Advancement in Acoustic Logging Techniques and Applications in Reservoir Characterization*

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Abstract

Sonic measurements have come a long way since their introduction 50 years ago. The latest advancement in sonic technology delivers the highest quality data seen to date, allowing acoustic measurements to characterize mechanical and fluid properties around the borehole and tens of feet into the formation. In their early days, sonic measurements were relatively simple. They began as a way to match seismic signal to rock layers. Today, sonic measurements reveal a multitude of reservoir and wellbore properties. They can be used to infer primary and secondary porosity, permeability, lithology, mineralogy, pore pressure, invasion, anisotropy, fluid type, stress magnitude and direction, the presence and alignment of fractures, and the quality of casing cement bonds. Improvements in sonic measurements are enhancing our ability to determine some of these properties. Accuracy is improving in the basic measurements, which consist of estimates of compressional (P), shear (S), and Stoneley (St) wave slowness. Variations in slowness can now be better characterized, leading to an improved understanding of how formation properties change with distance and direction. Improved characterization of compressional and shear slowness in terms of their radial, azimuthal, and axial variations is now possible with a new sonic technology. High-quality waveforms and advanced processing techniques lead to more accurate slowness estimates, even in unconsolidated sediments and large boreholes, as well as reliable through-casing slowness measurements. These improvements result in better characterization of subsurface rock and fluid properties, meaning more stable wellbores, long lasting completions, and enhanced production.

Advancement in Acoustic Logging Techniques and Applications in Reservoir Characterization

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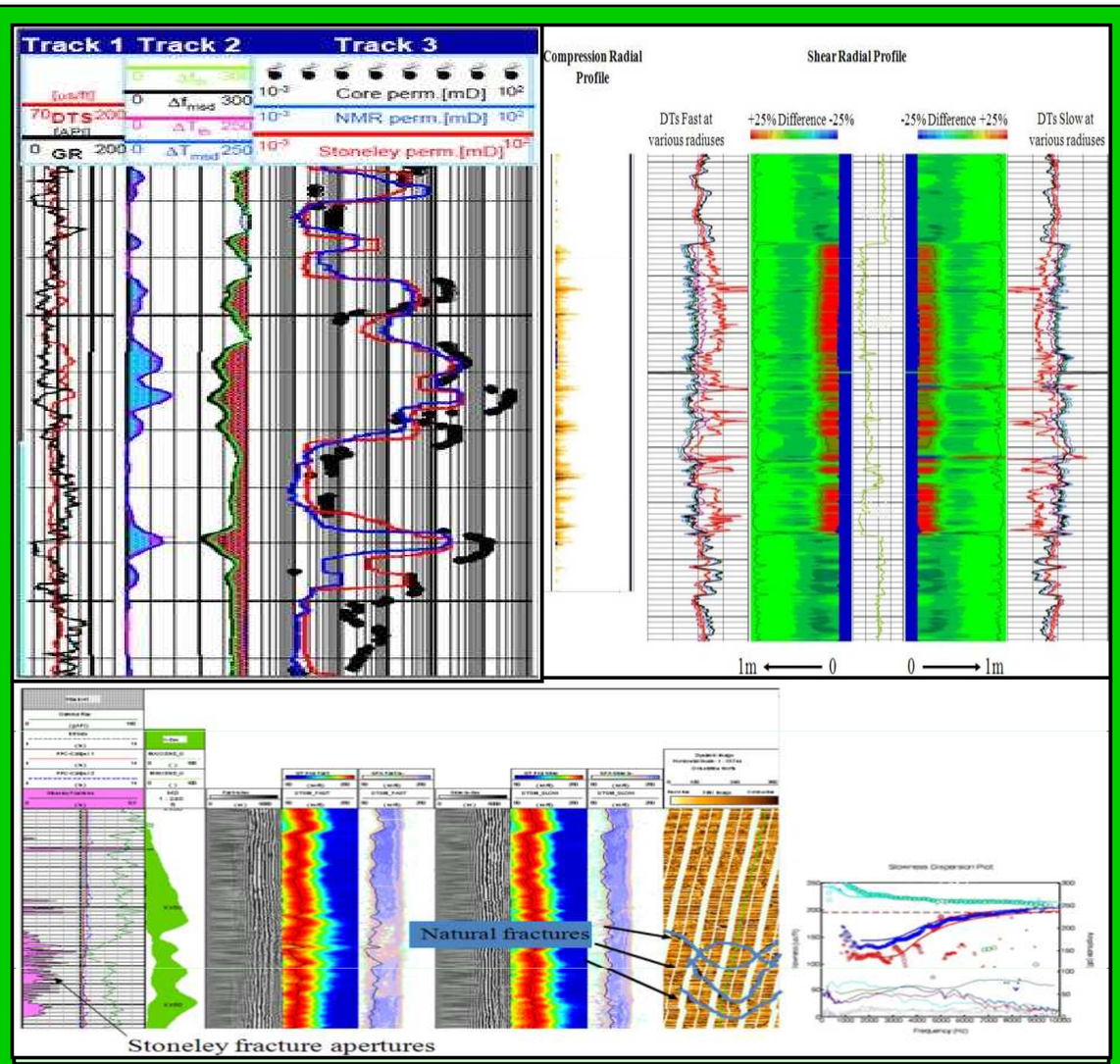

PRESENTATION OUTLINE

- Introduction
- Objective
- Applications
  - Shear Anisotropy
  - Fracture Identification
  - Mobility/Permeability estimation
  - Well-bore alteration/Damage
  - High Resolution Seismic Images
  - Cement Bond Evaluation
- Summary
- Acknowledgement

Introduction

- Acoustic measurements been around for long time.
- Longevity due to multi-disciplinary value for E&P.
- Influence of acoustic measurements from drilling to production.
- Improved electronics with large number of transmitter & receivers.
- Variety of answer products based upon advance acquisition and processing techniques

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Objective

To show value of advance acoustic measurements to industry professionals and bring all disciplines together for integrating sonic data in interpretation and model updating.

Shear Anisotropy

- Achieved with cross-dipole technology
- Can be intrinsic (shale bedding, fractures) and stress induced.
- Characterized with the help of Dispersion Plots.
- Important in Seismic application.
- Application in Geomechanics.
- Stress directions.
- Integrated with other technologies i.e. Stoneley, resistivity images, for fracture characterization.

