Marine Seismic Exploration

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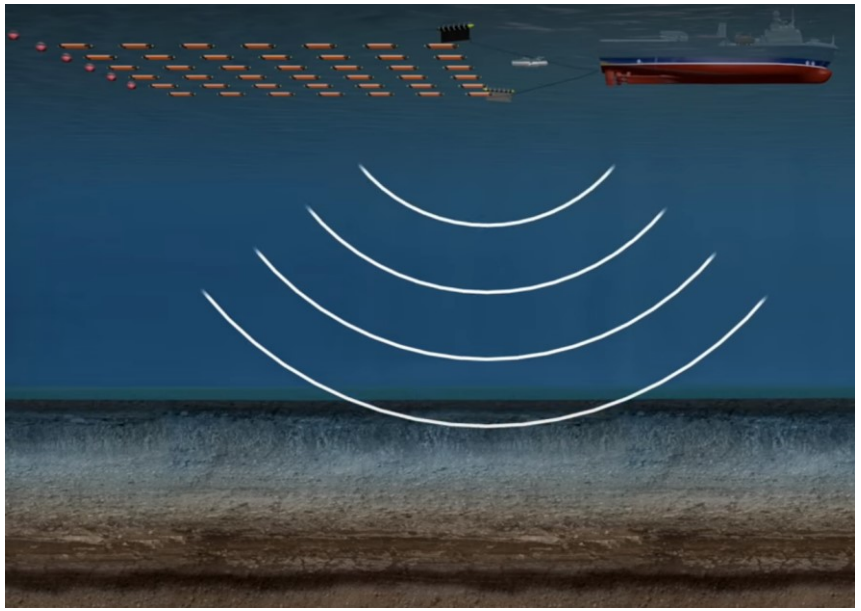
KEY TOPIC COVERED IN TODAY'S TALK

Marine Seismic Acquisition

Seismic Data Processing

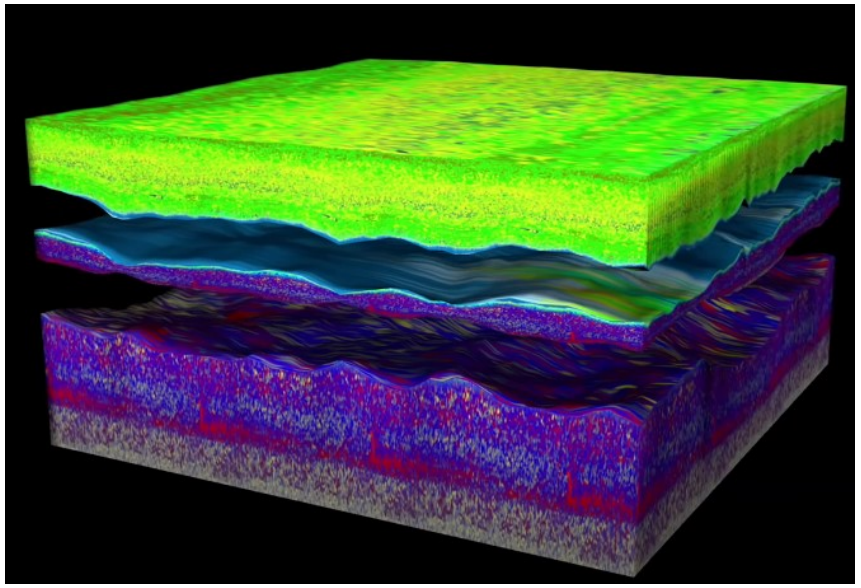
Structural Interpretation

How Marine Seismic Exploration works?



Sound energy is used in marine seismic surveys to map geological structures beneath the seabed.

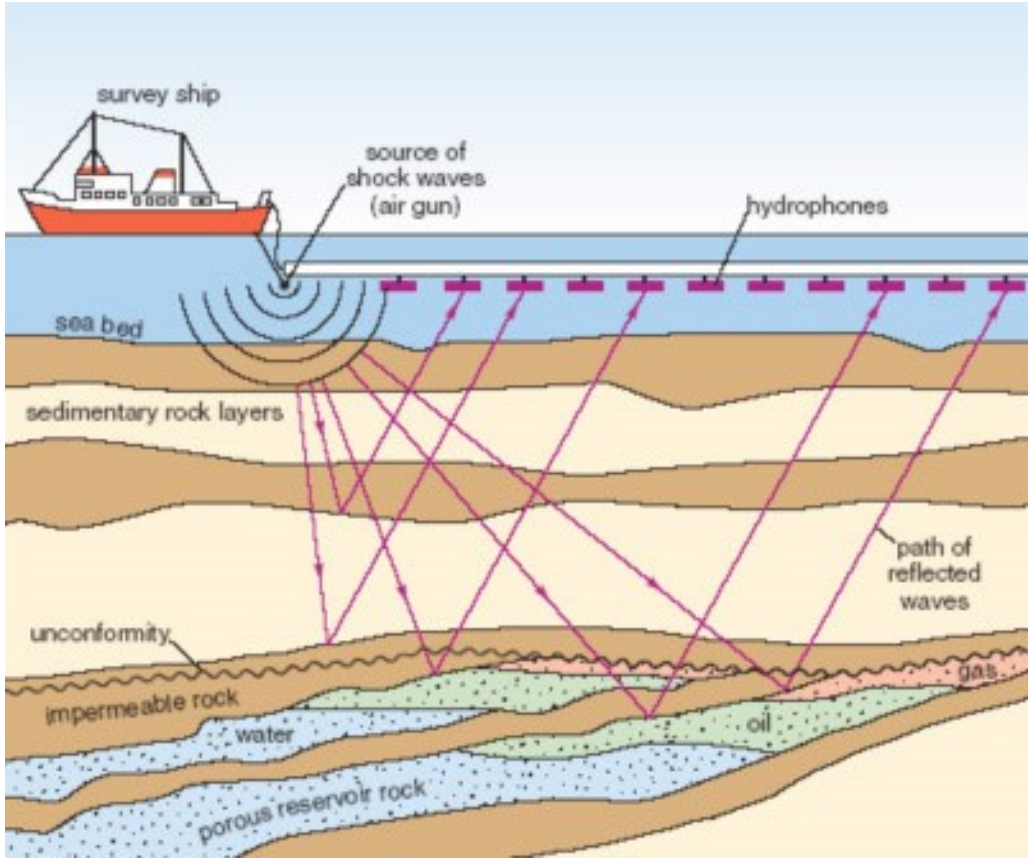
Reverberate back to the ocean surface, where hydrophone receivers record the strength and return time of each sound wave.

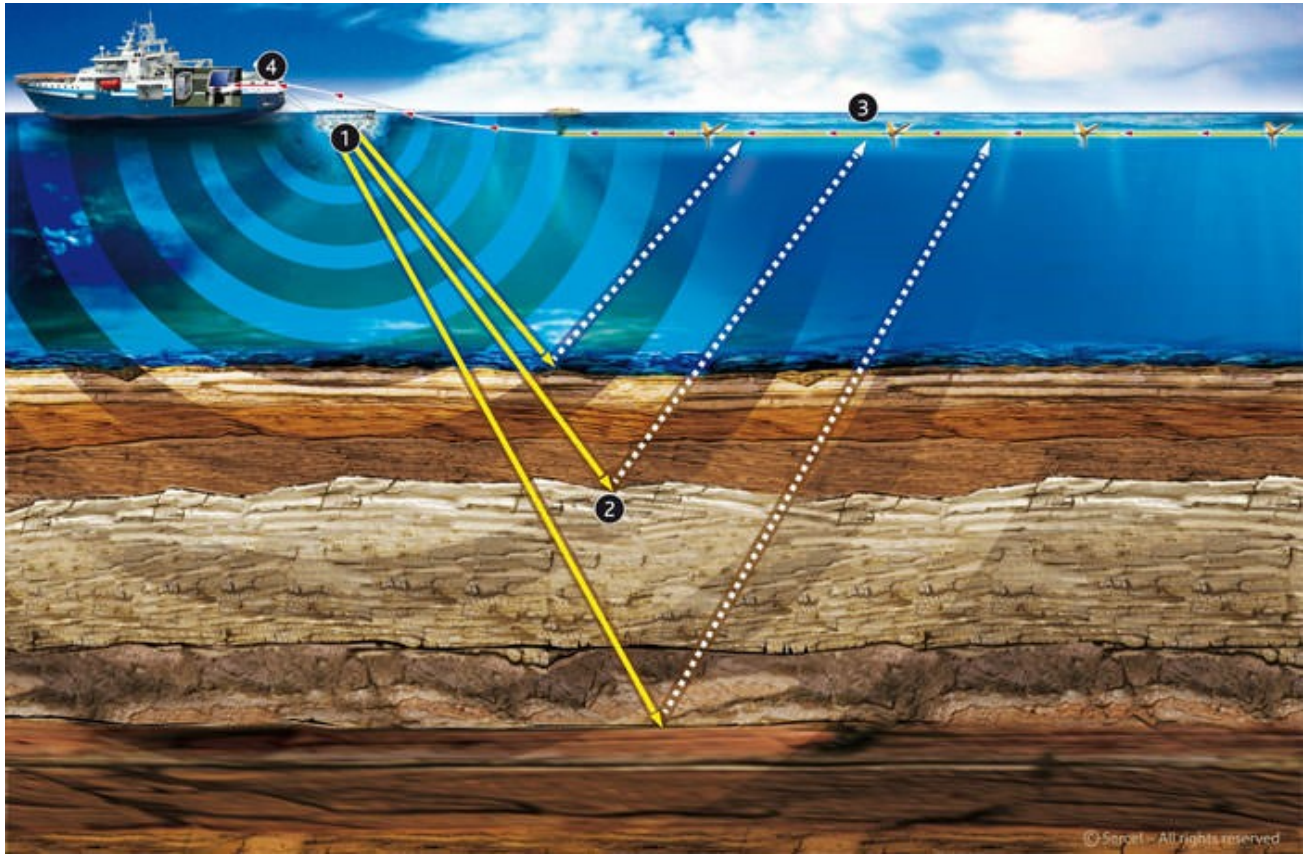


Maps of the geology beneath the seabed are created using this data.

Some seismic waves can penetrate solid rock and fluids into the earth's deep inner layers, while others can only travel along the earth's surface, like ripples on water.

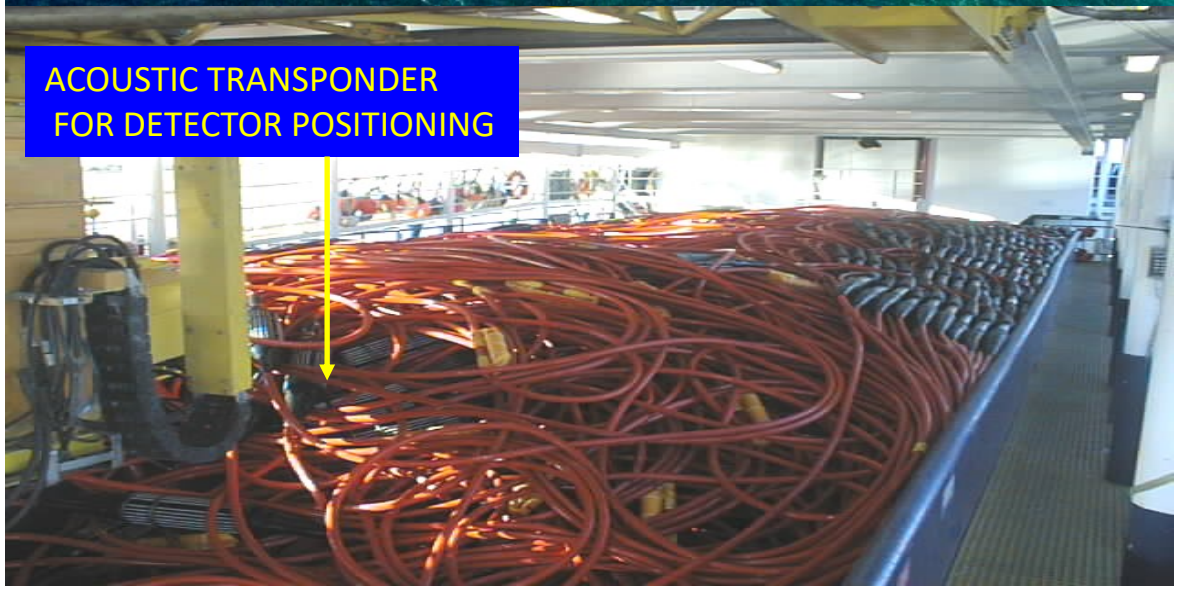
Seismic Marine Acquisition





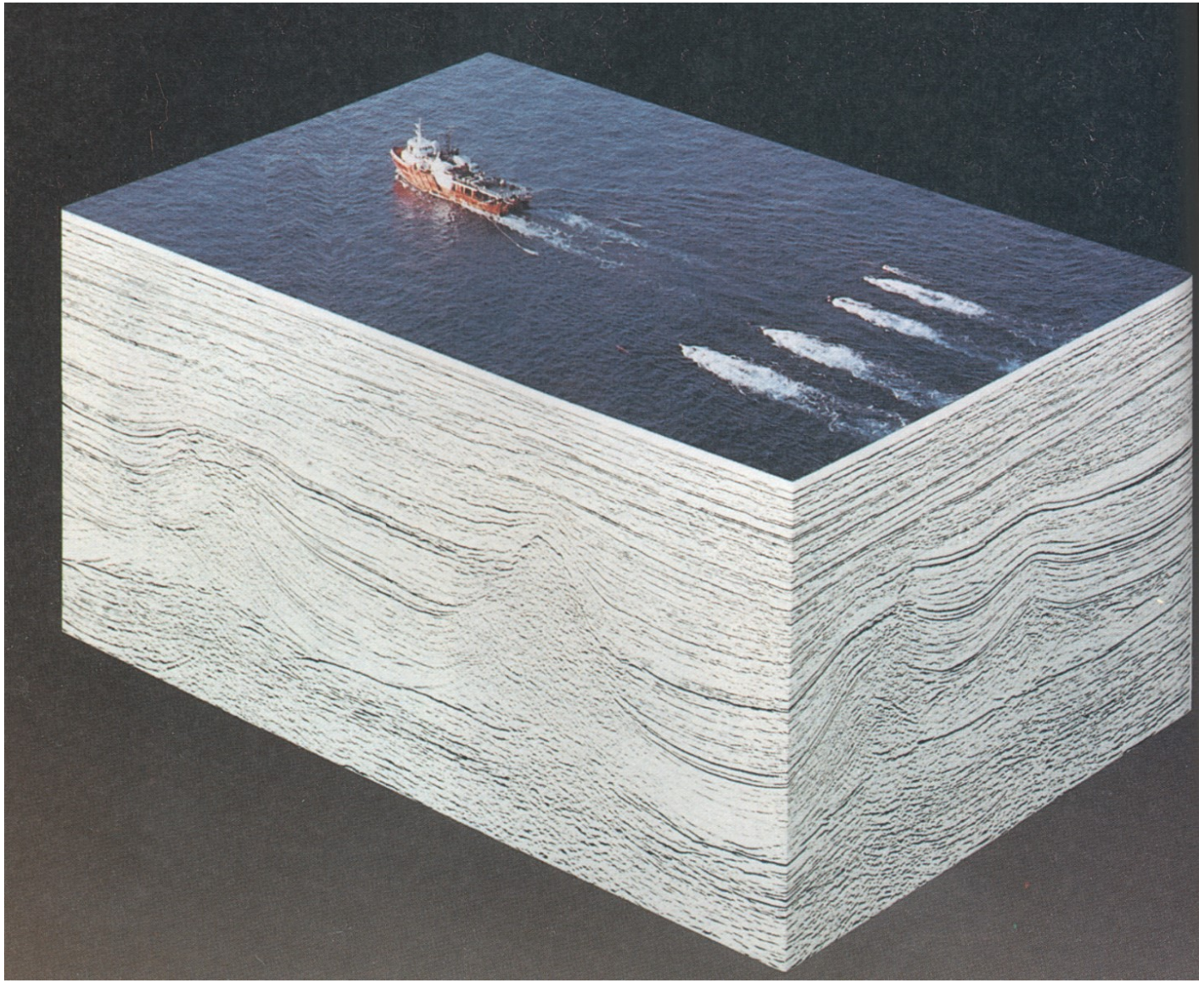
Structure and Capacity of Marine vessel

Seismic Acquisition Marine



8km streamer cable

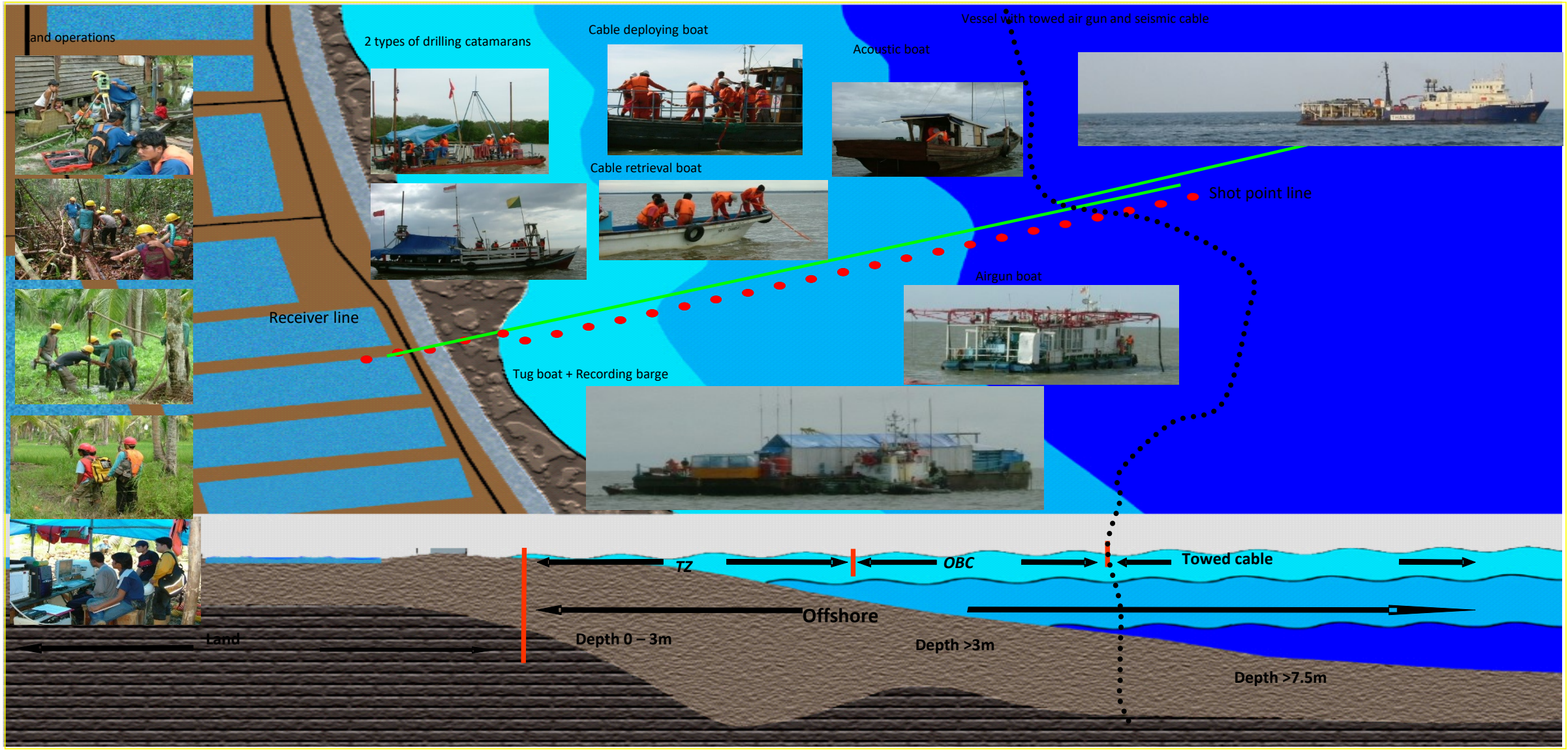
Seismic Data in 3-dimensions (3D Seismic)



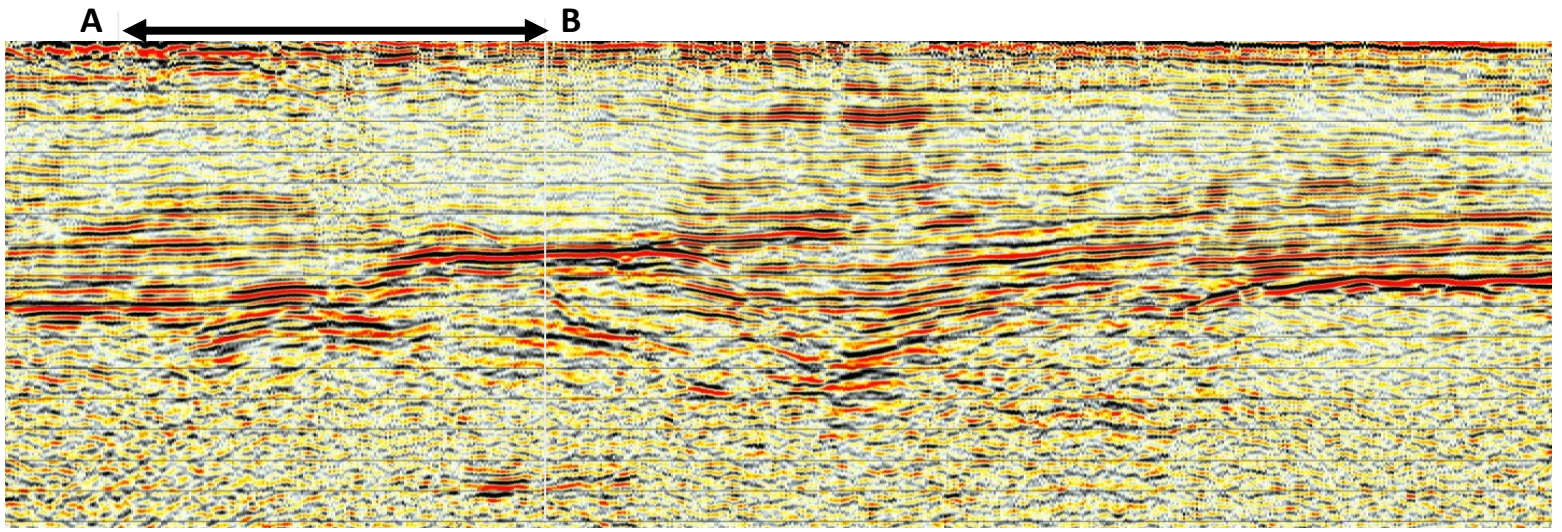
Acquisition Geophysicists in Operation…

Support boat crew prepares or repairs damaged seismic acquisition cable equipment

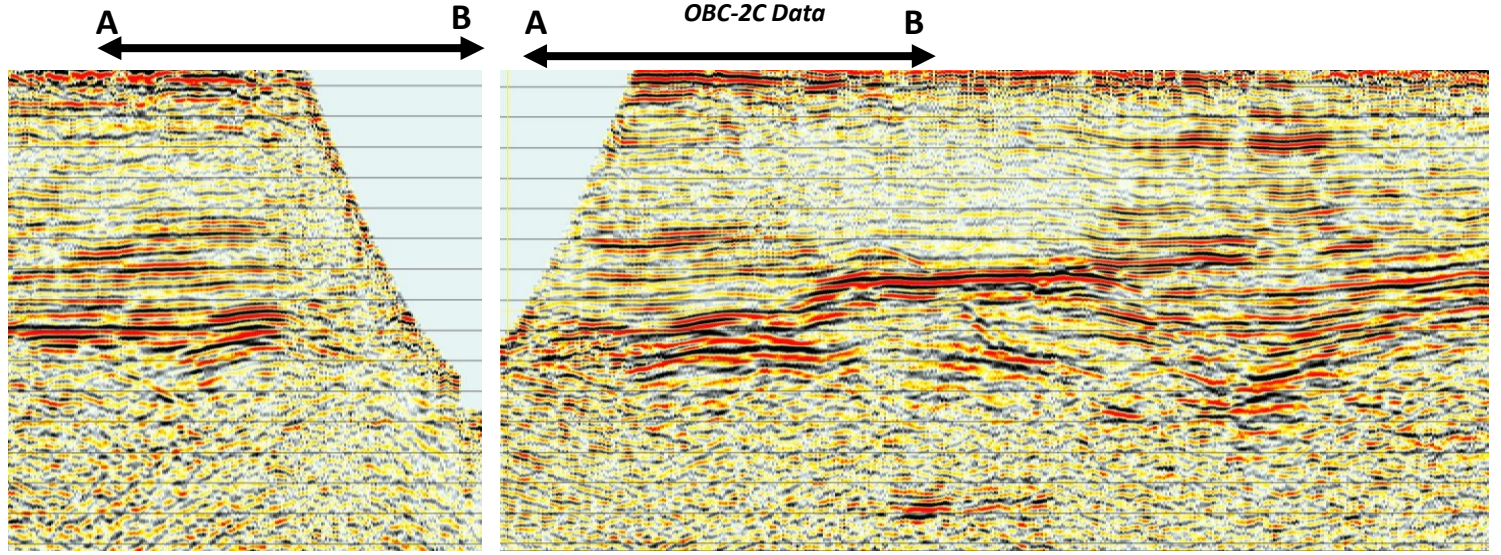
SEISMIC SURVEY : Tanjung Jabung, Indonesia Transition Zone (Land, OBC, Marine)



Tanjung Jabung: Data Merge



AFTER



BEFORE

Merged

Note : Data in mute zone not shown but used in merge

Marine Seismic Sources

Marine Sources: Used in Offshore Surveys

Explosive Sources using Dynamite

- ***Flexotir:*** Small pellet of dynamite embedded in a plastic cartridge. This charge is detonated at the center of a cast-iron spherical shell towed behind the ship at 40 ft depth. It pumps out water under high pressure.
- ***MaxiPulse:*** Charge packed in a can, injected into the water at 40 ft depth by a delivery device trailed from the ship. On detonation, it forms a bubble.

