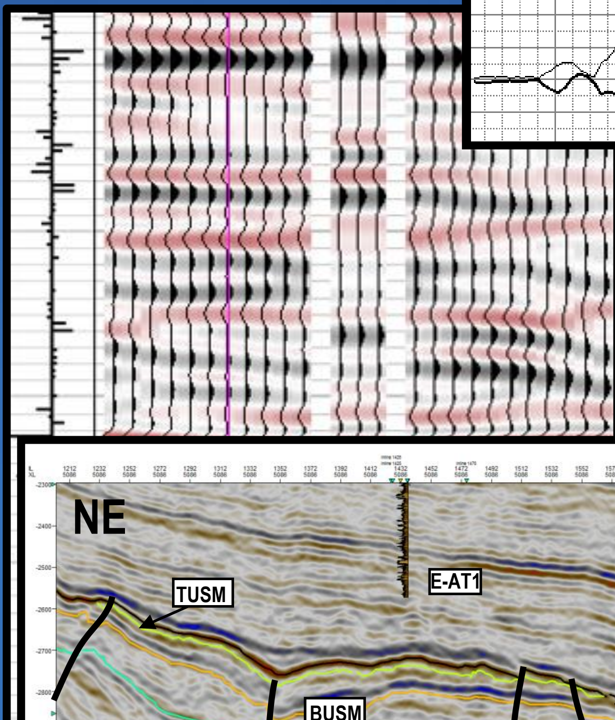
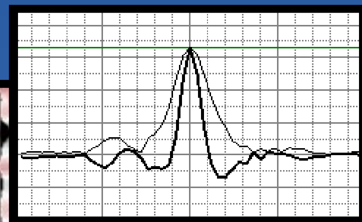


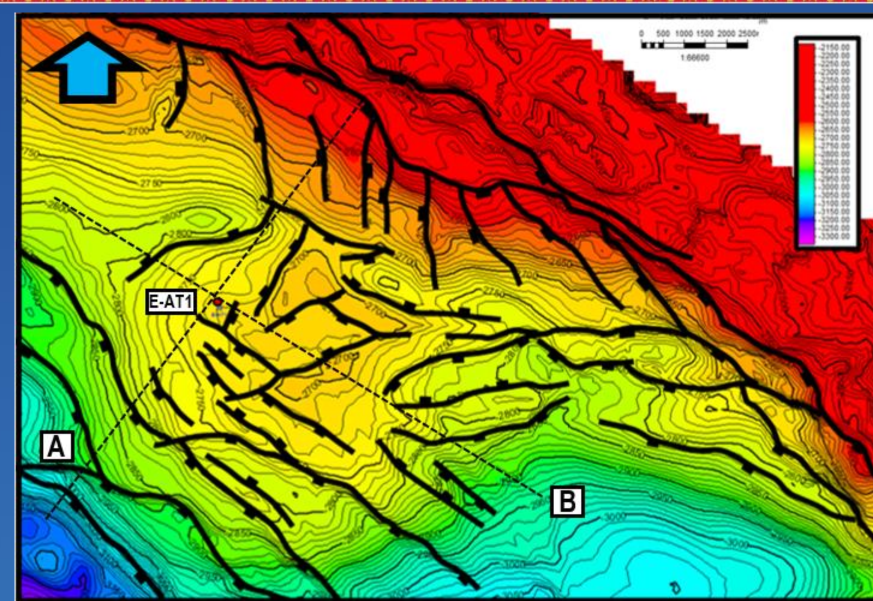
Workflow: Reservoir characterization by AVO classification using depth-trend inputs



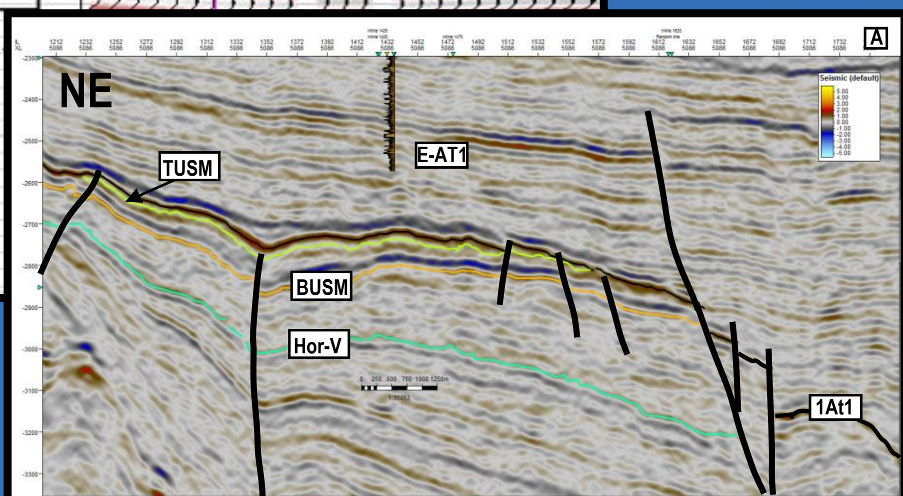
1.-3D Interpretation of Exploration opportunity:







3D seismic interpretation



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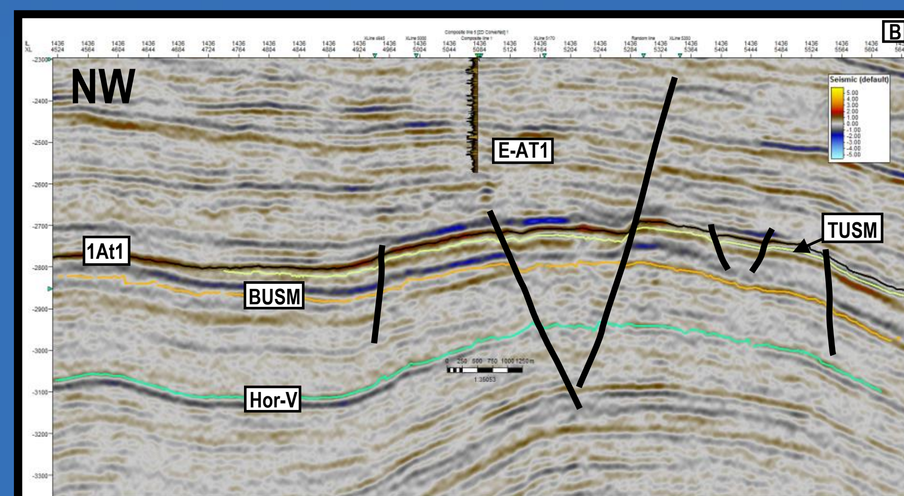