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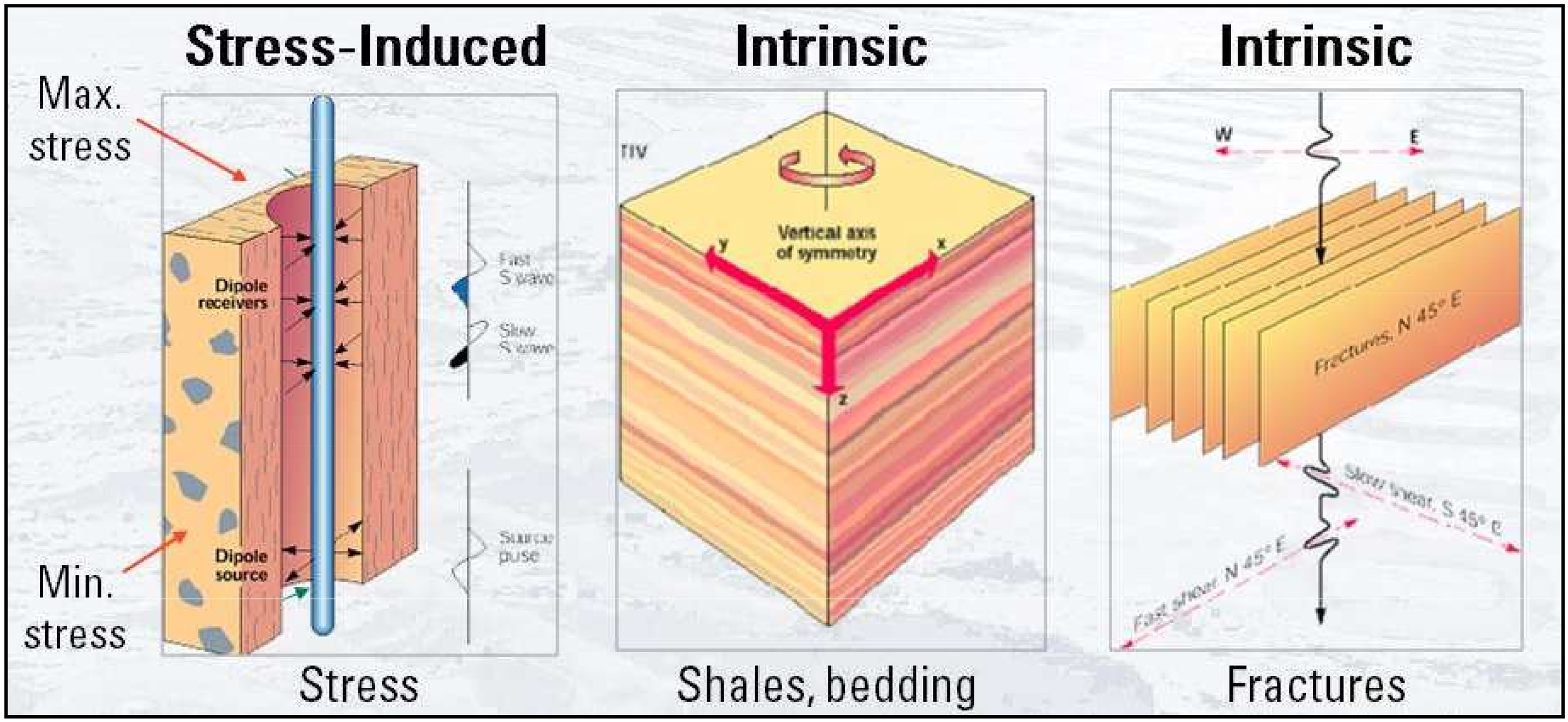
Shear Anisotropy



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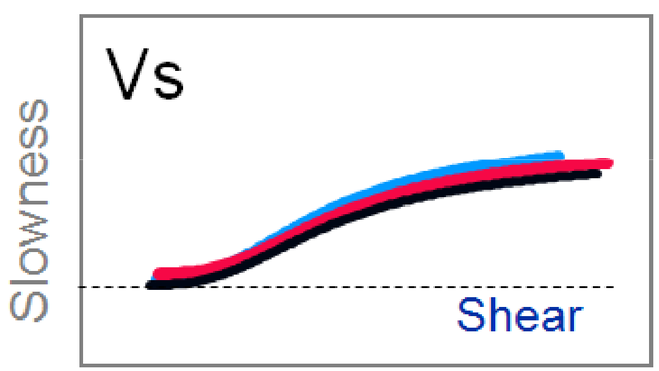
Shear Anisotropy

