

# Corporate Presentation

*2D and 3D Seismic from the Block VMM-18,  
Middle Magdalena Basin*



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All figures in US\$ unless otherwise specified.

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# INFO GEOSCIENCES TECHNOLOGY AND SERVICES, HOUSTON TX

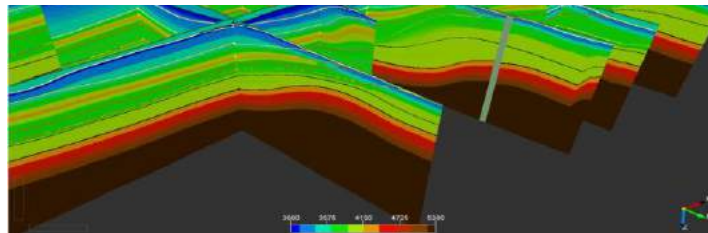
## Seismic Reprocessing VMM-18, 2021

- **Objectives:**

- ✓ Time to depth conversion and derived properties
- ✓ Estimation of elastic properties through inversion of seismic amplitudes and characterization of reservoir properties
- ✓ Seismic reprocessing of the 3D volume
- ✓ Seismic inversion and reservoir estimators in 3D cube

- **Technical Team:**

- ✓ Info Geosciences technicians.: *Miguel Bosch / Raul Colmenares / Adriana Moreno*
- ✓ NSE: *Arturo Lara / Juan F. Arminio*

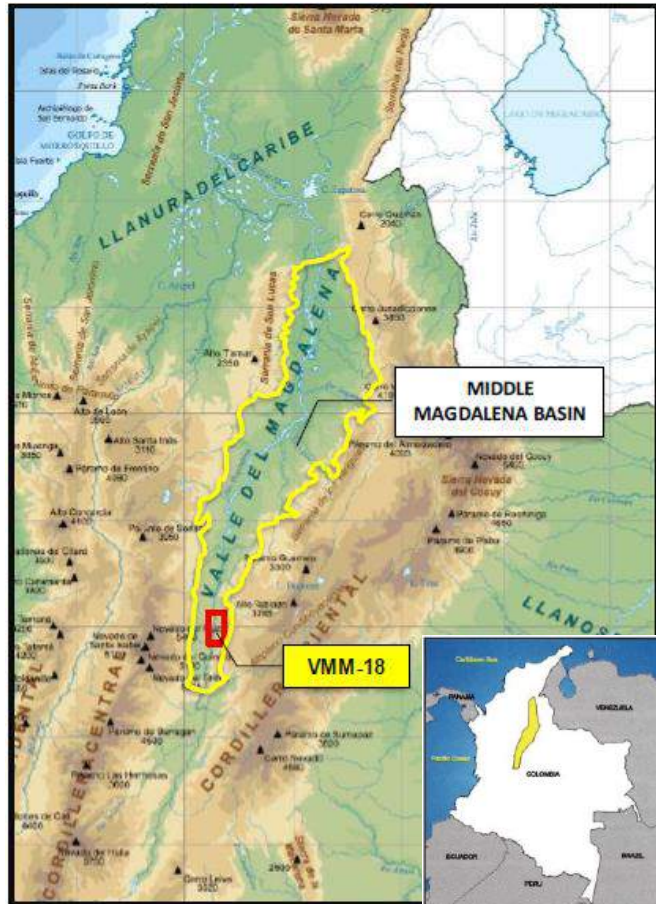


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## **Regional Geology and Location of VMM-18 and seismic and well data**

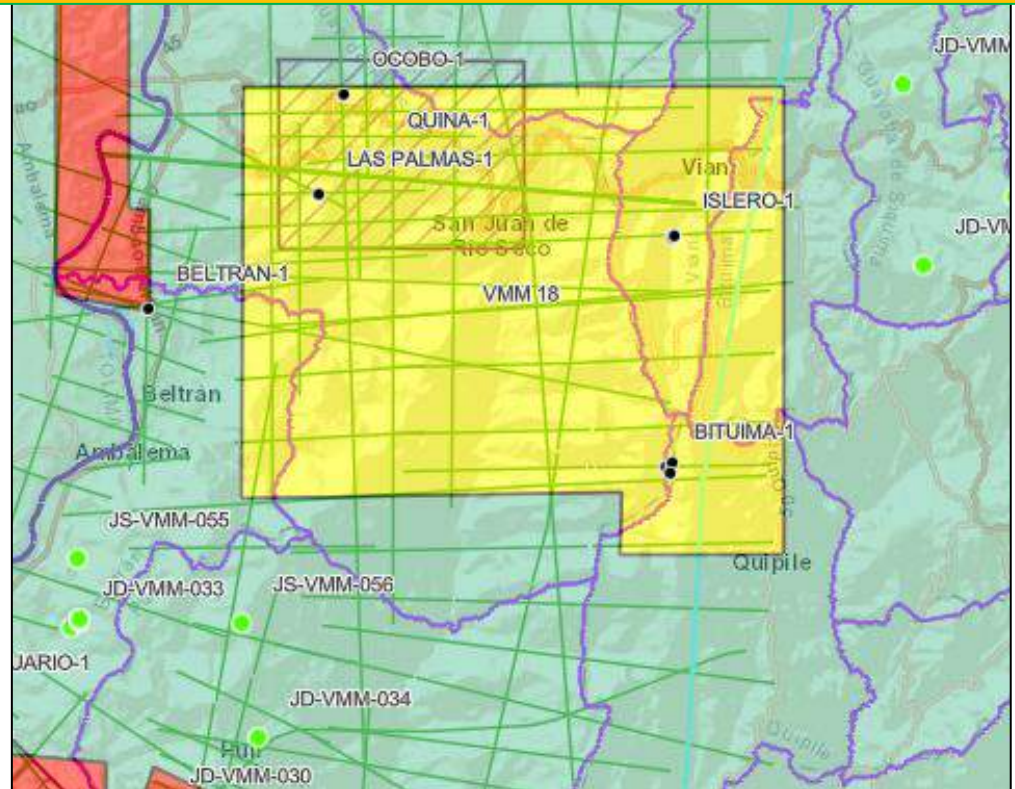


# VMM-18 Location; Seismic & Well data

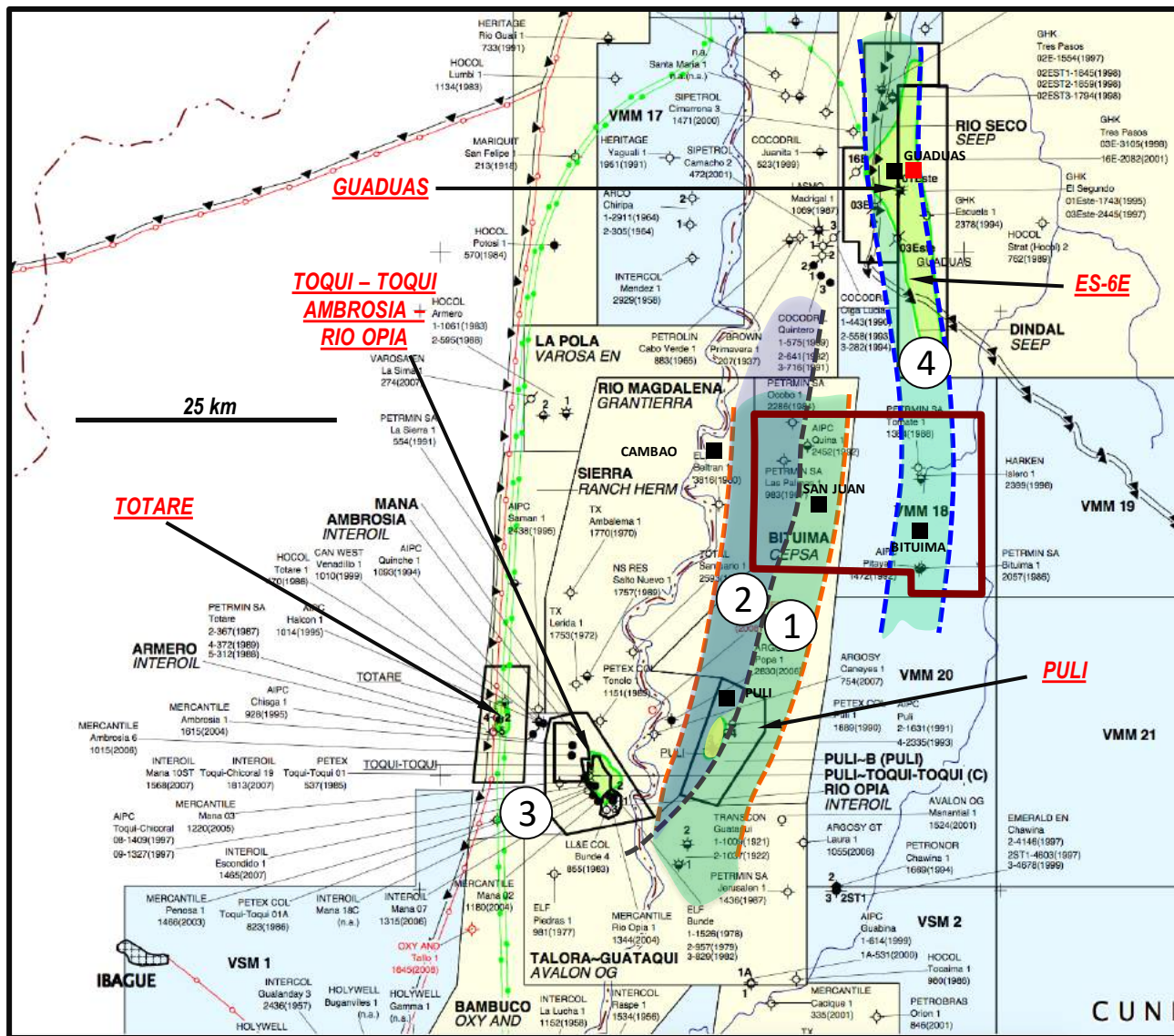


## Seismic reprocessing 2021 database available:

- 25 2D-Seismic lines (~400 km)
- 60 km<sup>2</sup> 3D-cube 2013
- Wells: Quina; Ocobo; Las Palmas; Islero; Beltran; Bituima



# Oilfields, Play Trends and Infrastructure



**Oilfield**

**ALTO MAGDALENA PIPELINE (OAM)**

**GUADUAS DELIVERY POINT**

**TOWN**

## Play trends

- 1 **Puli - type thrust play: light oil in Guadalupe sands**
- 2 **Sub thrust play: light / medium oil in Paleogene sands**
- 3 **Toqui Toqui-type shallow thrusts play medium oil in Tertiary clastics**
- 4 **Guaduas - type heavy and light oil in fractured Cimarrosa carbonates**





# Stratigraphy of the Southern VMM

| EDAD        | UNIDAD                 | LITOLOGIA                              | MAIN LITHOLOGY                        | ENVIRONMENT                       | TECTONIC SETTING                                      | PETROLEUM SYSTEM |
|-------------|------------------------|--|---------------------------------------|-----------------------------------|---|------------------|
| CUATERNARIO | HOLOCENO - PLEISTOCENO | Aluviones, Oolitas, Y. Locales         | CONGLOMERATES                         | ALLUVIAL PLAIN                    |   |                  |
| TERCIARIO   | NEÓGENO                | MIOCENO TEMPRANO A TARDÍO              | CONGLOMERATES, SANDS AND CLAYS        | ALLUVIAL PLAIN                    | MAIN ANDEAN UPLIFT<br><i>Missing: Early - Mid Mio</i> | O                |
|             |                        | OLIGOC. TARDÍO - MIOCENO TEMPRANO?     |                                       |                                   |   |                  |
|             | PALEÓGENO              | Fm. Santa Teresa                       |                                       |                                   |   |                  |
|             |                        | Esf5                                   |                                       |                                   |   |                  |
|             |                        | Esf4                                   |                                       |                                   |   |                  |
|             |                        | Fm. San Juan de Río-seco               |                                       |                                   | EARLY ANDEAN UPLIFT                                   |                  |
|             |                        | Esf3                                   |                                       |                                   |   |                  |
|             |                        | Esf2                                   | CLAY, MUDS & SUBORD. SILTS            | FLOODPLAIN                        |   | S                |
|             |                        | Esf1                                   | CONGLOMERATIC TO MEDIUM SANDS & CLAYS | FLUVIAL PLAIN: CHANNEL & OVERBANK |   | R                |
|             |                        | Esf3                                   |                                       |                                   |   | O                |
|             |                        | Esf2                                   |                                       |                                   |   | S                |
|             |                        | Esf1                                   |                                       |                                   |   | R                |
| CRETÁCICO   | SUPERIOR               | Eocene - OLIGOC. TEMPRANO?             |                                       |                                   |   |                  |
|             |                        | Fm. Hoyón                              |                                       |                                   |   |                  |
|             |                        | Esf3                                   |                                       |                                   |   |                  |
|             |                        | Esf2                                   |                                       |                                   |   |                  |
|             | INFERIOR               | Maastricht. TARDÍO - PALEOCENO         | MUDSTONE, CLAY, SOME COALS & SILTS    | COASTAL PLAIN                     | <i>Missing: L. Paleocene Mid Eocene</i>               | S                |
|             |                        | Fm. Seca                               |                                       |                                   |   |                  |
|             |                        | Maastricht. Fm. Monserrate / Cimarrona | SANDSTONE (W) CARBONATES (E)          | SHALLOW MARINE                    | CORDILLERA CENTRAL UPLIFT                             | R R              |
|             |                        | Fm. Buscavida                          |                                       |                                   |   |                  |
|             |                        | CON. TAR. - CAMPAN.                    |                                       |                                   |   |                  |
|             |                        | Gr. Olini                              |                                       |                                   |   |                  |
|             |                        | TURON. - CONIAC. TEMPRANO?             |                                       |                                   | BACK ARC BASIN  | S S              |
|             |                        | Fm. La Frontera                        |                                       |                                   |   |                  |
|             |                        | Fm. Simijaca                           |                                       |                                   |   |                  |
|             |                        | Fm. Hiló                               |                                       |                                   |   |                  |
|             |                        | Fm. Capotes                            |                                       |                                   |   |                  |