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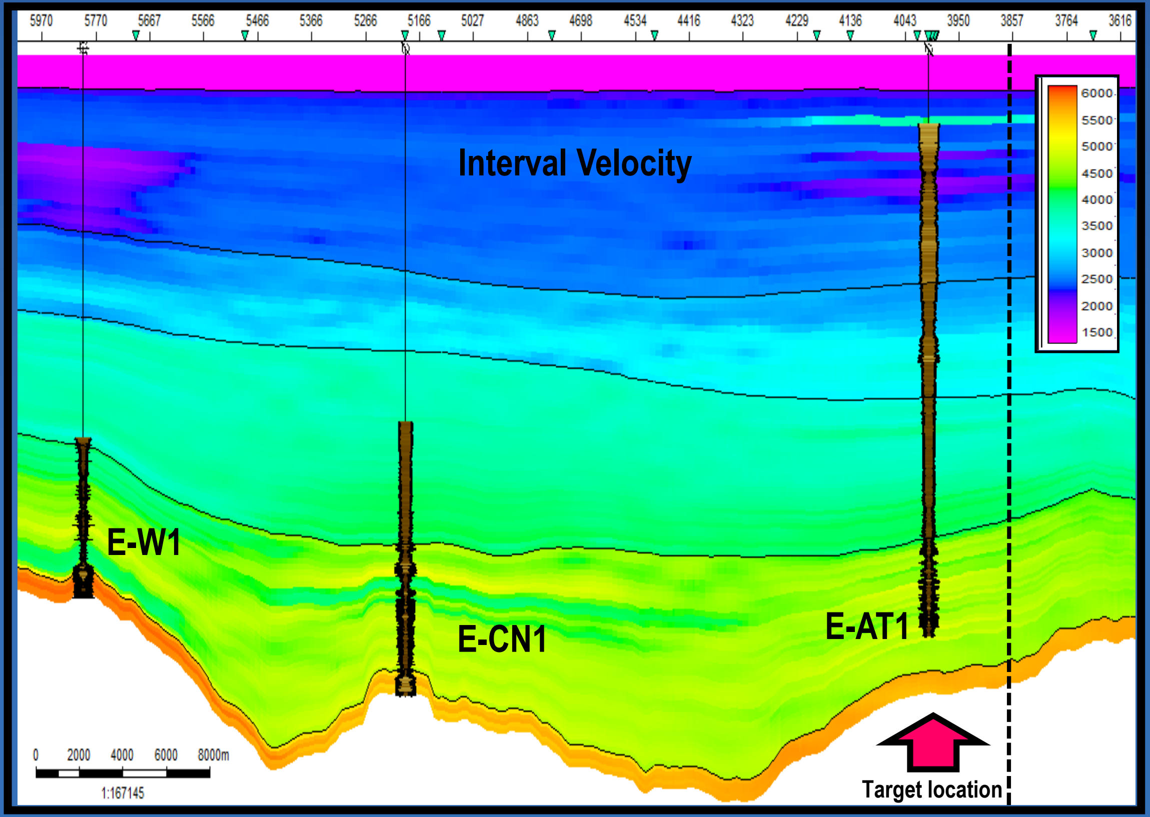
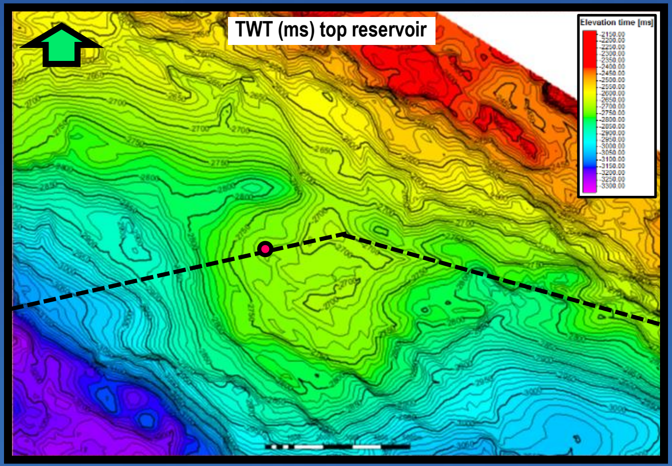
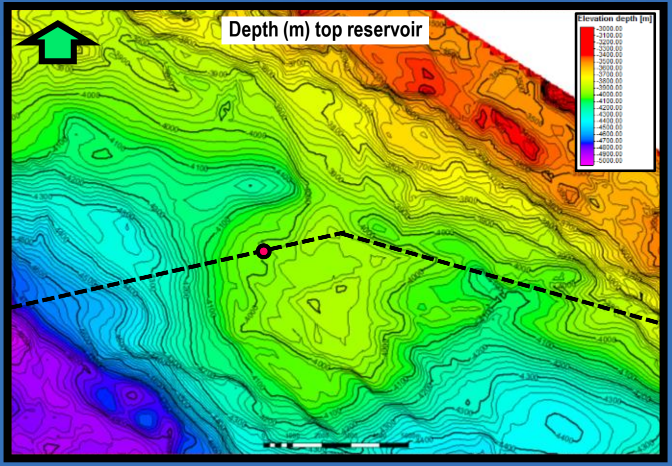
2.-Velocity Model and Time-Depth conversion:

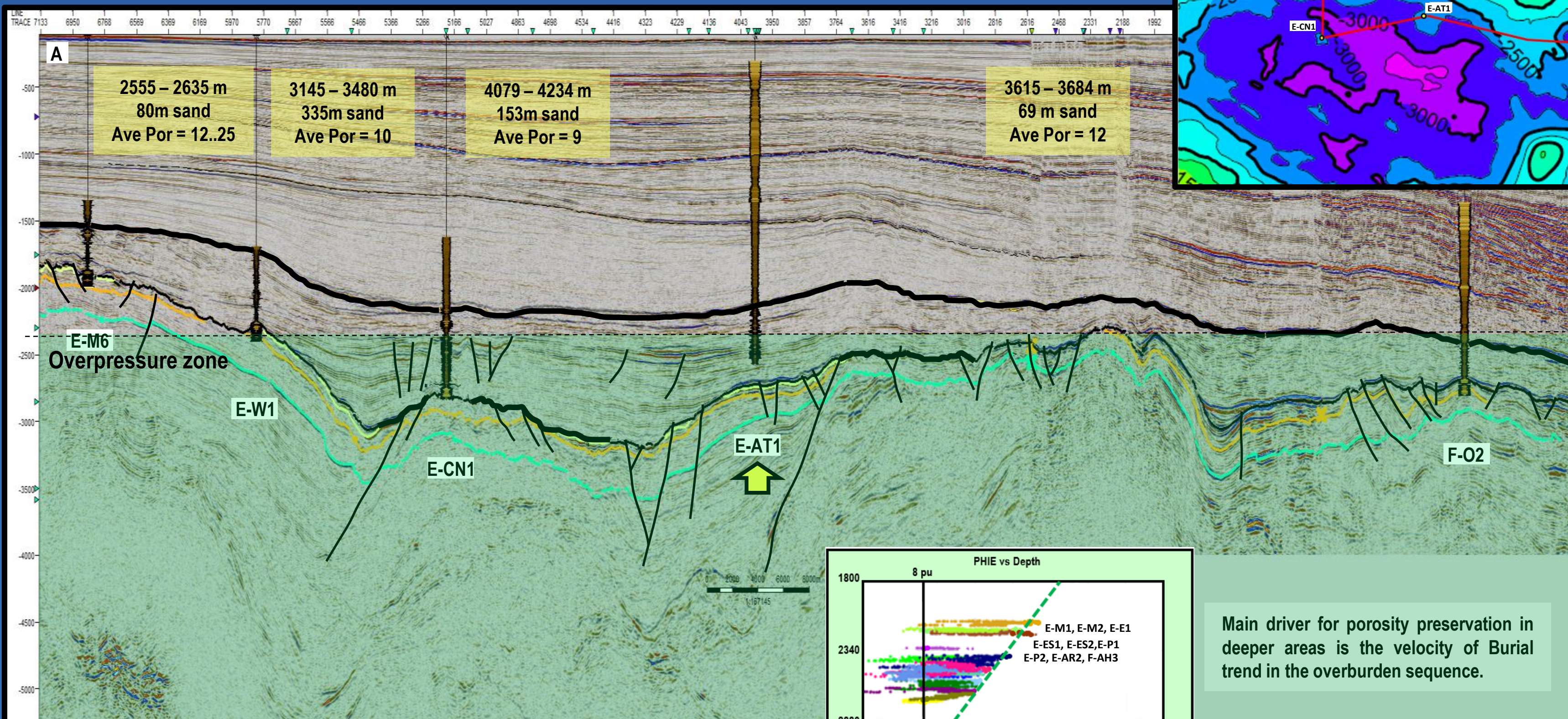


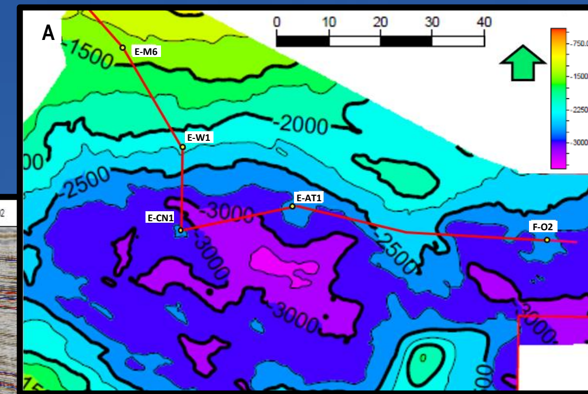
Surface mapping

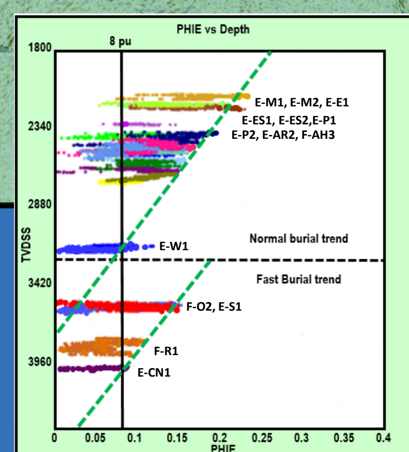




Analogous wells representative of target response

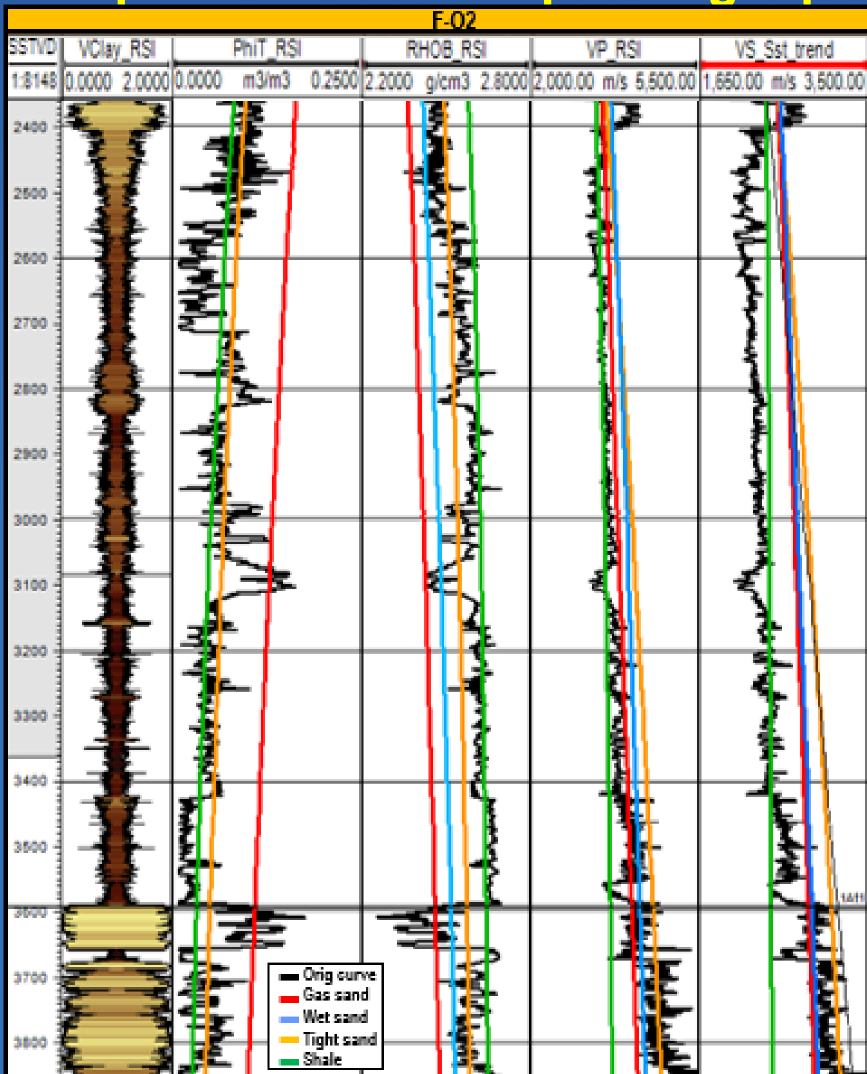






Main driver for porosity preservation in deeper areas is the velocity of Burial trend in the overburden sequence.

3.-Depth-Trends: Predicting elastic (vp,vs, density) depth trends on F-O2 to compute values at depth-target prospect (E-AT≈4000m).