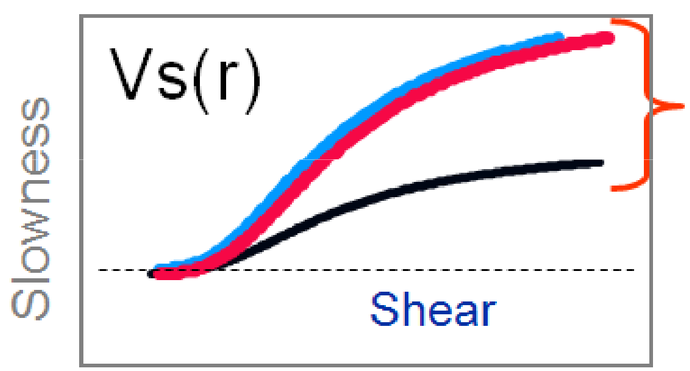
Pakistan Section

Homogeneous Isotropic

Far from Failure



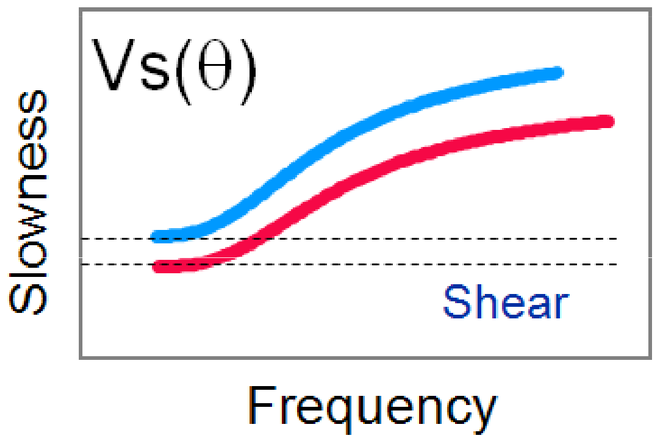
Inhomogeneous Isotropic



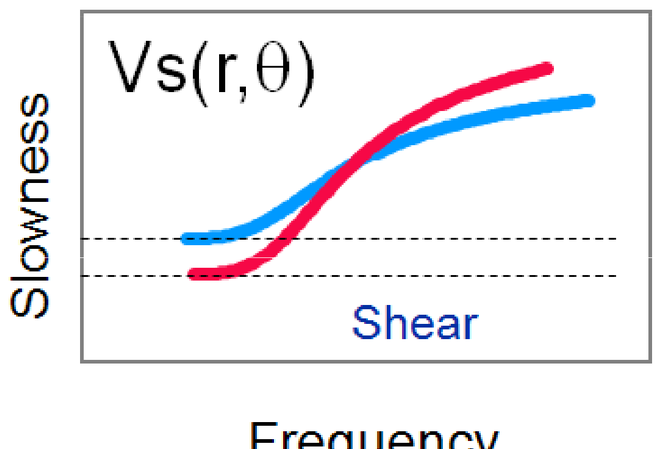
Damaged, Near Failure

Homogeneous Anisotropic

Intrinsic
-Shales
- Fractures



Inhomogeneous Anisotropic



Stress Induced

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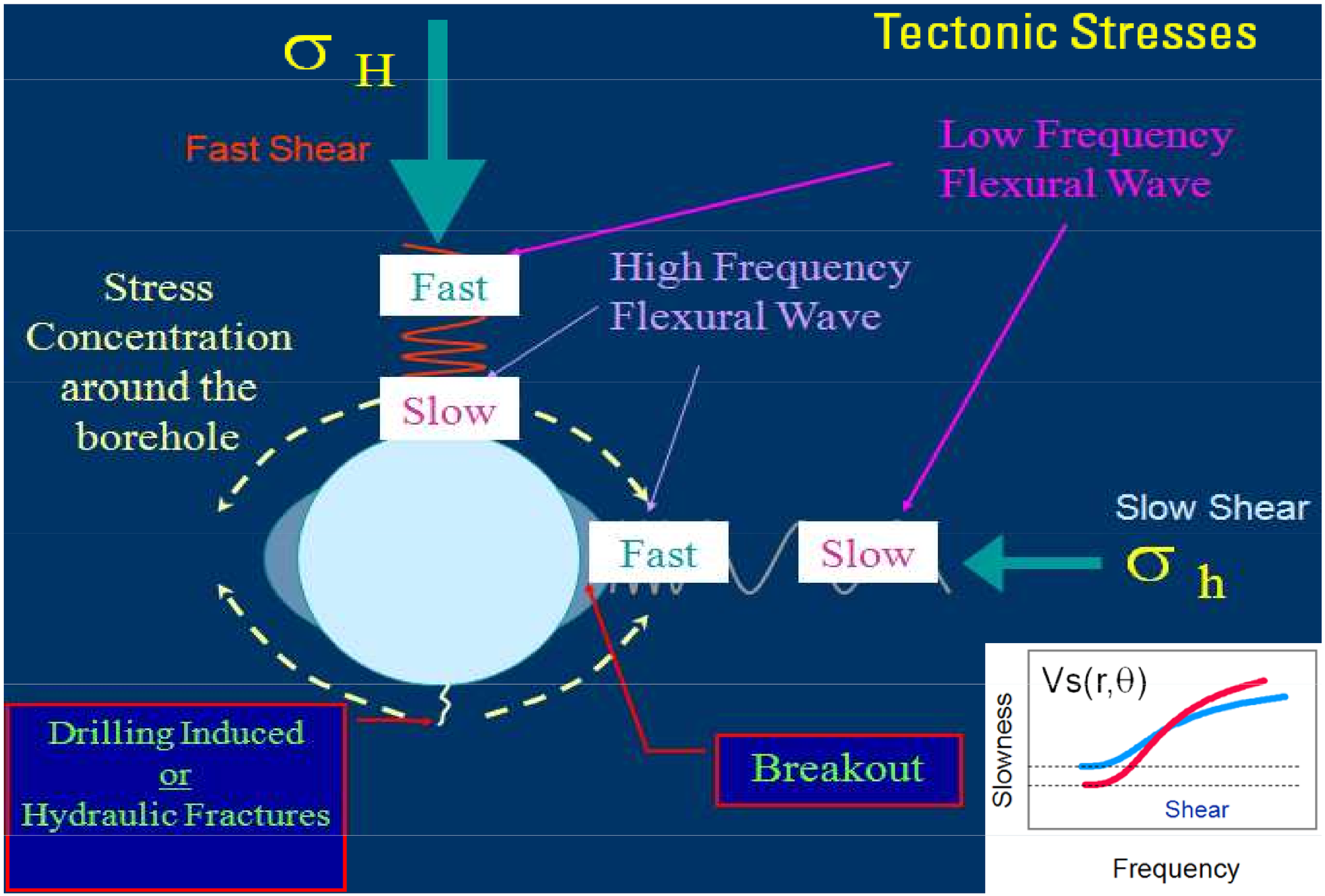
Shear Anisotropy