Almacigo Esj2 clay prone local member






Oligocene fluvial Doima sands equivalent to San Juan's Armadillos basal unit are effective reservoir in Toqui - Toqui

Hoyon's local Agua Clara mudstone member  
Eocene fluvial Chicoral sands equivalent to basal Hoyon (Cambao) are effective reservoir in Toqui - Toqui

Seca fm. regional shale unit

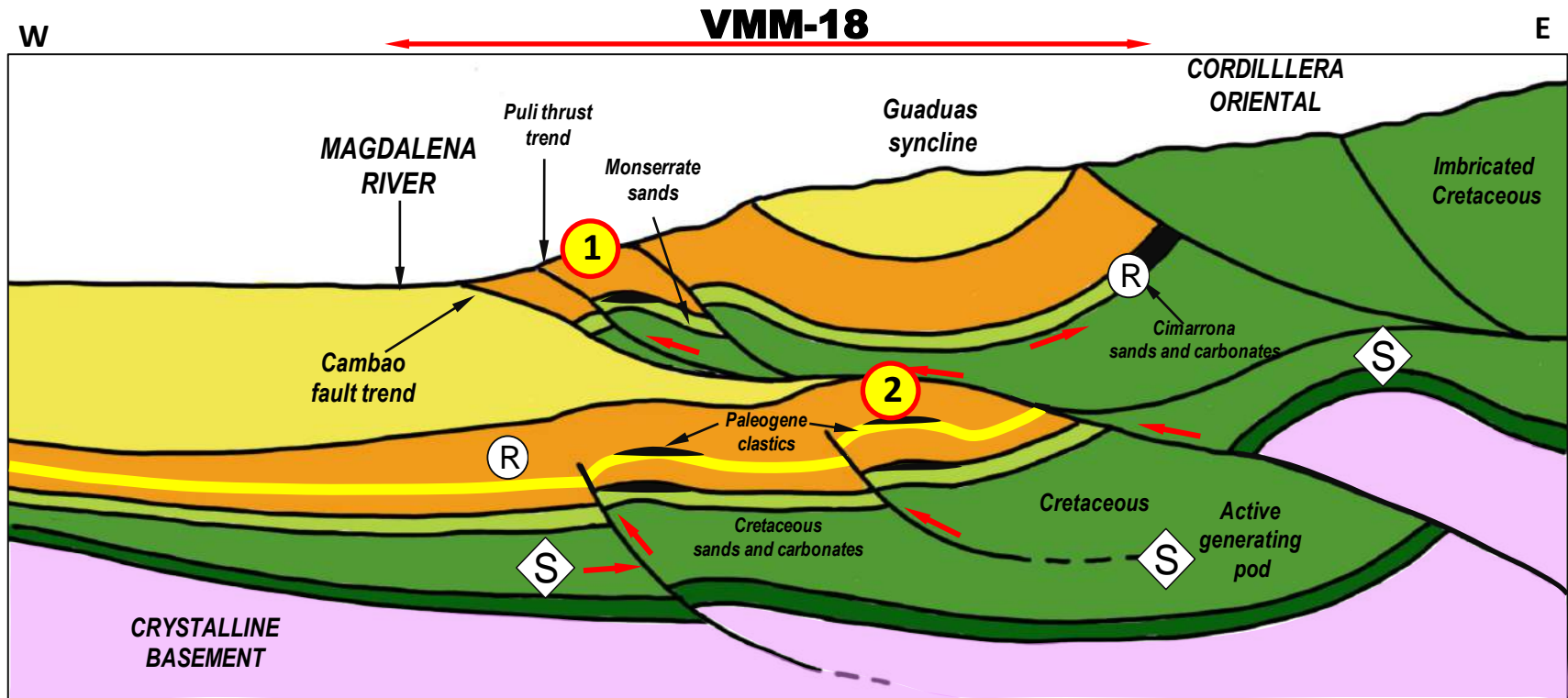
Monserate sand reservoir in Puli and Quintero fields  
Cimarrona carbonate reservoir in Guaduas

## PETROLEUM SYSTEM

-  OVERBURDEN
-  SEAL
-  RESERVOIR (LIMESTONE)
-  RESERVOIR (SANDSTONE)
-  SOURCE



# Structure & Play concepts of the Southern VMM



*VMM-18 Block is an attractive asset with three main prospects and leads located in the Puli and Dindal-Rio Seco proven hydrocarbon trend of the VMM basin*

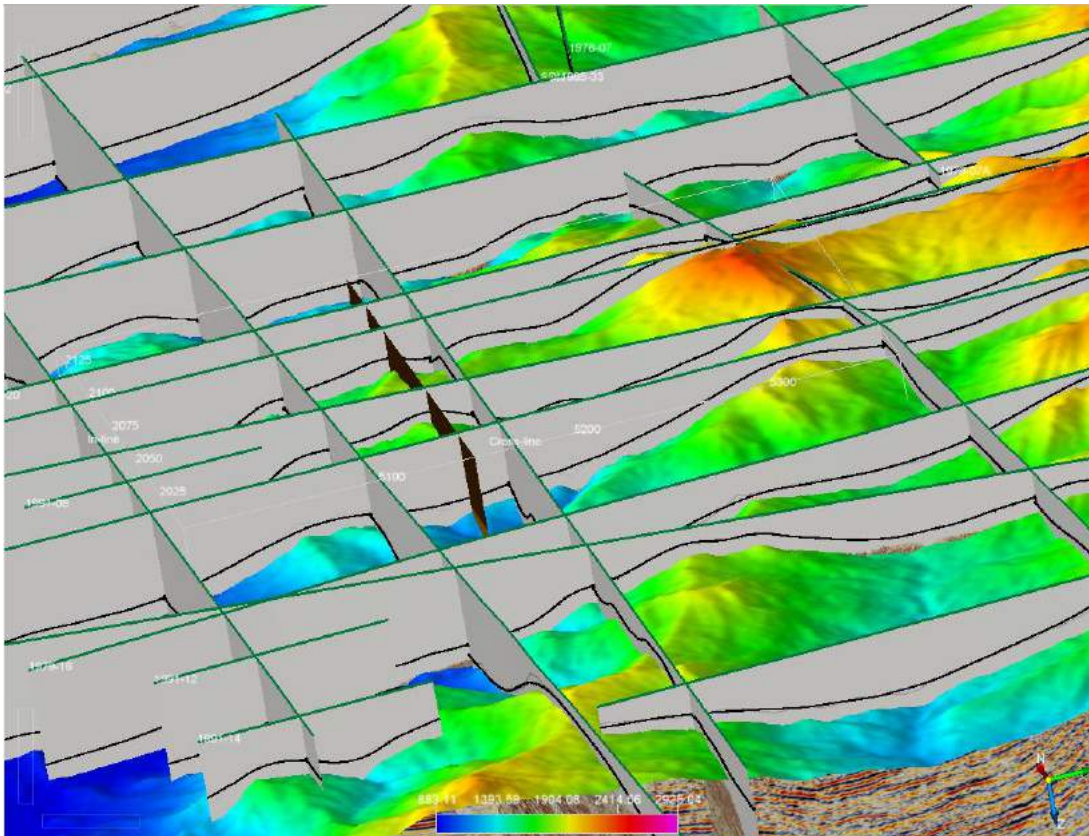
- 1** Hercules & Hercules Norte Prospects ➡ Puli-type thrust play (light oil in Guadalupe sands)
- 2** Cigarra Prospect ➡ Sub thrust play (light/medium oil in Paleogene sands)

## Seismic Reprocessing activities

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- ✓ Review and upload of seismic data.
- ✓ Review and treatment of well data.
- ✓ Review of vertical adjustments
- ✓ Interpretation of relevant horizons for the elaboration of the seismic velocity model.
- ✓ Elaboration of the prior model of compressional wave velocities ( $V_p$ ).
- ✓ Characterization of elastic, density and reservoir properties based on available well information.
- ✓ Elaboration of the prior model of shear wave velocity ( $V_s$ ) and mass density.
- ✓ Transformation of the vertical dimension from time to depth of the seismic.
- ✓ Seismic reprocessing of the 3D volume, starting from field data until PSTM migration.
- ✓ Inversion of data from 2D seismic lines and 3D seismic volume for the estimation of elastic properties and mass density.
- ✓ Estimation of lithology and porosity.
- ✓ Analysis of seismic sensitivity to fluids.
- ✓ Time-to-depth transformation of elastic and reservoir properties.

## Seismic 2D: vertical adjustment



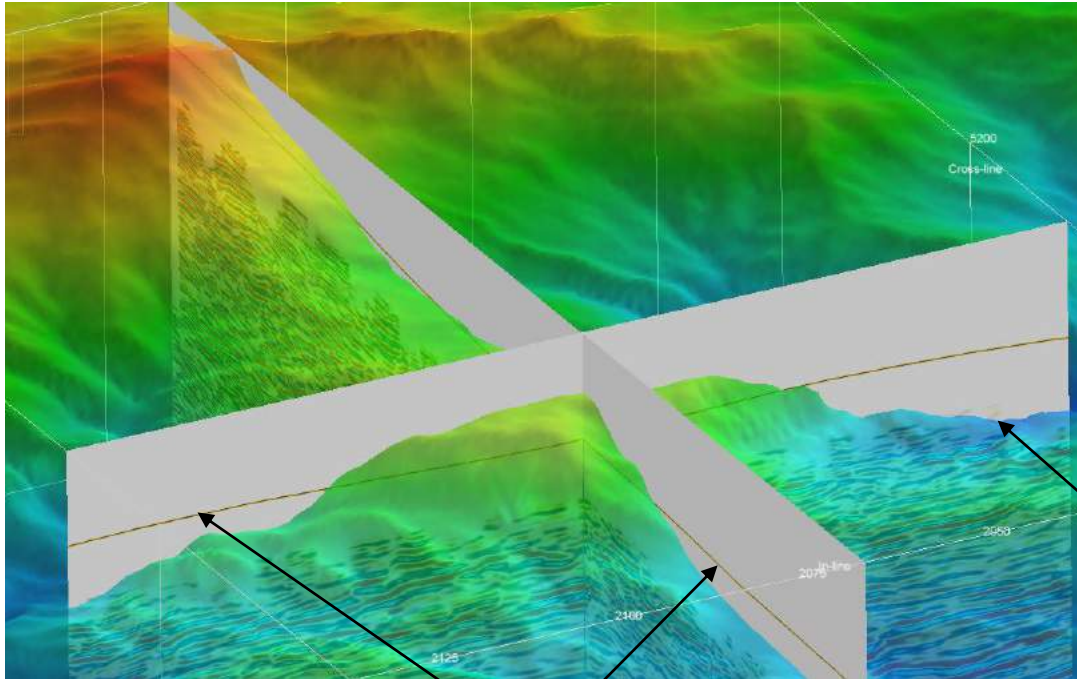
Landmark in seismic is not consistent with elevation map

- The nominal datum of 1800m-msl, the nominal replacement velocity of 3400 m/s are inconsistent with the actual elevations of the wells, seismic surface and digital elevation map of the area.

The seismic sections in time and depth have a vertical position difference with the elevation map, which required a detailed study, analysis and correction.



# 3D Cube Vertical Adjustment



Terrain elevations in the 3D cube show two problems:

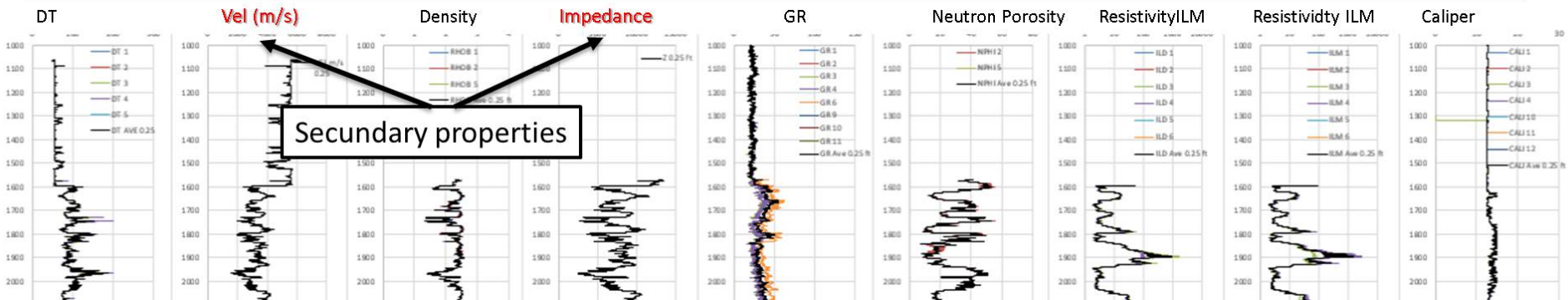
- The surface elevation profile was exaggeratedly smoothed for seismic processing
- There is an average downward shift of the actual elevation map.