MaxiPulse

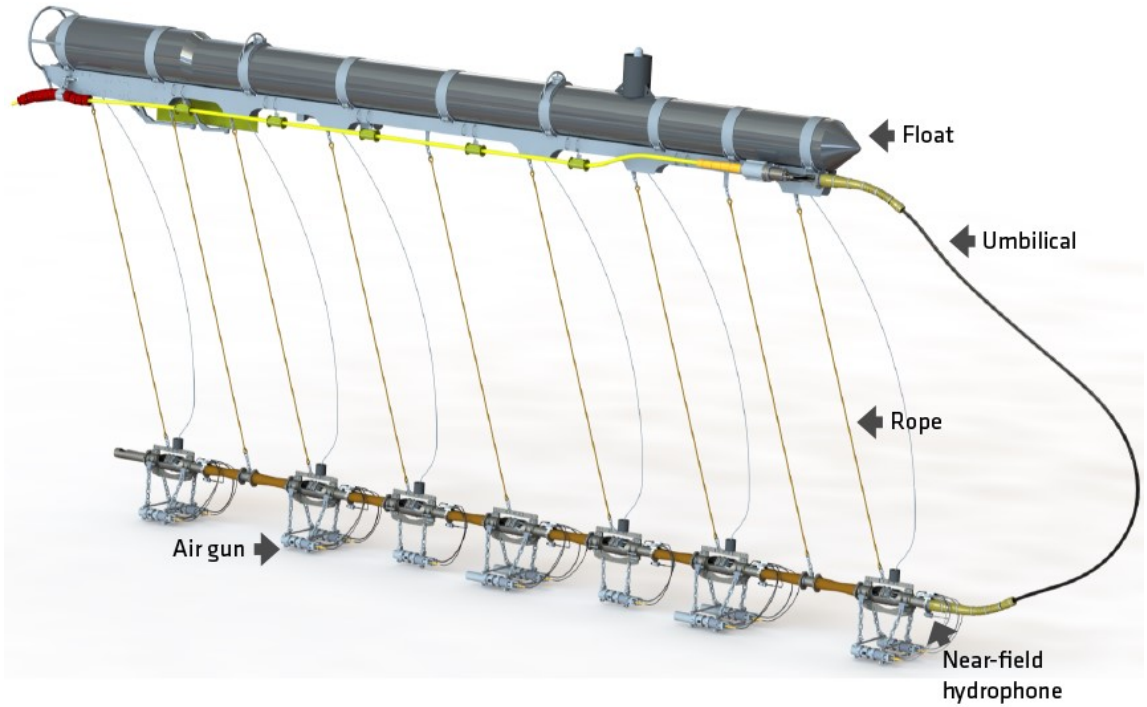
Non-Explosive Sources

- ***Sparker:*** Sudden discharge of current between electrodes in water generates seismic waves.
- ***Boomer:*** Current passes through Coil which moves a plate against water.
- ***Aqua Pulse:*** Enclosed underwater chamber (elongated heavy-rubber cylinder) filled with propane and oxygen. It is detonated by an electric spark. The explosion causes ballooning of the chamber which introduces a pressure pulse in water.
- ***Air Gun:*** High-pressure bubble released in water.

Sparker

Air Gun

Seismic airguns are used primarily to examine the layers of the seafloor to study Earth's history or locate subsea oil and gas deposits.
Airguns rapidly release compressed air, causing a bubble to be formed. The formation of the bubble produces a loud sound that travels through the water to the ocean floor.
Reflected sound travels back to the sea surface where it can be recorded by hydrophone arrays called streamers.



Azimuthal Diversity for complex structures (Marine)

Wide azimuth or (**WAZ**) is a term describing a seismic data acquisition technique with a wide distribution of source-receiver azimuths. They usually involve multiple source-boats or Ocean Bottom seismometers.

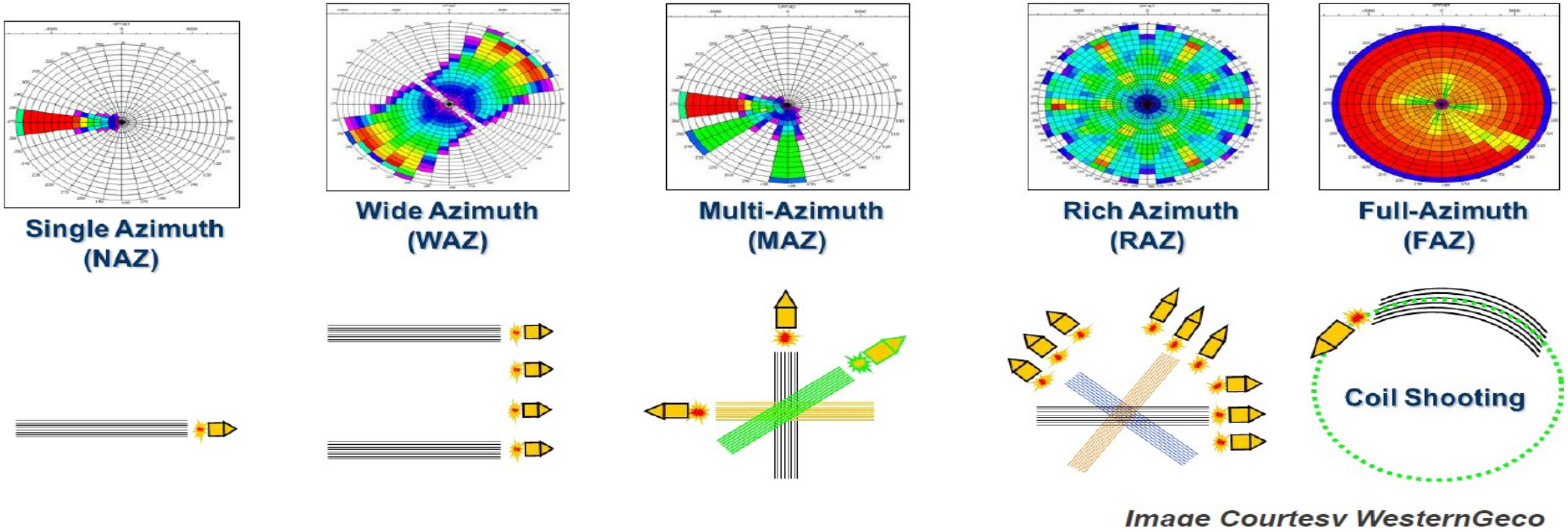


Image Courtesy WesternGeco

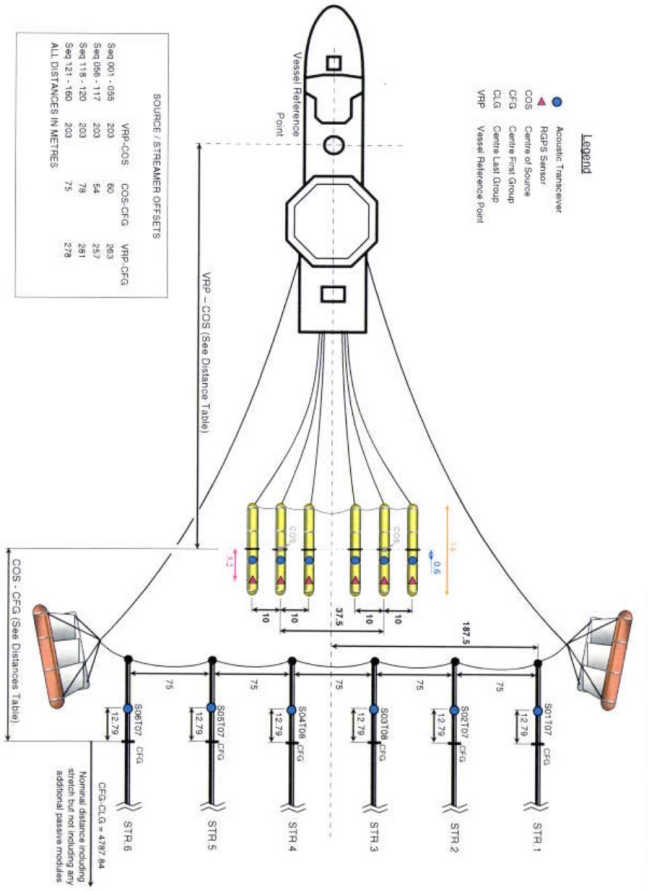
- ✓ For complex targets, azimuthal diversity is more important than offset diversity.
- ✓ Expended Azimuth designs provide better illumination of such targets as well as a higher signal-to-noise ratio.

Acquisition Parameter: Malaysia Field Data

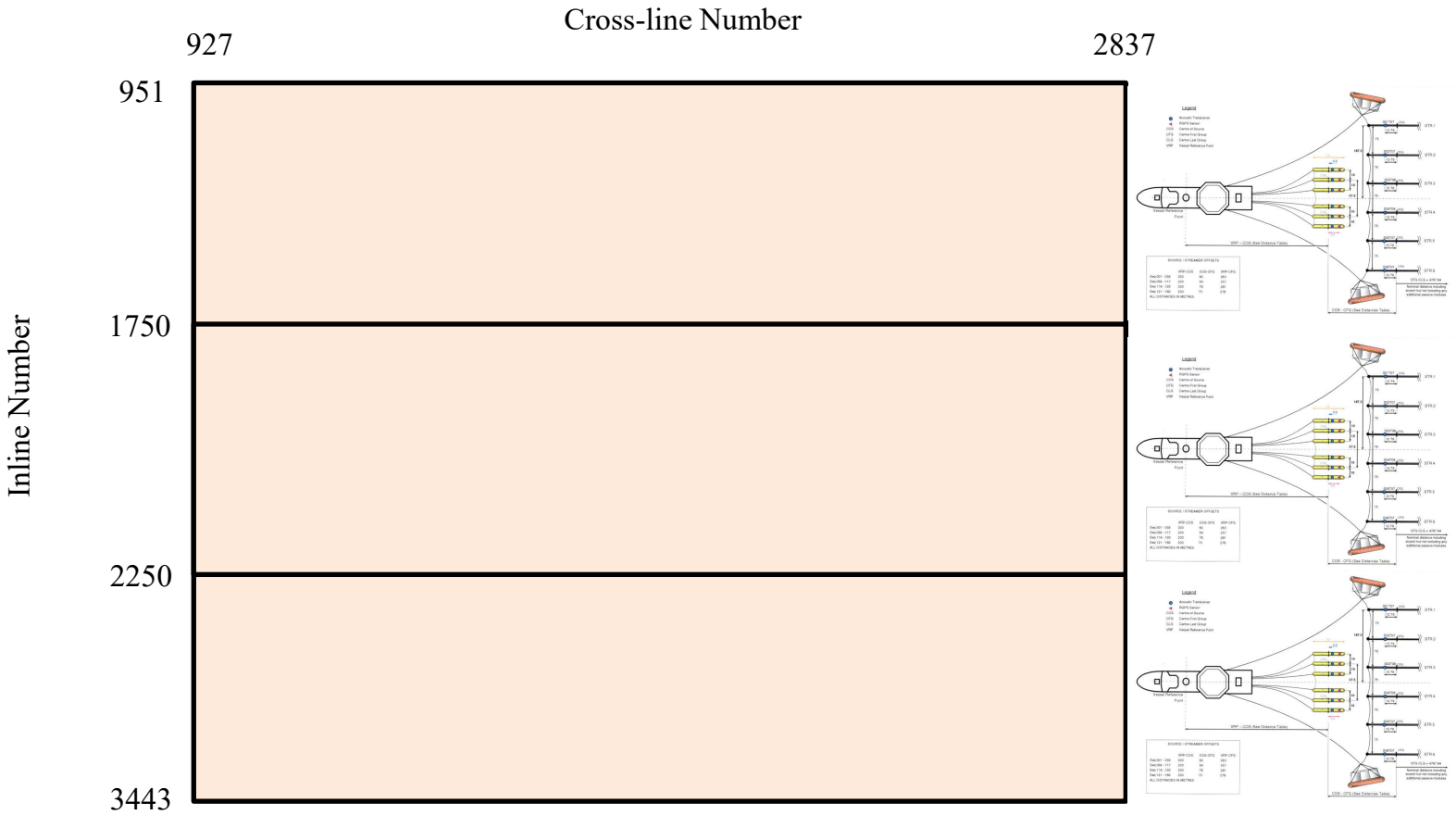
Recorded by	PGS Geophysical, Marine Acquisition
Date	2006
Recorded Length	5.7 Seconds
Sample Rate	2 ms
Recording filter	Low cut: 3Hz High cut: 218 Hz
Number of source	2
Volume of Sources	3090Cu. In. Dual Source Flip-flop
Pressure	2000 PSI
Source Depth	6 m
Shot Interval	18.75 m per CSP line
Number of Cables	6
Number of Groups	384 per Streamer
Cable Separation	75 m
Group Interval / length	12.5 m
Cable length	4800 m
Cable Depth	7 m
Near Offset	80 m

Table : Acquisition summary Sarawak Malaysia

Layout of Acquisition:

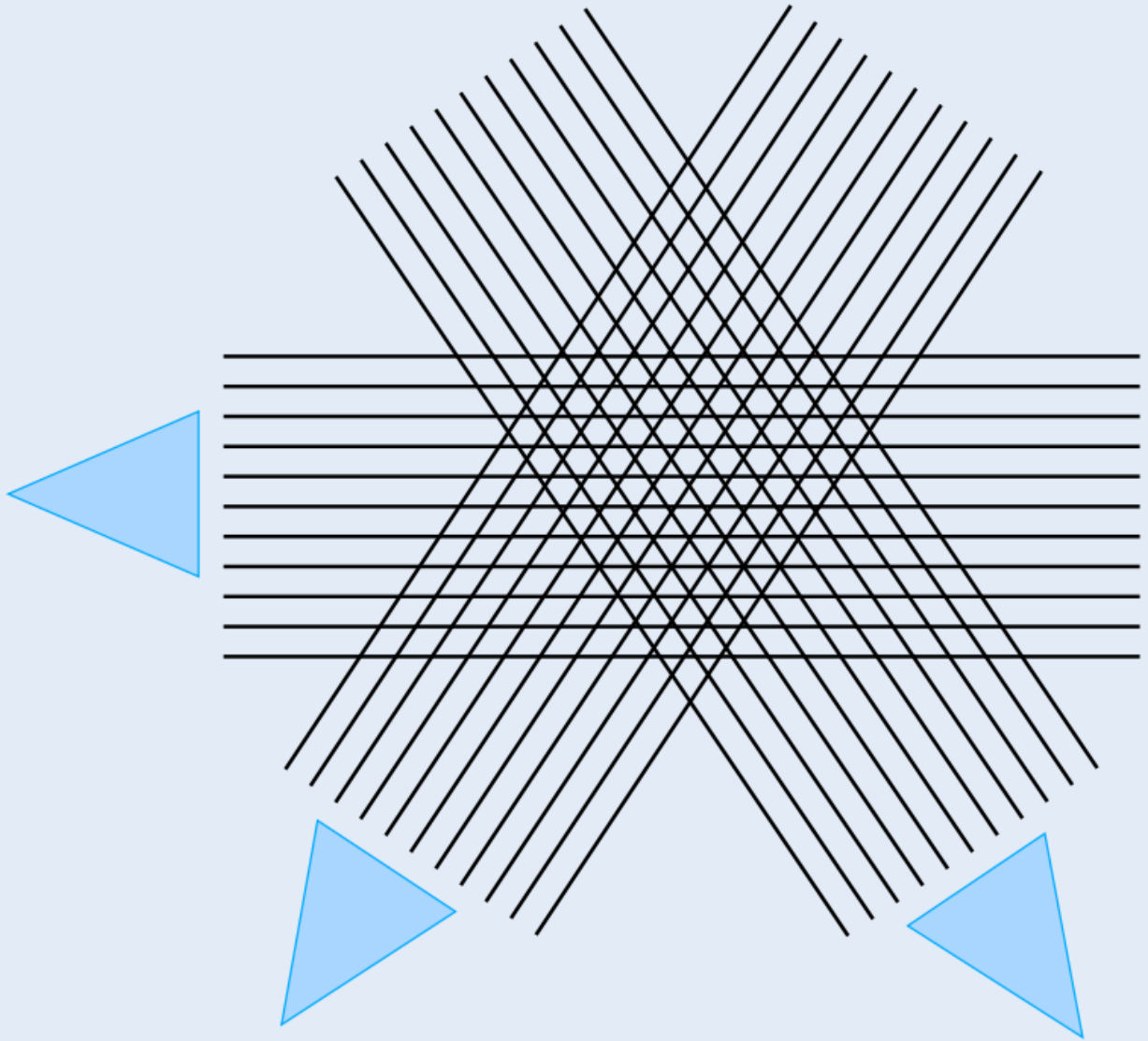


Layout of Acquisition Design: Marine

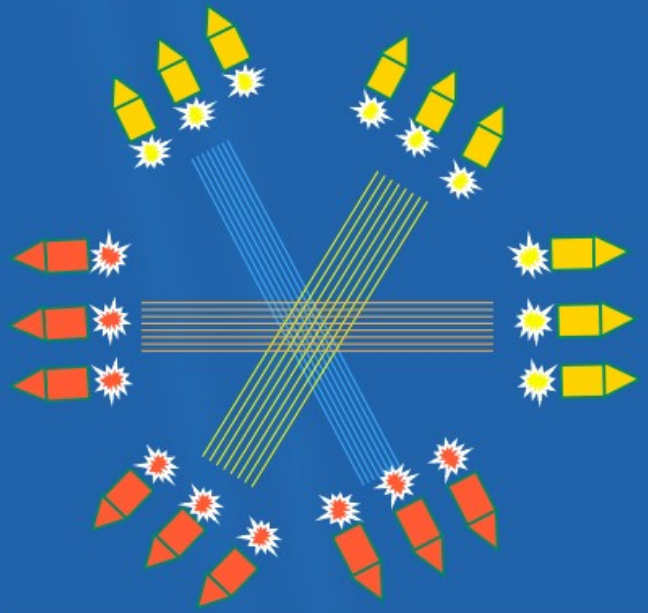


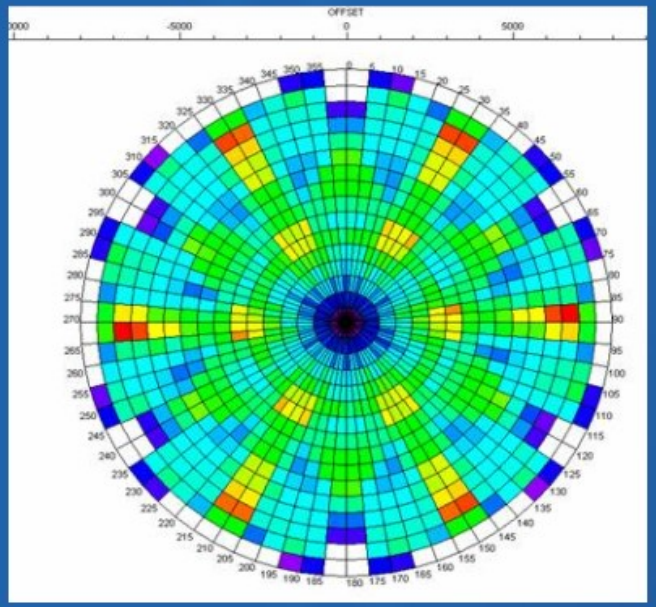
Single-Azimuth Acquisition

Multi-Azimuth Acquisition



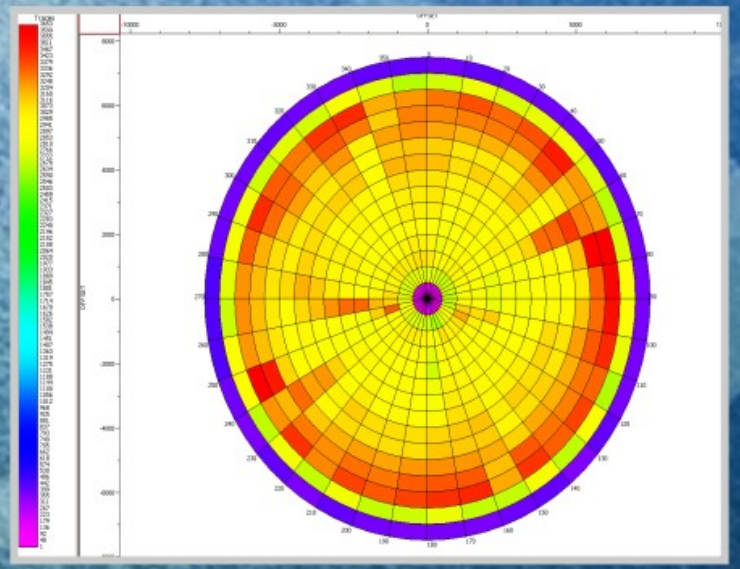
BHP Rich-azimuth 2006 Shenzi survey



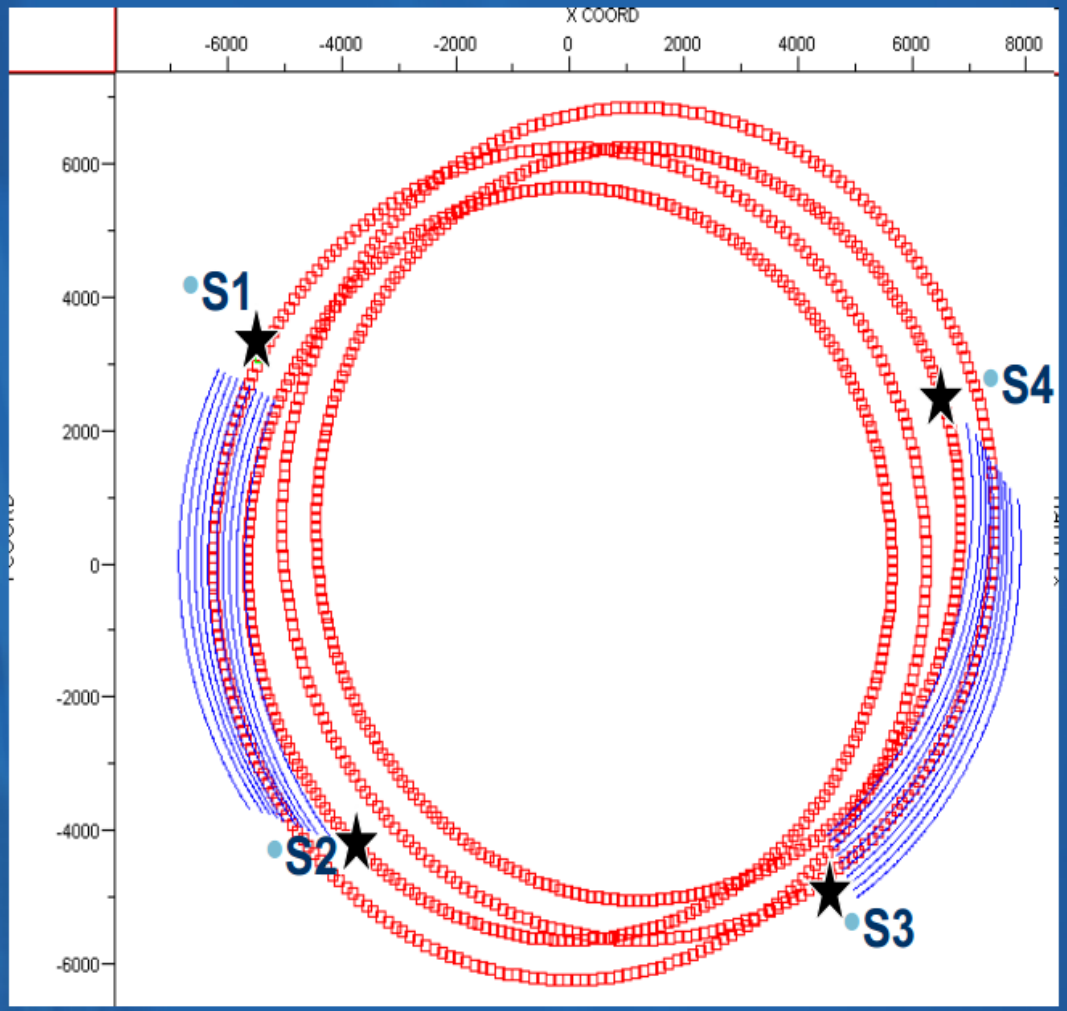


WesternGeco acquisition

Full Azimuth Single vessel Coil shooting

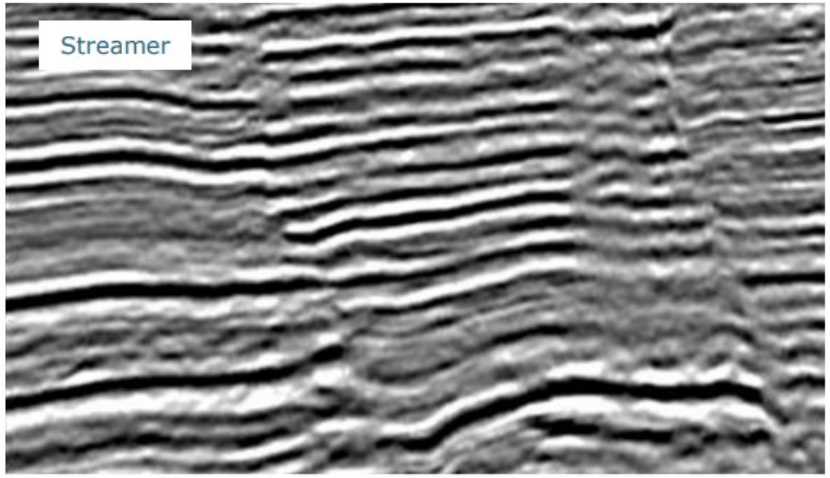


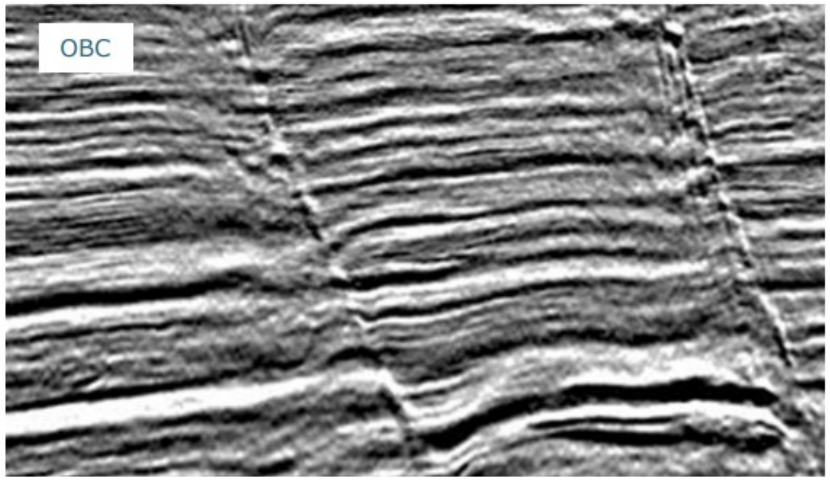
Full Azimuth Long Offset Multivessel Coil Shooting Configuration: two recording vessels and two source vessels