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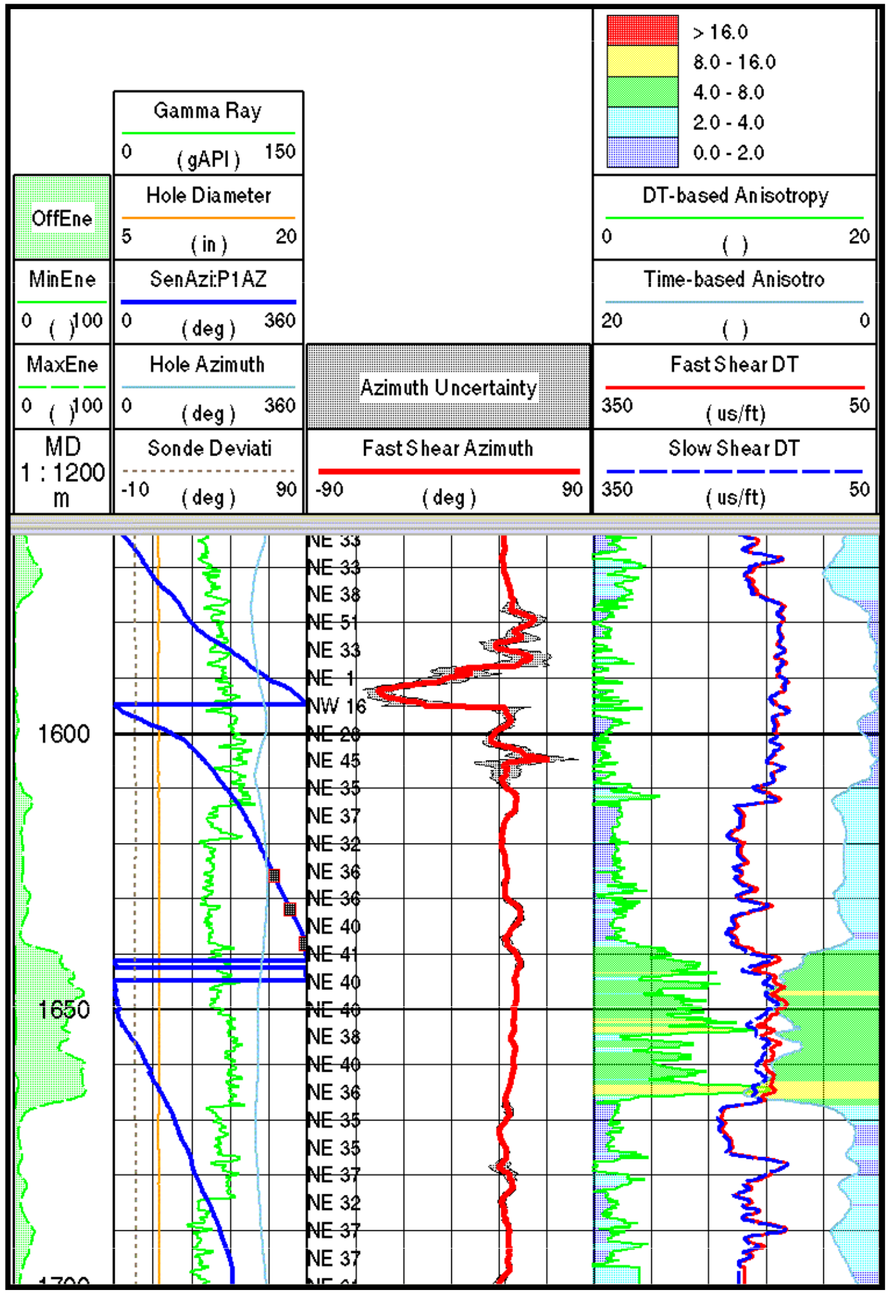
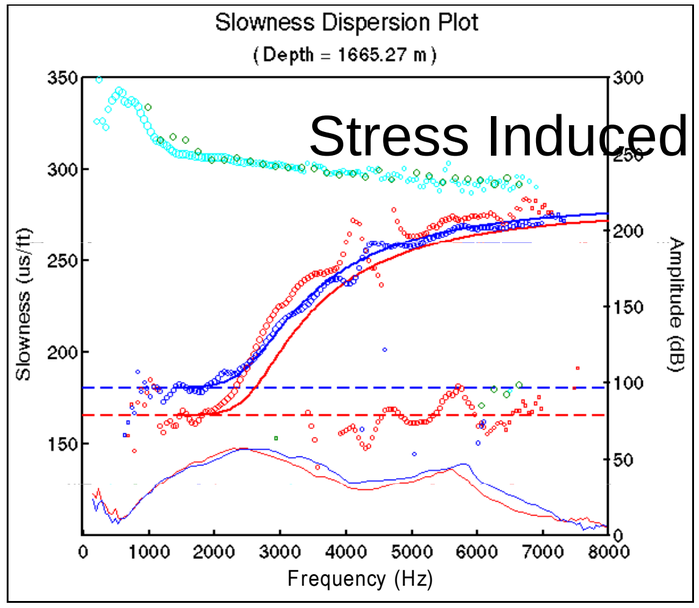
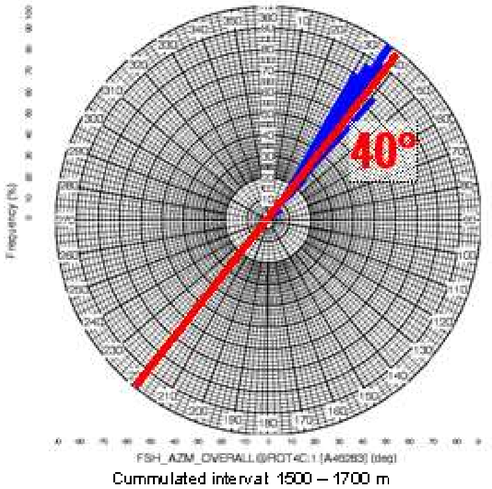
Shear Anisotropy