The Athys, 1930 equation is used to parameterize the porosity-depth (z) trends below:

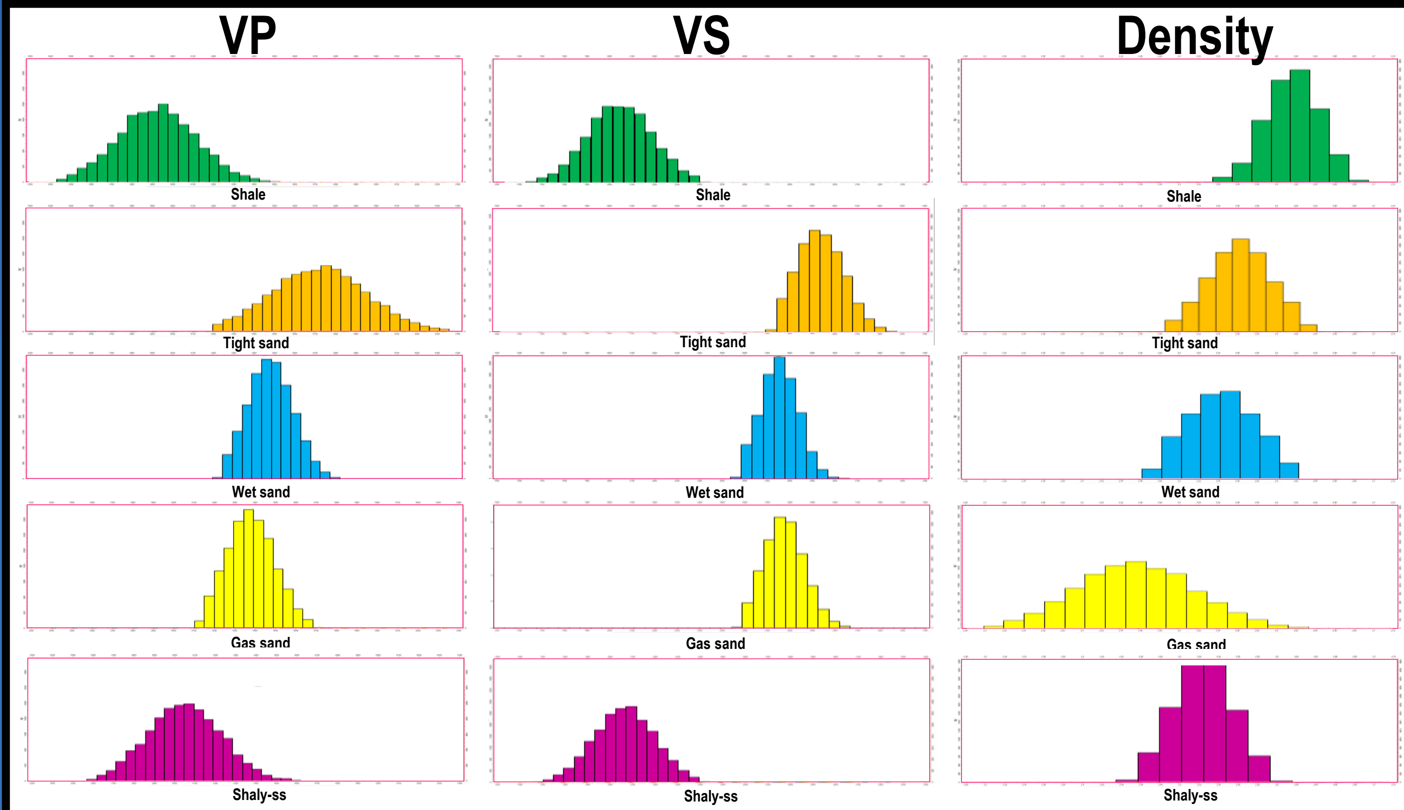
$$\phi = a_0 \exp(-z / z_{ref})$$

a0 = porosity at mudline (constrained to range 0.35 to 0.45 for sand, and 0.35 to 0.75 for shale)
Zref = inflection depth of porosity-depth trend.
z = depth below water bottom

4.-Generate Multi-Gaussian distribution: Histograms of Vp, Vs, density for different lithologies and fluids at the depth target (≈4000m).