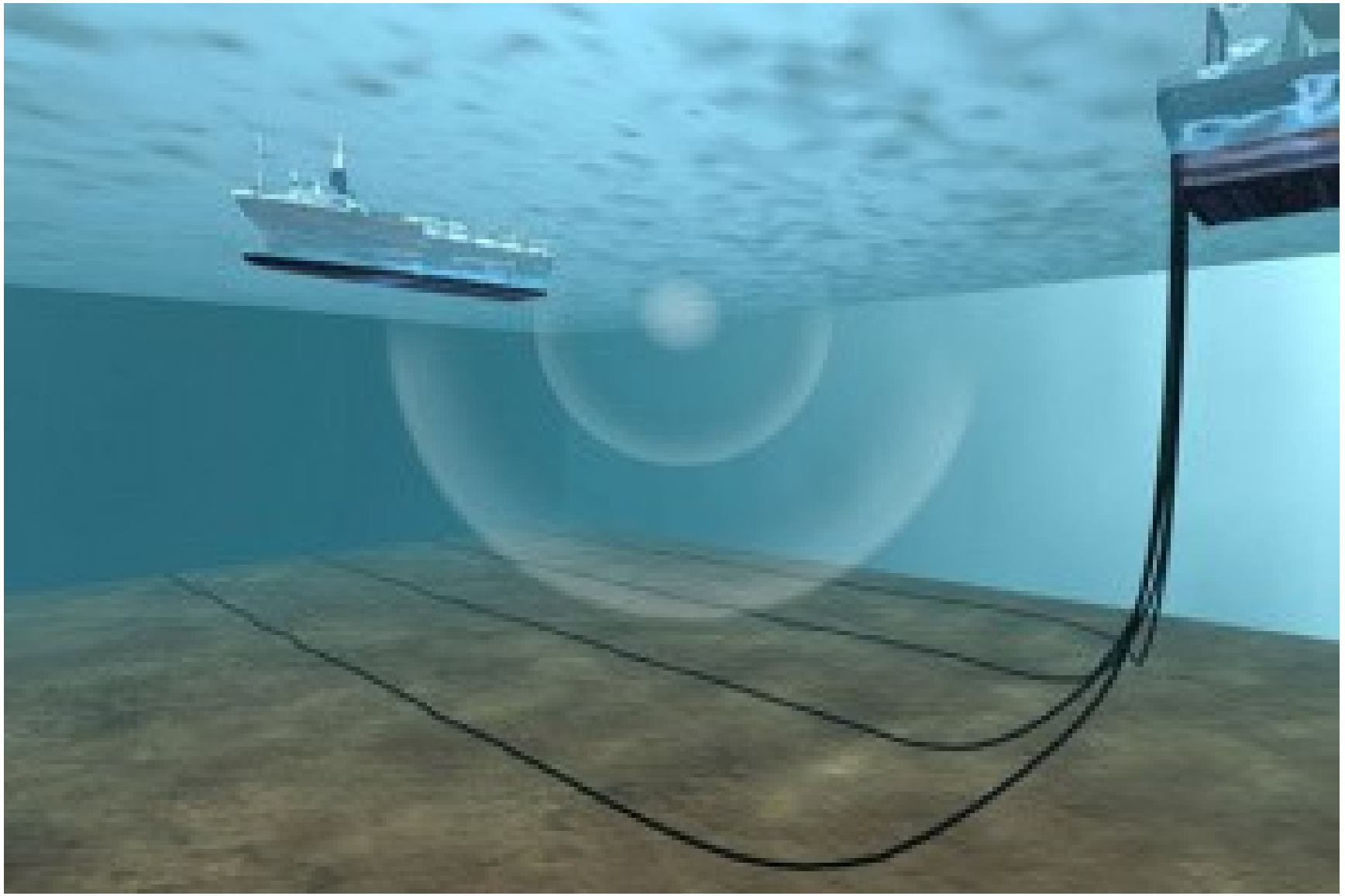
WesternGeco acquisition

Streamer Vs OBC





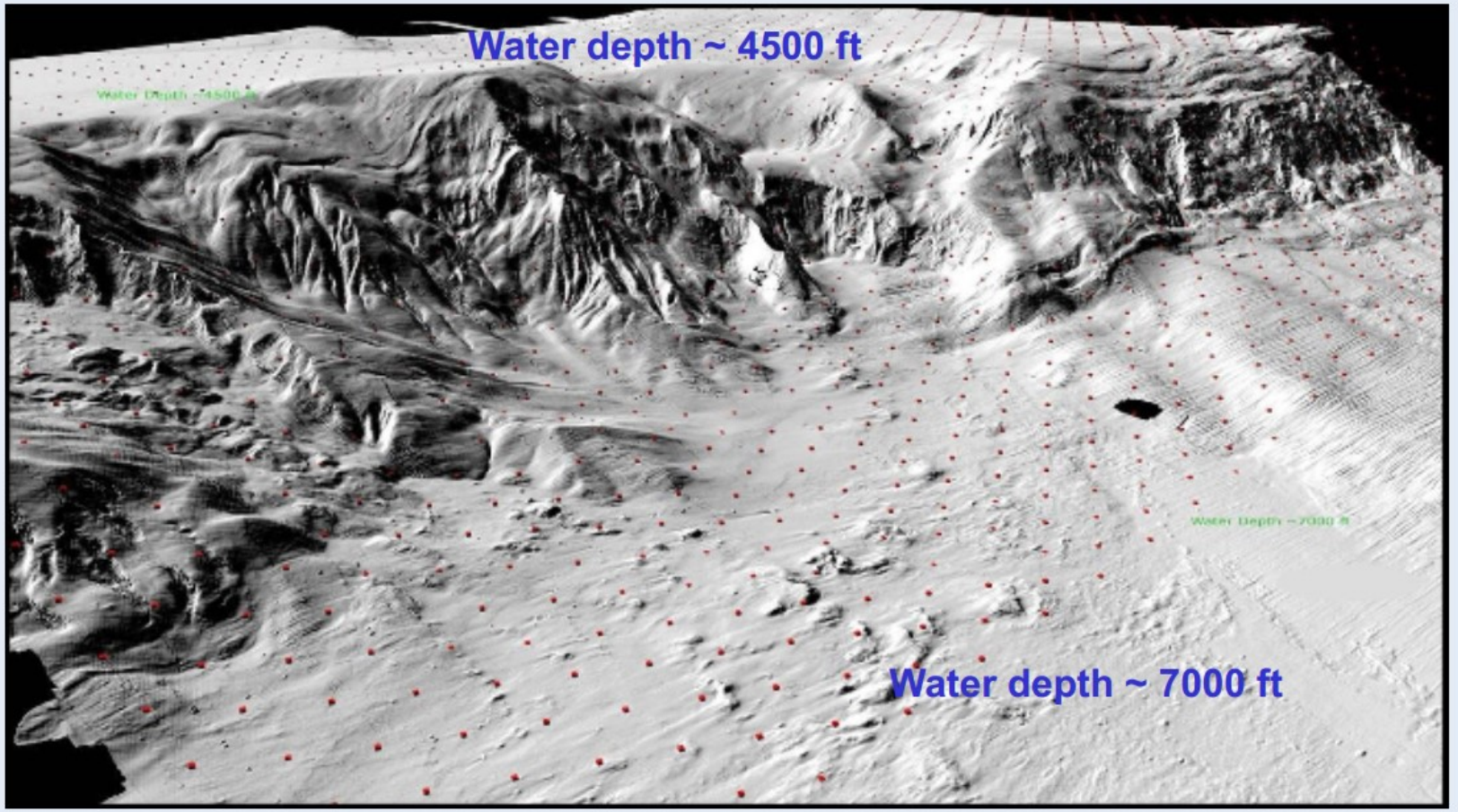
Ocean bottom Cable (OBC)



SEG

Ocean bottom Cable (OBC)

OBS in the Gulf of Mexico



Courtesy of Jerry Beaudoin and Alan Ross (BP) and BP partners in Atlantis

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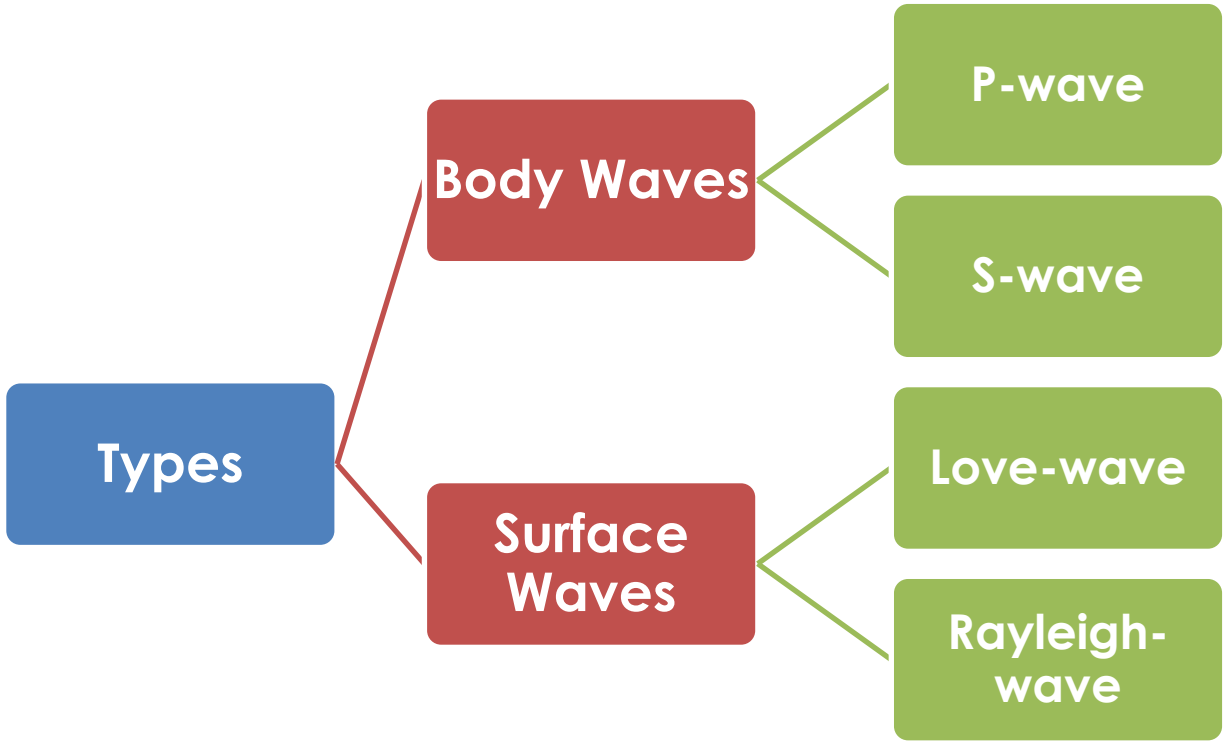
Structural Interpretation

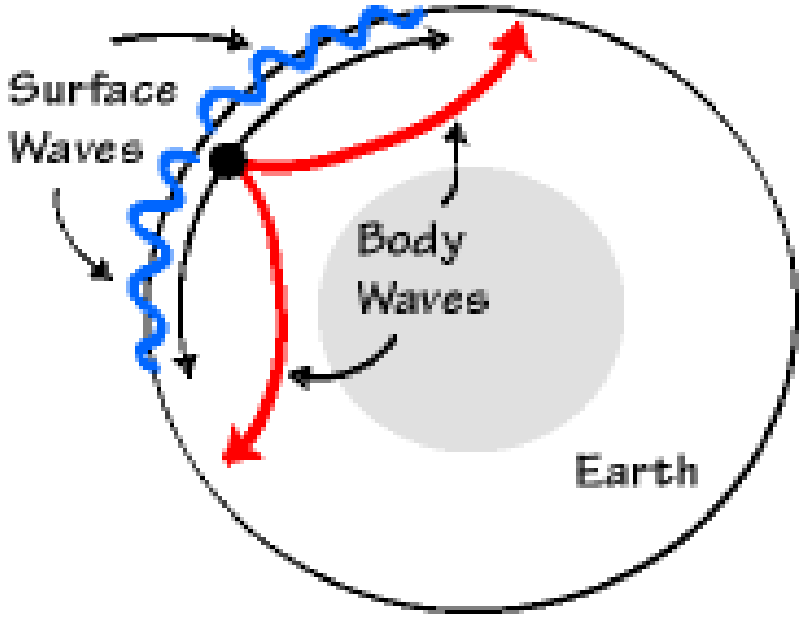
Waves

- A **wave** is the pattern in which some types of energy, such as sound, light, and heat, are spread or carried (Cambridge Dictionary).
- A wave is disturbance or oscillation (of a physical quantity), that travels through matter or space, accompanied by a transfer of energy (Wikipedia).
- *Examples:*
  - *Sound wave: variation of pressure in the air*
  - *Radio wave: variation of EM intensity*
  - *Water wave: variation of water surface*
  - *Seismic wave: variation of elastic deformation in rocks*
- Note that the medium doesn't travel along with the wave.
- Waves like the EM wave do not even need a medium to propagate.

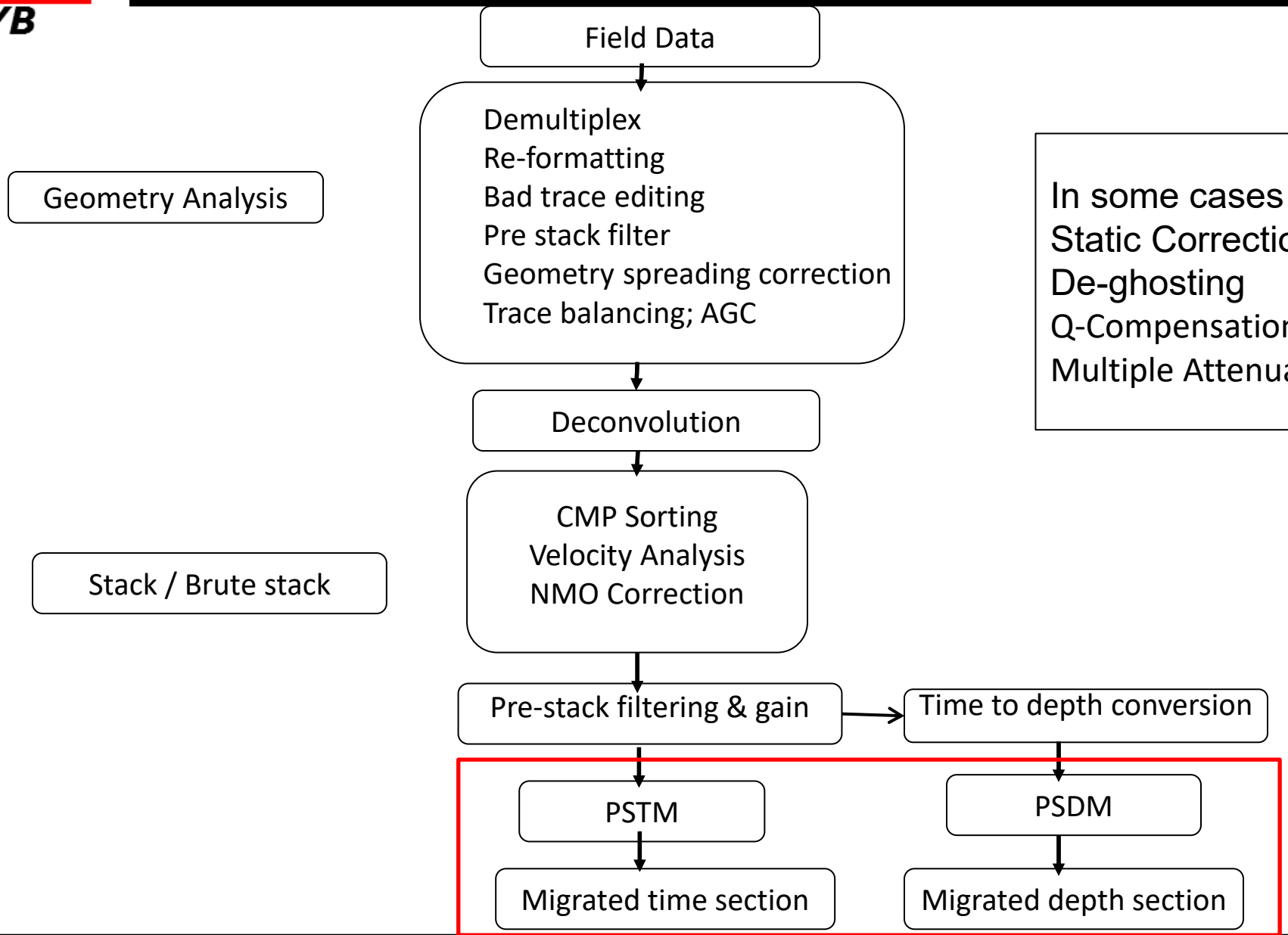
Types of Seismic Waves

- There are several different kinds of seismic waves, and they all move in different ways and travel at different velocities.
- Seismic waves travel through the Earth, as the result of a tectonic earthquake or an explosion. They propagate through a medium similar to sound waves. They are also called Elastic Waves.





Basic scheme of the seismic data processing



In some cases need to include:
Static Correction
De-ghosting
Q-Compensation
Multiple Attenuation

Velocity Analysis

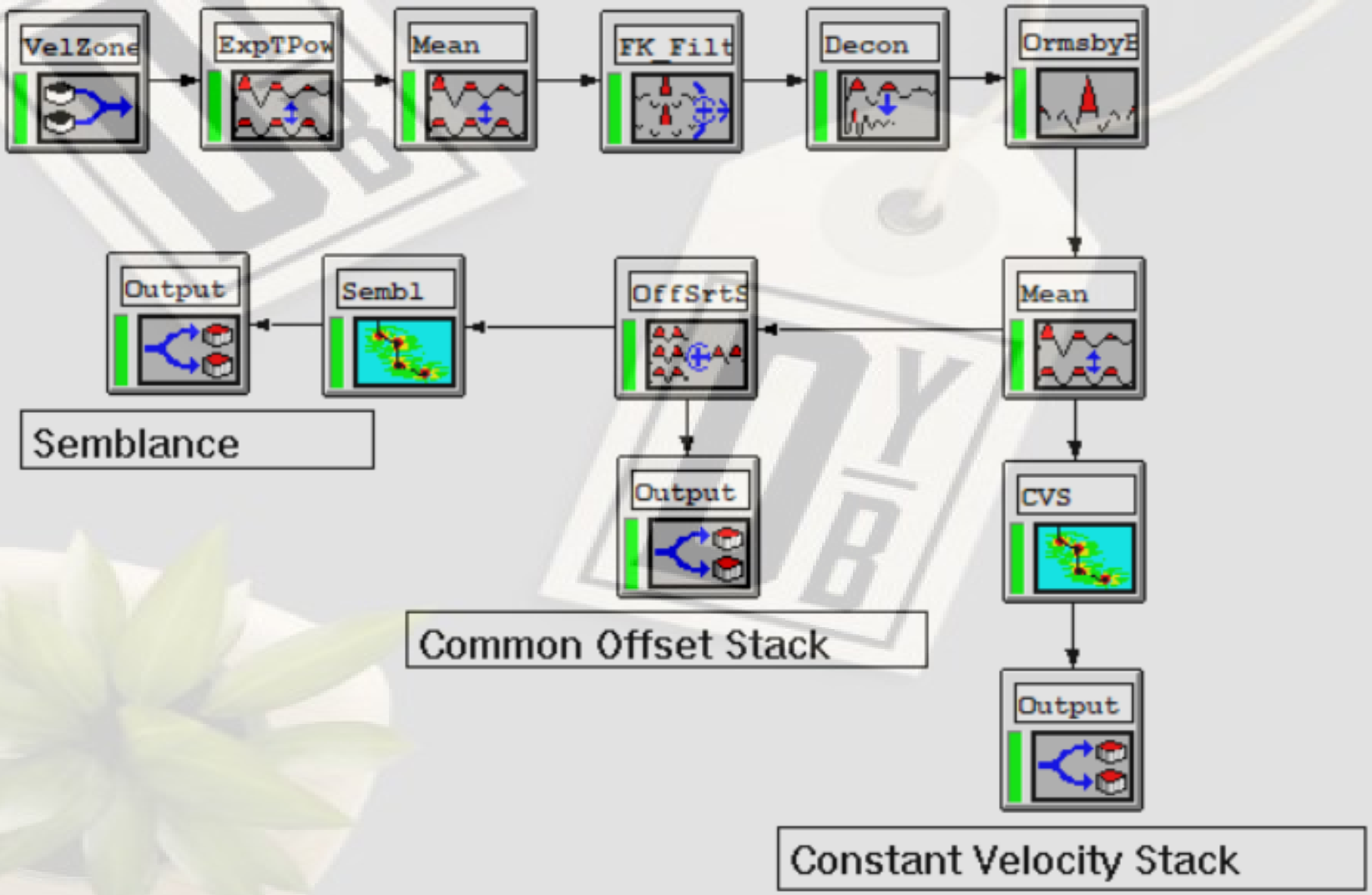
The aim of the velocity analysis is to find the velocity, that flattens a reflection hyperbola, which returns the best result when stacking is applied. This velocity is not always the real RMS velocity.

Therefore, a distinction is made between:
- vstack: the velocity that returns the best stacking result.
- vrms: the actual RMS-velocity of a layer.