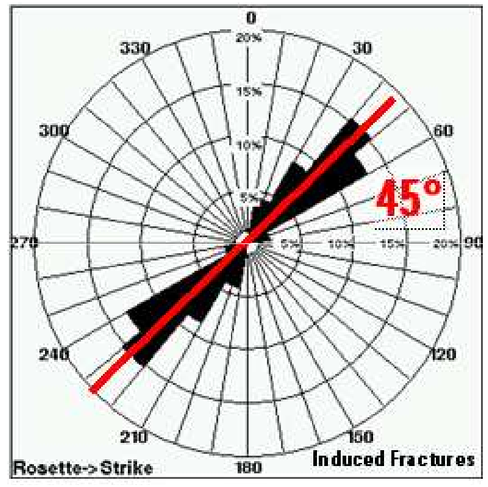


Sonic Fast Shear Azimuth



Cummulated interval 1500 – 1700 m

Images Induced fractures strike



Cummulated interval: 1500 – 1700 m

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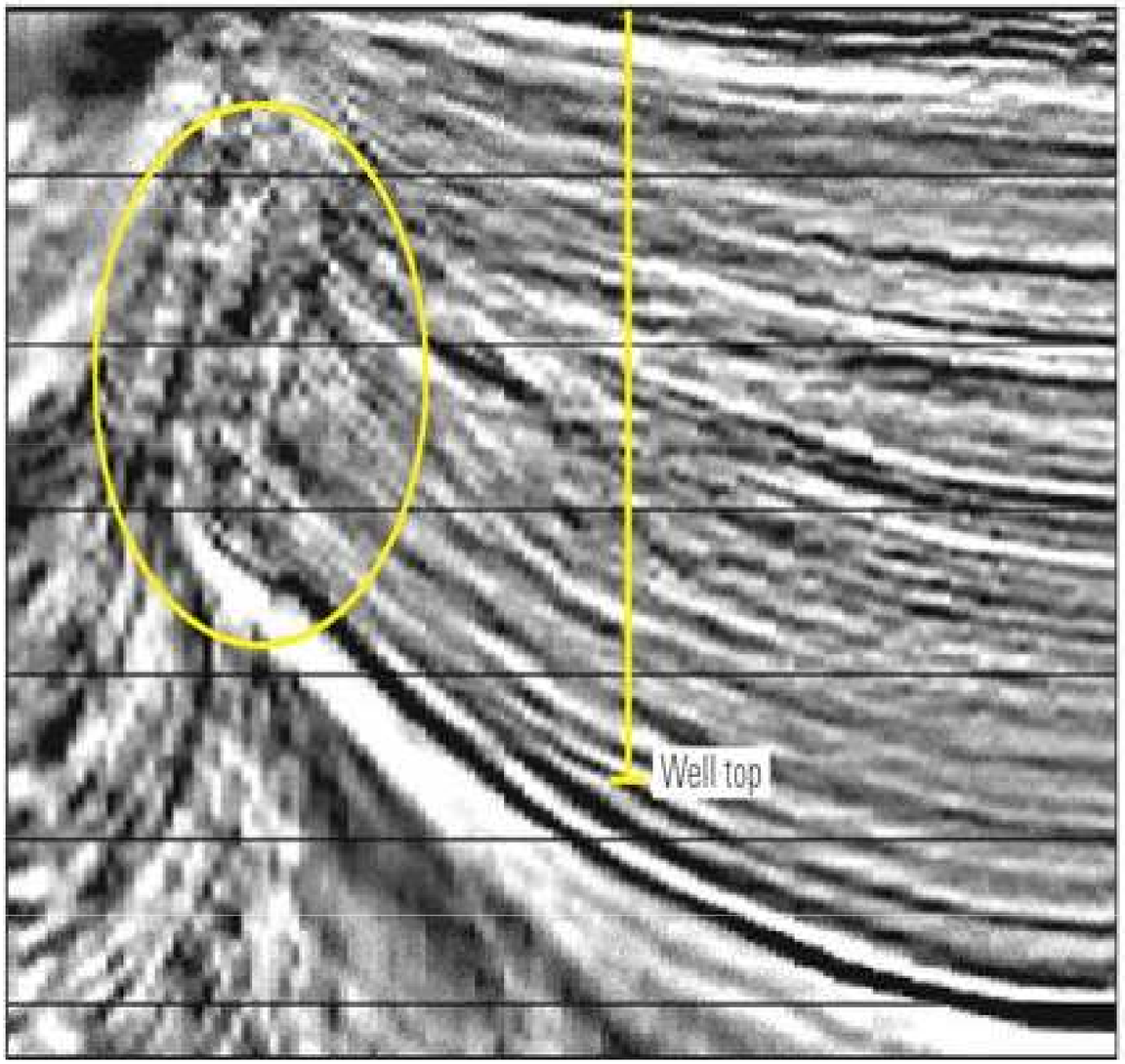
Anisotropy in Seismic