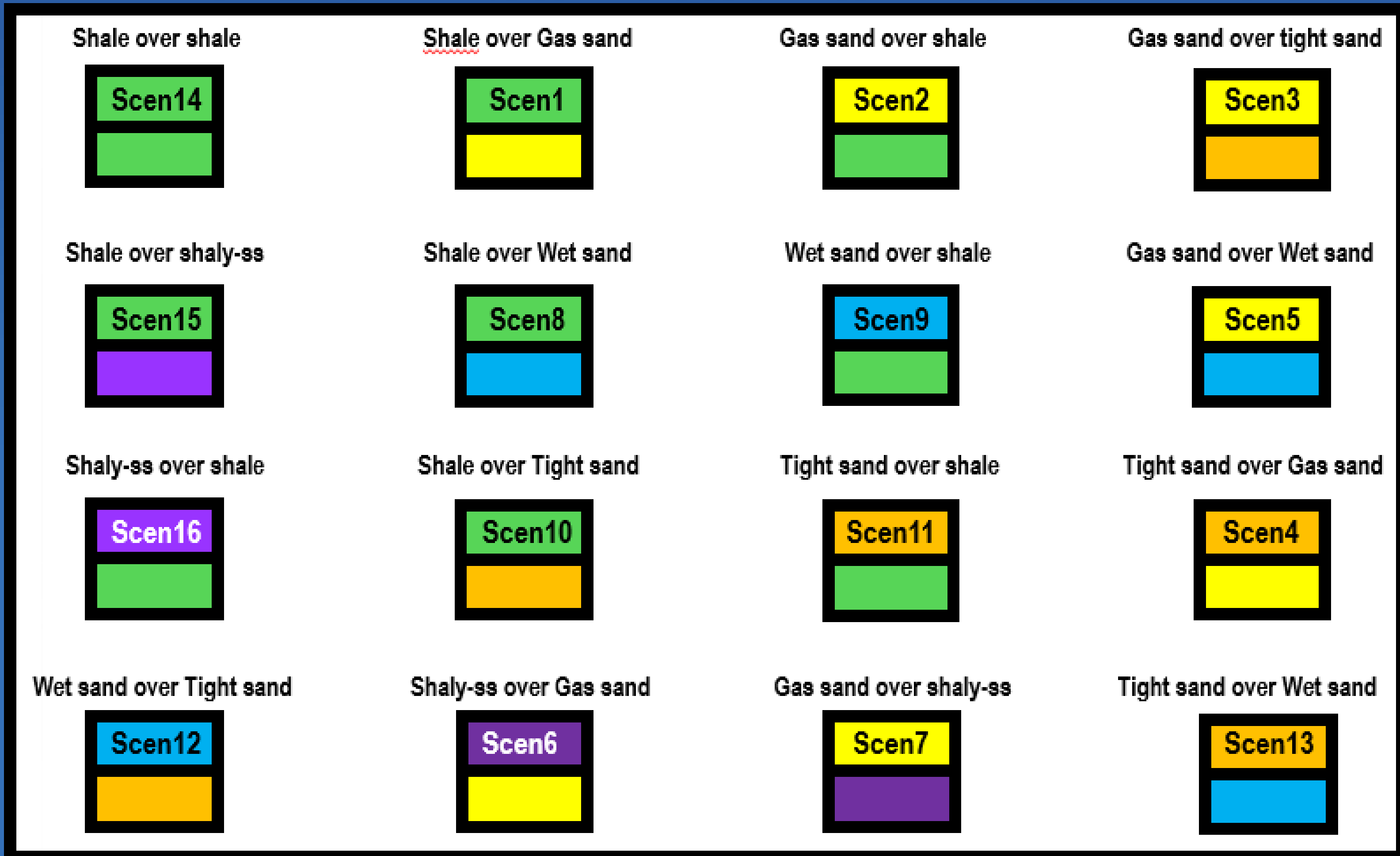
Inputs to build histograms come from depth-trends (mean) and analogous wells (STD, min-max)

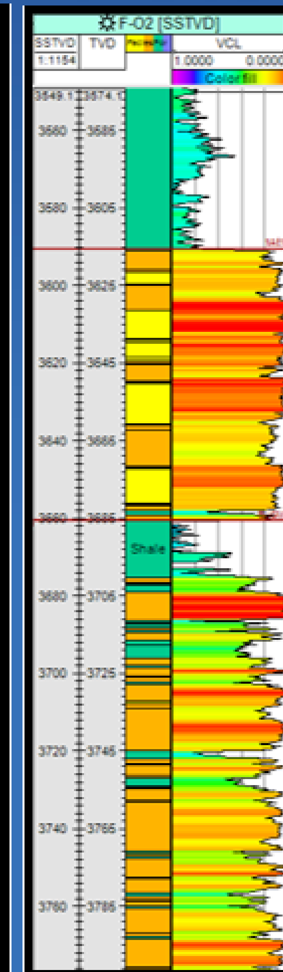
	VP	VS	RHOB
Shale			
Mean	3890.00	2035.00	2.62
Stardard deviation	191.24	150.32	0.03
Minimum	3415.85	1616.82	2.54
Maximum	4484.72	2412.22	2.68
Tight sand			
Mean	4735.00	2945.00	2.61
Stardard deviation	246.10	113.12	0.04
Minimum	4208.99	2744.15	2.52
Maximum	5397.56	3282.15	2.69
Wet sand			
Mean	4490.00	2770.00	2.54
Stardard deviation	122.83	90.89	0.04
Minimum	4242.29	2593.73	2.47
Maximum	4828.57	3093.10	2.62
Gas sand			
Mean	4380.00	2790.00	2.45
Stardard deviation	130.33	98.38	0.06
Minimum	4133.25	2598.74	2.31
Maximum	4709.48	3085.66	2.61
Shaly-ss			
Mean	4050.00	2095.00	2.55
Stardard deviation	191.24	150.32	0.03
Minimum	3905.85	2371.82	2.47
Maximum	4974.72	3167.22	2.61