For a horizontal layer and small offsets, both velocities are similar. When the reflectors are dipping then vstack is not equal to the actual velocity, but equal to the velocity that results in a similar reflection hyperbola

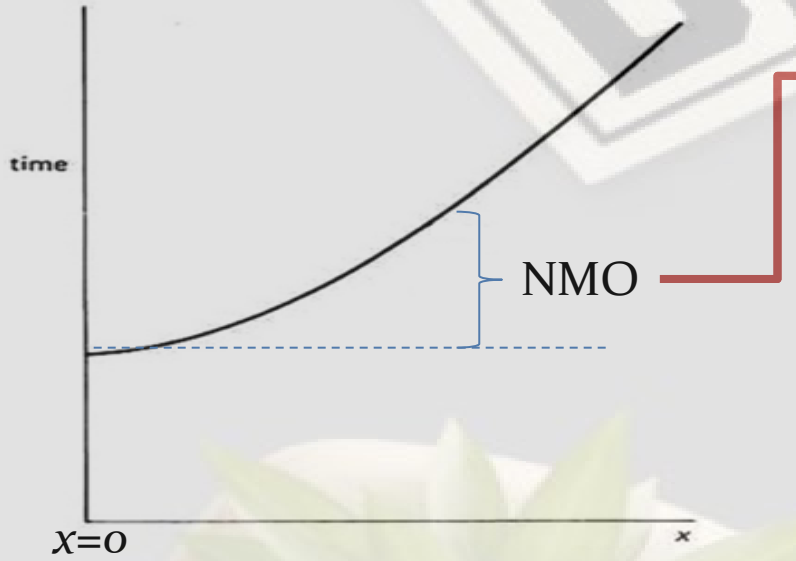
Semblance, Offset and CVS

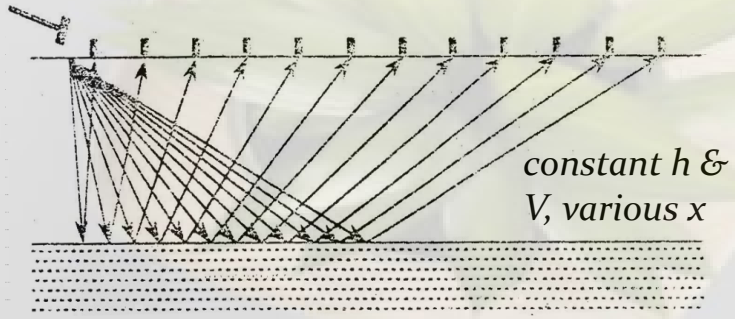
A Generalized Flow of a software to create you Semblance, CMP and CVS gather data.



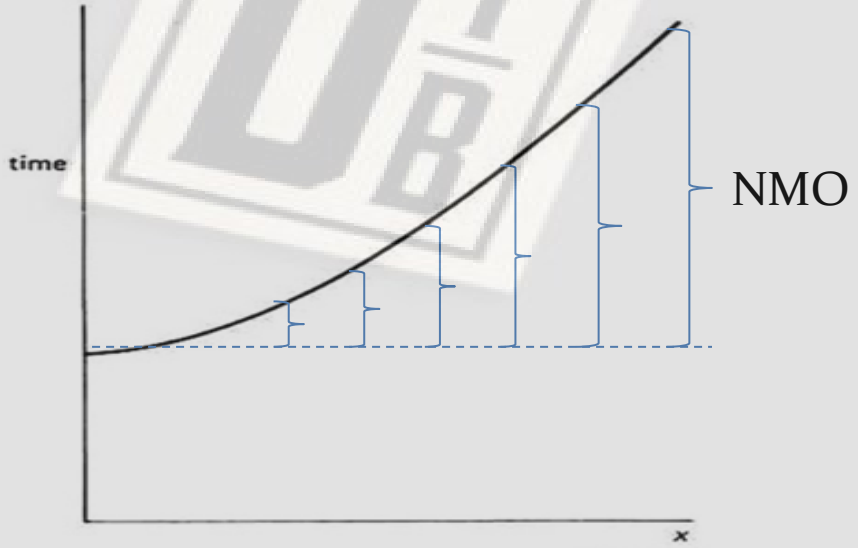
Concept of Normal Move-Out (NMO)

Difference in reflection travel-times from a horizontal reflecting surface due to variations in source-receiver distance.



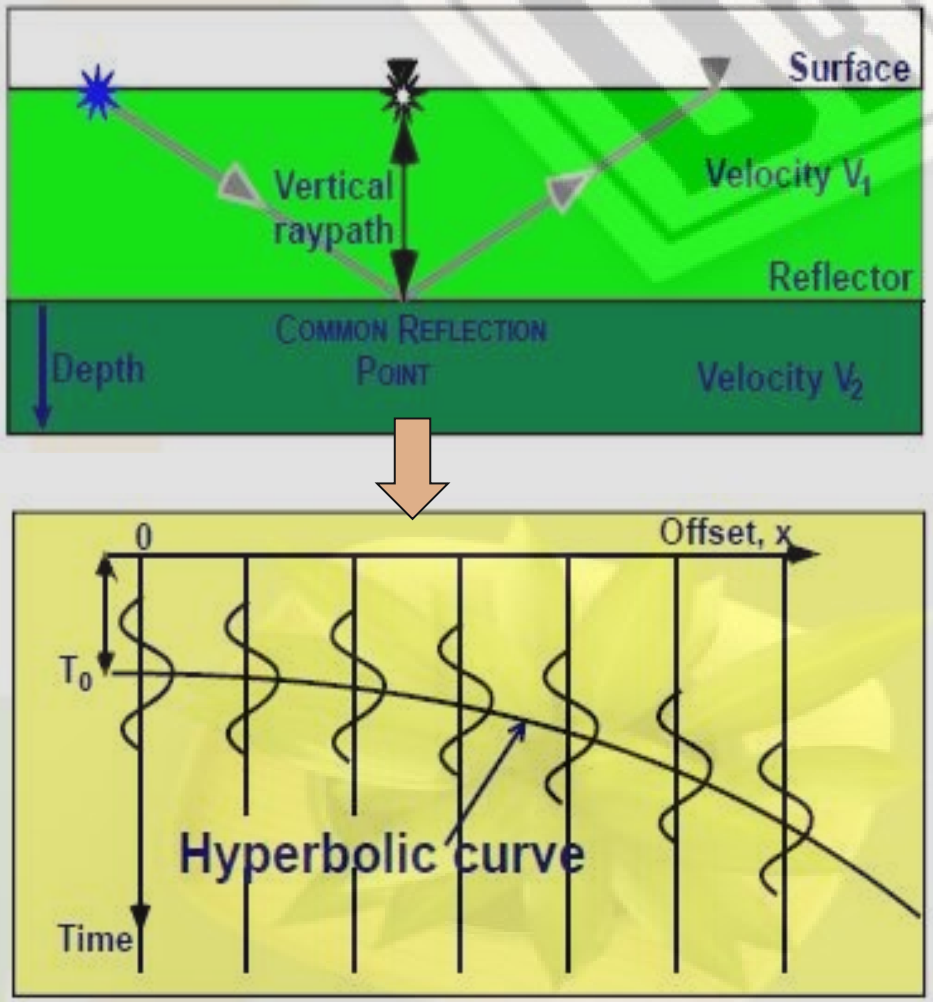


- For a horizontal layer, with thickness h and velocity V:
  - ✓ *the further the distance, the bigger the move-out.*



Normal Move Out (NMO)

- Difference between travel time at given offset & at zero offset is called NMO
- Velocity calculated from the hyperbola is known as NMO Velocity



NMO Equation:

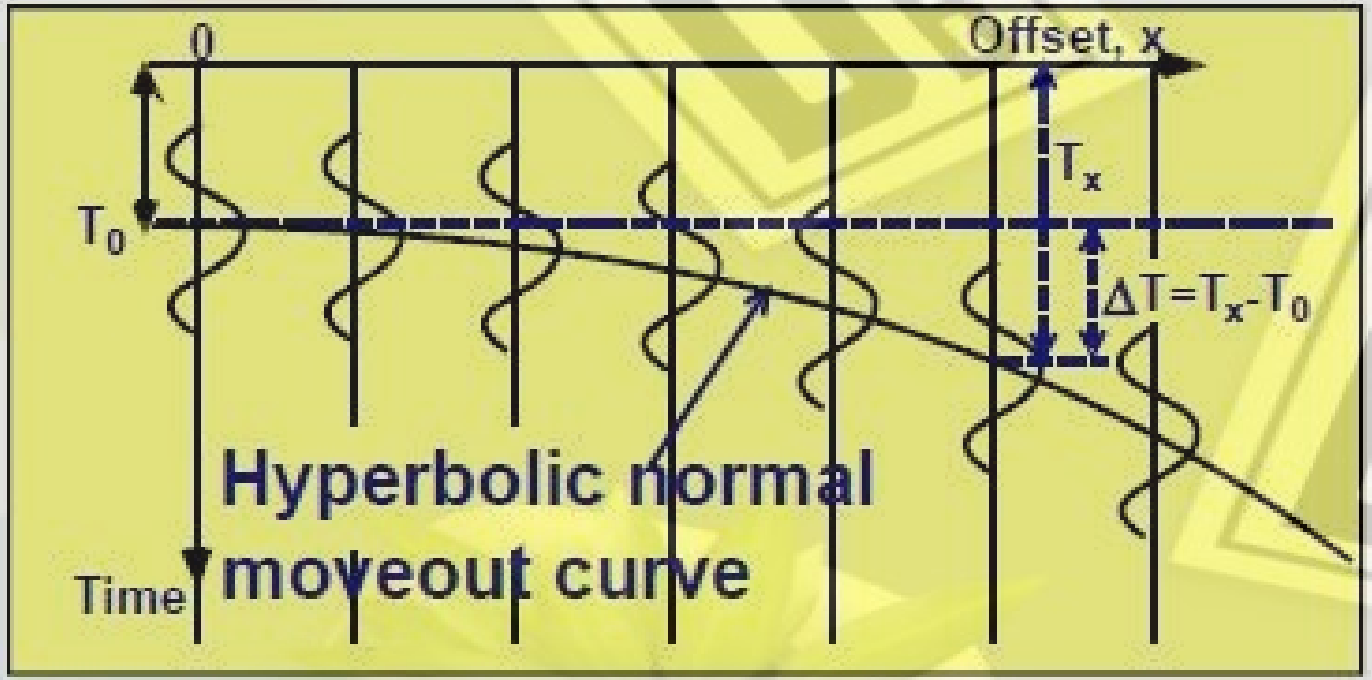
$$t^2 = t_0^2 + \frac{x^2}{v^2}$$

$$t_2 - t_1 \approx \frac{x_2^2 - x_1^2}{2v^2 t_0}$$

The NMO-correction is also called a dynamic correction.

NMO Correction

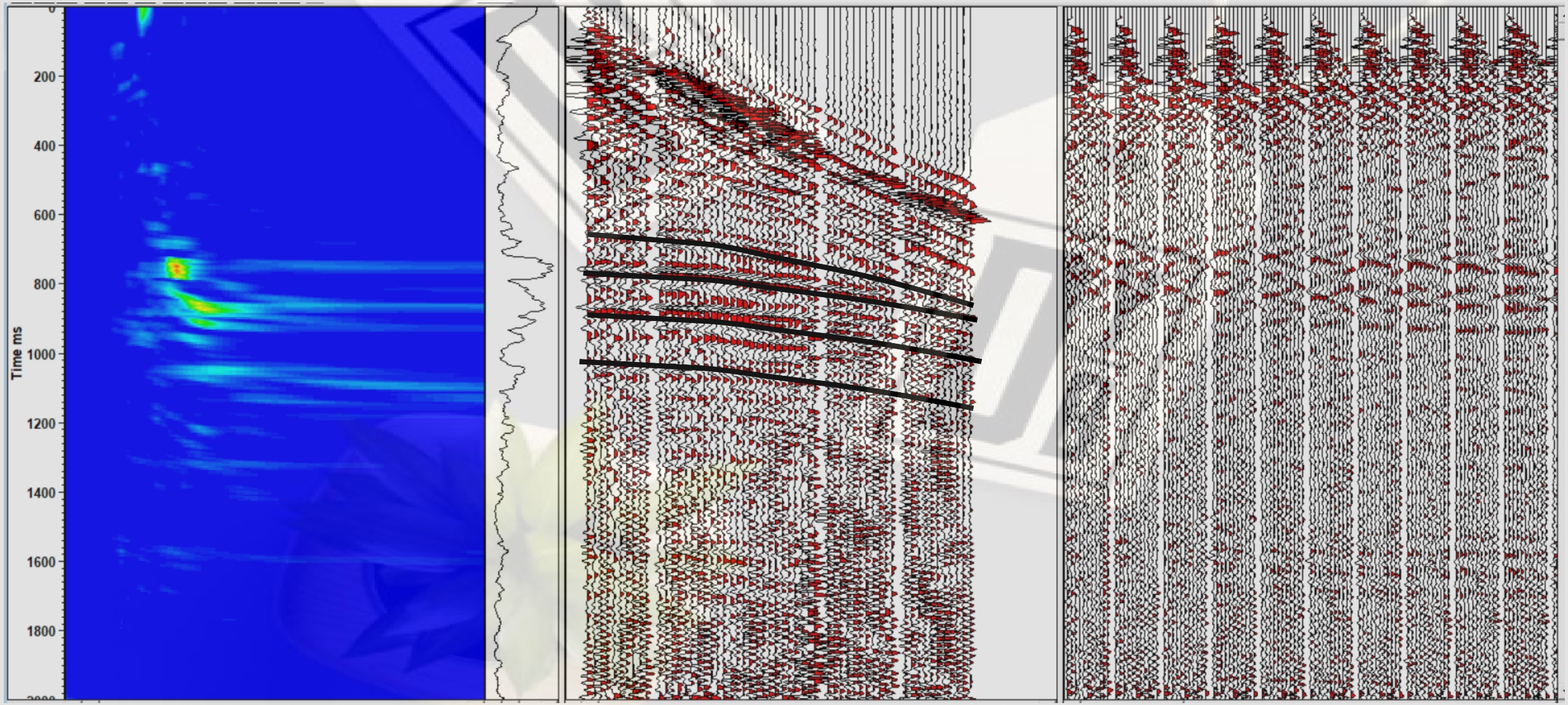
- Calculate NMO velocity & apply the correction to remove the effect of the offset.



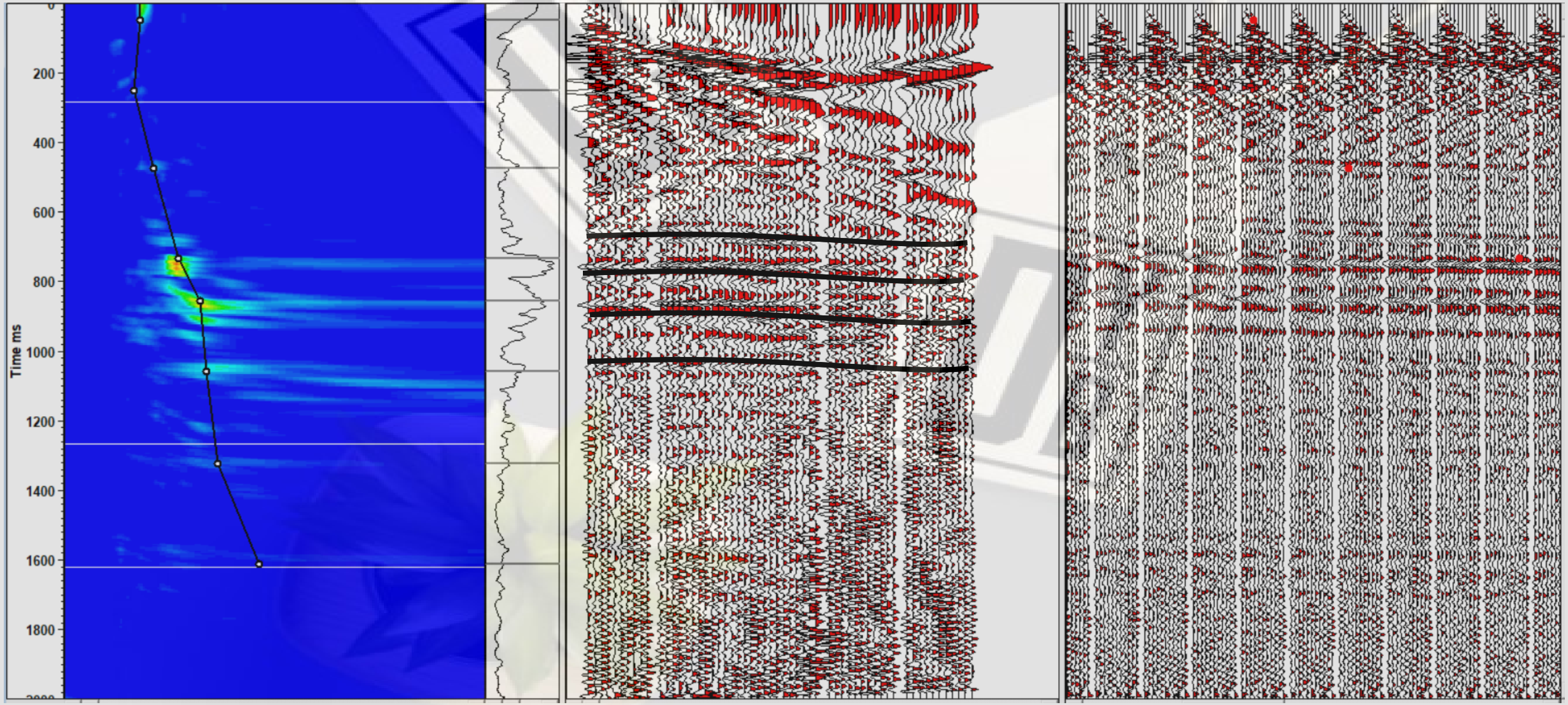
- Offset Increase, ΔT_{NMO} increase.
- Depth of Reflector increases, ΔT_{NMO} decrease.
- Velocity increases, ΔT_{NMO} decreases