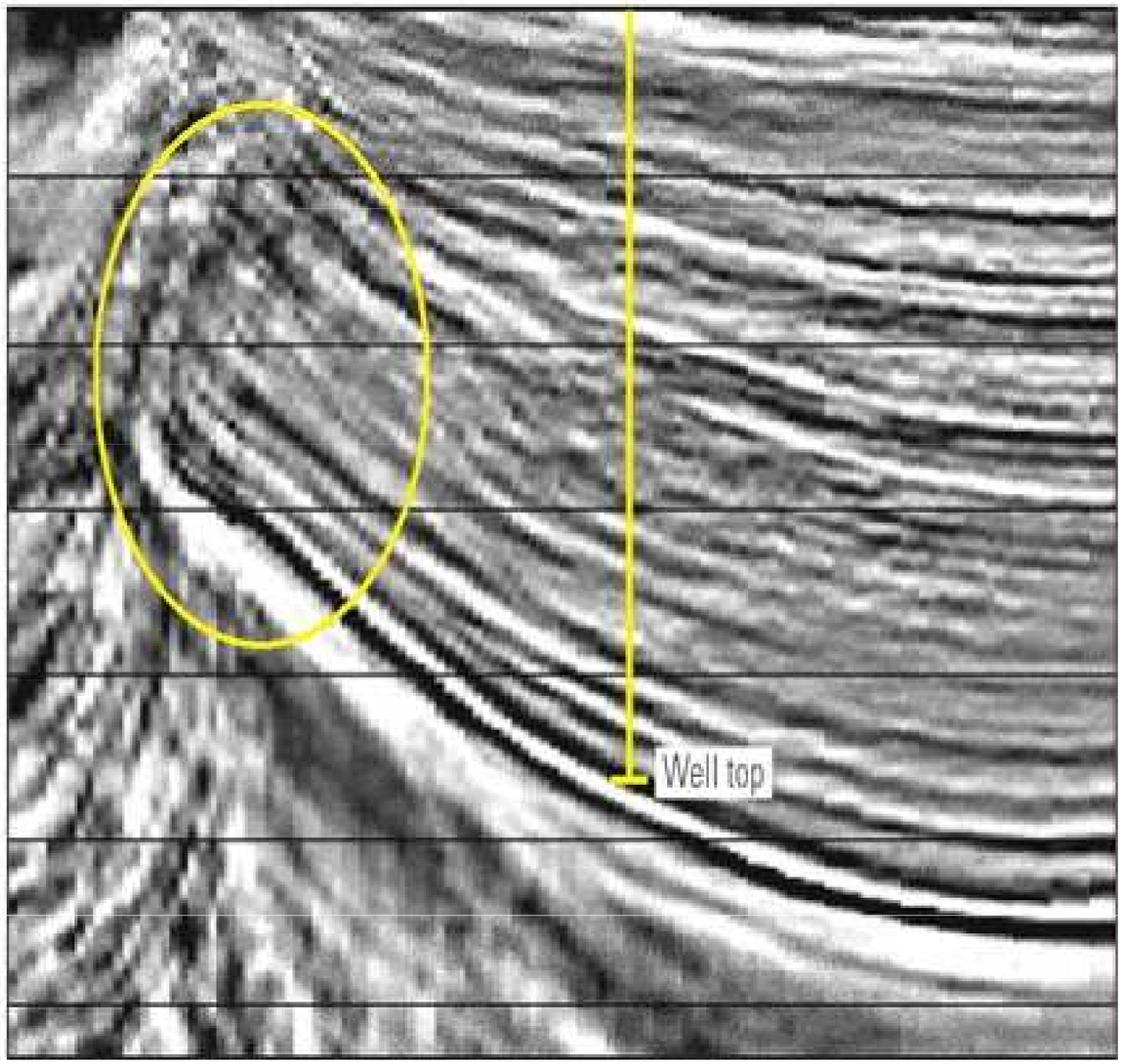
Pakistan Section

Isotropic Depth Imaging



error in position of reflectors

Anisotropic Depth Imaging



better positioning & focus

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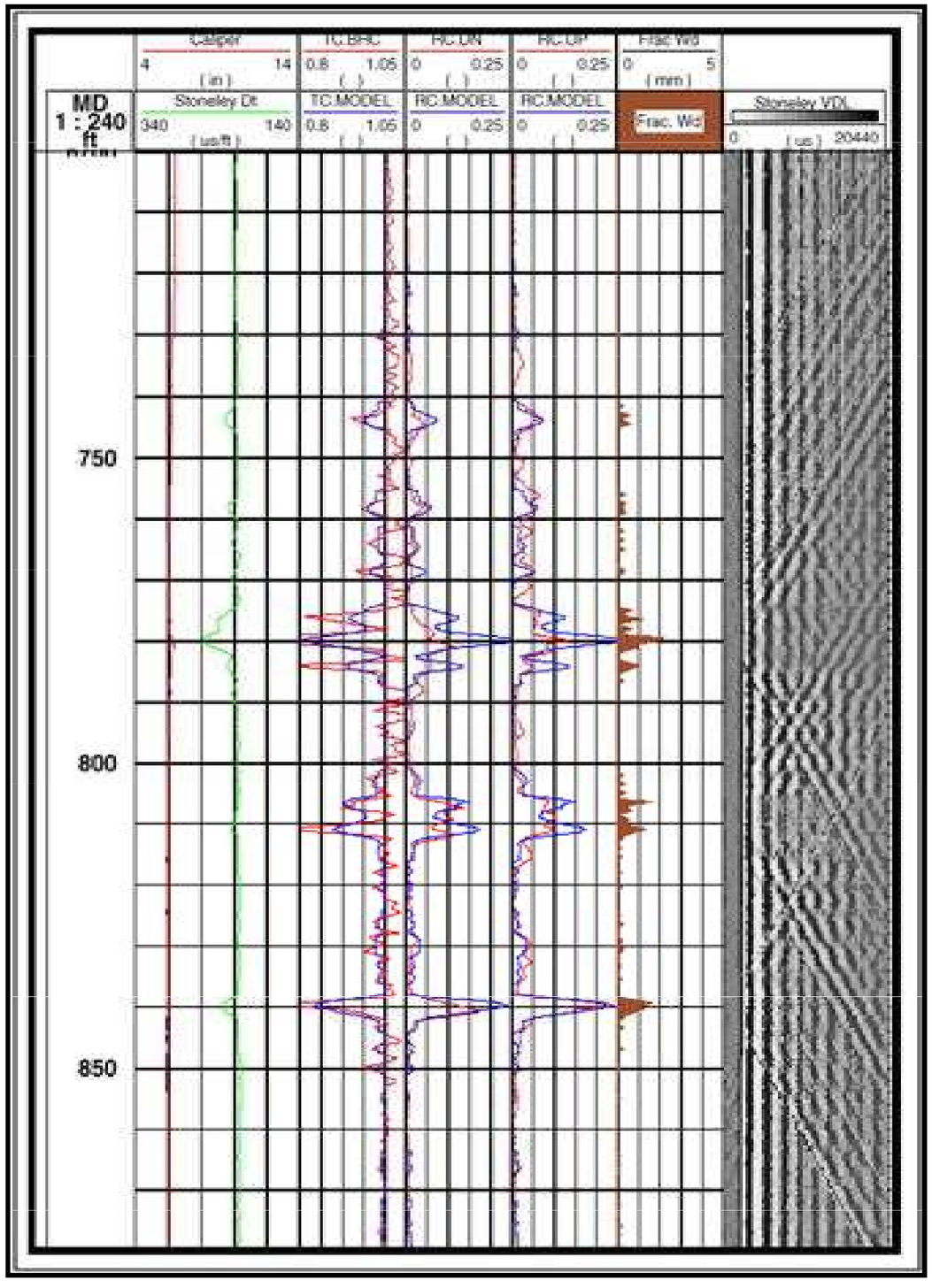
Fracture Identification through Stoneley

- Stoneley, guided mode traveling up in piston-like motion.
- Attenuate and generates reflected waveforms in presence of open natural fractures
- Used in conjunction with resistivity and ultrasonic images to differentiate between reflections by acoustic impedance and natural fractures.



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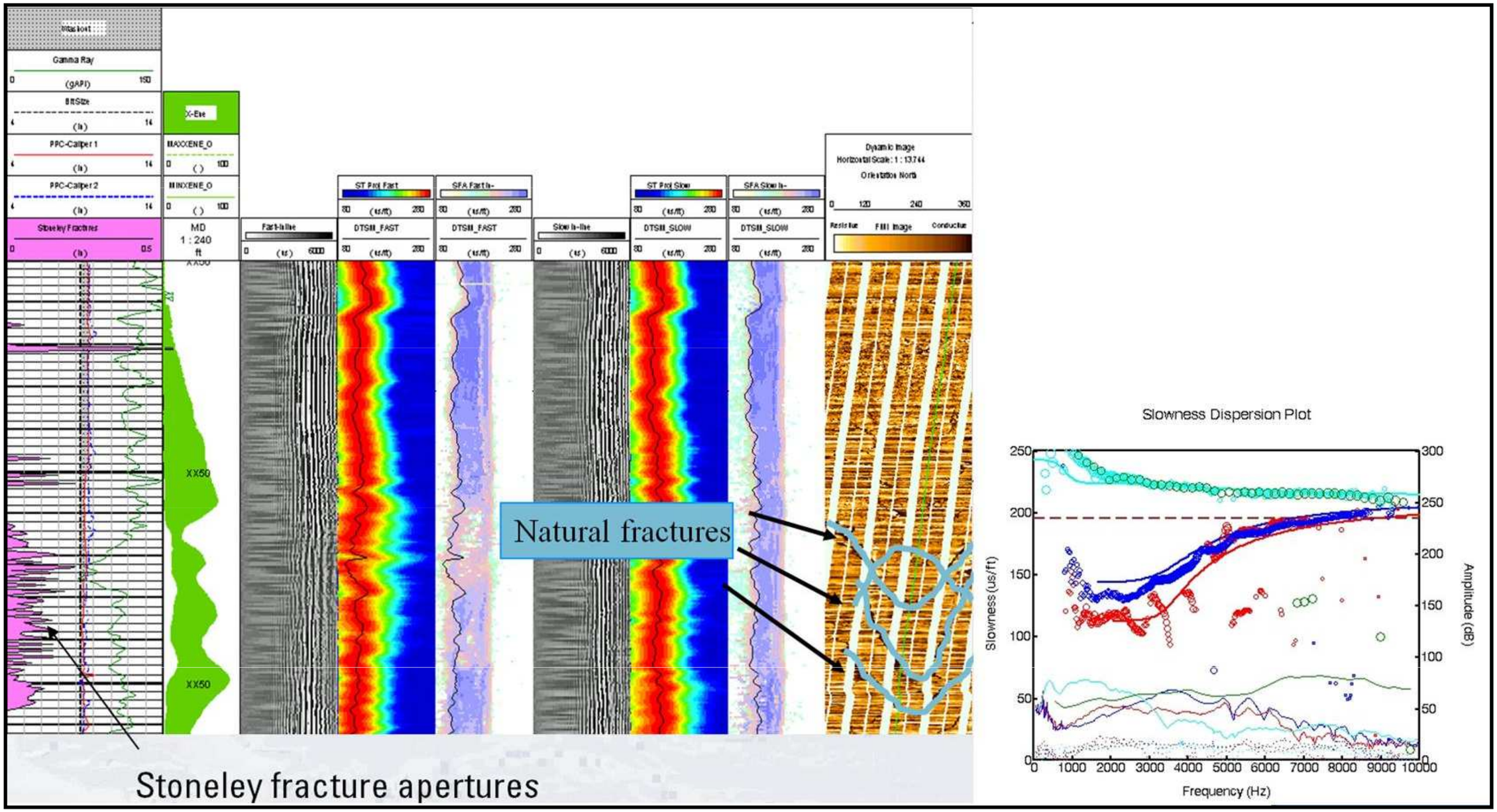
Integrated Fracture Identification