On average the true elevations are displaced down from respect to the used in the processing

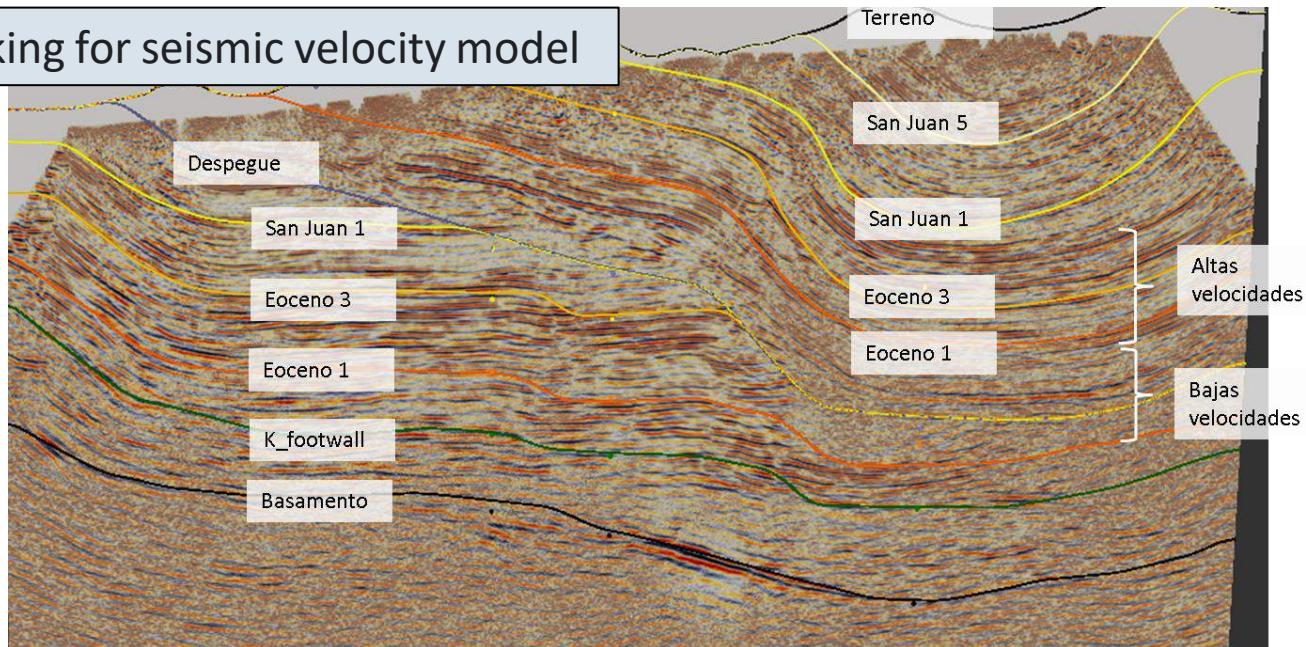
Surface elevation is very smoothed compared to the real one

# Seismic Reprocessing Process

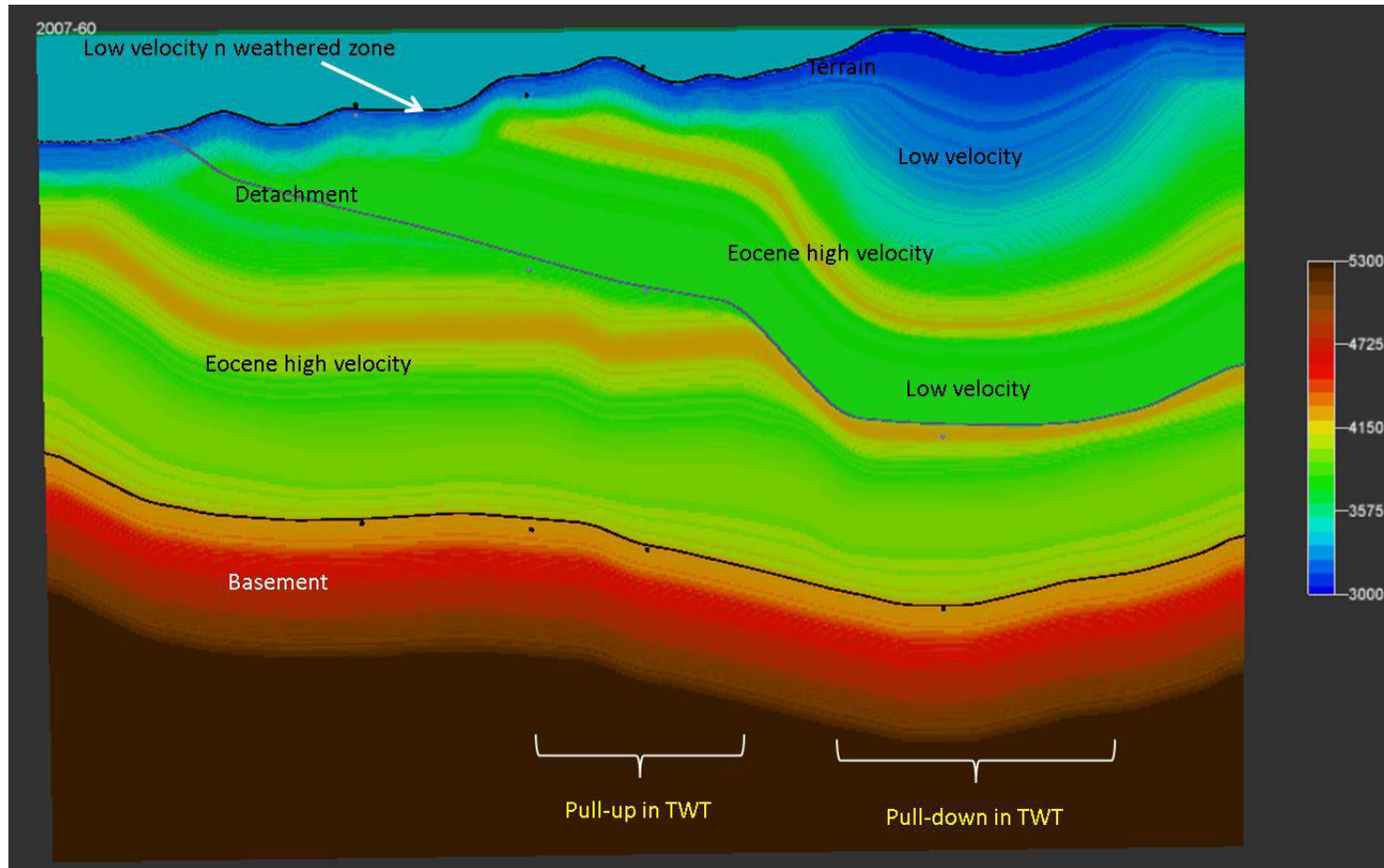
## Well data compilation & treatment



## Horizon picking for seismic velocity model



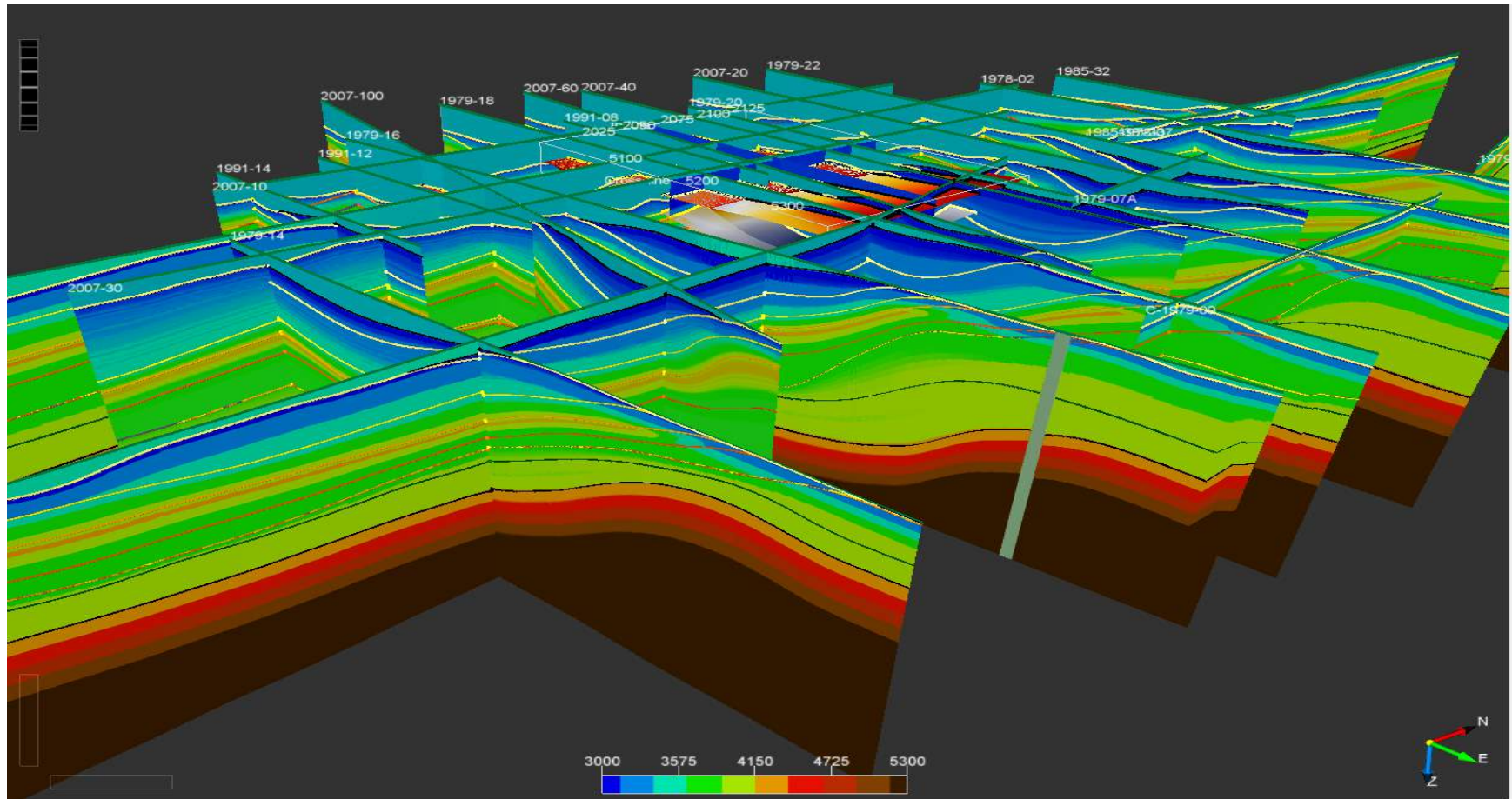
# Seismic Velocity Model 2D-3D





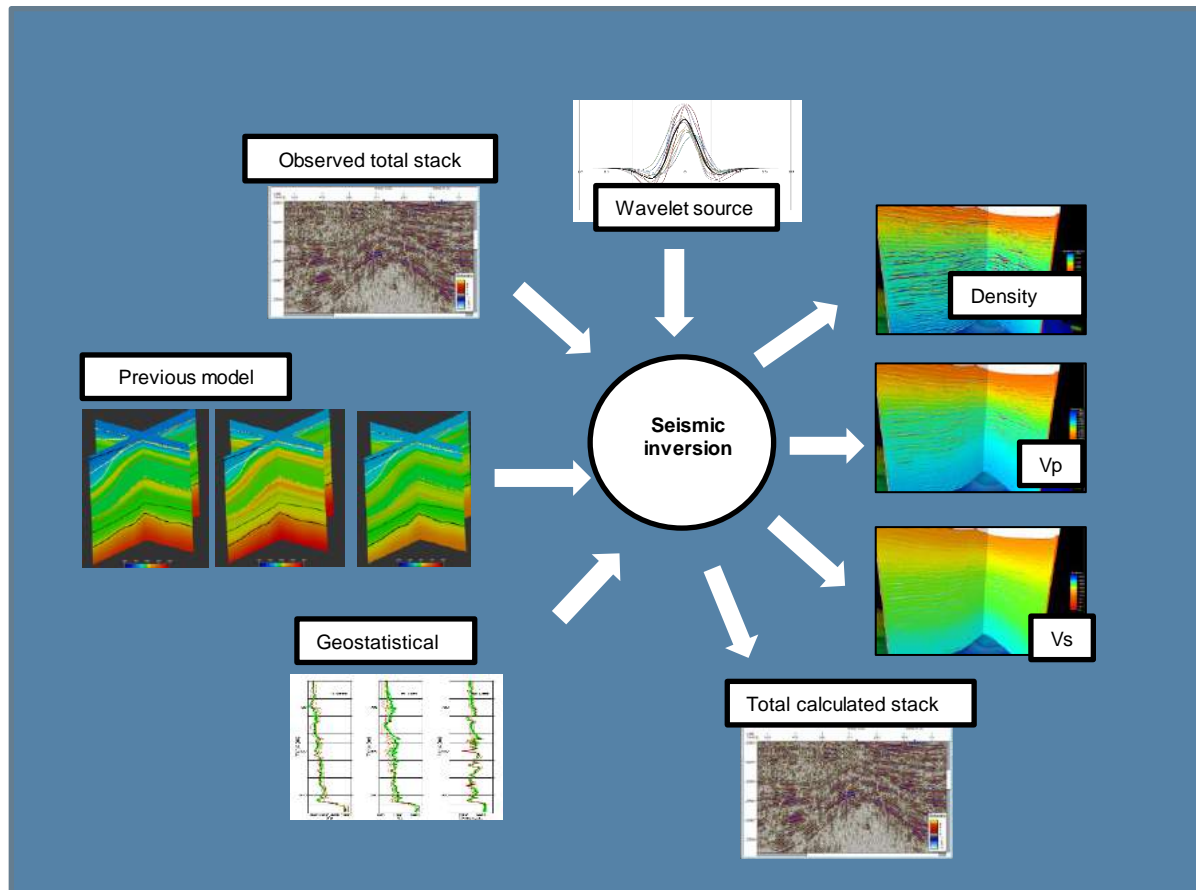
# Seismic Velocity Model Extrapolation

## 2D & 3D seismic integrated velocity model



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# Elastic Inversion of Seismic Data

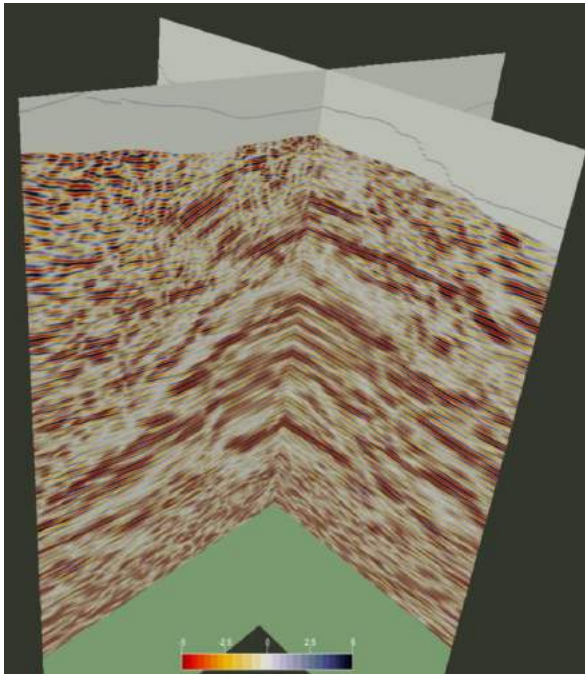


The seismic inversion estimates the elastic parameter models that explain the reflectivity in total stacking, or various stacks by incidence angle ranges. The seismic calculated from the estimated model reproduces the observed seismic, except for residuals due to noise or anomalous amplitudes of the processing. The inversion was calibrated by validating the source wavelet in pilot tests, and the spatial covariance of the properties in the well was characterized