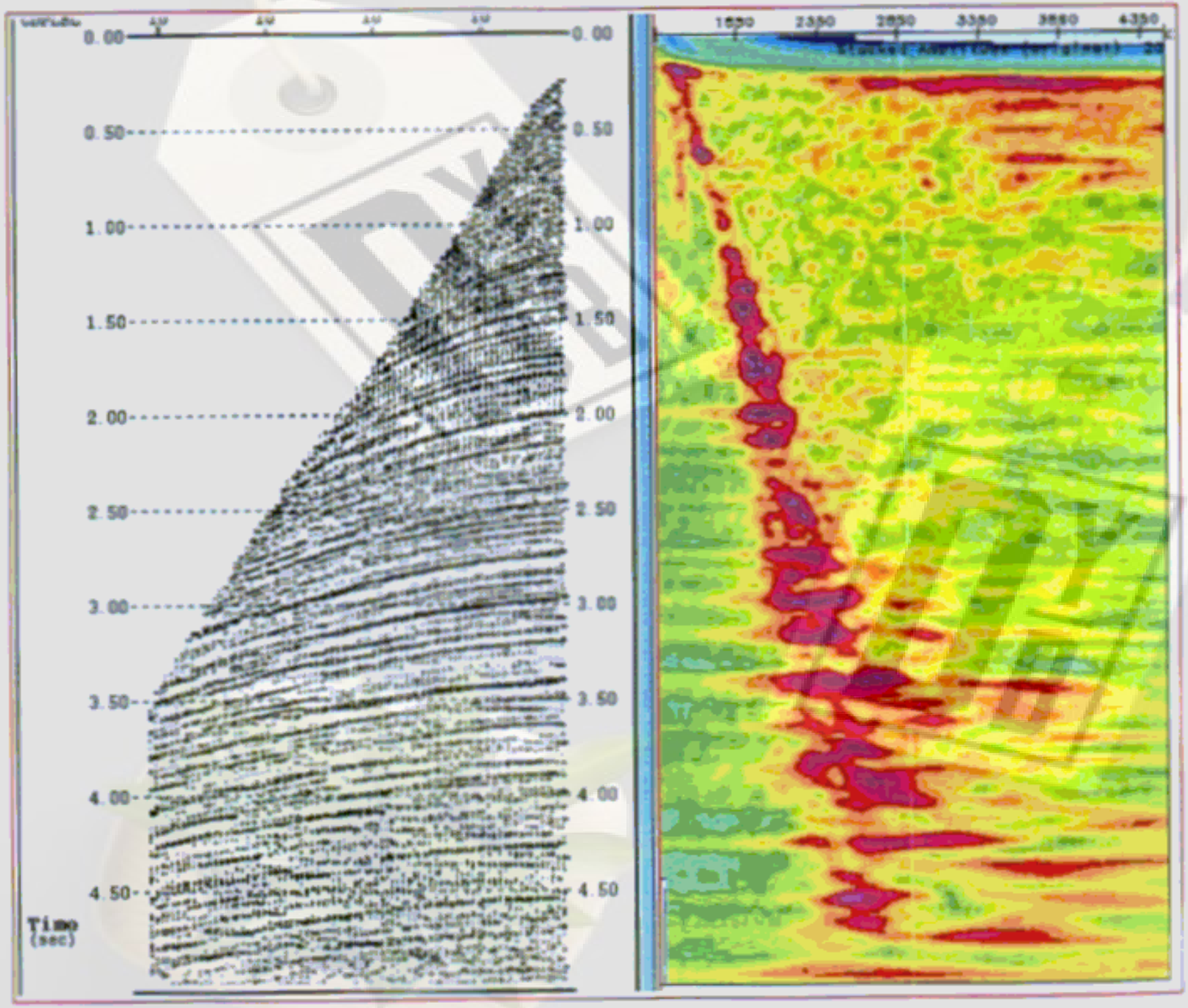
$$\Delta t_{nmo} = t_x - t_0$$

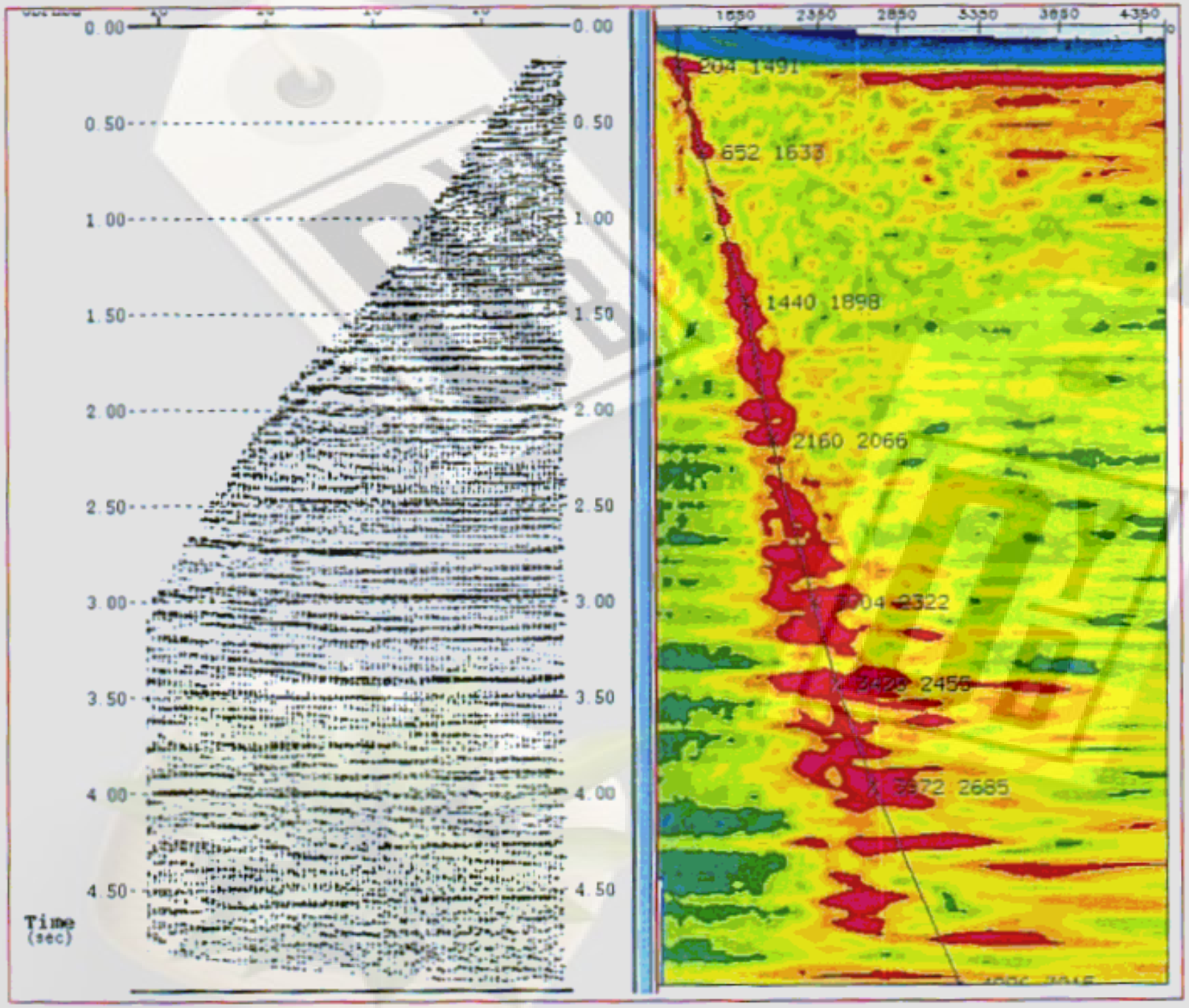
Velocity Picking and NMO



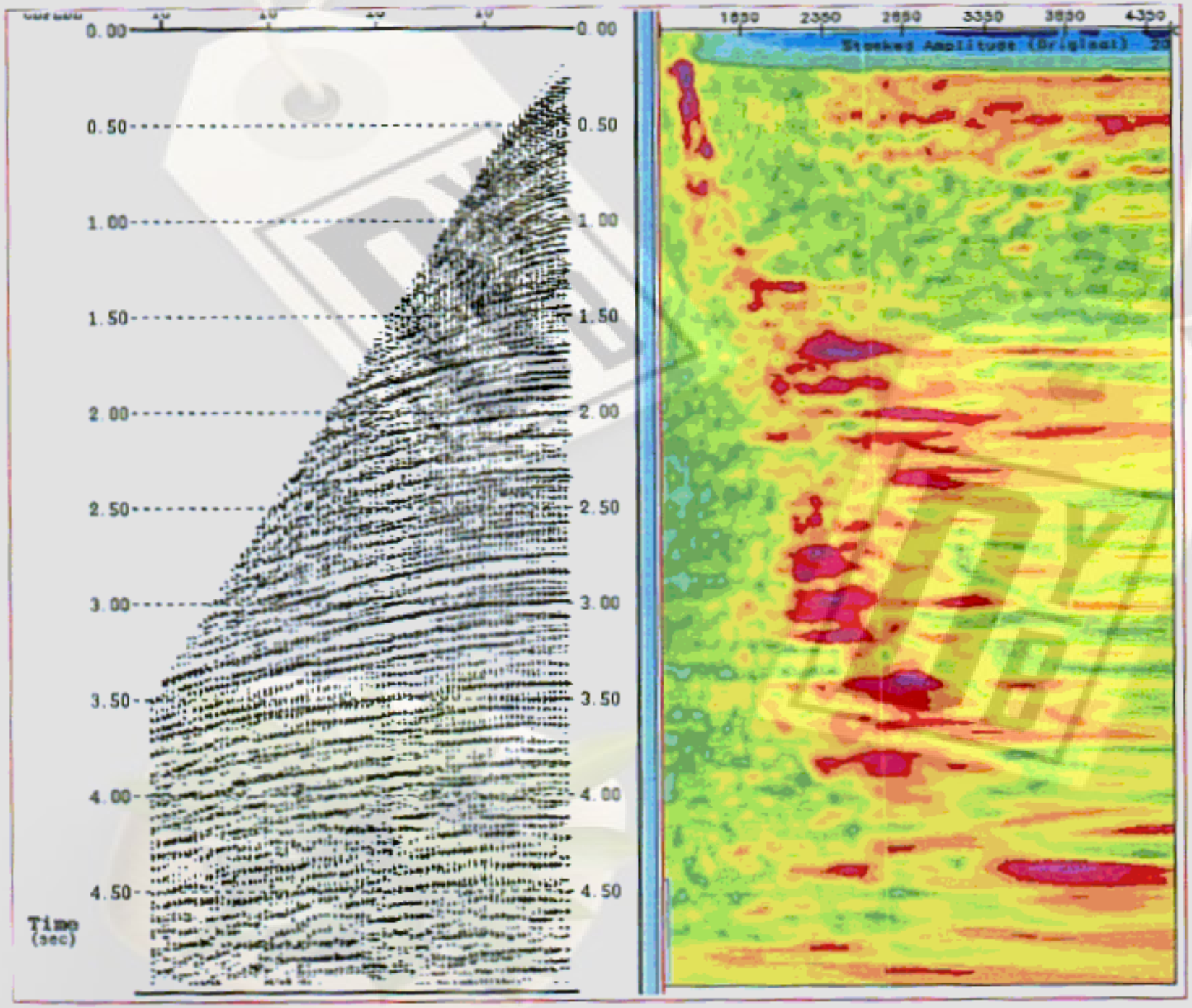
Velocity Picking and NMO

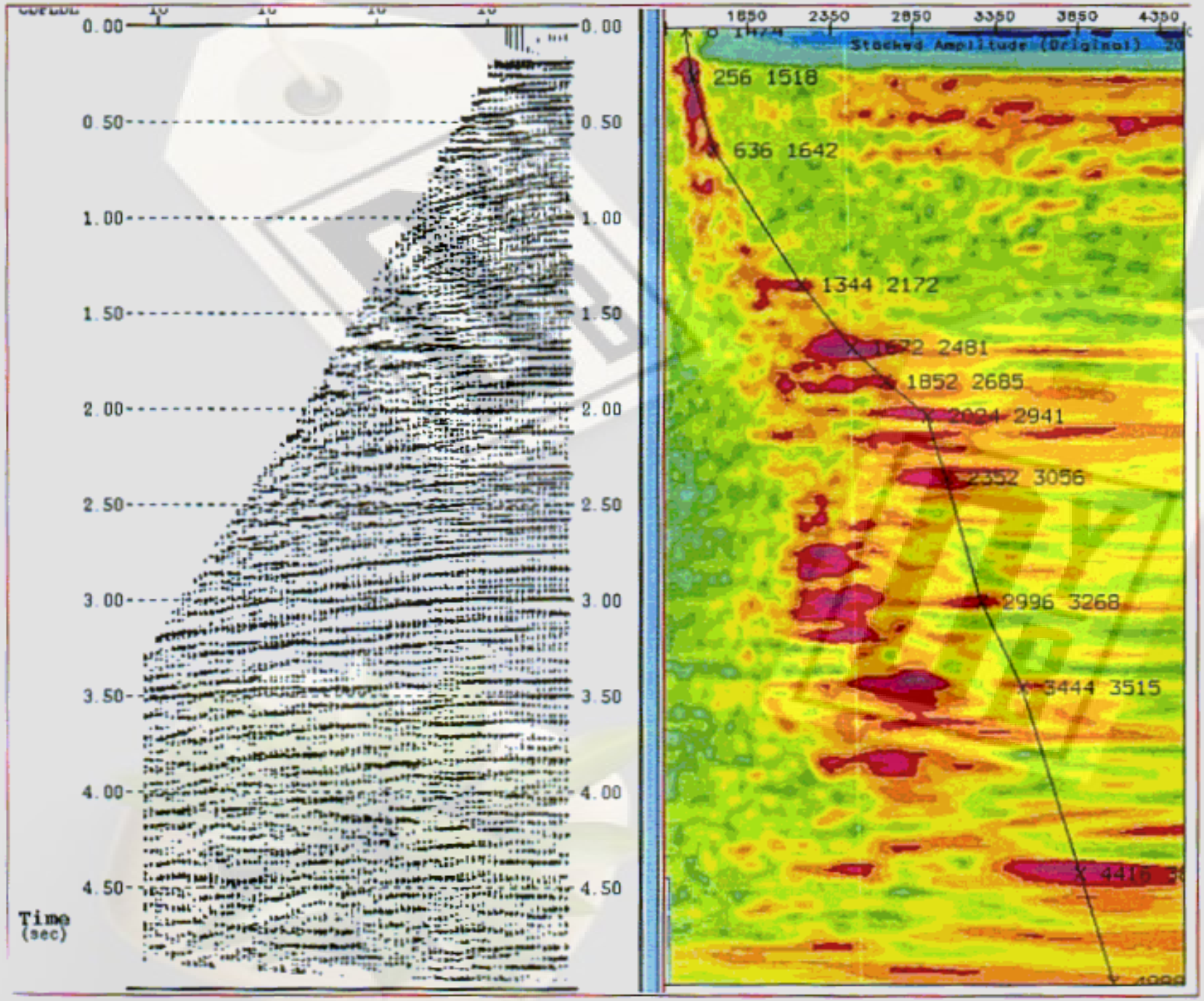



0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
Time
(sec)
1650
2350
2850
3350
3850
4350

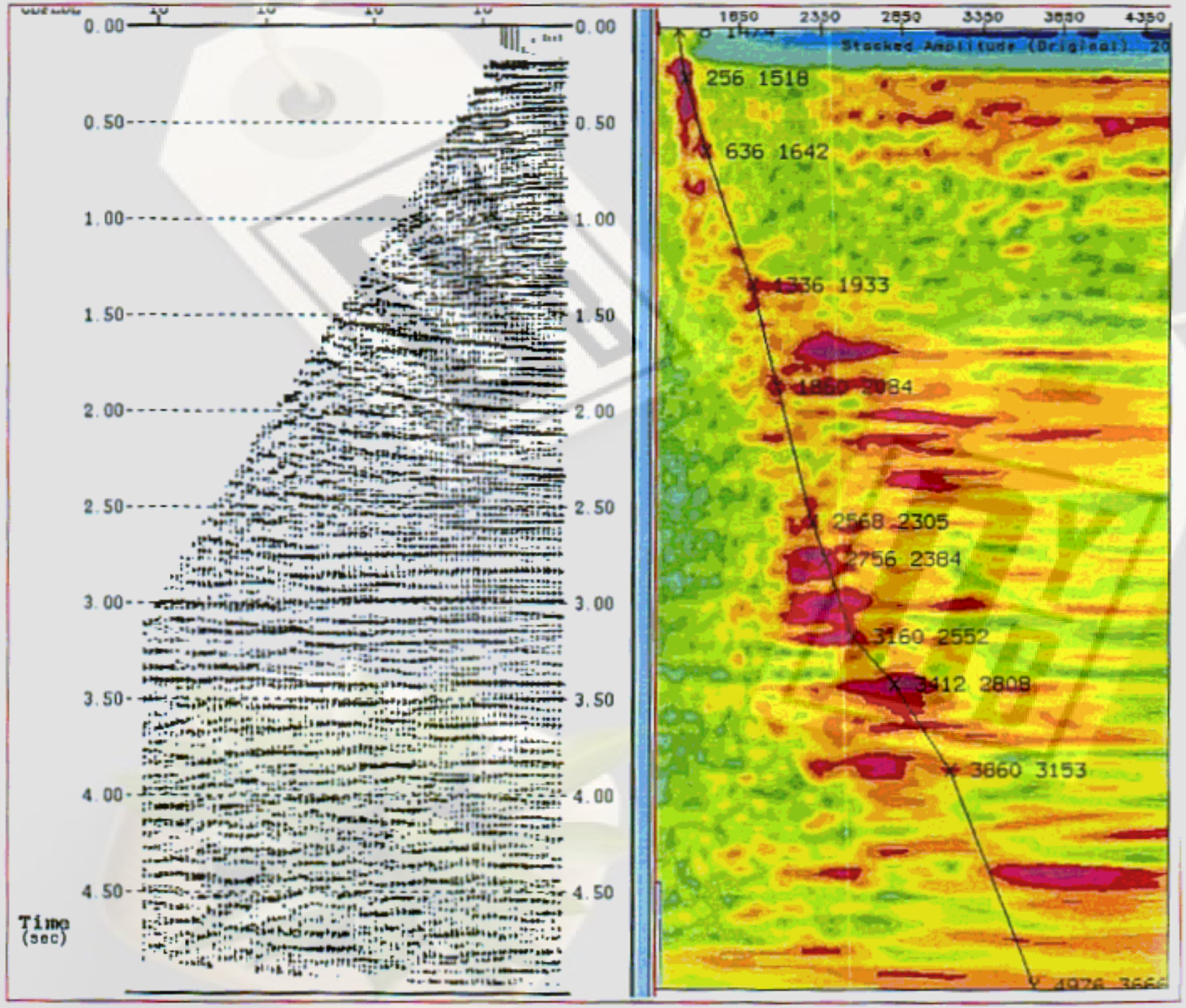


With moveout correction to the data set using DMO-corrected velocity function that is posted on the spectrum.


0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
Time
(sec)
1850
2350
2850
3350
3850
4350
Stacked Amplitude (Original)



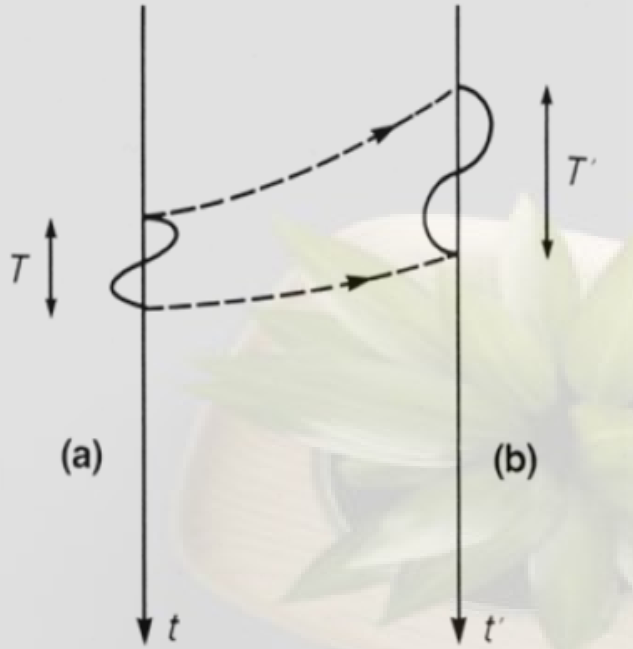
With moveout correction to the data set. This velocity function is appropriate for the steeply dipping events associated with the fault-plane reflection



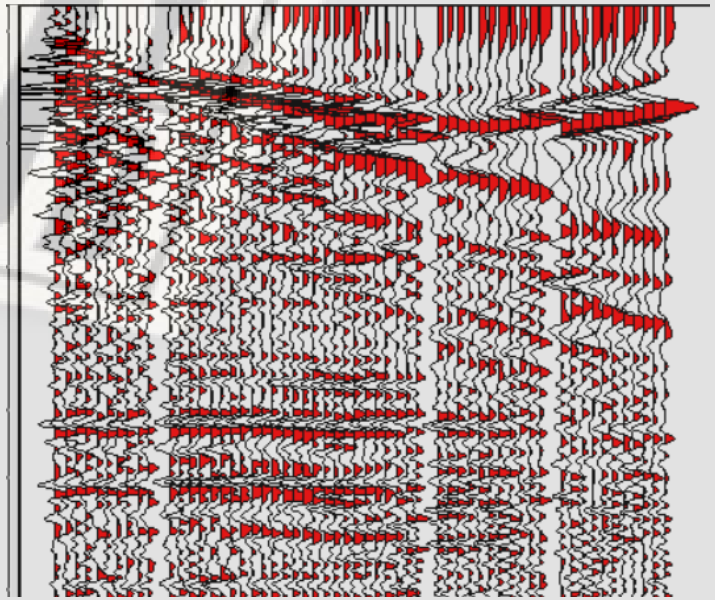
With moveout correction to the data set. This velocity function is appropriate for the nearly flat events associated with sedimentary strata.

Velocity Stretch

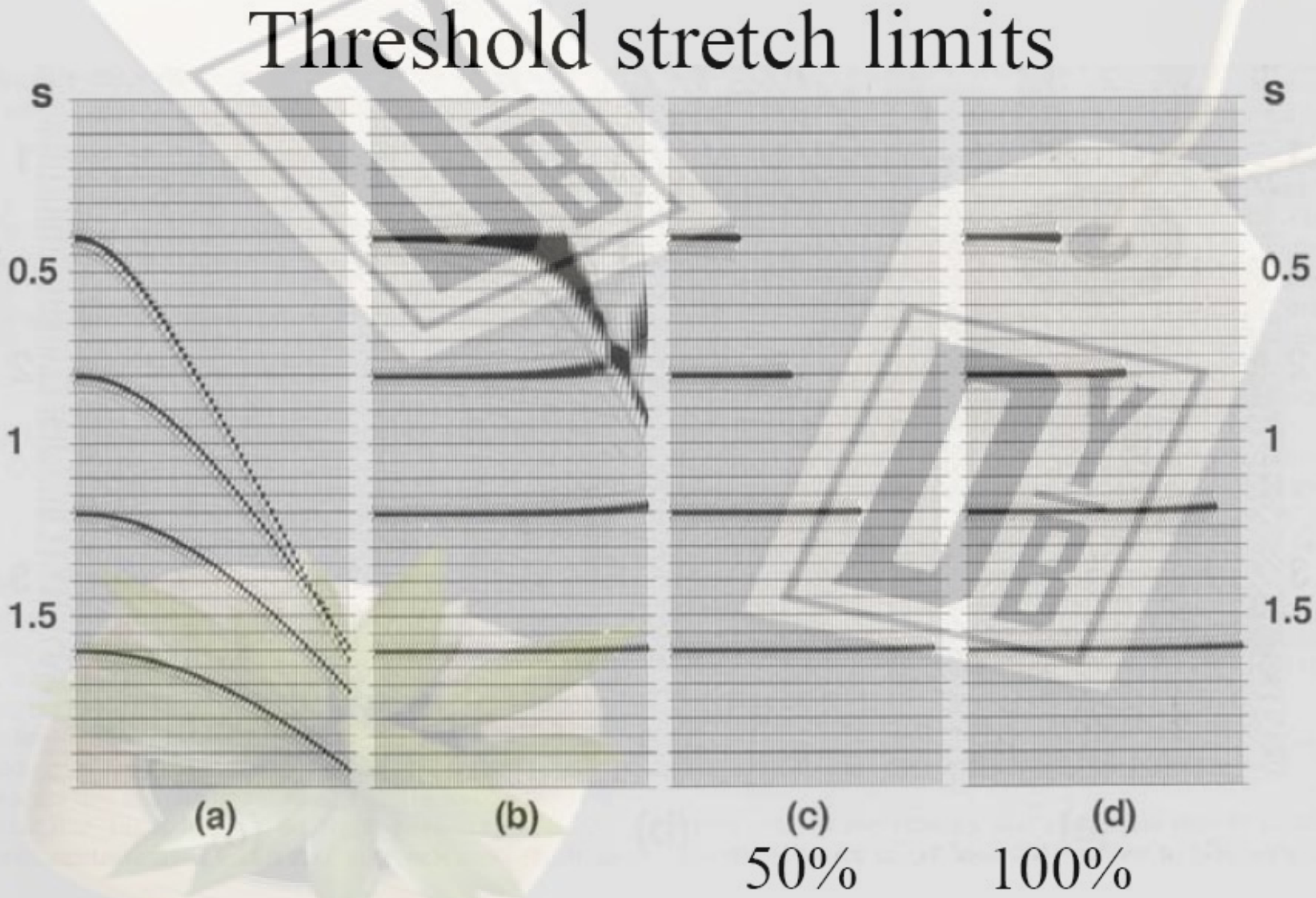
- NMO is a dynamic correction, that means that the values of a single trace are shifted with different amounts.
- This results for larger offsets in a stretching of the data and an artificial increase of the wavelength occurs.
- This effect is relatively large for horizontal reflections with low velocities.
- To reduce the effect of the stretching on the result of the stacking procedure, the part with severe stretching of the data is muted from the data (“stretch-mute”).