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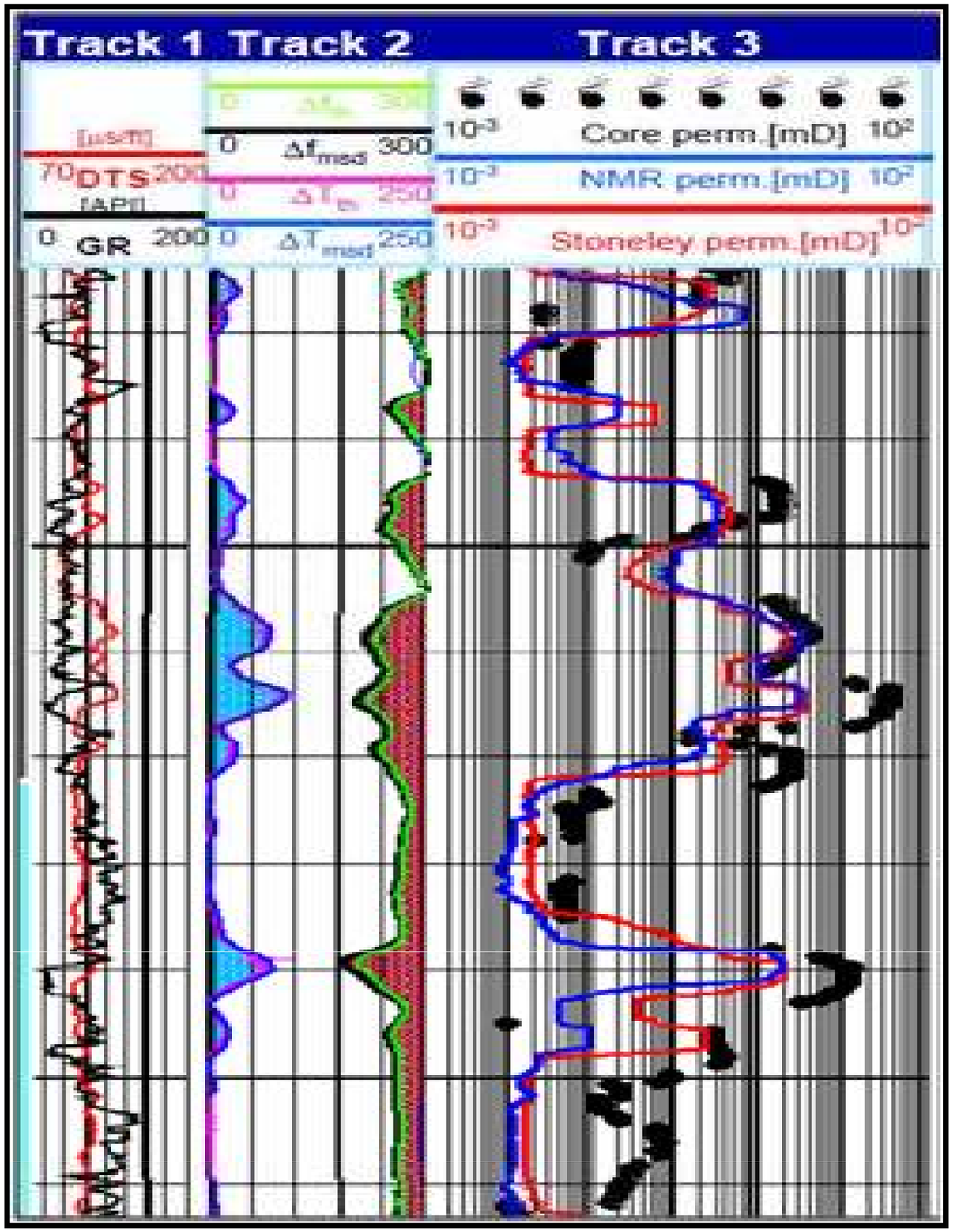
Mobility Estimation

- Effect of permeability on Stoneley wave well known theoretically and experimentally.
- mobility evaluation done by multi-parameter inversion of acoustic waves.
- It is a continuous measurement



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Well-bore Alteration/Damage

- Variations in formation properties around the wellbore.
- Either true formation property or induced by drilling and or other E&P practices.
- Multitude of transmitter/receivers fully characterize acoustic waves in large volume around borehole.
- Near arrays sample the zone near to the well bore, while far arrays see quite away in the formation.
- Differential is displayed as alteration.
- Helps in completion design and fluid sampling.
- Information can be incorporated in updating the MEM (Mechanical Earth Model).