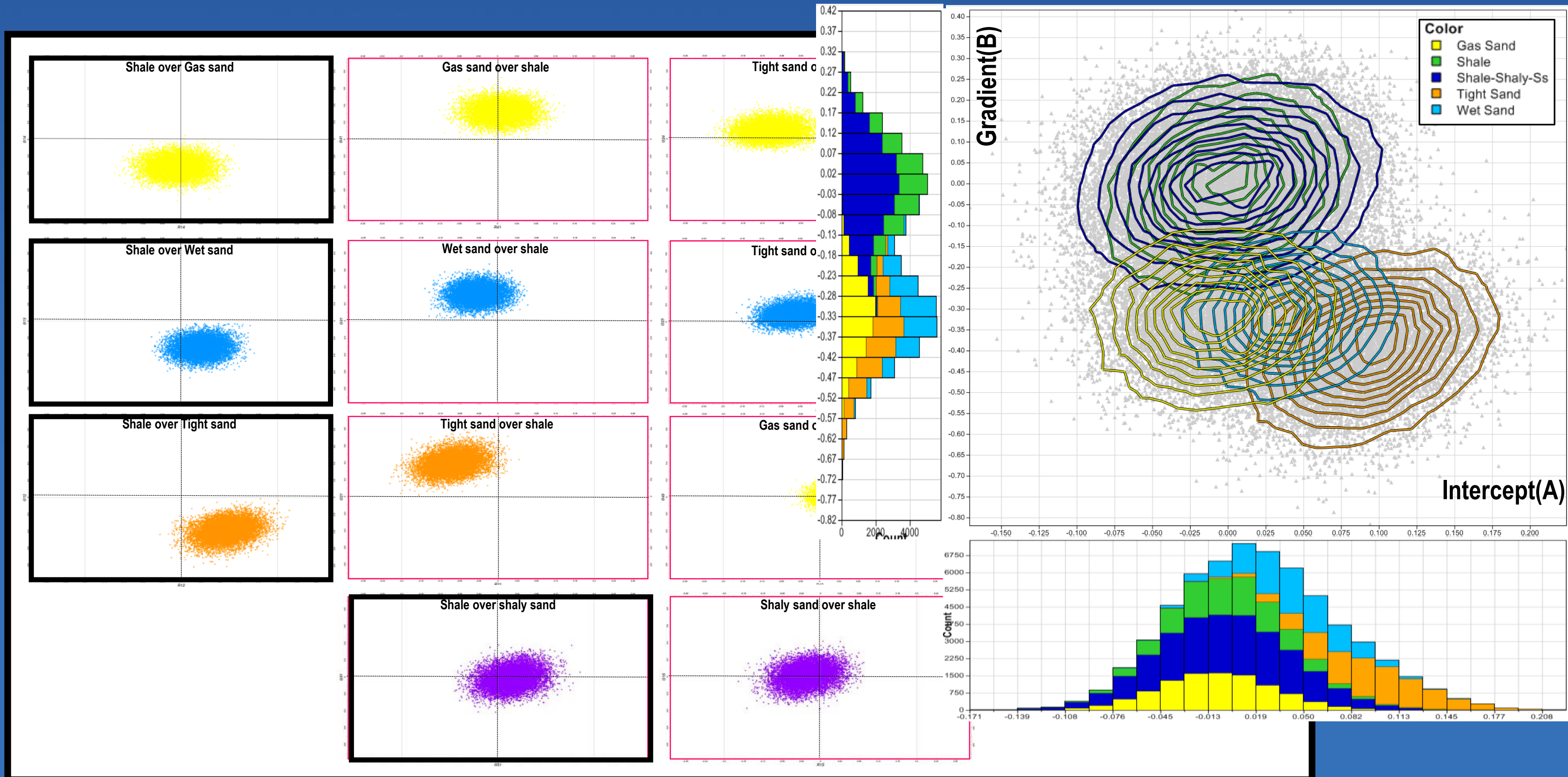
Monte Carlo simulation is used to estimate the distribution of Vp, Vs, and density

5.-Interfaces scenarios: Facies interface scenarios expected for a shallow marine low poro-perm sands environment.





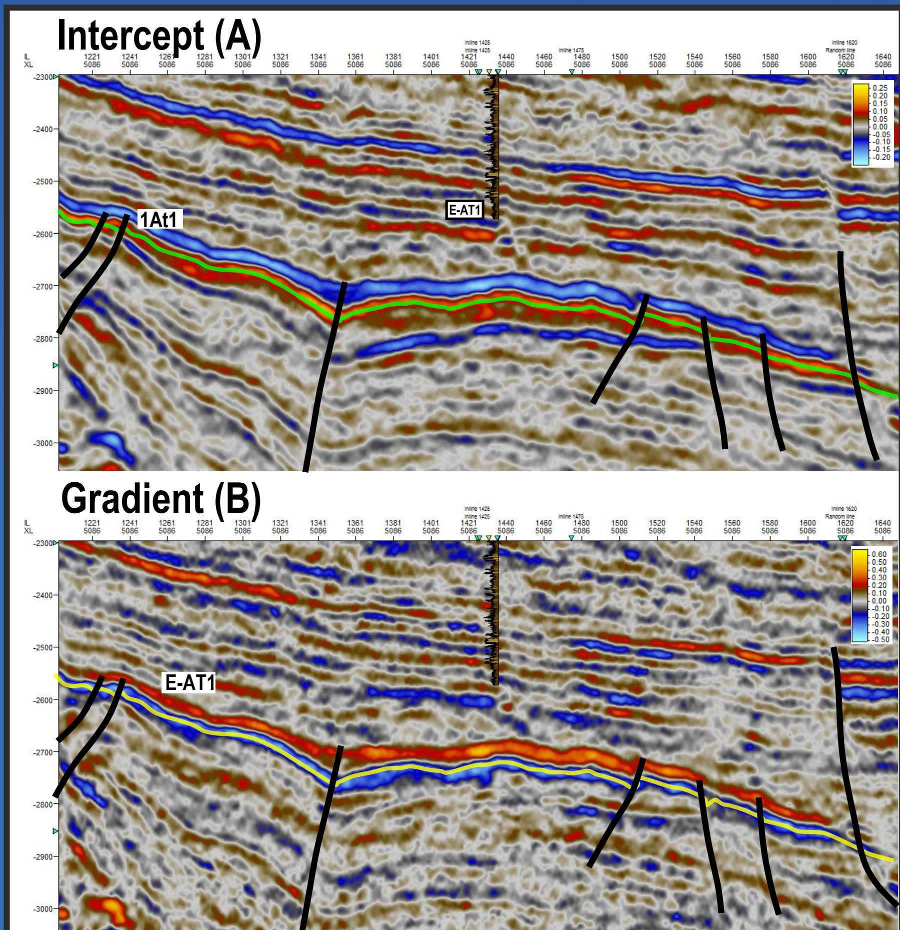
6.-Calculate AVO response and PDFs: Modeled AVO plots of Intercept versus Gradient for different interface scenarios at target depth.