$$\Delta t_{NMO} = t_0 - t \approx \frac{x^2}{2v_{stack}^2 t_0}$$

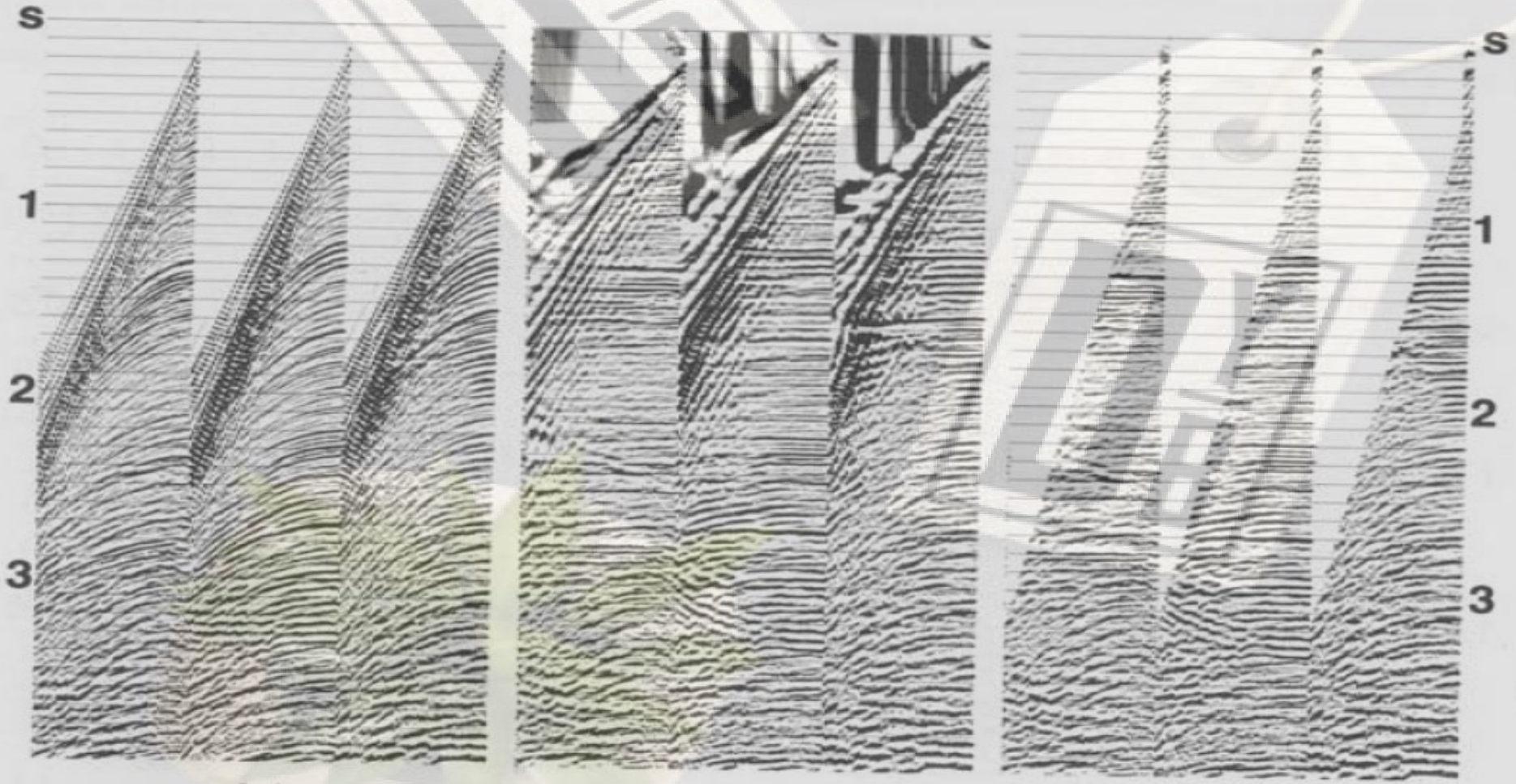


Velocity Stretch



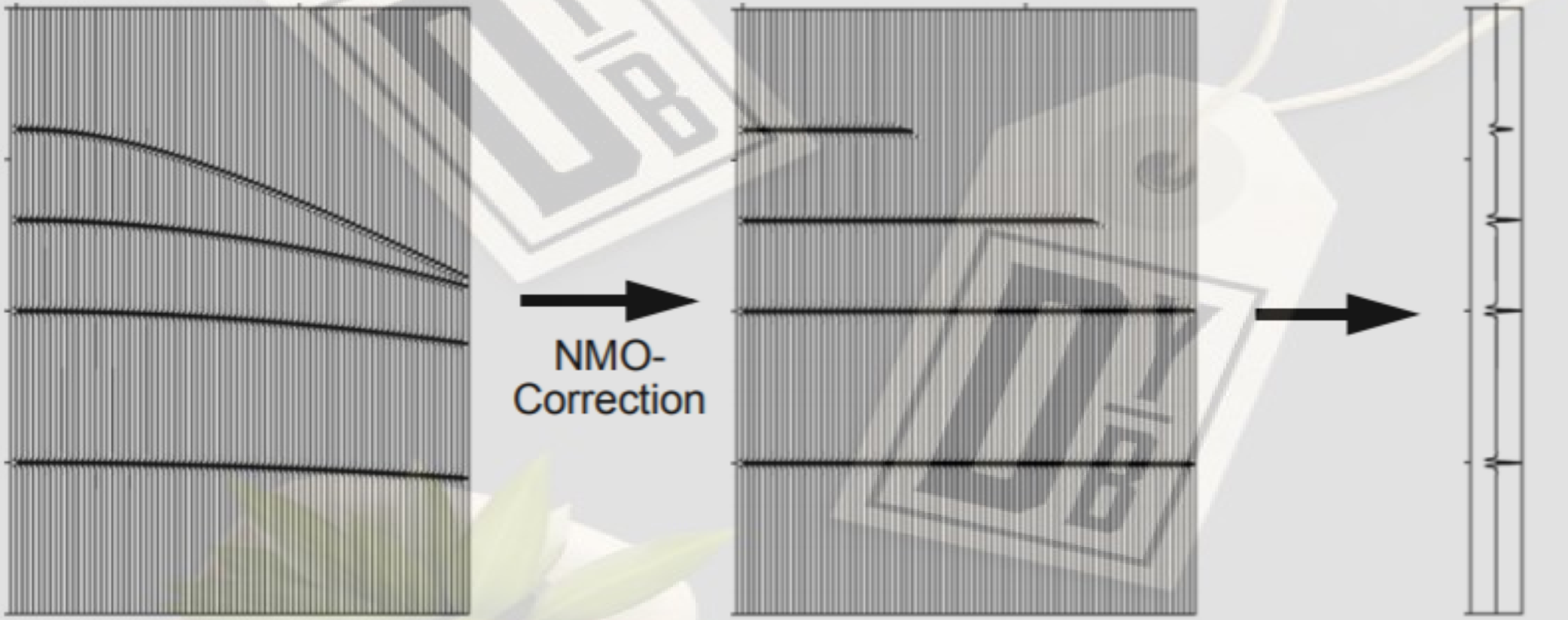
Velocity Stretch

NMO correction and muting of a stretched zone

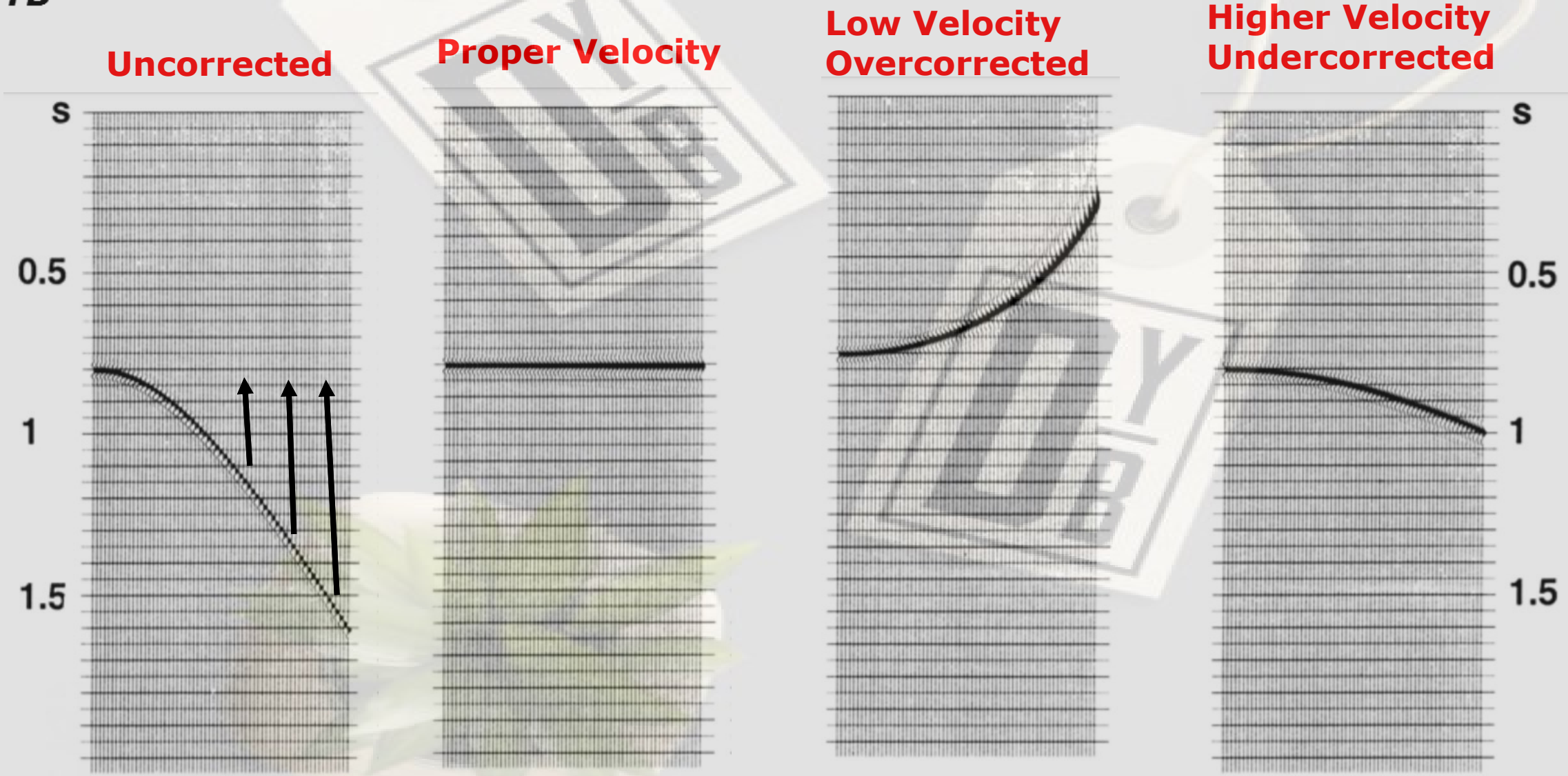


Yilmaz, 1987

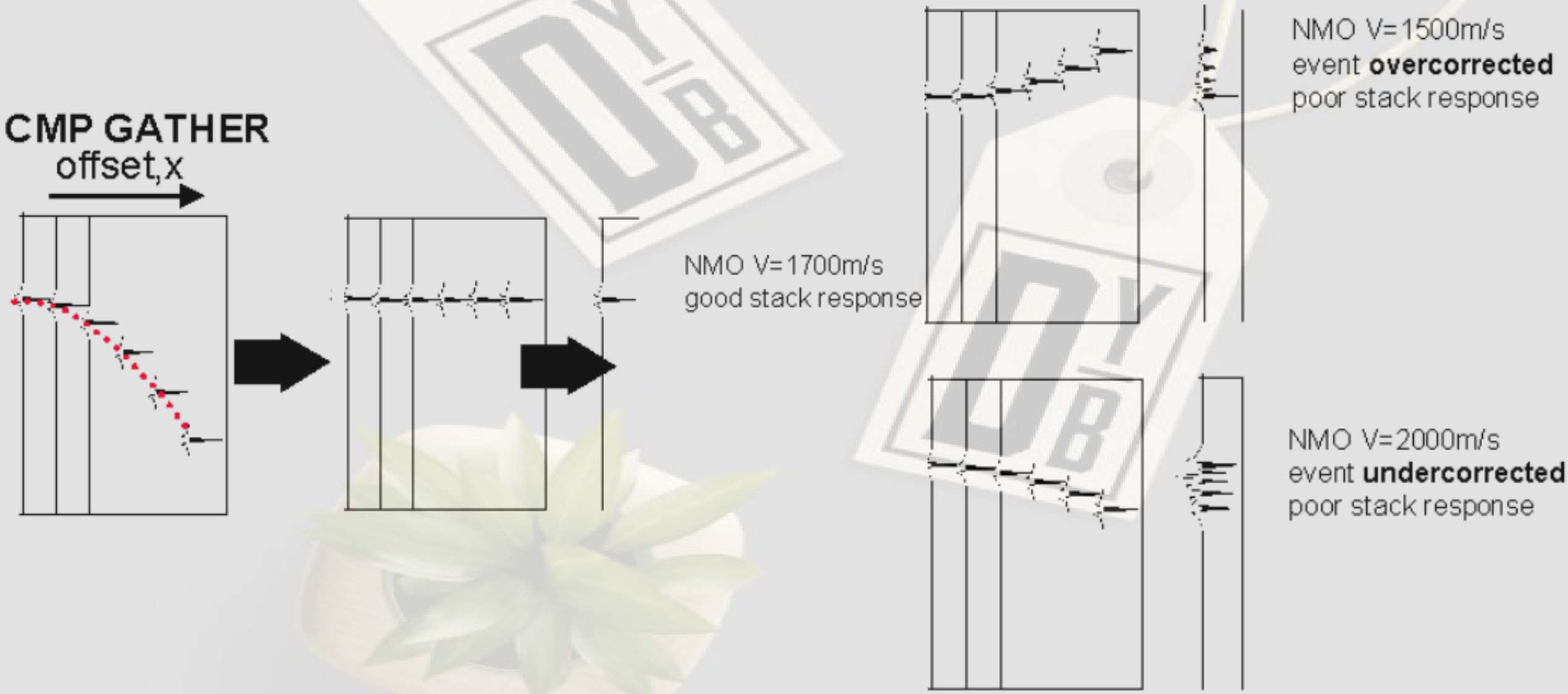
Ultimate Goal of NMO



Over and Under Corrected NMO

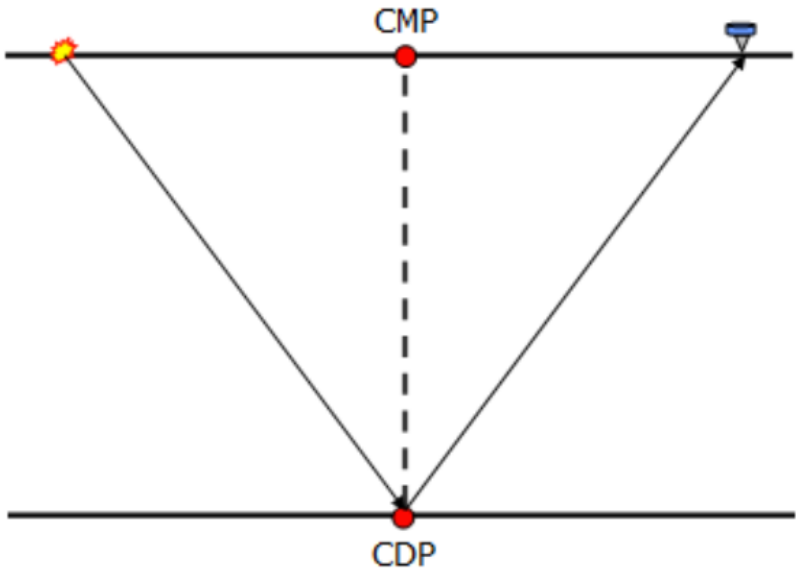


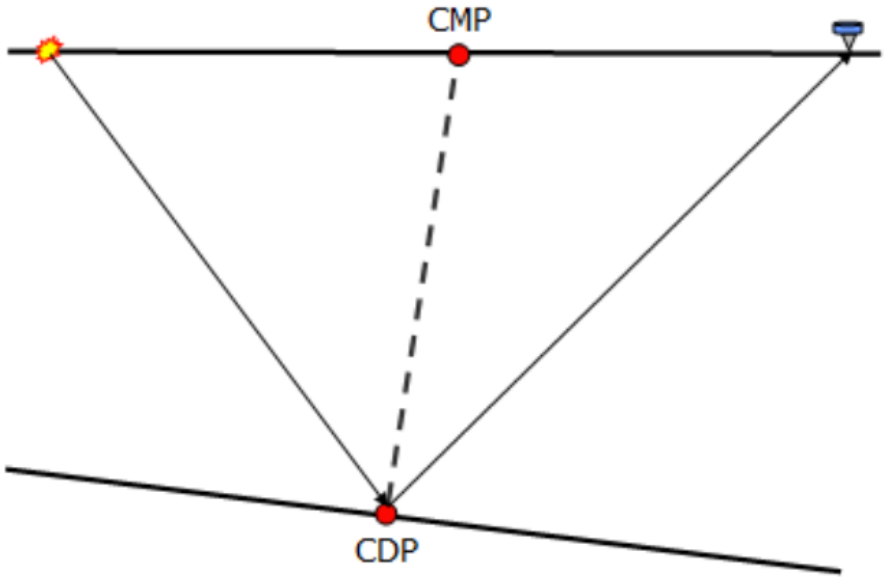
Benefits of Correct NMO Correction



Why Seismic Migration

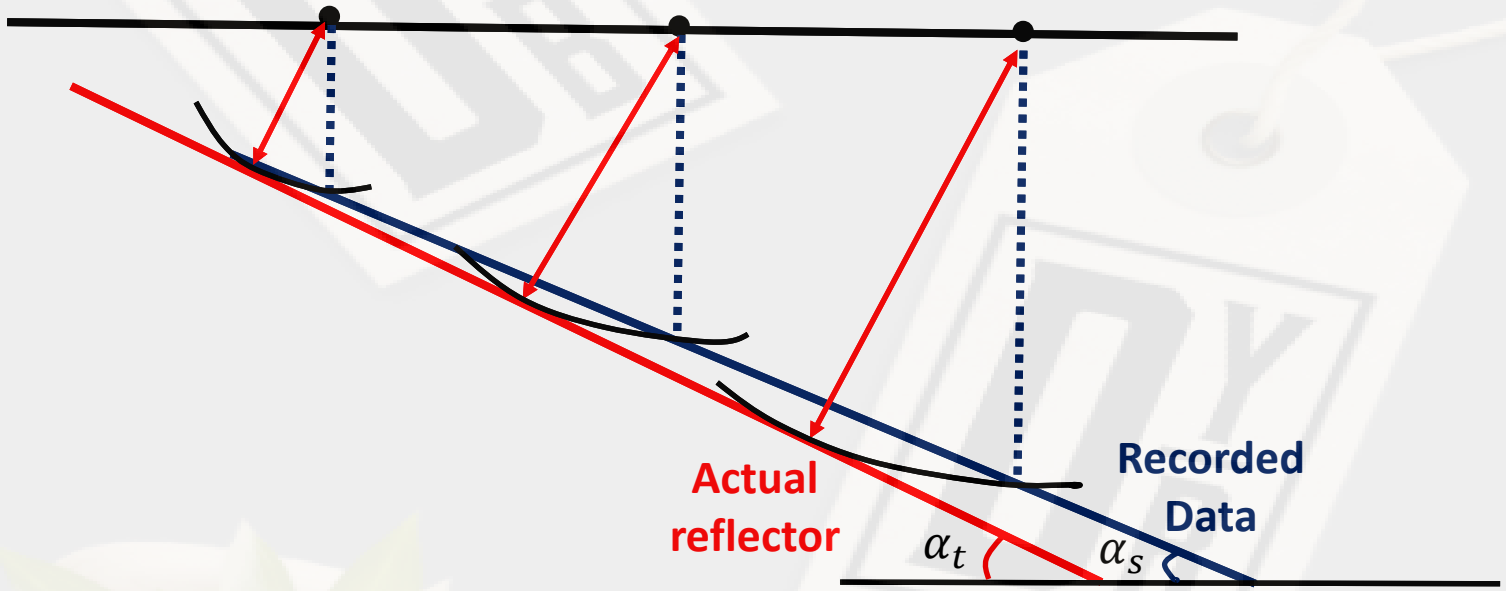
To understand why seismic expression does not show the true position of events, consider the following figures.
At the surface the common mid point (CMP) lies at the middle of shot and receiver positions. For a horizontal bed the common depth point (CDP) lies exactly below the CMP.





The seismic section will still show the CDP below the CMP, thus we need to shift it to its true position.

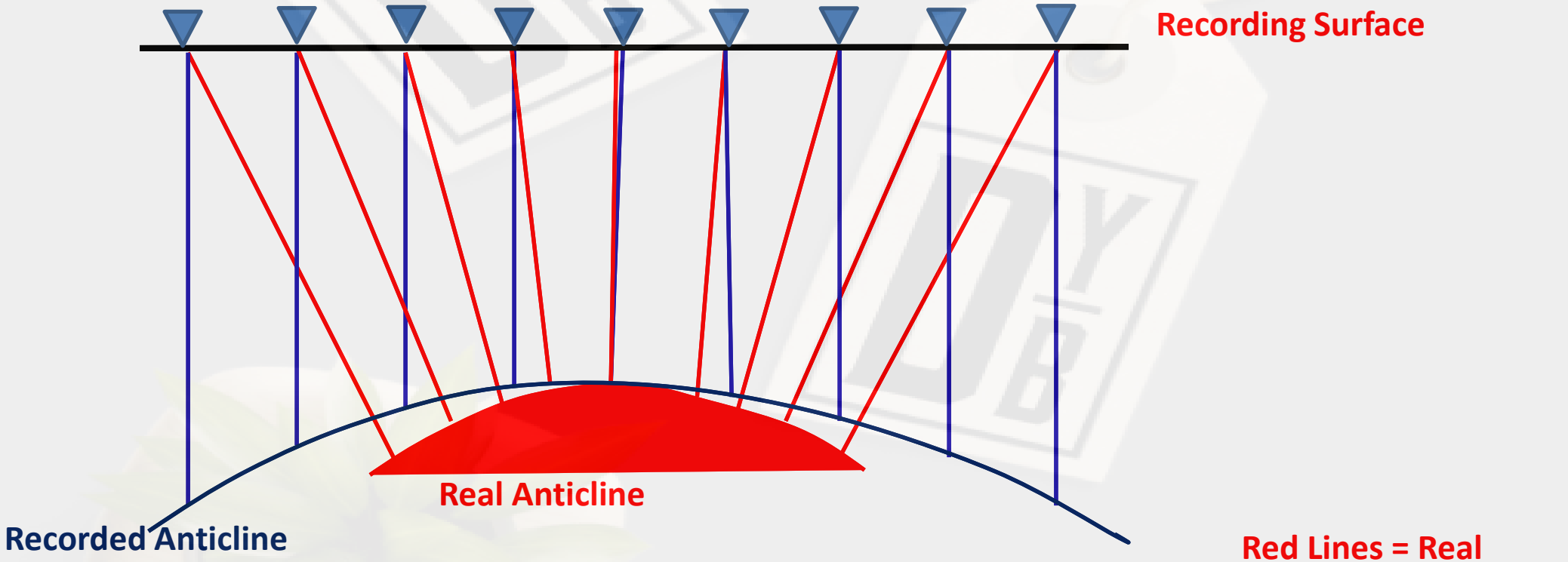
Dipping Reflector



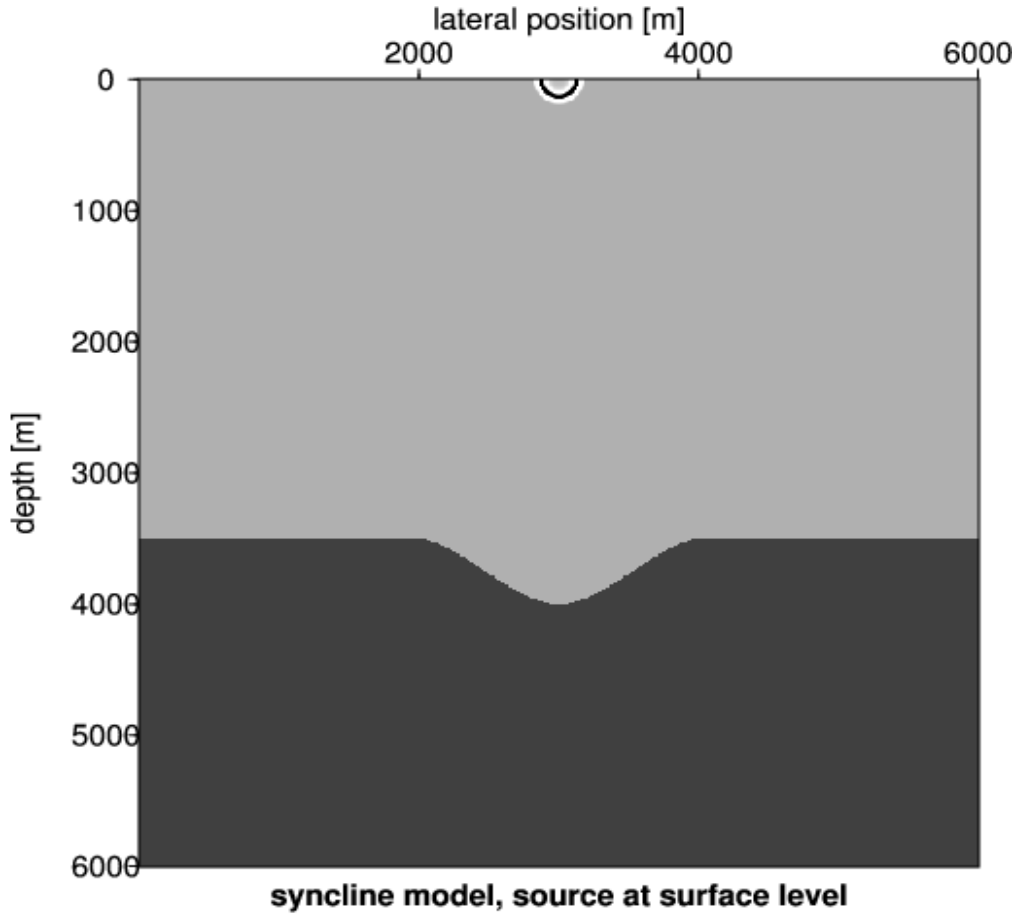
$$\sin(\alpha_{real}) = \tan(\alpha_{stacking})$$

Seismic response and migration of Anticline

Anticline structure will appear larger with wider flanks in seismic recorded data.



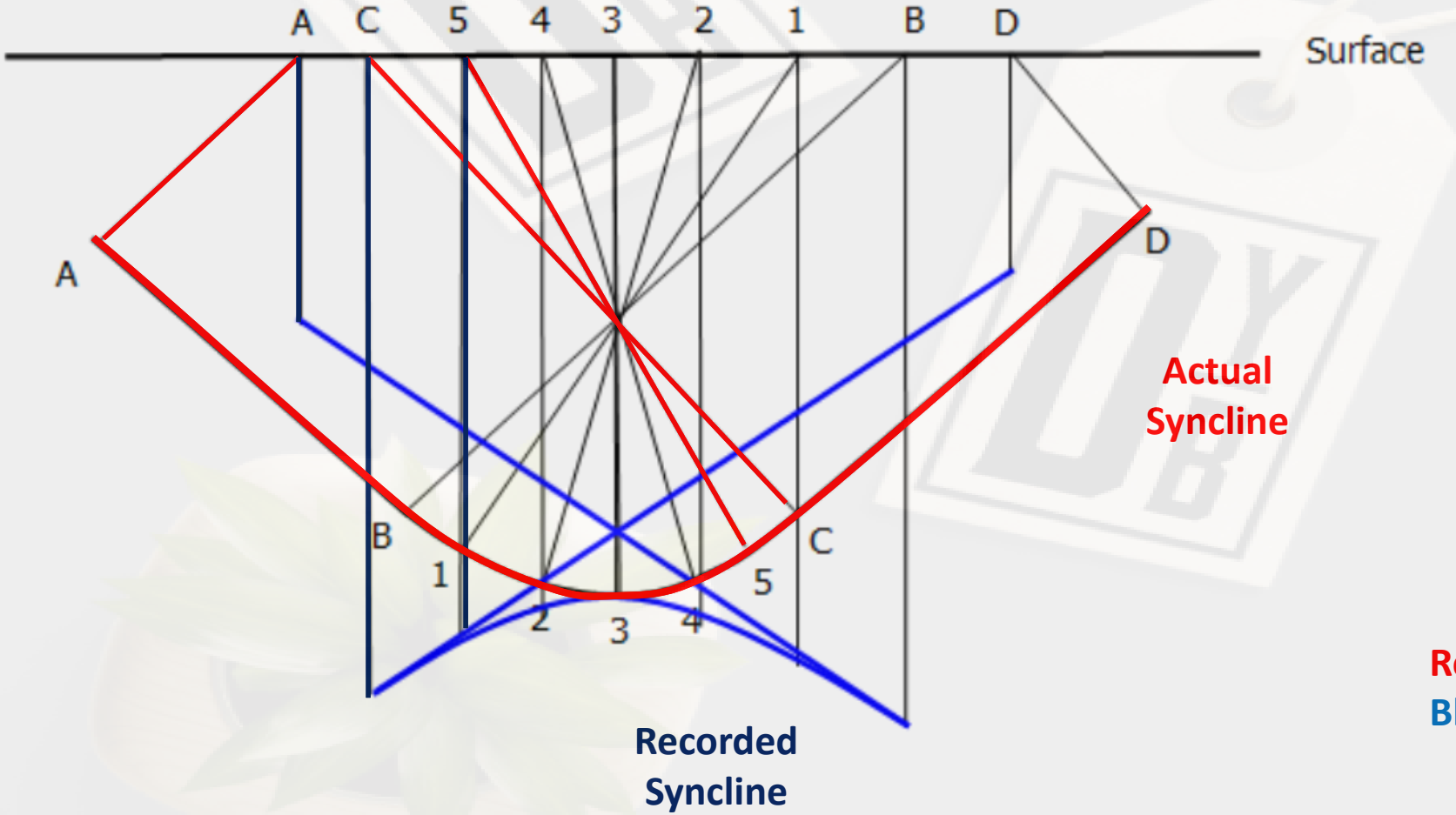
Bow-Tie Seismic Response



Seismic imaging simulates a section generated by having source and receivers located on reflector - Huygen's Principle

Seismic response and migration of Syncline

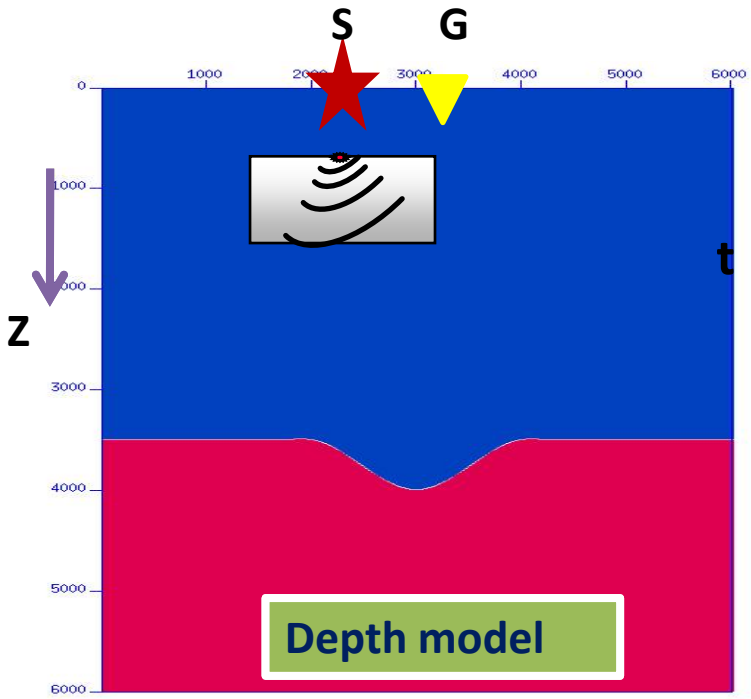
syncline will appear as a bow-tie in seismic