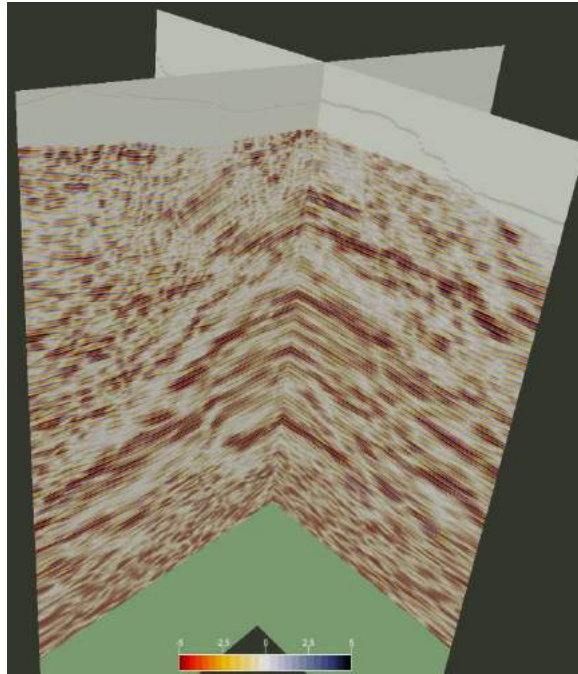


# Seismic inversion Vp, Vs & Density (3D)

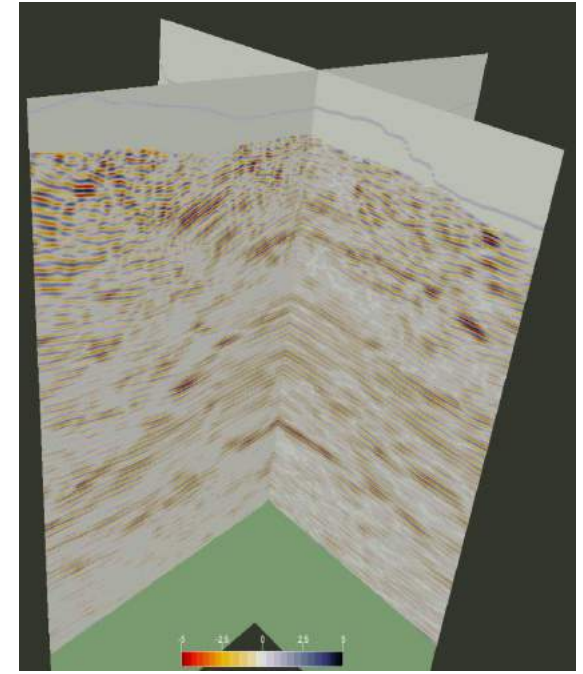
Observed seismic



Calculated seismic



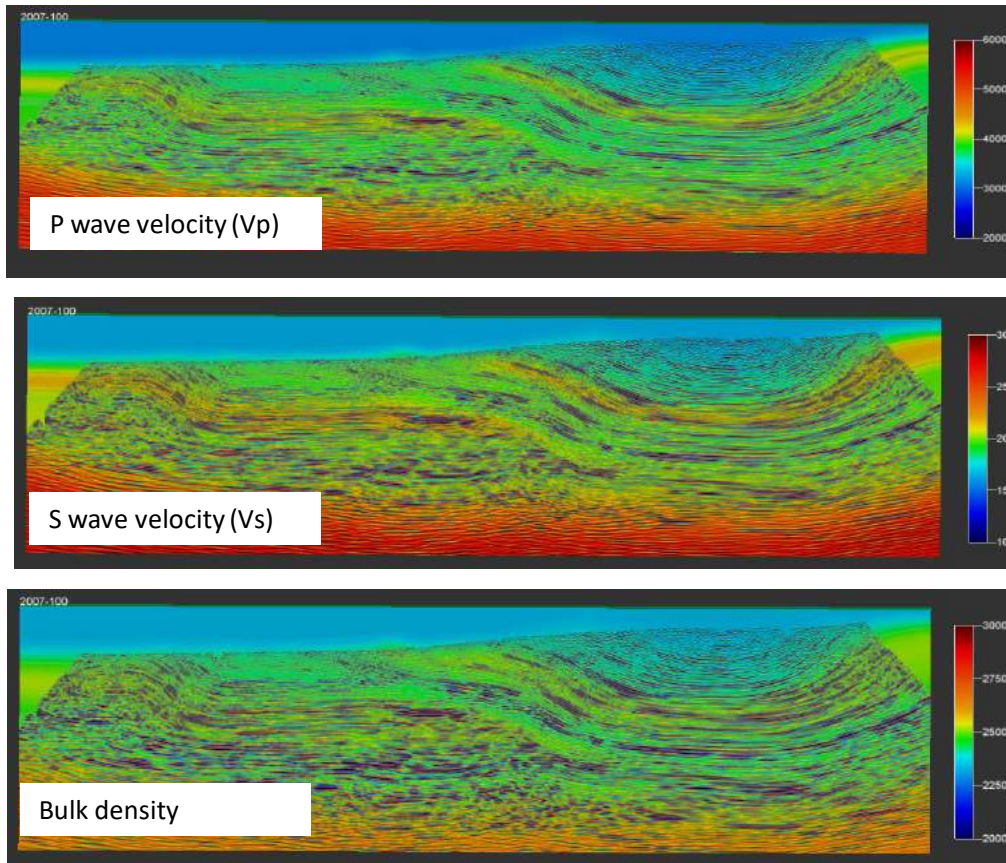
Residual seismic



The seismic calculated from the estimated properties reproduces the observed seismic, leaving noise and anomalous amplitudes in the residue.

A source wavelet with a dominant frequency of 35Hz and zero phase in SEG standard polarity was used - positive impedance contrasts produce negative reflections

# Seismic Inversion - Estimated Properties

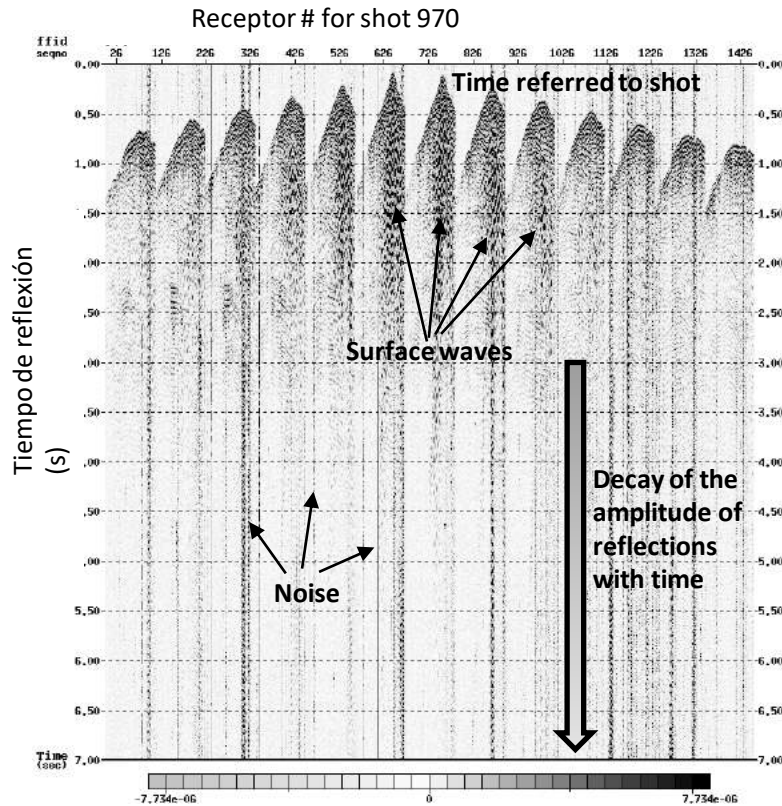


The seismic inversion technique allows estimating the elastic properties of the medium that explain the observed seismic reflections. The reflectivity is calculated by the well-known Zoeppritz formula; an advanced estimation algorithm is used taking into account the previous information on the elastic properties and the source seismic wavelet.

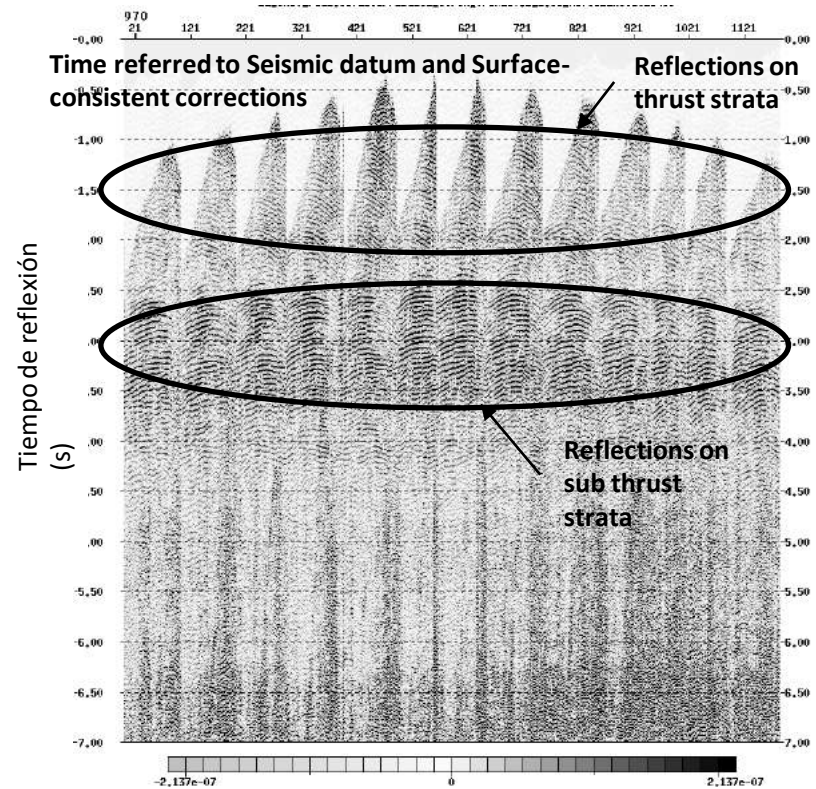


# Pre-stack Signal Enhancement Process

a) Raw shot example



b) After pre-stacking process

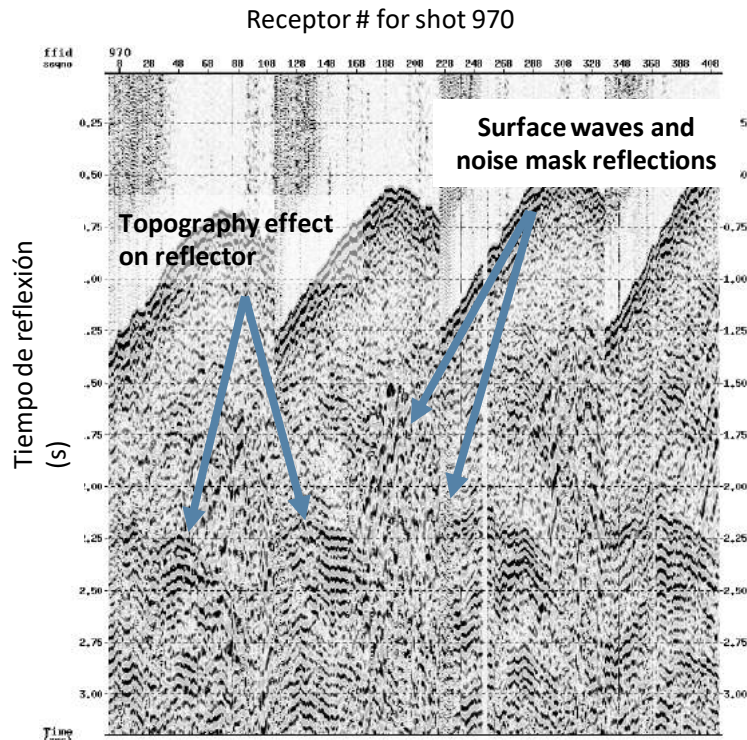


Pre-stacking data preparation in common shot domain corrects for time shifts due to surface and retains the signal from primary reflections while attenuating other recorded components: such as surface waves and ambient noise.