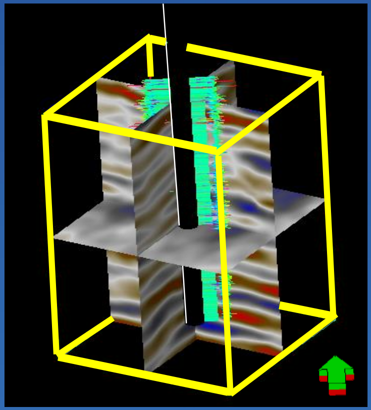


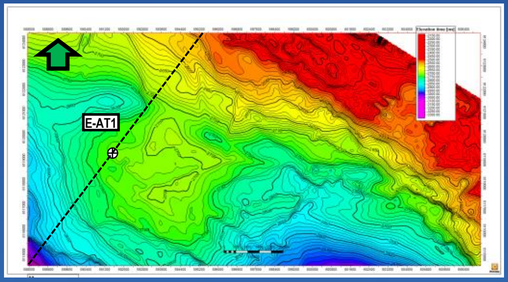
$$A(0)=0.5*((\Delta VP/VP)+(\Delta\rho/\rho))$$

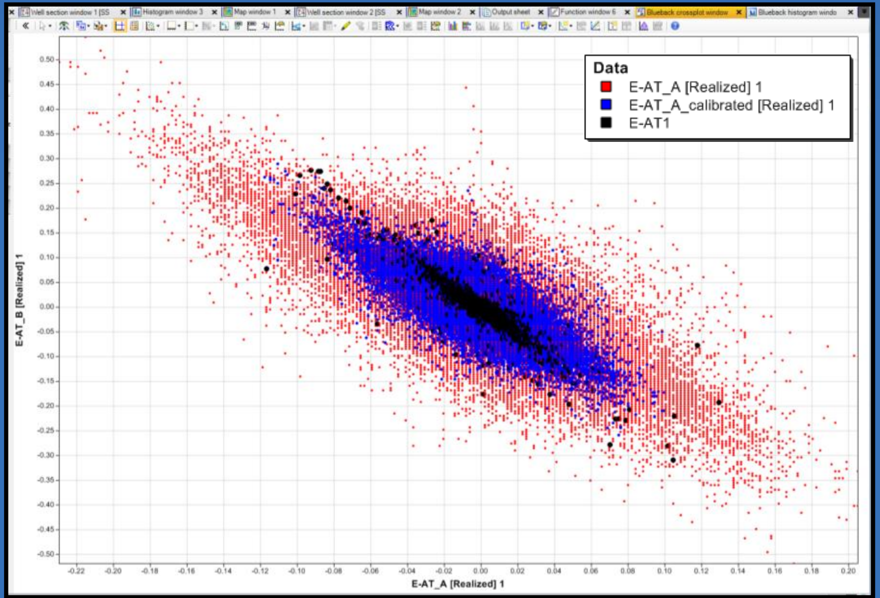
$$B=0.5*(\Delta VP/VP)-2*((VS*VS)/(VP*VP))*((\Delta\rho/\rho)+2*(\Delta VS/VS))$$

7-8.-AVO Attributes Generation: Intercept (A) & Gradient (B) & Calibration to well data









Name	Color	No. points	Min	Max	Delta	Mean	Median	Std. dev.	Variance
E-AT_A [Realized] 1		93500	-0.23	0.20	0.43	0.00	0.00	0.04	0.00
E-AT_A_calibrated [Realized] 1		93500	-0.12	0.10	0.22	0.00	0.00	0.02	0.00
E-AT1		3001	-0.12	0.13	0.25	0.00	0.00	0.02	0.00

9.-AVO Classification: Bayesian classification using calibrated seismic (A-B) and litho-pore fluid PDFs

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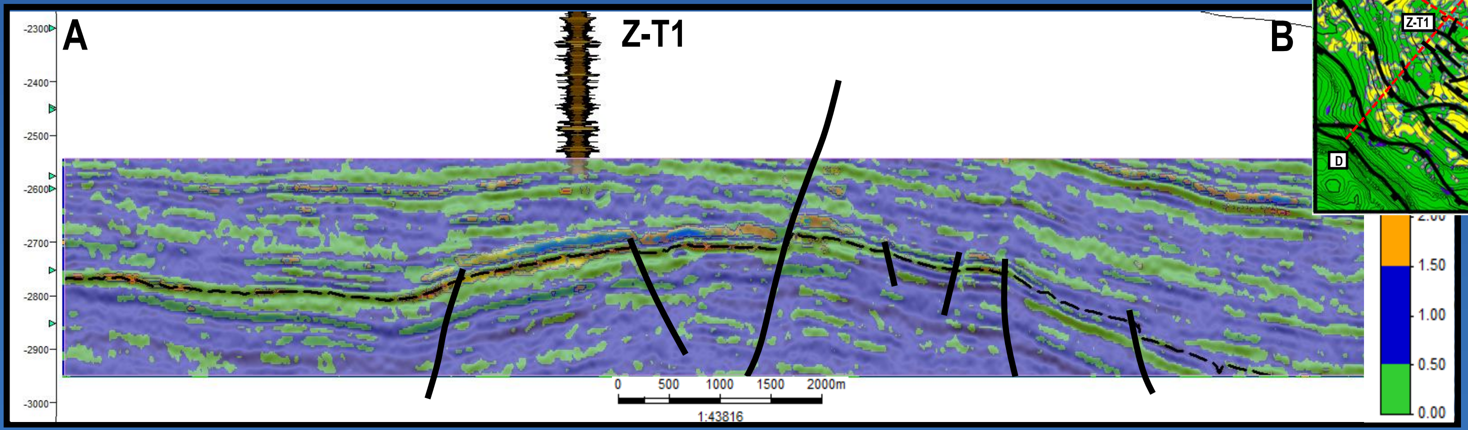