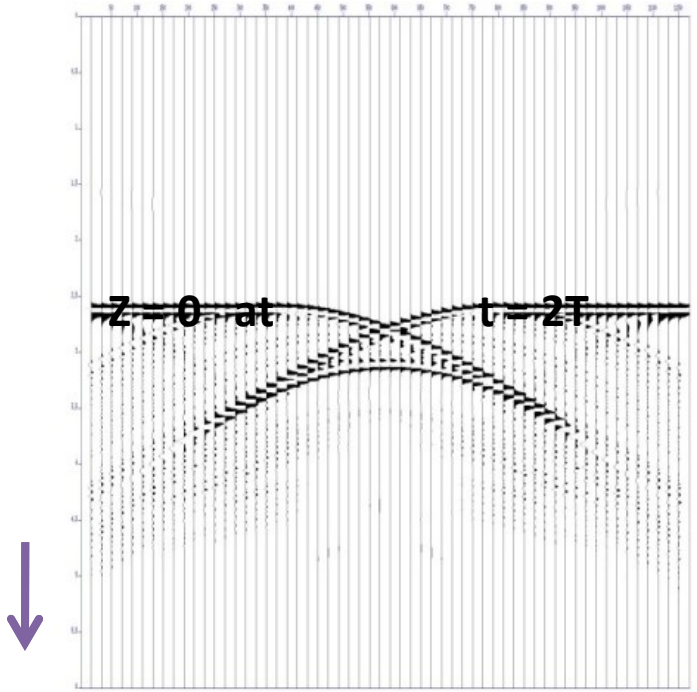
Red Lines = Real

Blude line = Recorded

Seismic Imaging a Focusing Process



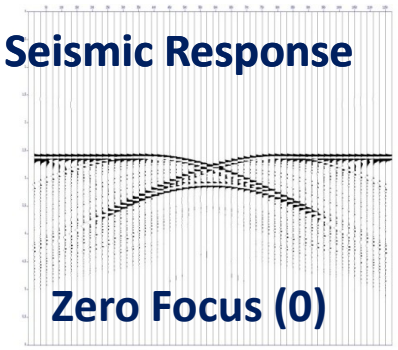
Z = 0



Zero Focus Seismic Response

Seismic Imaging a Focusing Process

Back propagate until recorded time is up

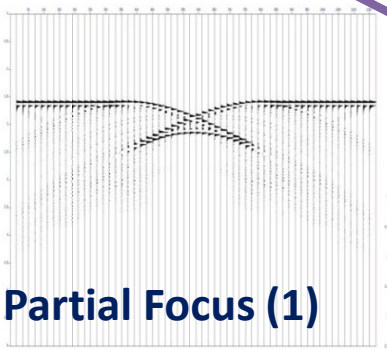


Seismic Response

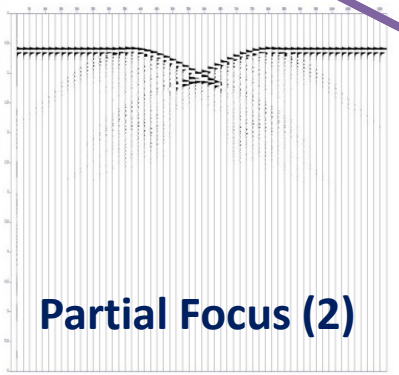
Zero Focus (0)

t = 2T

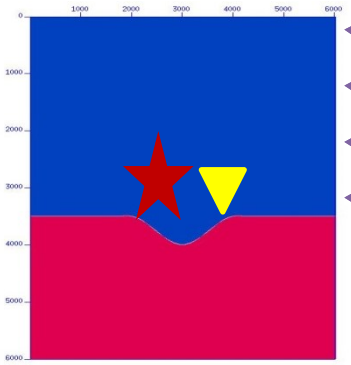
z = 0



Partial Focus (1)



Partial Focus (2)

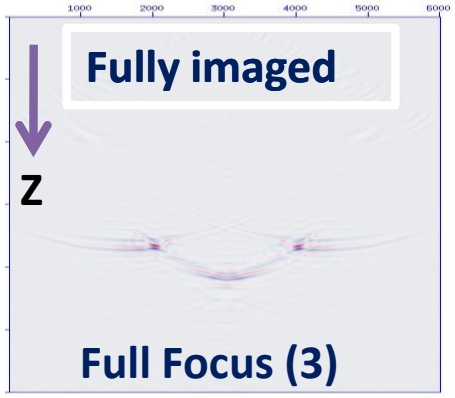


0

1

2

3



Fully imaged

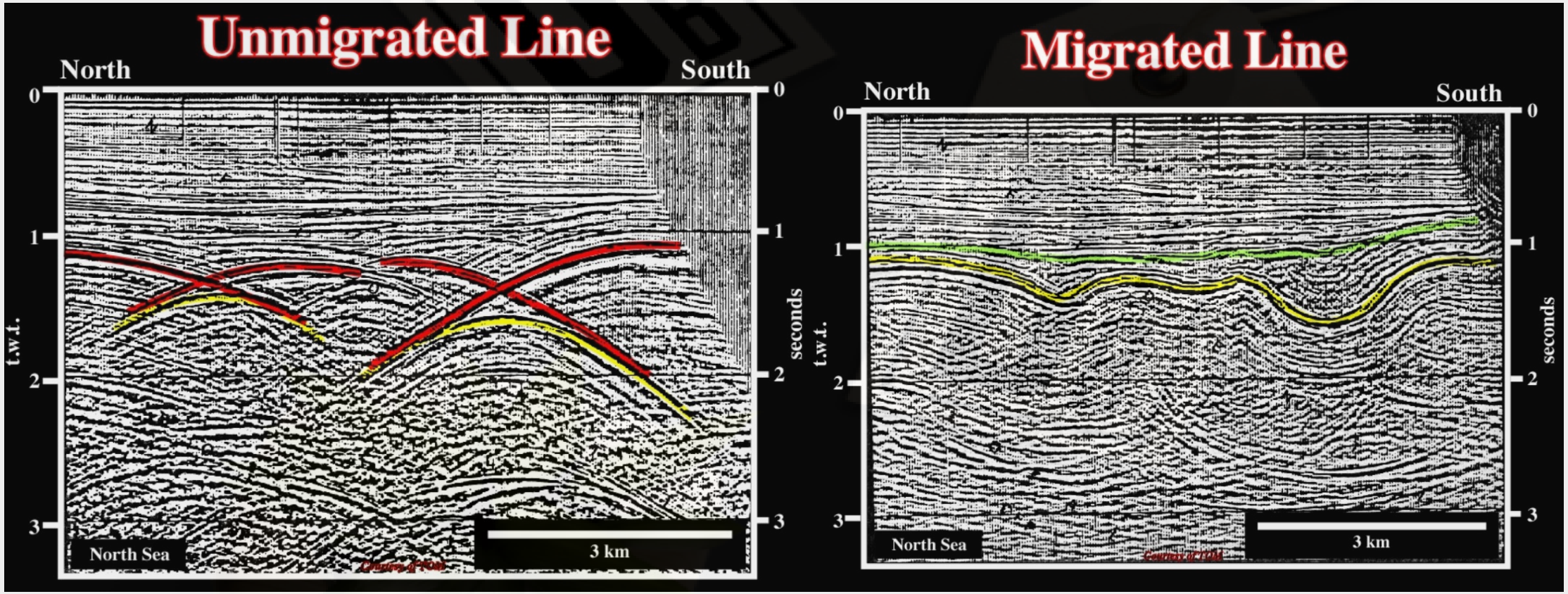
Z

Full Focus (3)

t = 0

z = Z

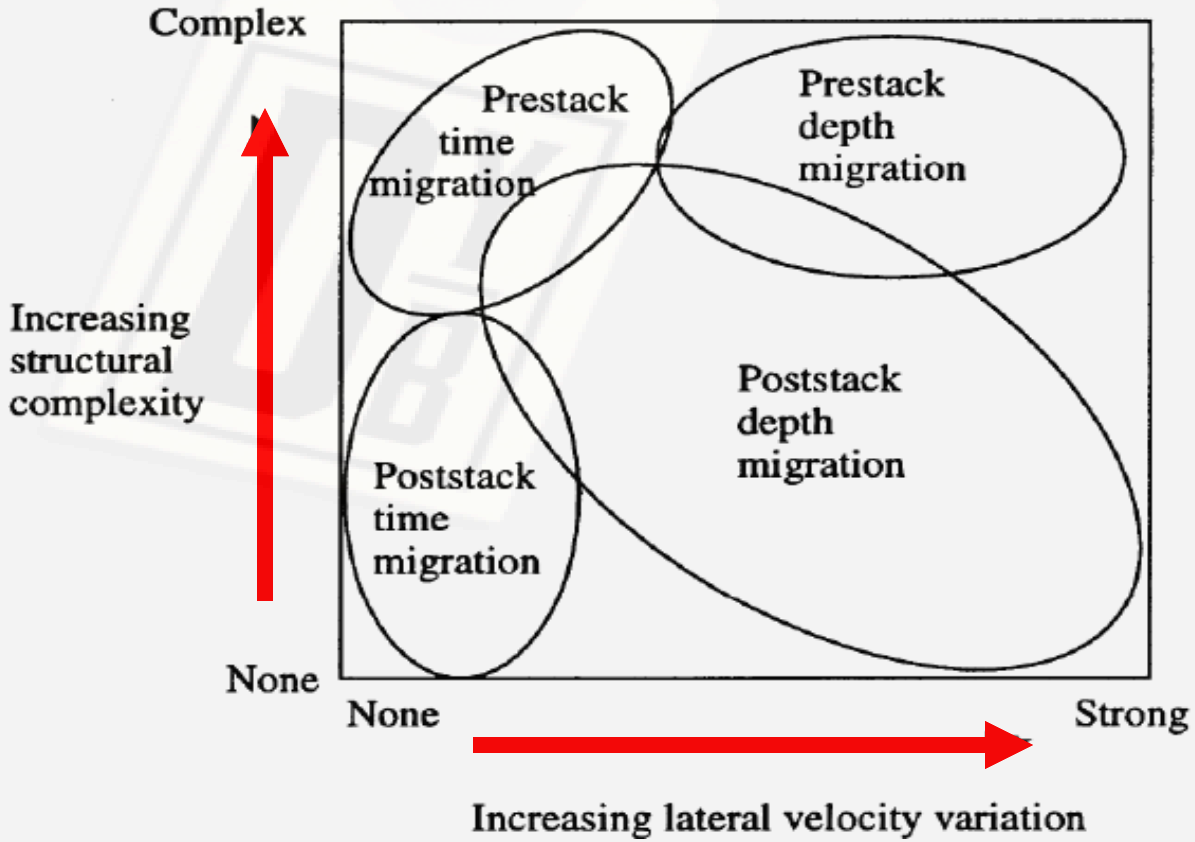
Seismic Migration of Syncline: Real data



Types of migration (cheap / expensive)

4 combinations possible

- Post-stack Time Migration
- Post-stack Depth Migration
- Pre-stack Time Migration
- Pre-stack Depth Migration



3D velocity model

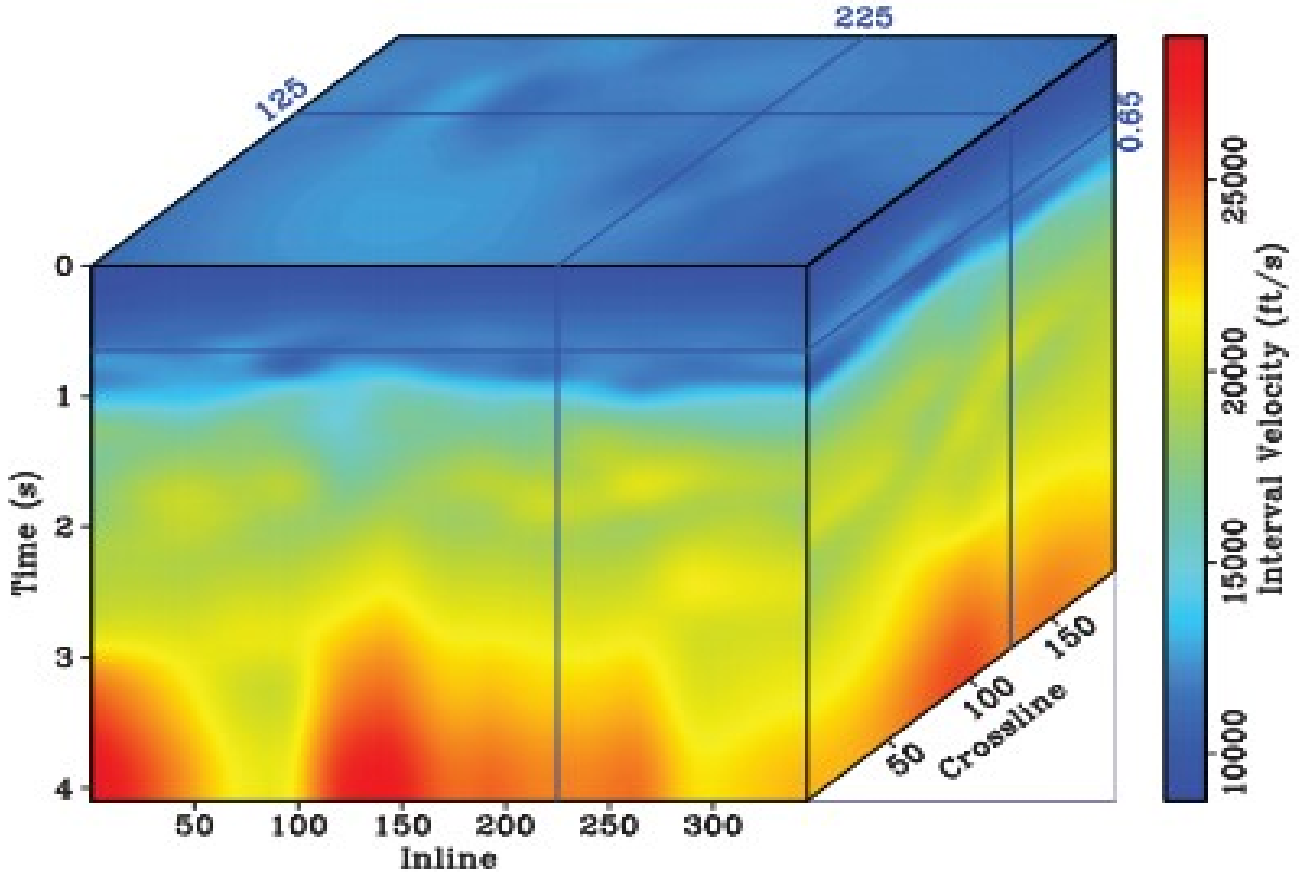


Figure 13. A 3D interval velocity model in time for the Teapot Dome data set. This plot displays selected sections as the faces of the cube. For this cube plot, the top, side, and front frame numbers are selected to be 0.65 s, 225, and 125, respectively. This figure can be created by typing *scons vel/vint3d.view*.

Oren, C., & Nowack, R. L. (2018).

Stacked 3D cube

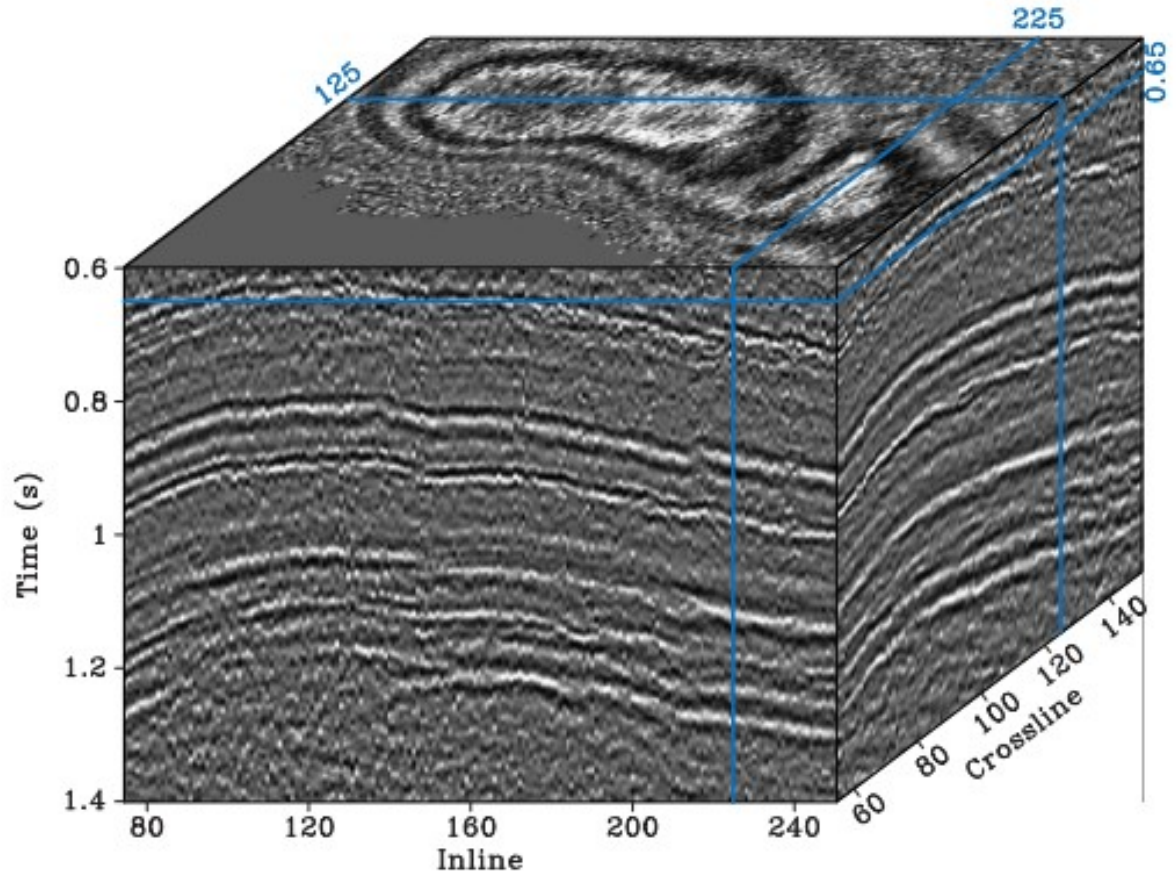


Figure 14. The stacked 3D cube for the Teapot Dome data after applying a band-pass filter between 12 and 90 Hz. This plot displays selected sections as the faces of the cube. For this cube plot, the top, side, and front frame numbers are selected to be 0.65 s, 225, and 125, respectively. This figure can be created by typing *scons nmostack/npr3_stack.view*.

Oren, C., & Nowack, R. L. (2018).

Depth Migrated

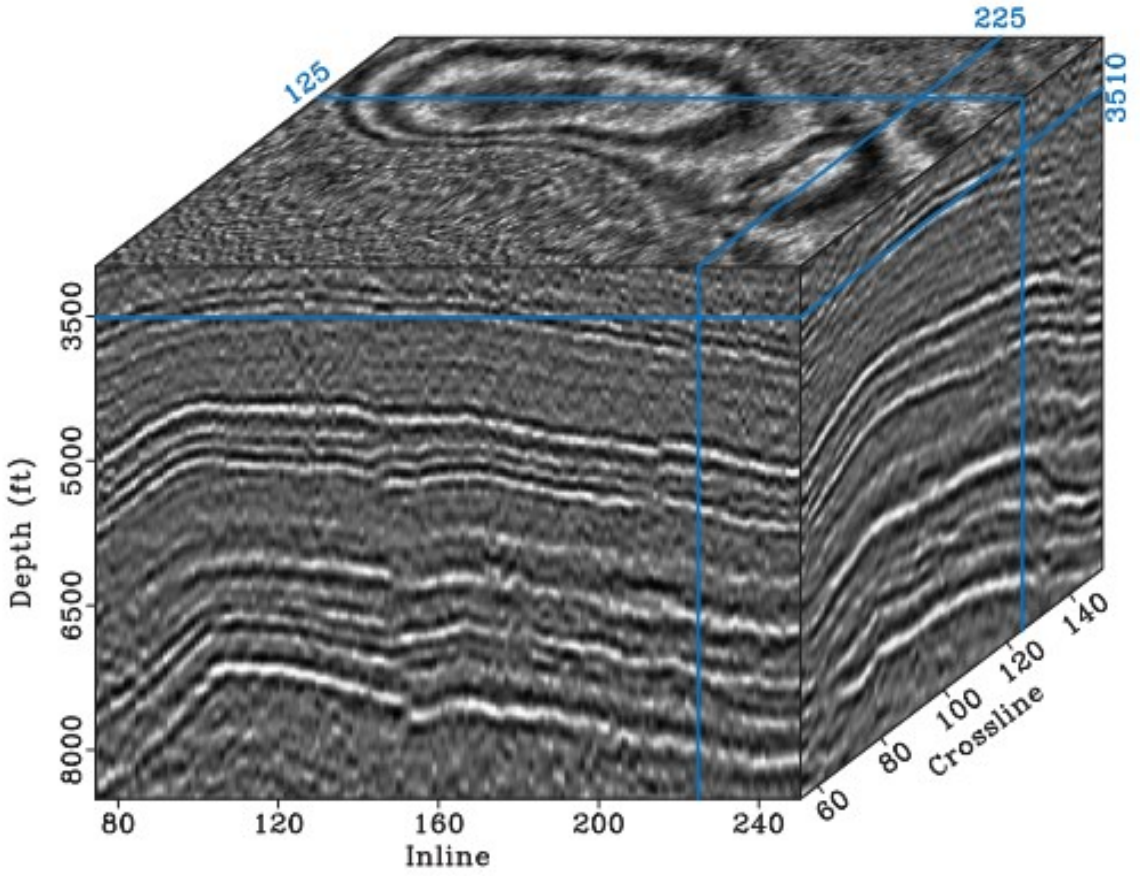


Figure 17. A 3D poststack depth-migrated image of the Teapot Dome data set using the extended split-step method. This plot displays selected sections as the faces of the cube. For this cube plot, the top, side, and front frame numbers are selected to be 3510 ft, 225, and 125, respectively. Compare to Figure 14 to see the effect of migration process. This figure can be created by typing *scons mig/ssfmigz.view*.

Oren, C., & Nowack, R. L. (2018).

f-x Deconvolution

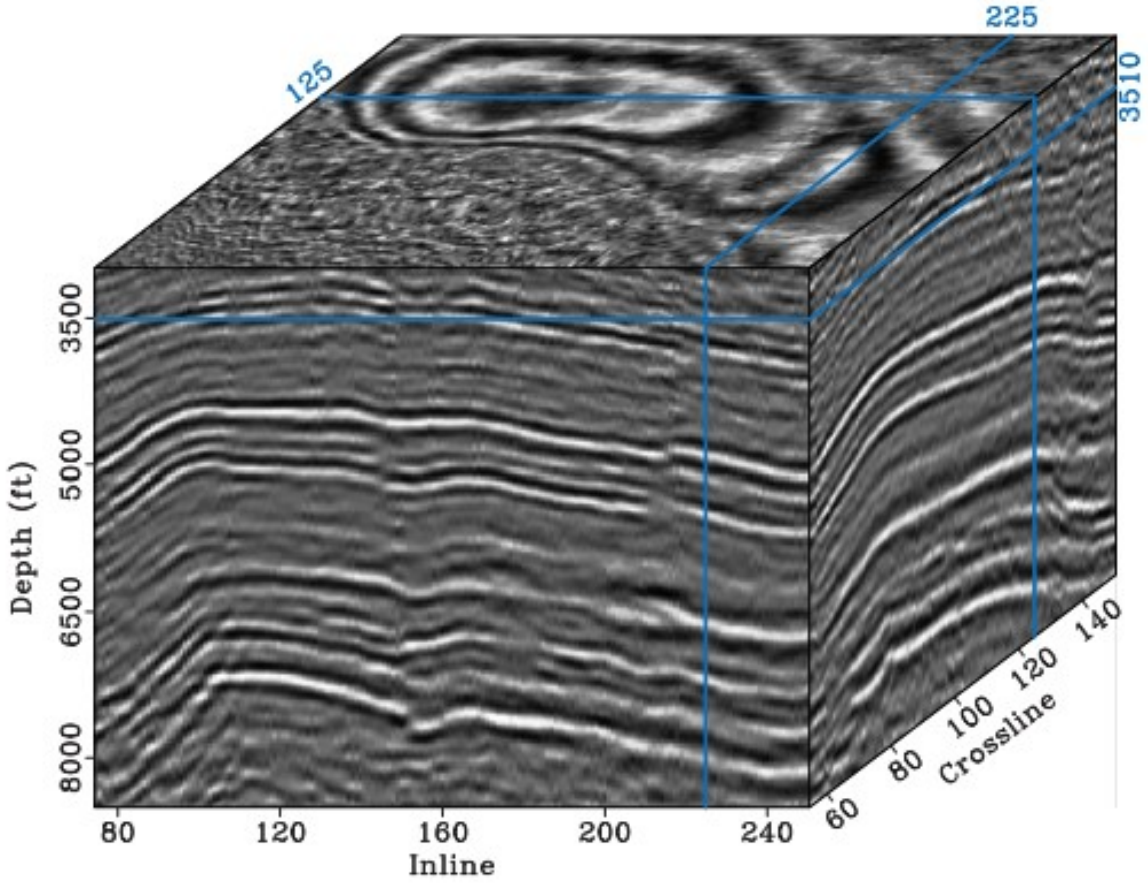


Figure 18. A 3D seismic image after applying f-x deconvolution to the image shown in Figure 17. This plot displays selected sections as the faces of the cube. For this cube plot, the top, side, and front frame numbers are selected to be 3510 ft, 225, and 125, respectively. Compare to Figure 17 to see the effect of f-x deconvolution. This figure can be created by typing *scons mig/ssfmigz_fx.view*.