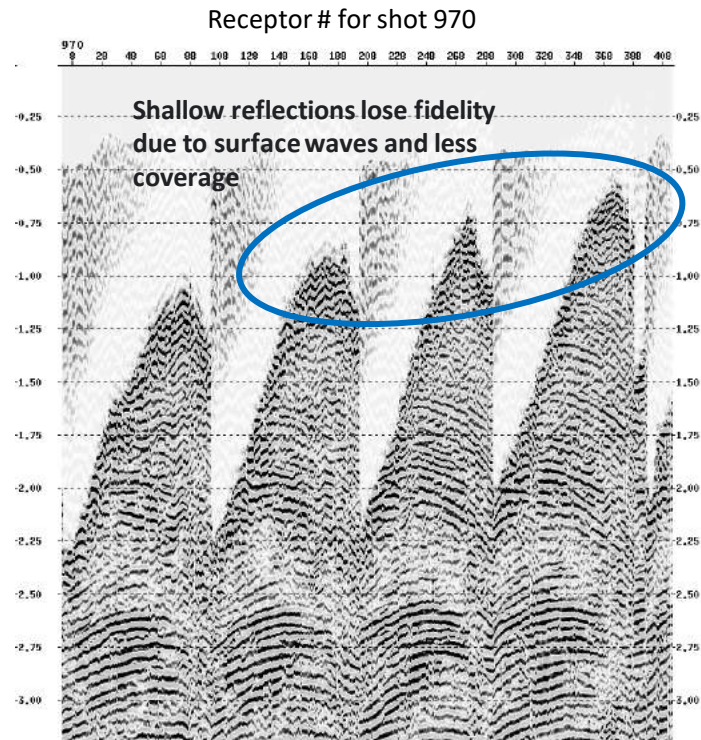


# Pre-stack Signal Enhancement Process

a) Raw shot example

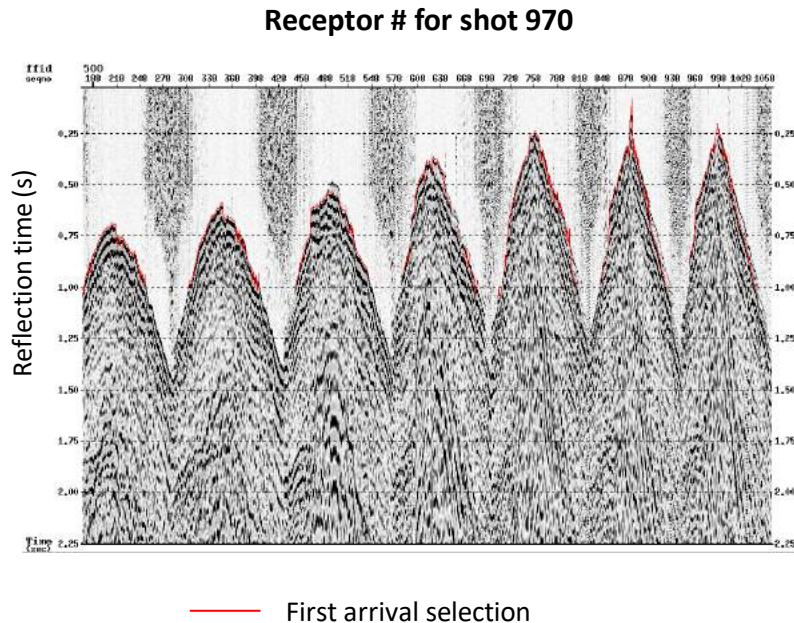


b) After pre-stacking process



Pre-stacking data preparation in common shot domain corrects for time shifts due to surface and retains the signal from primary reflections while attenuating other recorded components: such as surface waves and ambient noise.

# Time Correction for Terrain Elevation and Shallow Layer Velocities



An algorithm based on the energy arrival time is used for the automatic selection of the first arrivals for all shots.

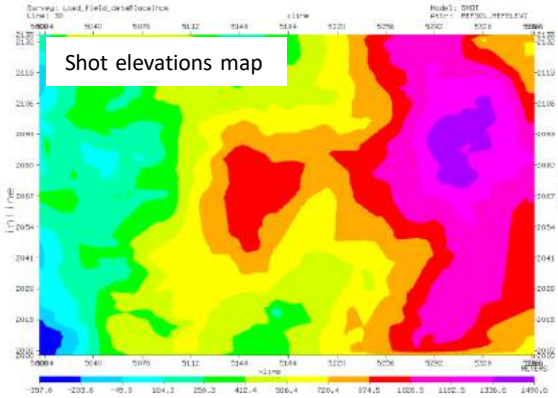
This selection is the basis for a refraction analysis that allows estimating the velocities of the first two layers of the soil and removing effects close to the source and receiver.

These first arrivals, together with the data of elevations and positions of receivers and shots are used for the joint estimation of the following time corrections:

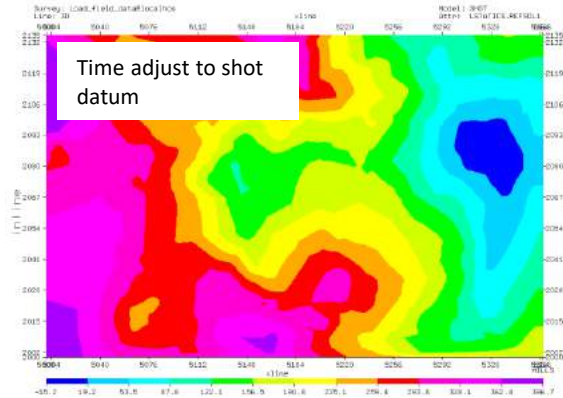
- By receiver elevation
- By elevation shot
- By receptor soil layer
- Per ground layer shot

# Time Correction for Terrain Elevation and Shallow Layer Velocities

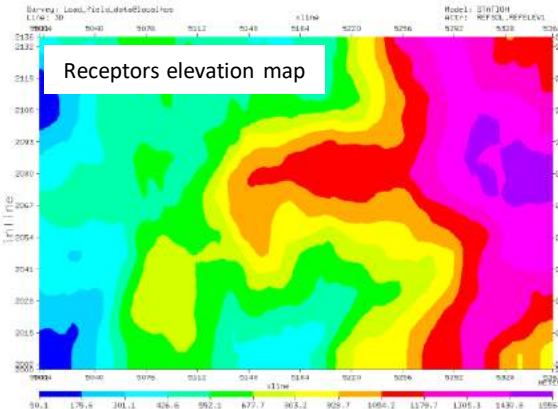
Shot elevations map



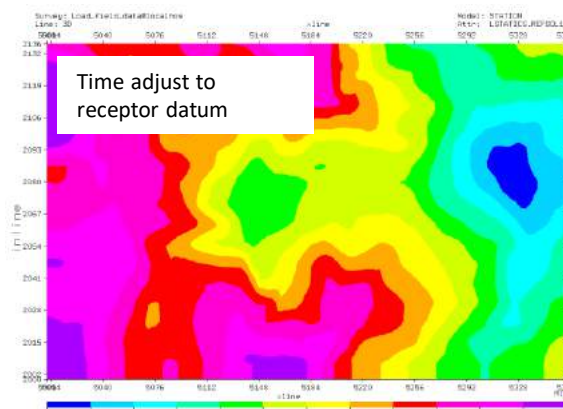
Time adjust to shot datum



Receptors elevation map



Time adjust to receptor datum



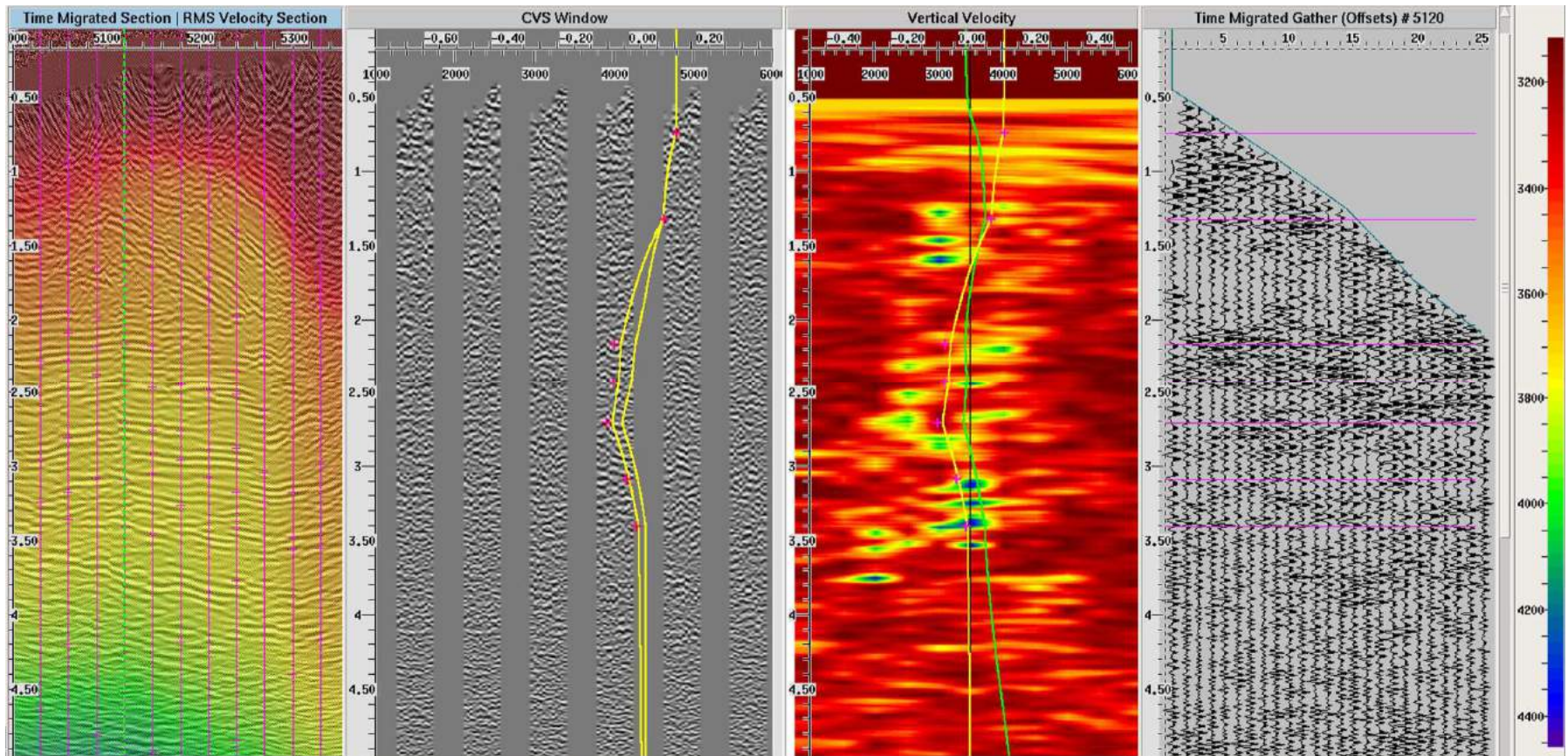
The elevations of receivers and shots to the seismic datum are calculated according to their elevation, using:

- The seismic DATUM is set at 1800 m above sea level The replacement seismic wave velocity is taken at 3400 m/s
- The elevations and the corresponding time corrections in receiver and shot are presented in the graphs of this sheet.



# 3D cube: Migration pre & post stack

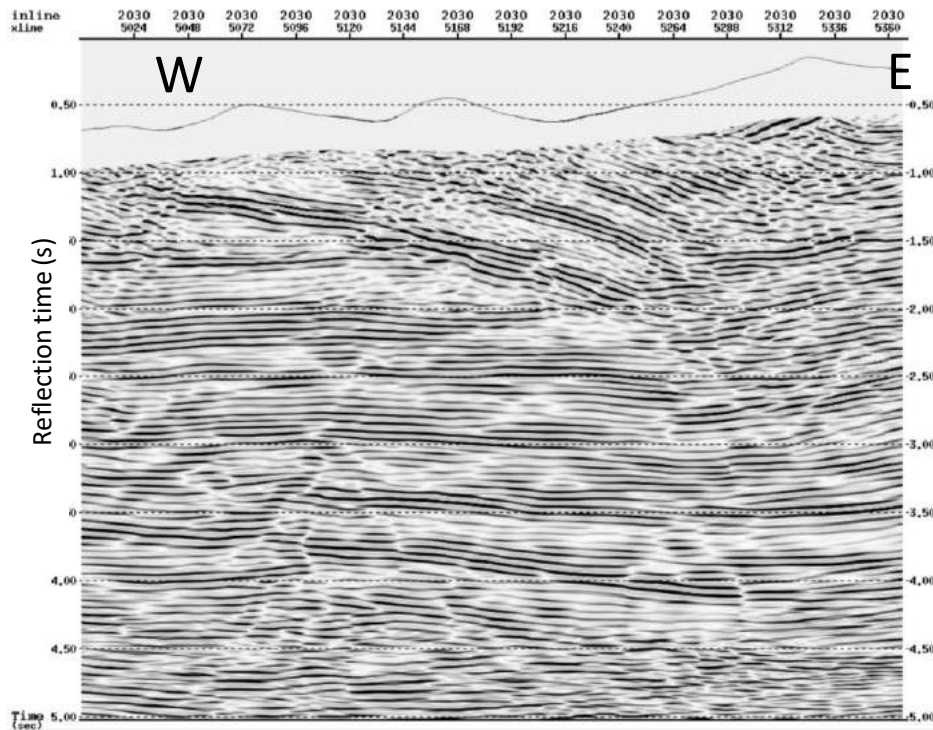
## Velocity analysis



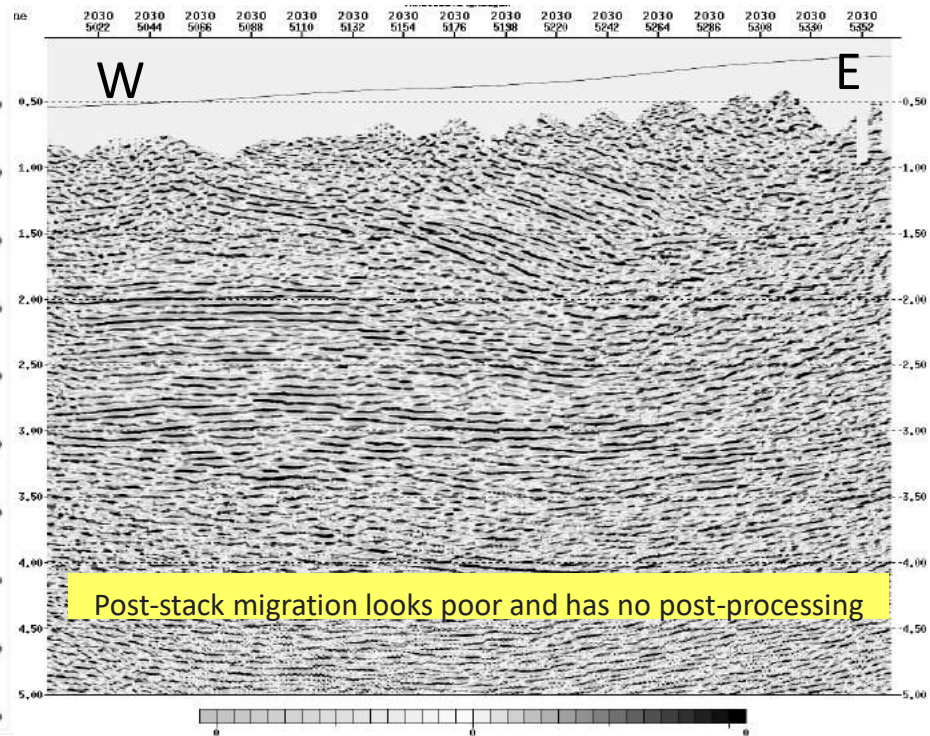
Residual velocity analysis module for Geodepth migration (ECHOSParadigm)