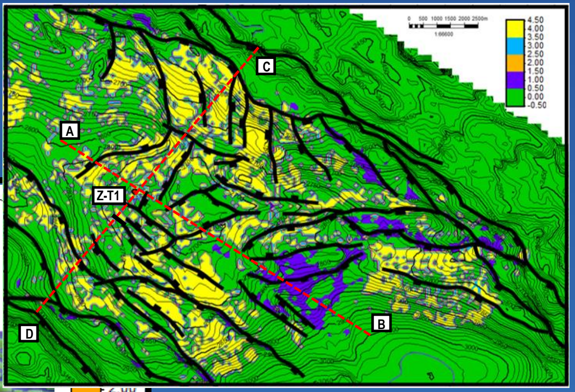

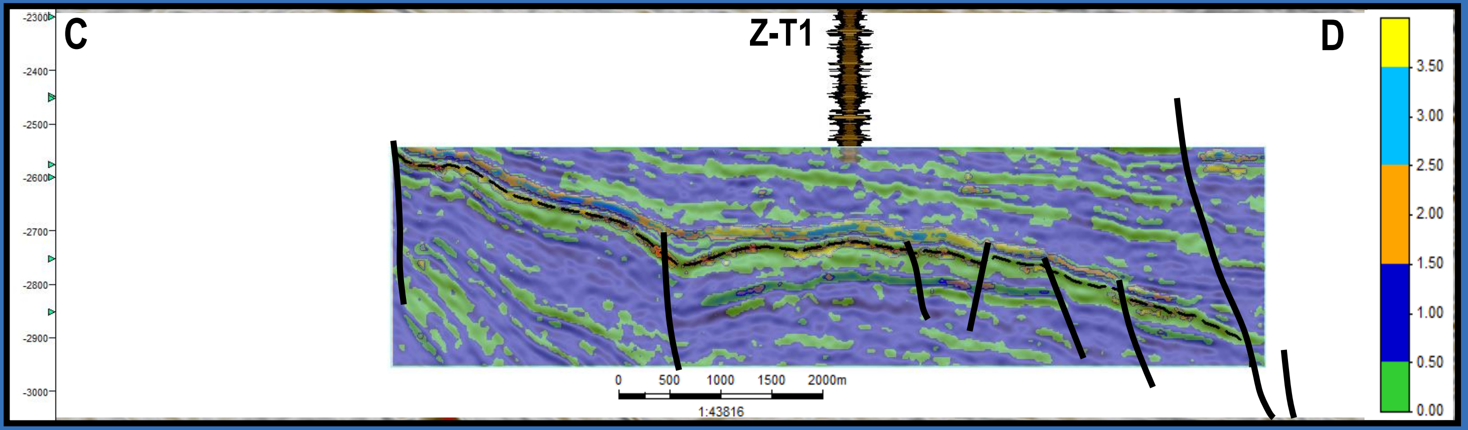

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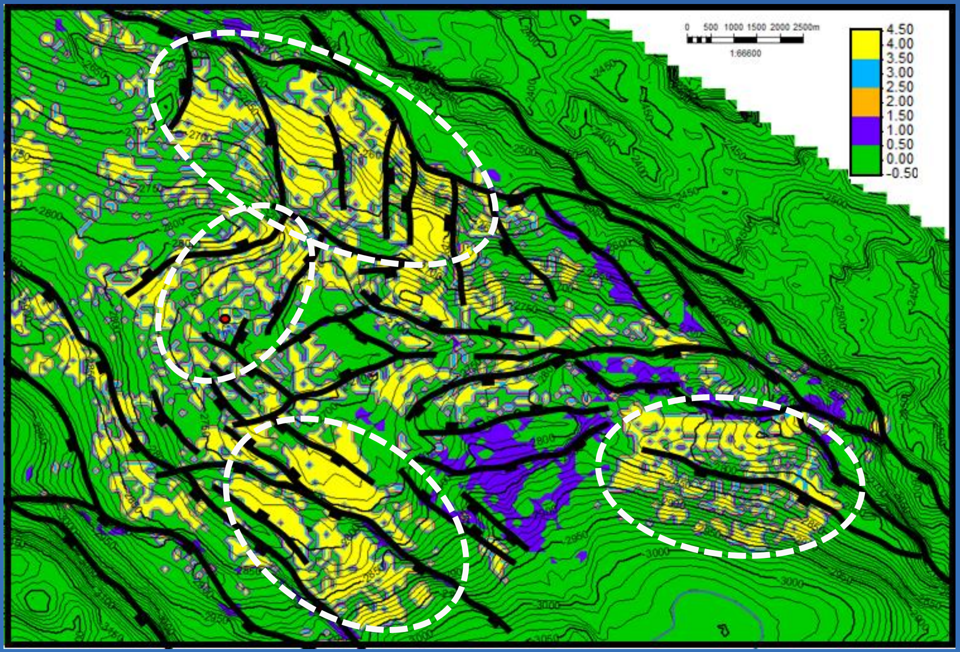
10.-Observations & conclusions:

- This workflow is not well data-dependent and therefore its outcomes are not conditioned for well-seismic tie.
- Porosity (enhanced) at the depth of interest (≈4000m) is expected to be around 10% based on the depth-trend analysis performed in analogous well F-O2.
- Main driver for an efficient AVO classification in this low poro-perm reservoir is controlled by the porosity, so an overlapping between interface clusters in the A-B domain is anticipated. On the other hand, a background PDF sensitivity was made to prevent any values no large enough to be considered a winning facie (false winner). The outcome stabilized at around 5%.
- AVO classification in the reservoir interval still shows some room to discriminate between lithology, and with lesser degree between pore-fluids.

10.-Observations & conclusions II:

- The interpretation of the results show a gas sand facies (yellow) in the anticline's flank where the E-AT1 (central anticline block) was drilled. However, it was noticed the presence of 3 additional sweet-spot zones; One in the southern flank of the structure (2), and two more outside the anticline structure. One toward the north in the foot-wall block (3) and another structural nose isolated in the eastern side of the prospect (4).



- PetroSA
- AAPG
- Gervasio Robles