Oren, C., & Nowack, R. L. (2018).

lower-upper-middle (LUM) filtering

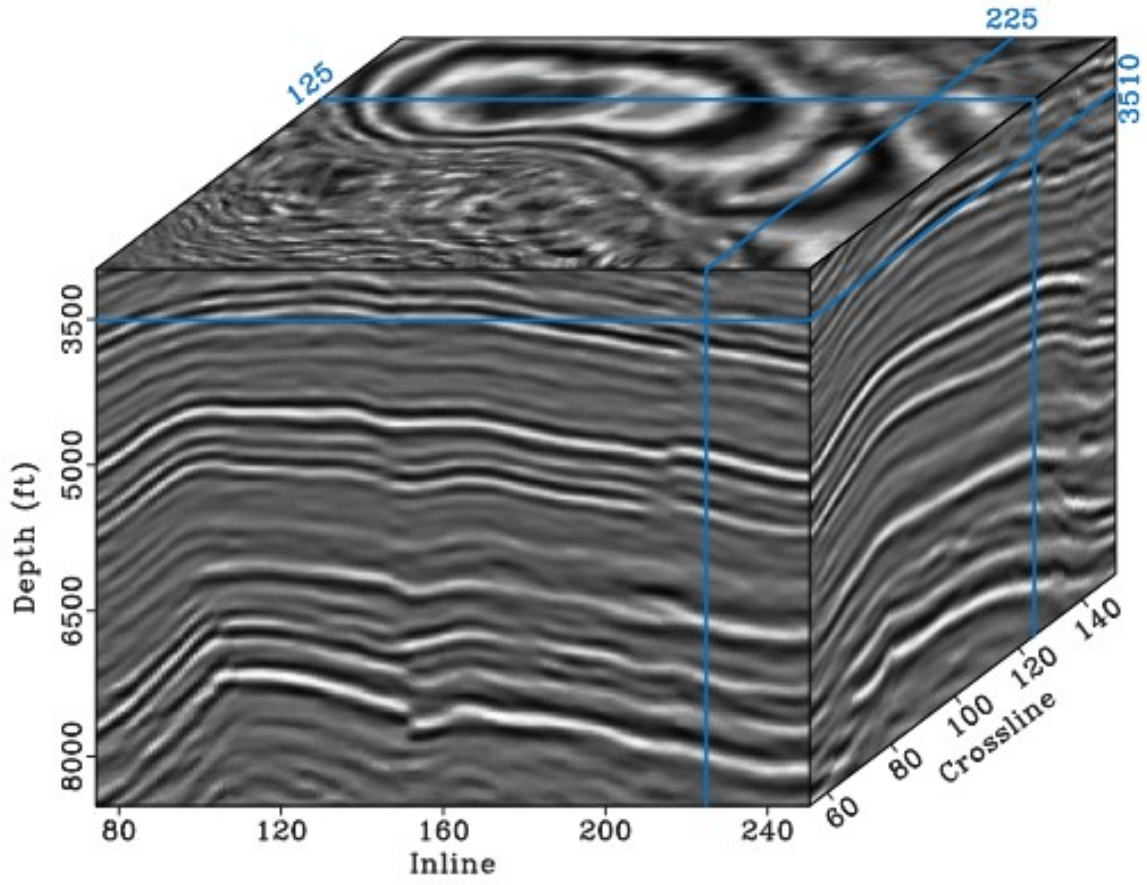


Figure 19. Structure-enhancing result using LUM filtering. This plot displays selected sections as the faces of the cube. For this cube plot, the top, side, and front frame numbers are selected to be 3510 ft, 225, and 125, respectively. Compare to Figure 18 to see how the remaining random noise is attenuated while preserving the geologic structures. This figure can be created by typing *scons mig/*

Oren, C., & Nowack, R. L. (2018).

KEY TOPIC COVERED IN TODAY'S TALK

Marine Seismic Acquisition

Seismic Data Processing

Structural Interpretation

What is SI and Importance of SI

What ???

- Seismic interpretation is the science (and art) of inferring the geology at some depth from the processed seismic record. (SEG wiki)

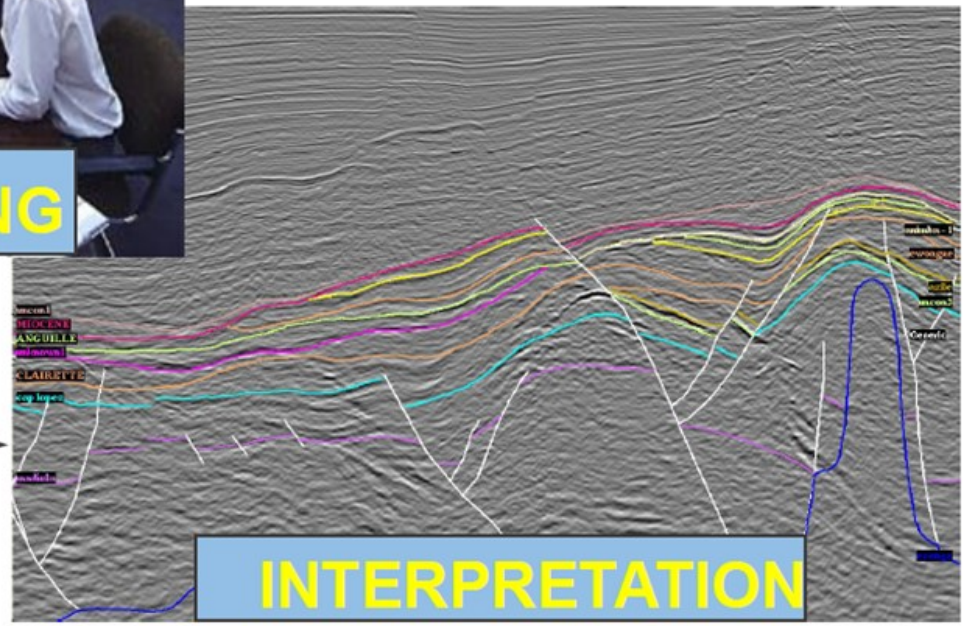
Why ???

- Seismic Interpretation can help locate ground water, minerals and mines are used to investigate locations for landfills, and characterize how an area will shake during an earthquake,

- Deep Seismic interpretation is primarily used for oil and gas exploration.

Seismic Life cycle : Where is Interpretation?

Drill here



Steps to perform Interpretation

1. **Step one: interpretation plan**
    - What are my objectives?
    - What are the regional tectonic, structural, and depositional trends?
    - What seismic patterns should I be looking for?
2. **Step two: building and merging datasets**
    - Seismic, Well logs, Models
3. **Step three: interpretation**
    - Well to seismic tie,
    - Horizon picking, Structural & Stratigraphic interpretation

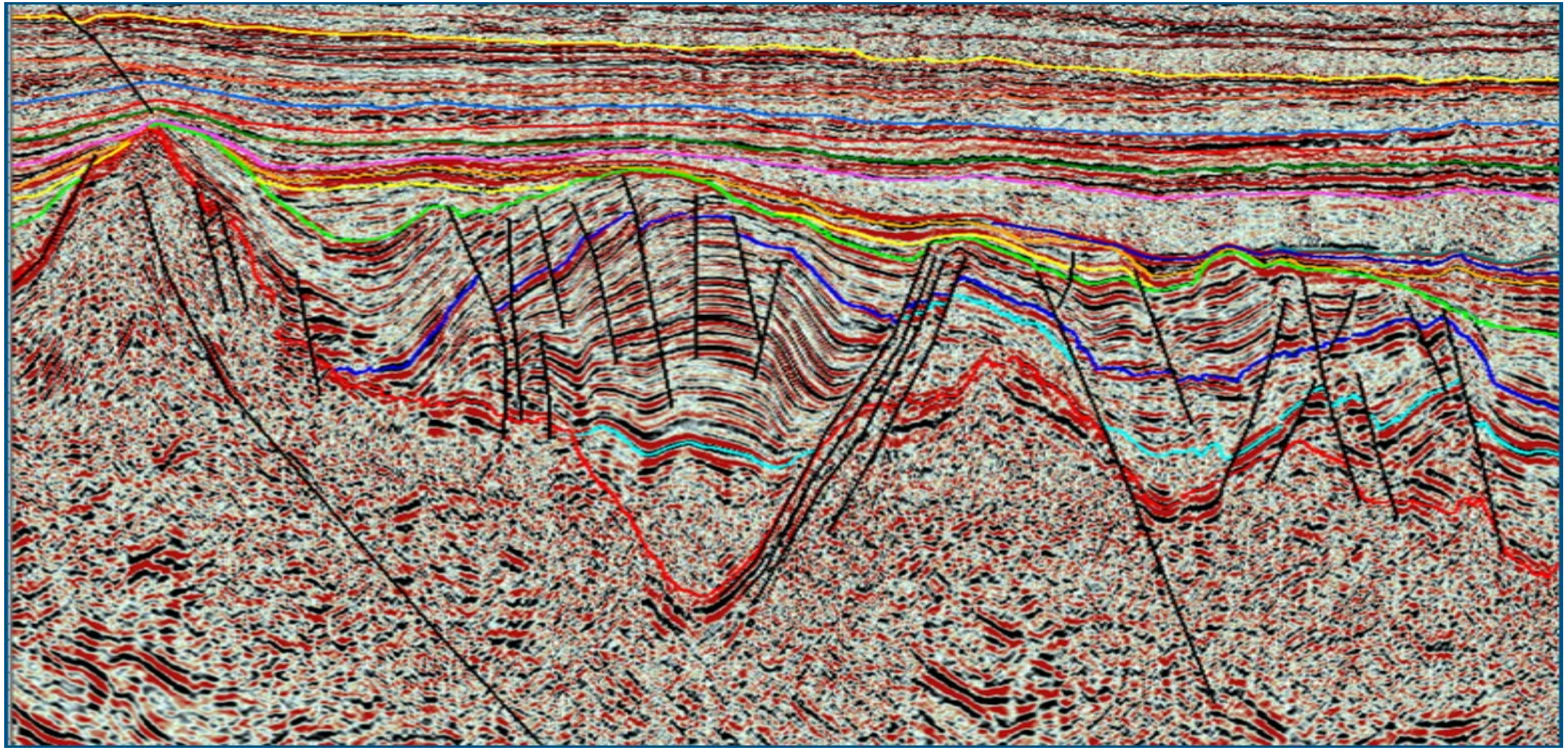
3) Interpretation

- The process of interpreting seismic data eventually comes down to putting pencil to paper or cursor to screen.
- Well to Seismic Tie. Horizon, Faults picking.
- Time structure maps with faults
- Depth structure maps
- Seismic facies maps for reservoir, source, or seal analysis
- Seismic amplitude maps for DHI analysis
- Thickness maps inferred from seismic tuning analysis
- Fault plane maps
- Fault plane maps with cross-fault sand juxtaposition for seal analysis
- Isochron or isopach maps showing growth or thinning in a stratigraphic interval
- Seismic velocity maps for lithology determination or depth conversion

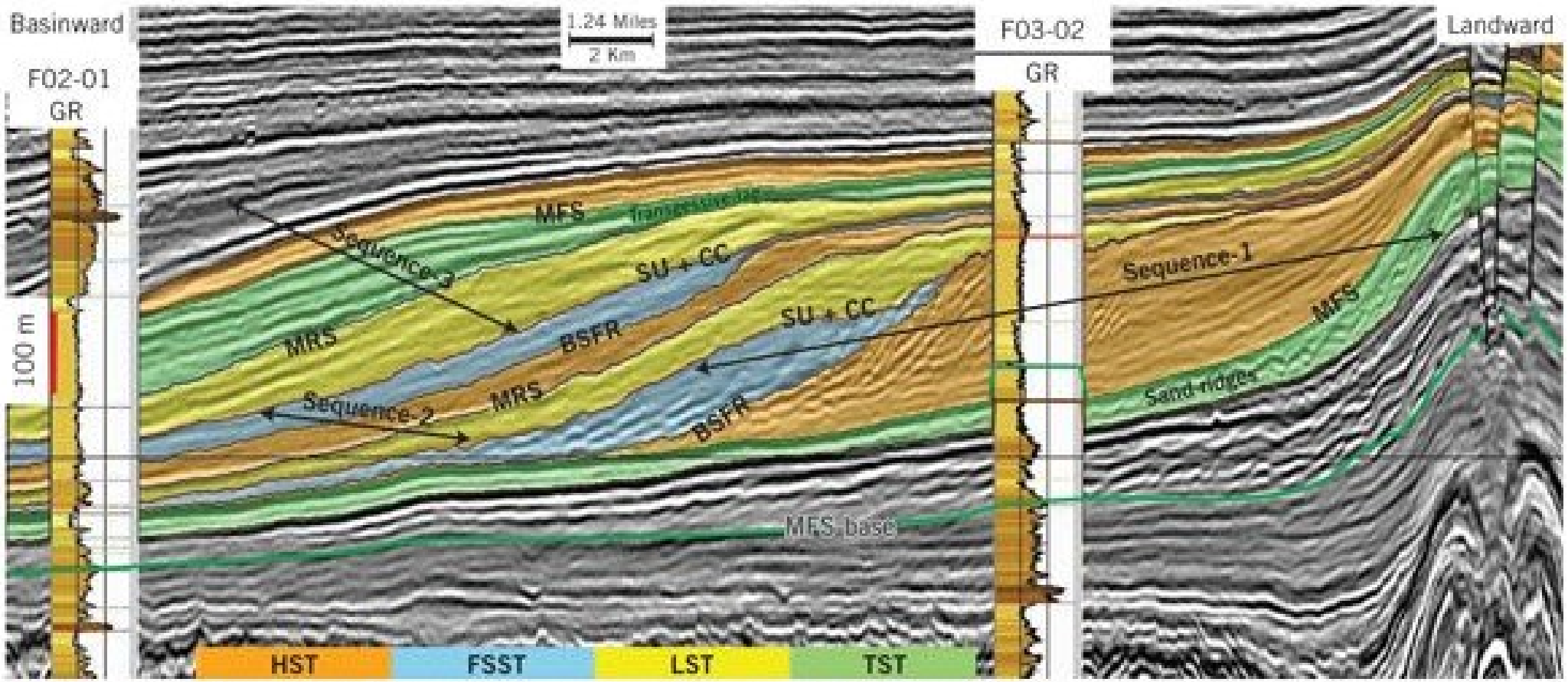
“The overall aim of seismic interpretation is to aid in constructing the most accurate earth model or reservoir description possible”

DYB

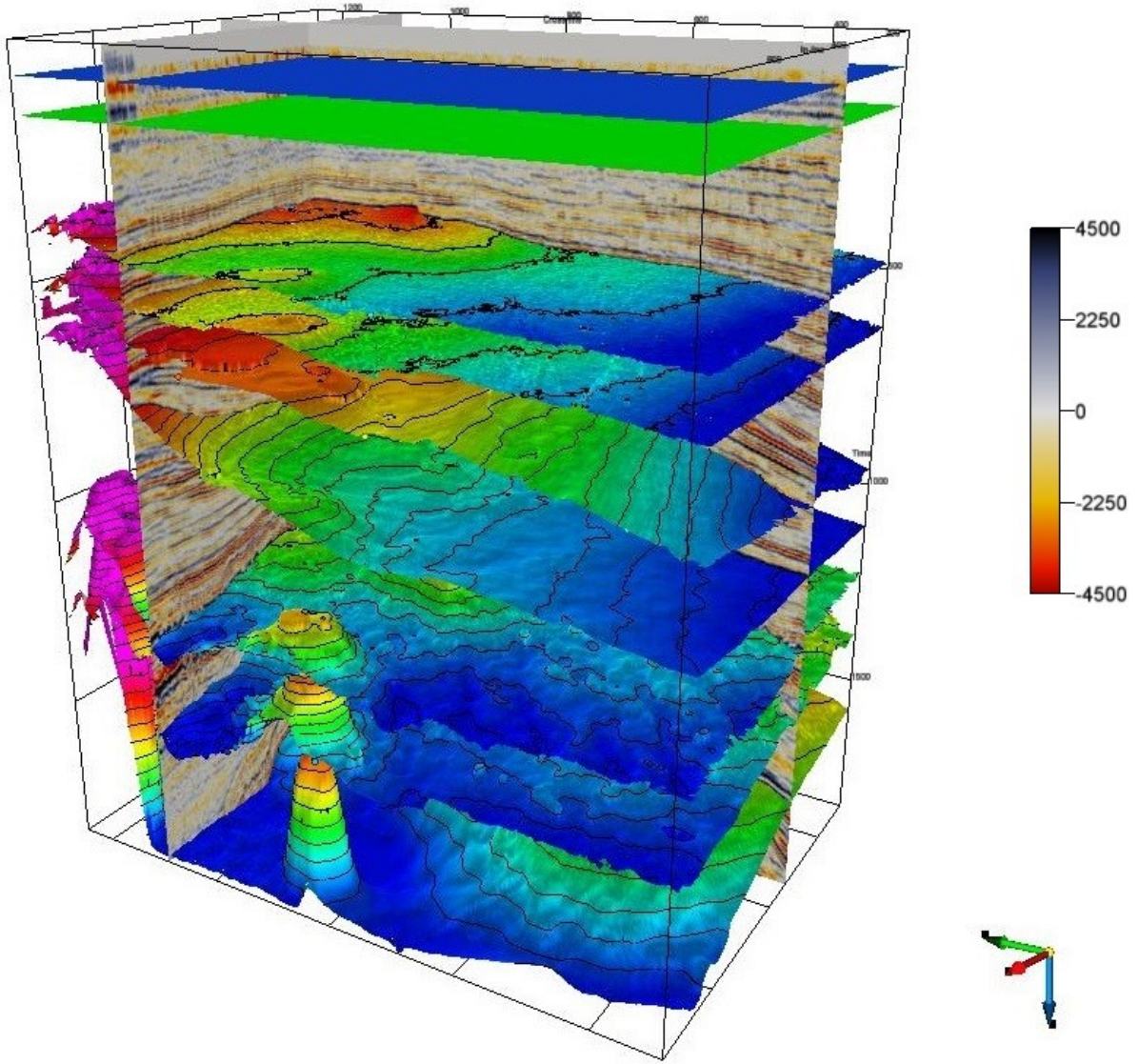
Seismic Interpretation and Prospectively | TGS



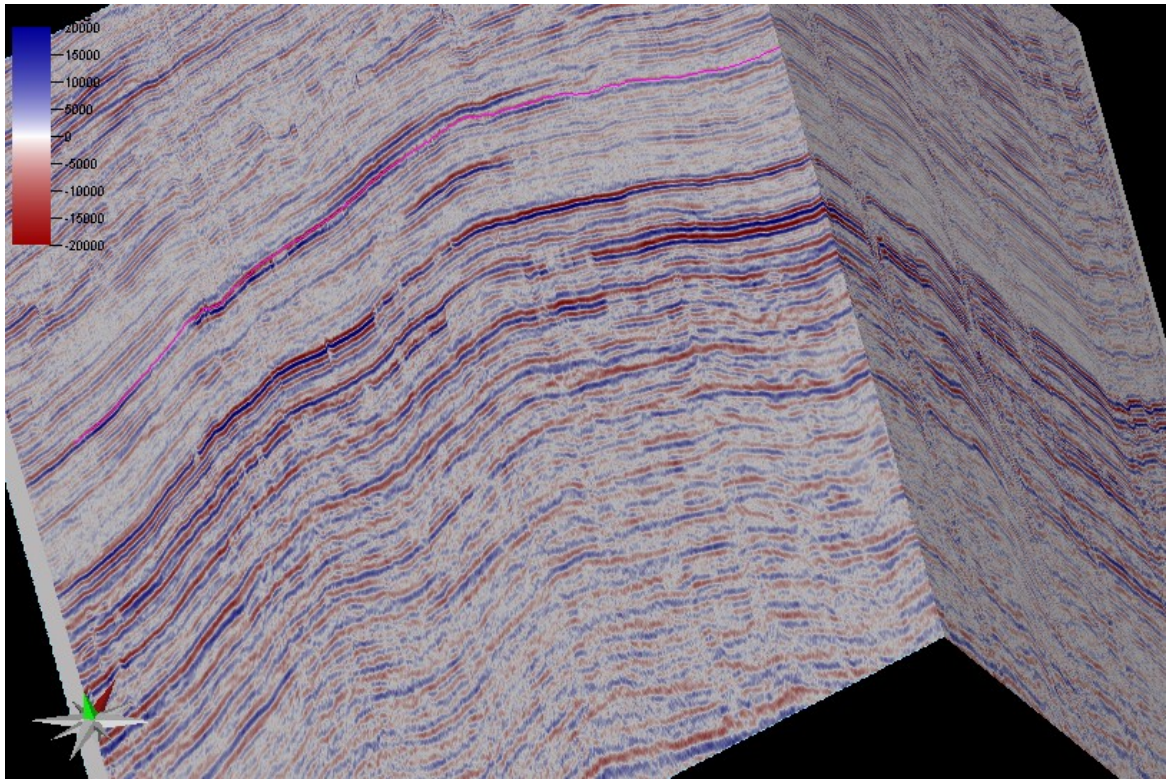
Seismic Interpretation Stratigraphy



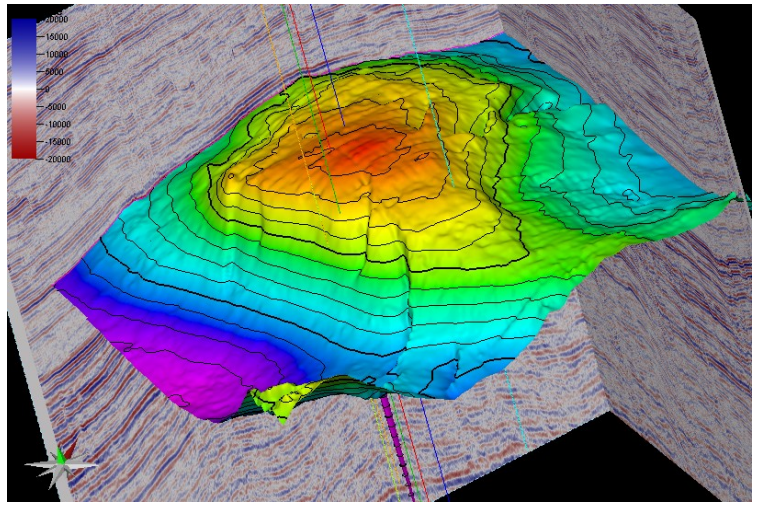
Horizons and surface maps



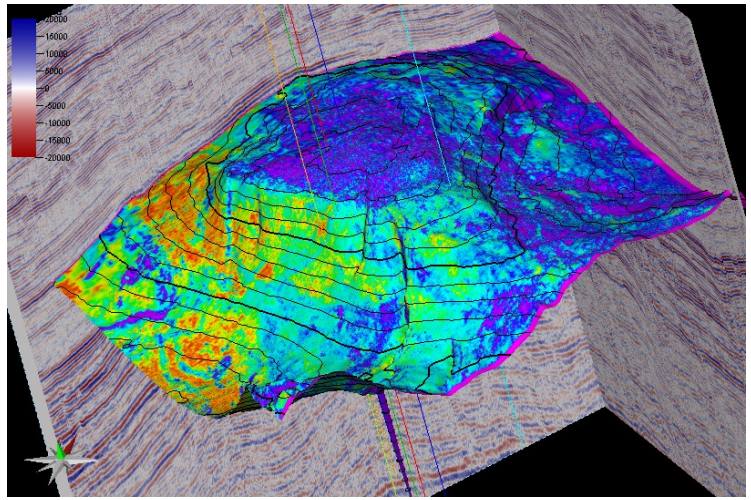
3D data after processing : ready for Interpretation



Input Processed Seismic data for structural Interpretation



3D structure interpretation with contour lines



Amplitude plotted on the 3D surface map shows the distribution of porosity and hydrocarbon

Summary

- **To Explore the Oil & Gas preserved In Offshore (70% is water)**
- **Marin life should be safe (start with low to high sound signal)**
- **Government Licensed Area for Exploration**
- **A Signal to noise ratio is enhanced during processing**
- **Interpretation, Prospect Maturation and Field development**

Acknowledgements / Thank You / Questions

Thank you to **USM**, School of Physics, Geophysics Section.

&

Thanks to **ITS** for the invitation as a Guest speaker.

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