# Comparison between 2021 & 2014 Reprocessing (Post-stack migrated sections)

Inline 2030 Migration post-stack **2021**



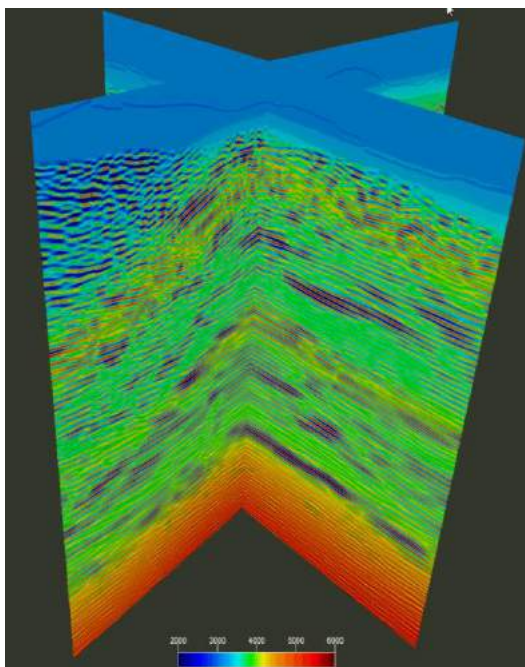
Inline 2030 Migration post-stack **2014**



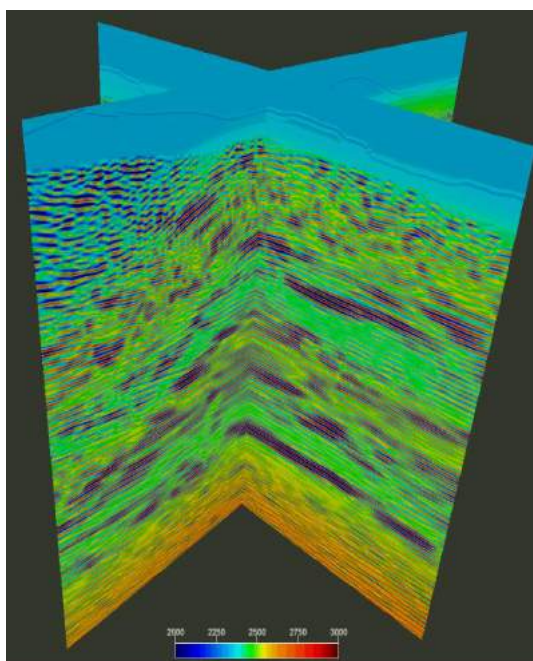


# Seismic Inversion Results for Vp, Vs and Density (3D)

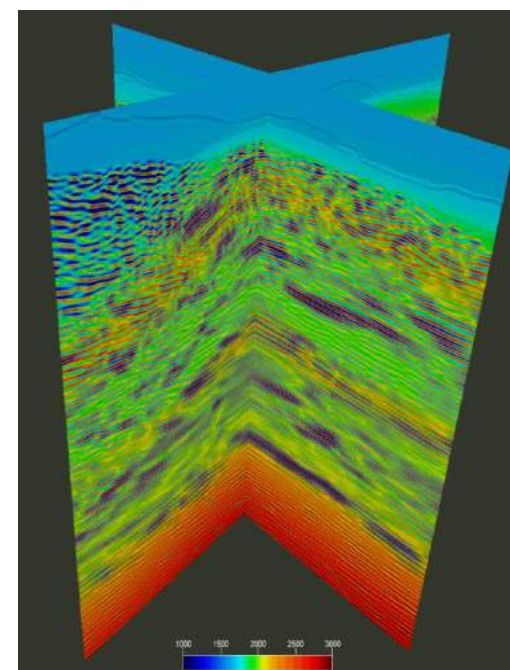
P-Wave velocity (Vp)



S-Wave velocity (Vs)



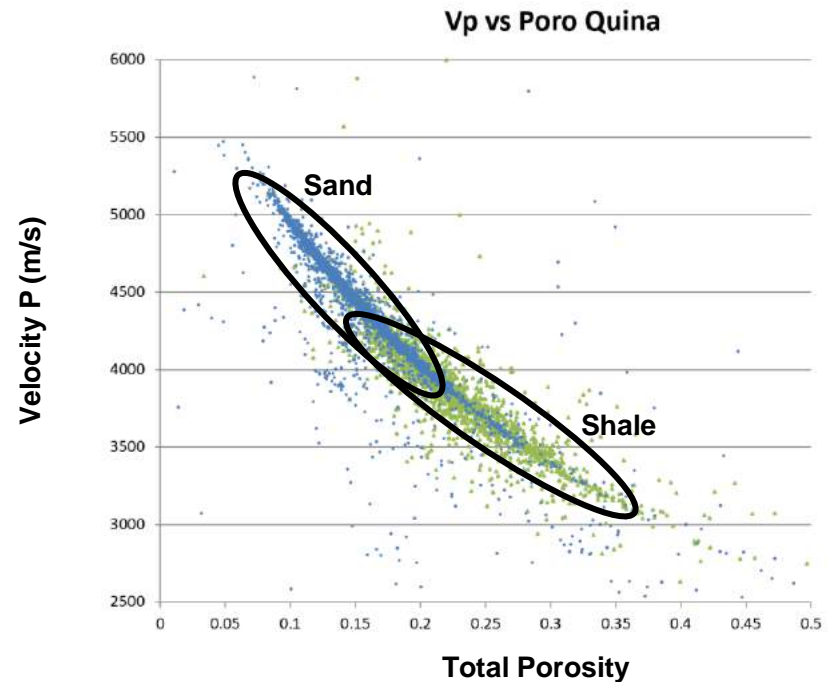
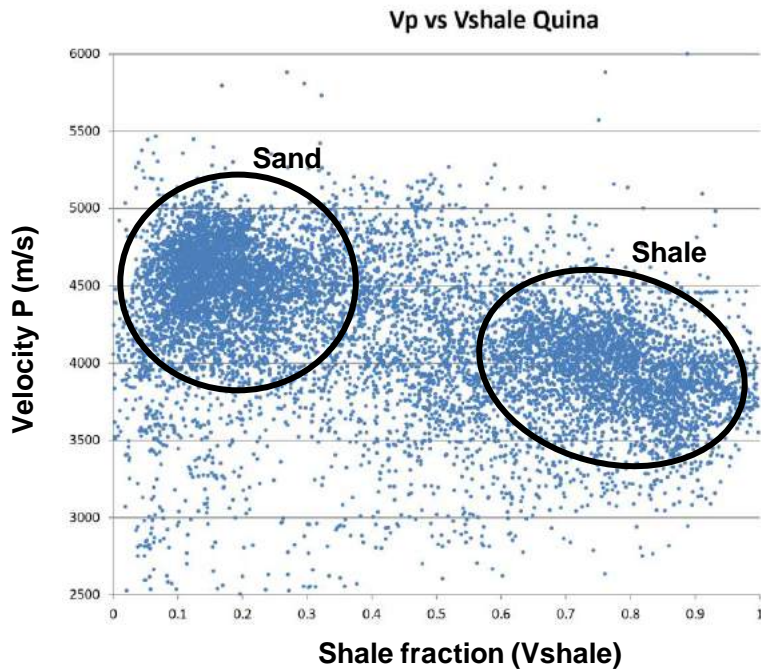
Bulk Density





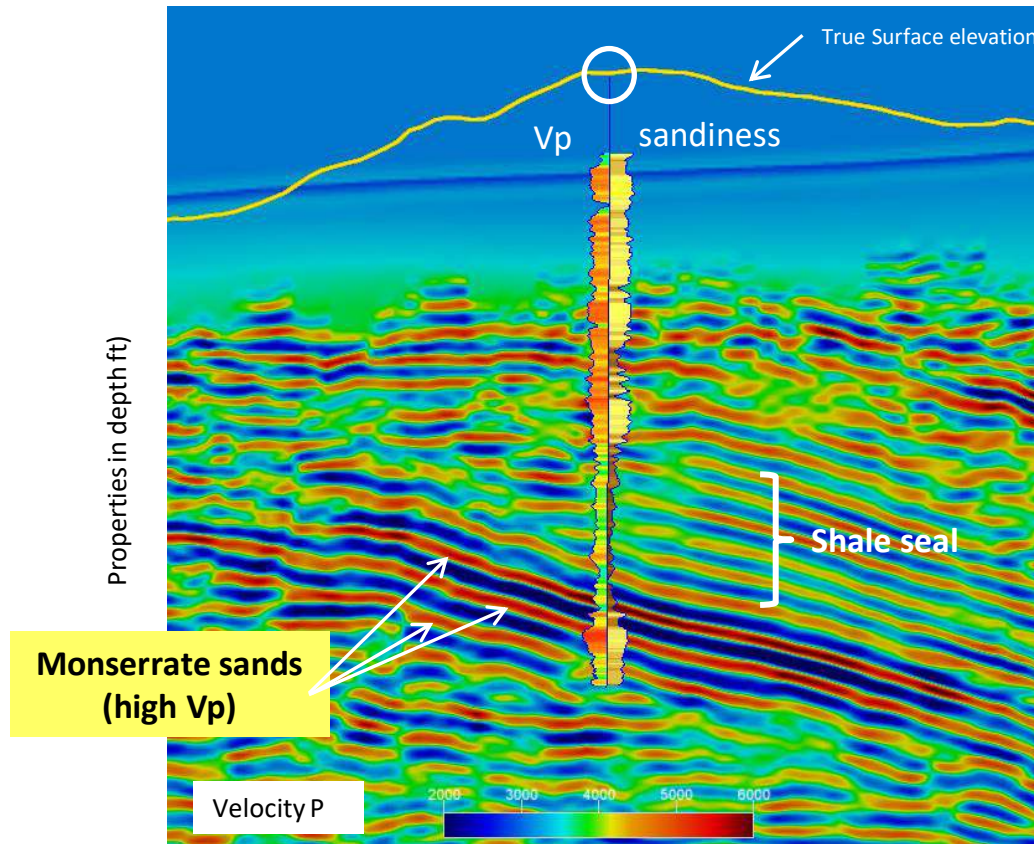
## *Lithology & Porosity plots*

The sands in this area are characterized by a higher seismic velocity than shale, as well as lower porosity, higher acoustic impedance and density than clays. This allows to discriminate sands and clays from the properties estimated with the investment

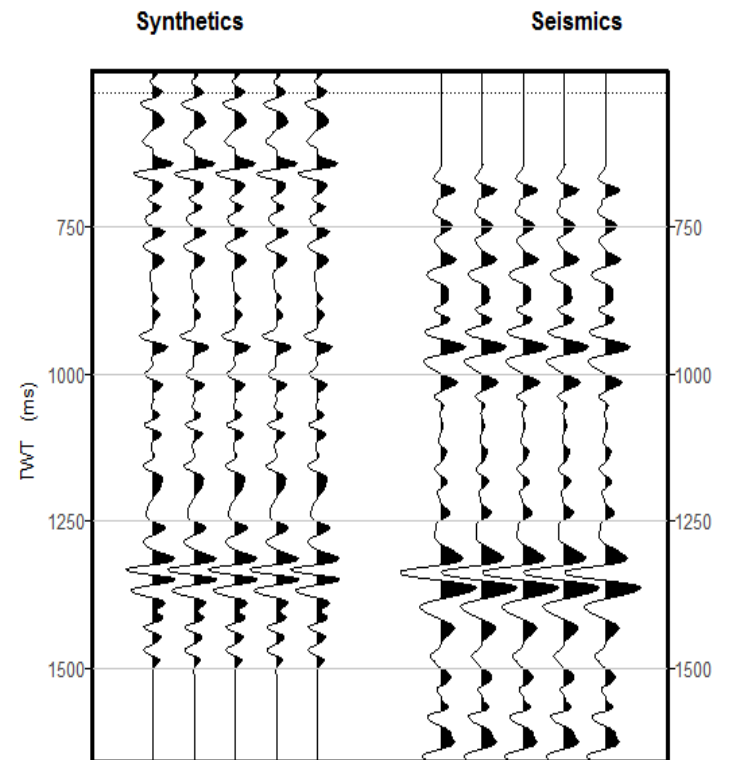


## Well Quina (Inline 2067 )

P velocity in log and seismic



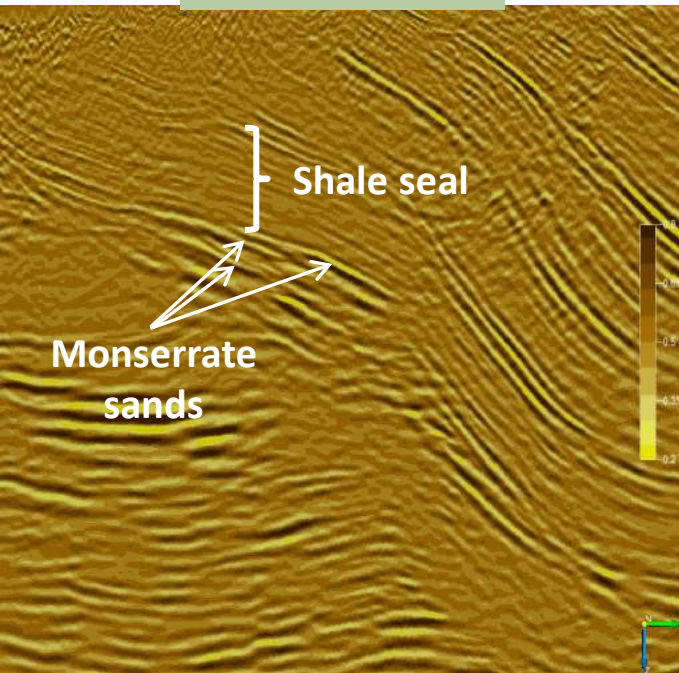
Seismic – log tie in time domain



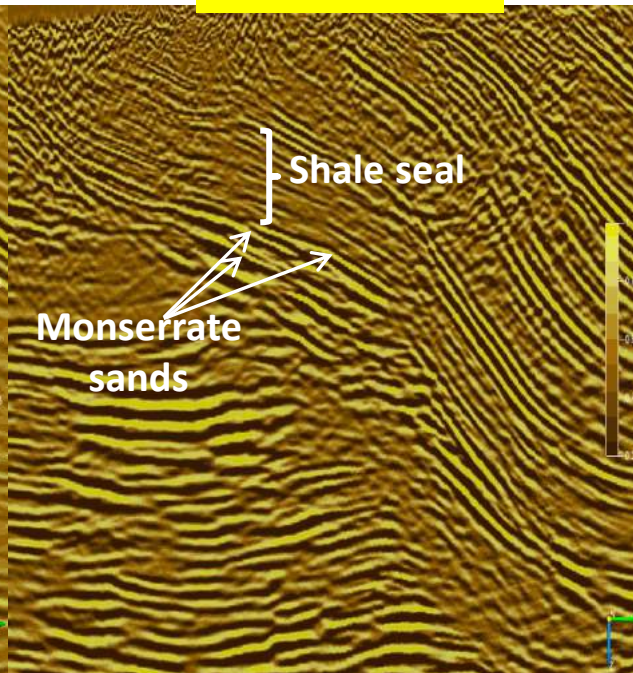


# Reservoir Properties Characterization

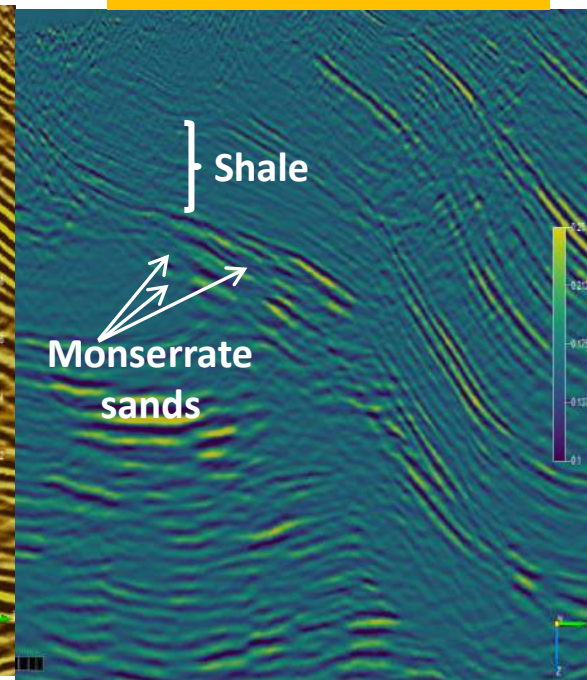
Vshale estimation



Sand Indications



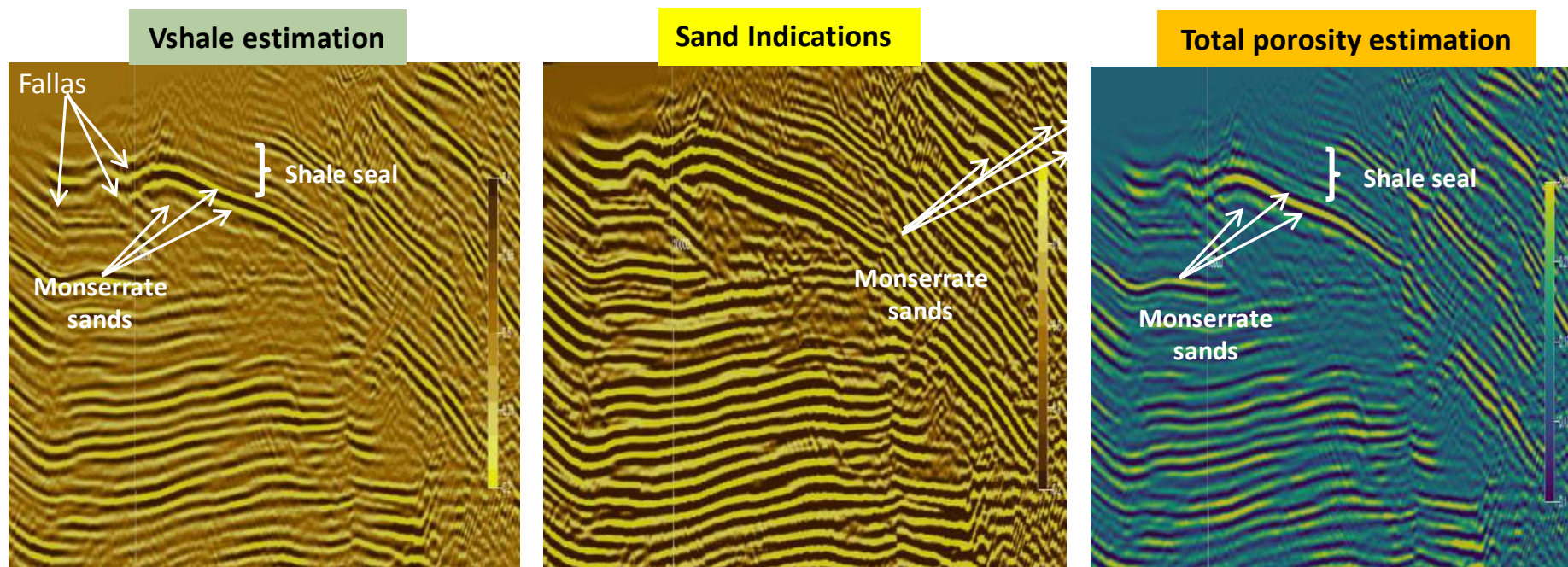
Total porosity estimation



Hercules Prospect (*line 2007-100*)



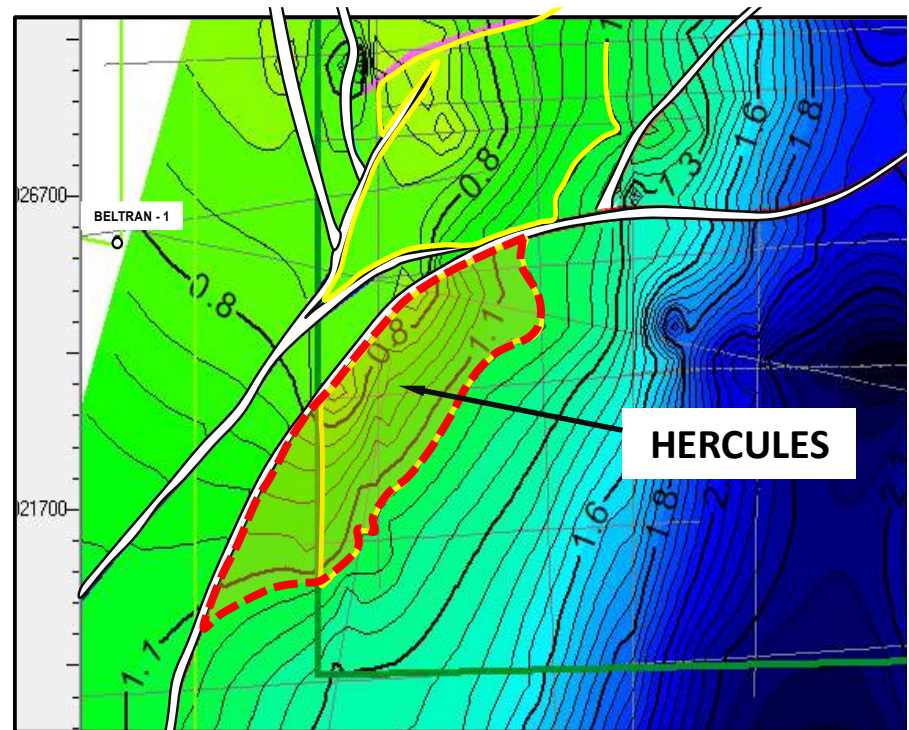
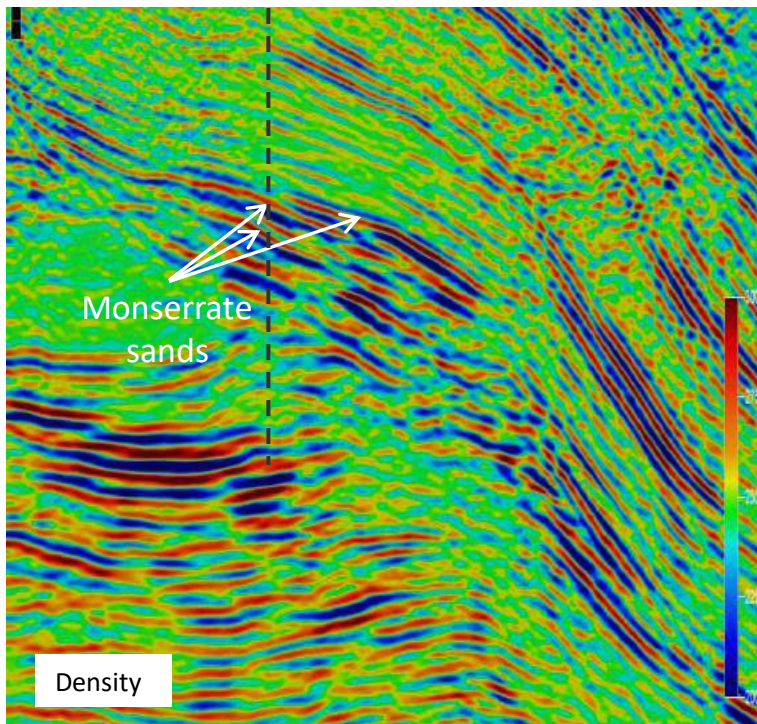
# Reservoir Properties Characterization



*Hércules Norte (line 1979-18)*

## Hercules Prospect

**Hercules-1**  
(proposed vertical trajectory)

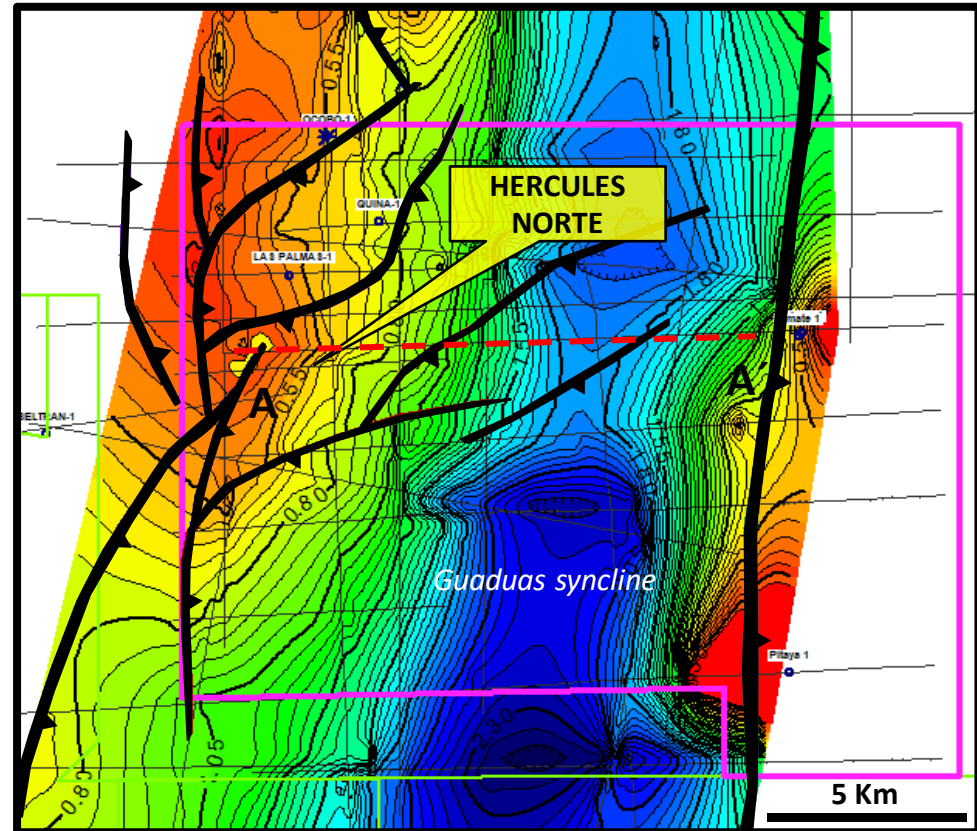
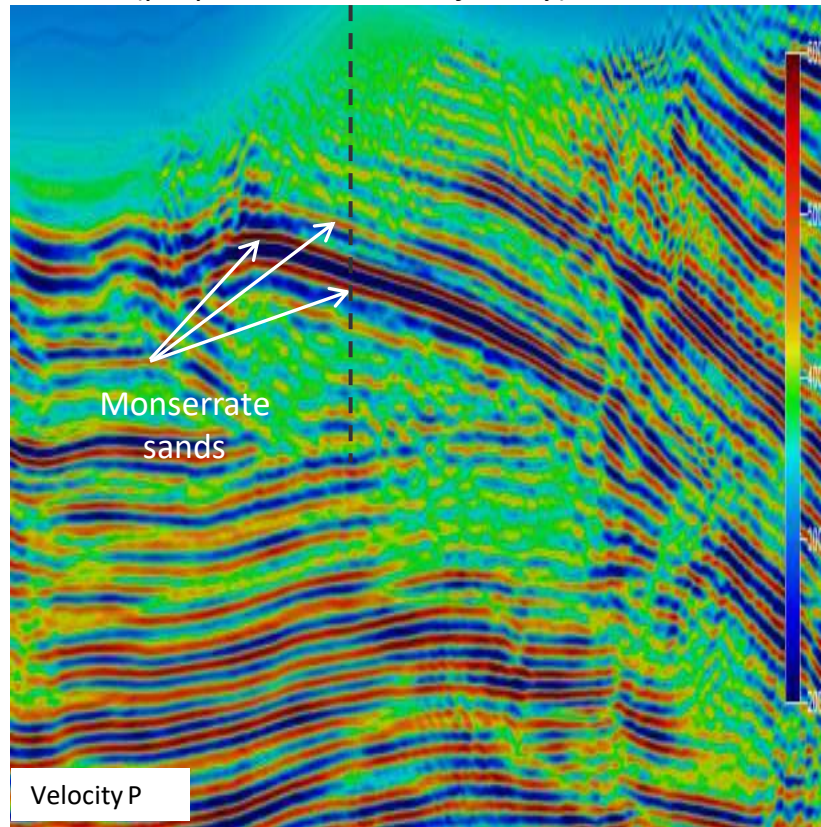


Maximum closure 4586 acres



## Hercules Norte Prospect

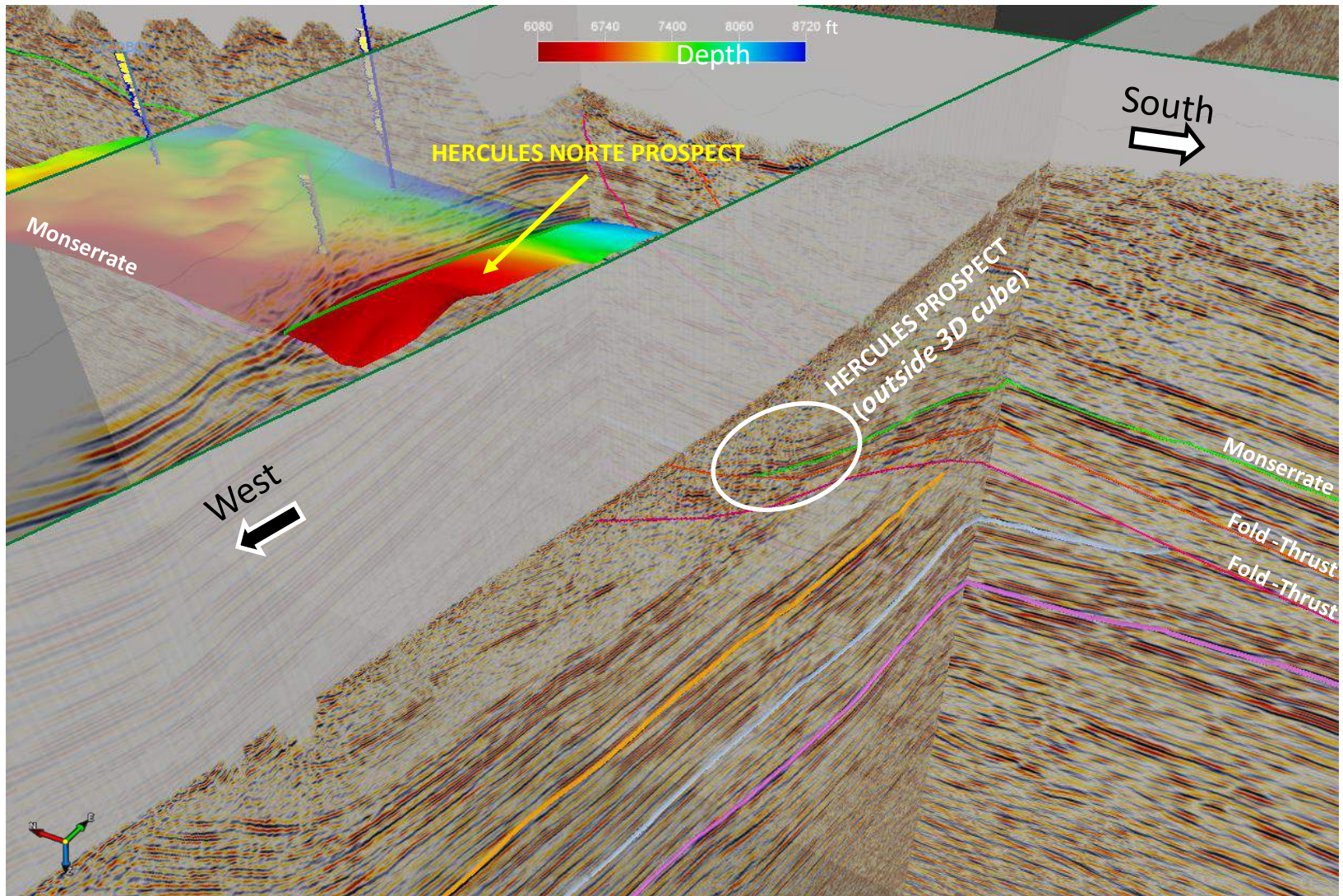
**Hercules Norte-1**  
(proposed vertical trajectory)



Maximum closure 5200 acres

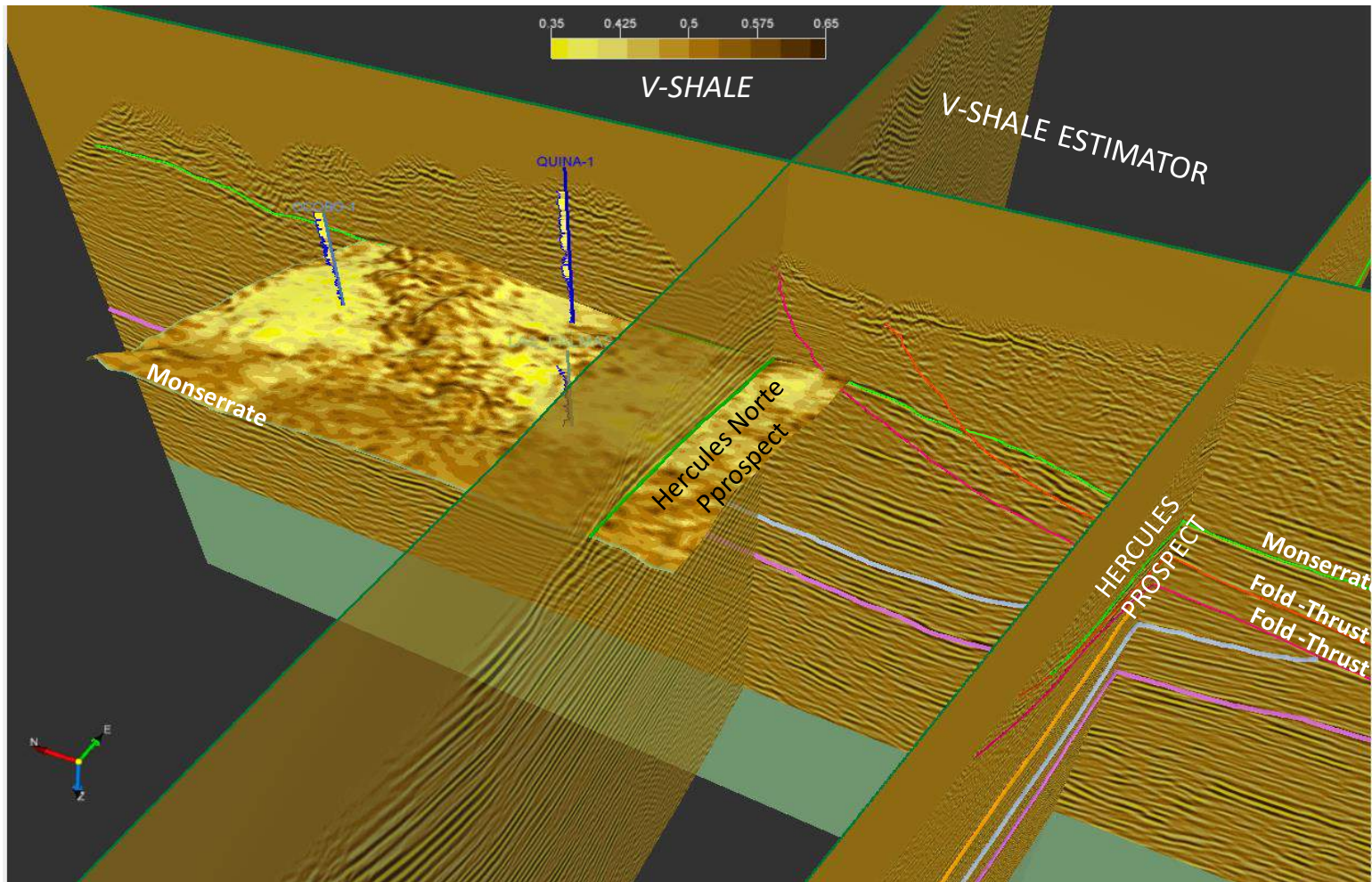


# Hercules Norte Prospect / Partial 3D View





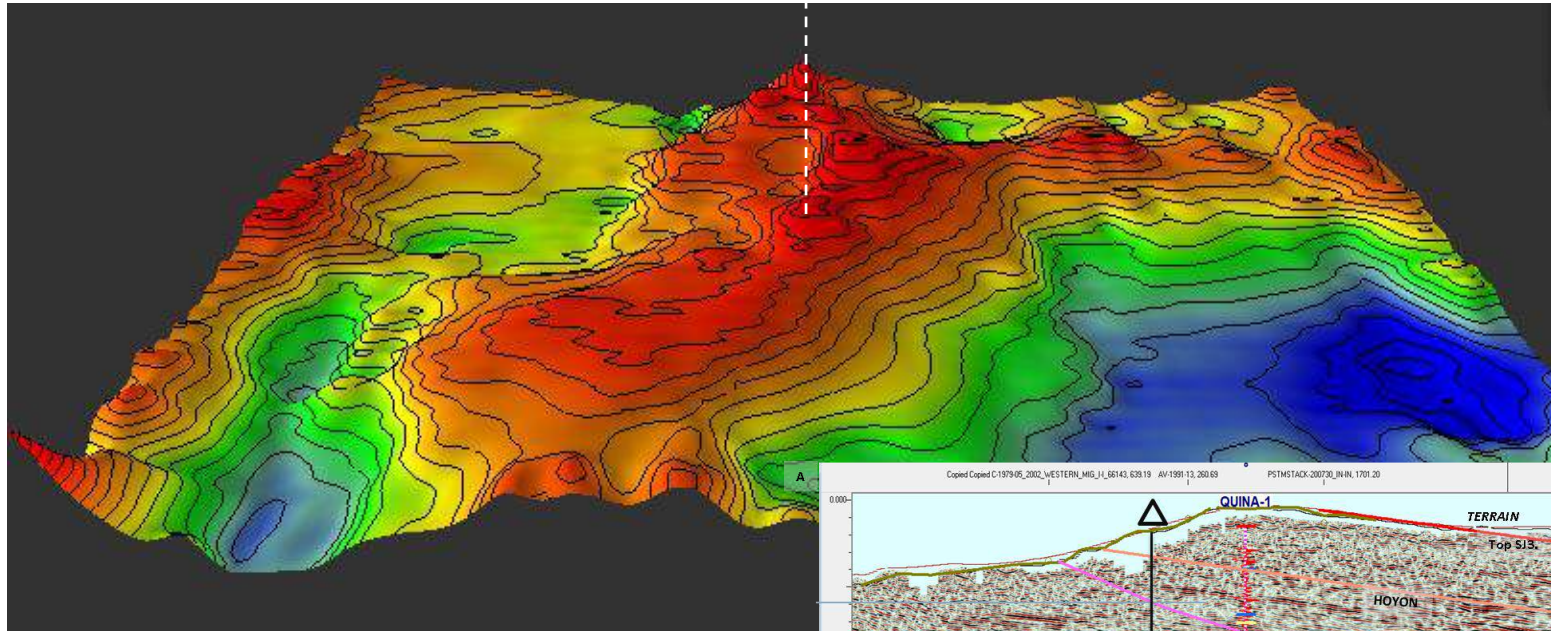
## Sand – Shale Indicator





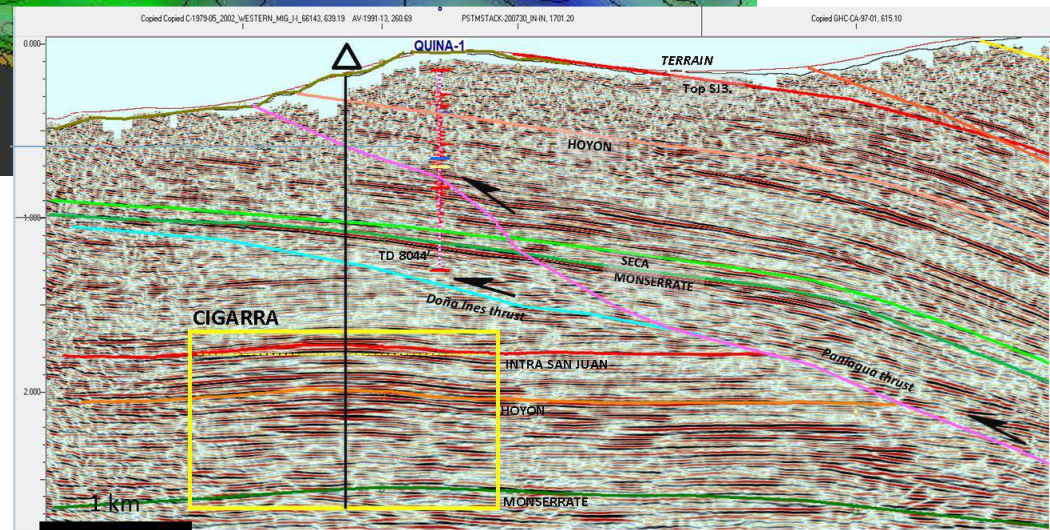
# Cigarra Sub Thrust @ Monserrate Formation

## Cigarra-1 (Vert. Trajectory)



### Monserrate Fm:

- $\emptyset$ : 13%
- Hc Sat: 65%
- Area closure: 38000 a
- Net Pay: 47 - 73 ft







*For Further Information:*

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