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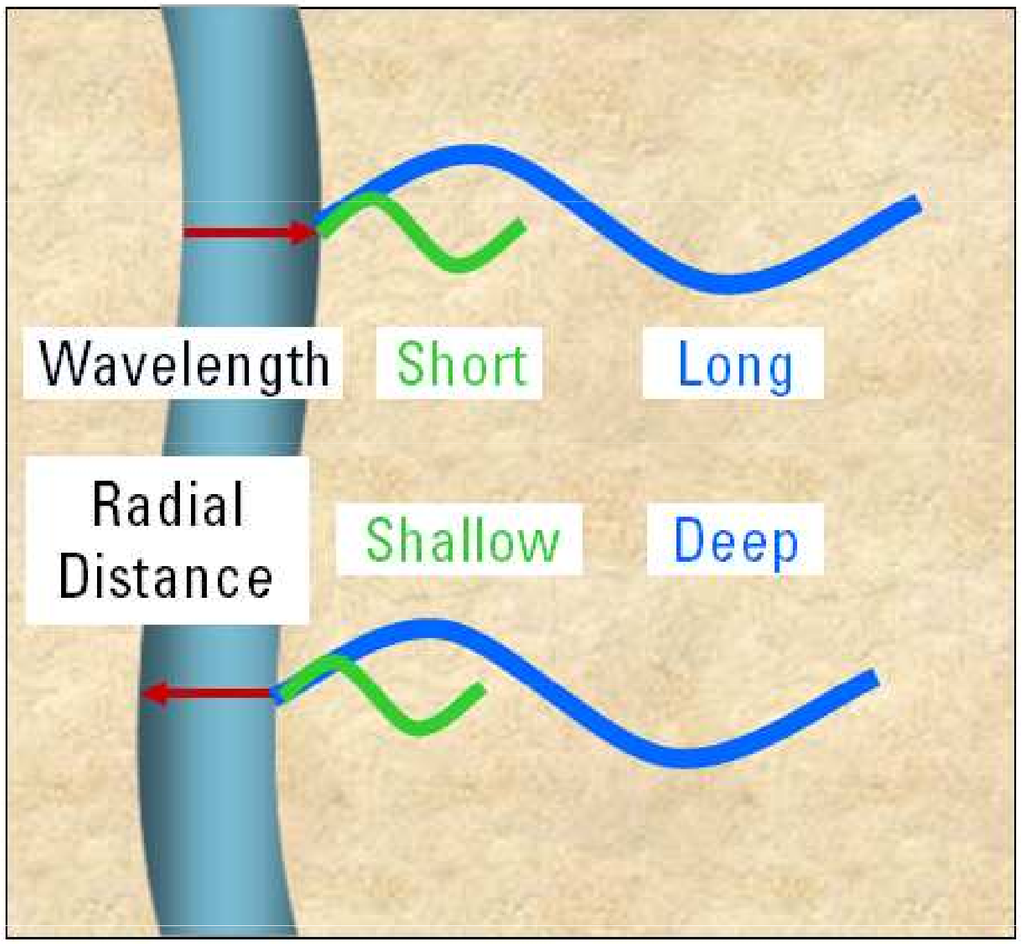
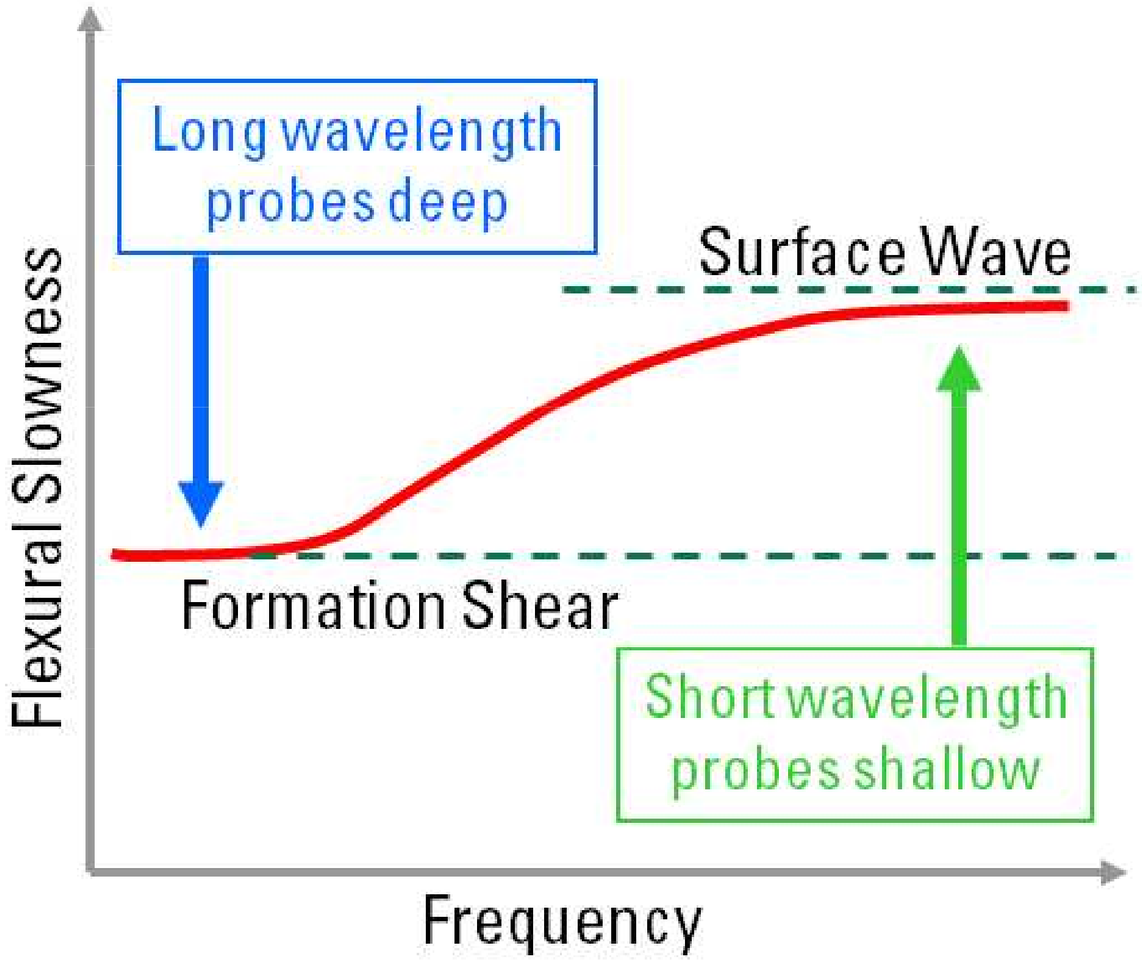
Well-bore Alteration/Damage



Dipole Source



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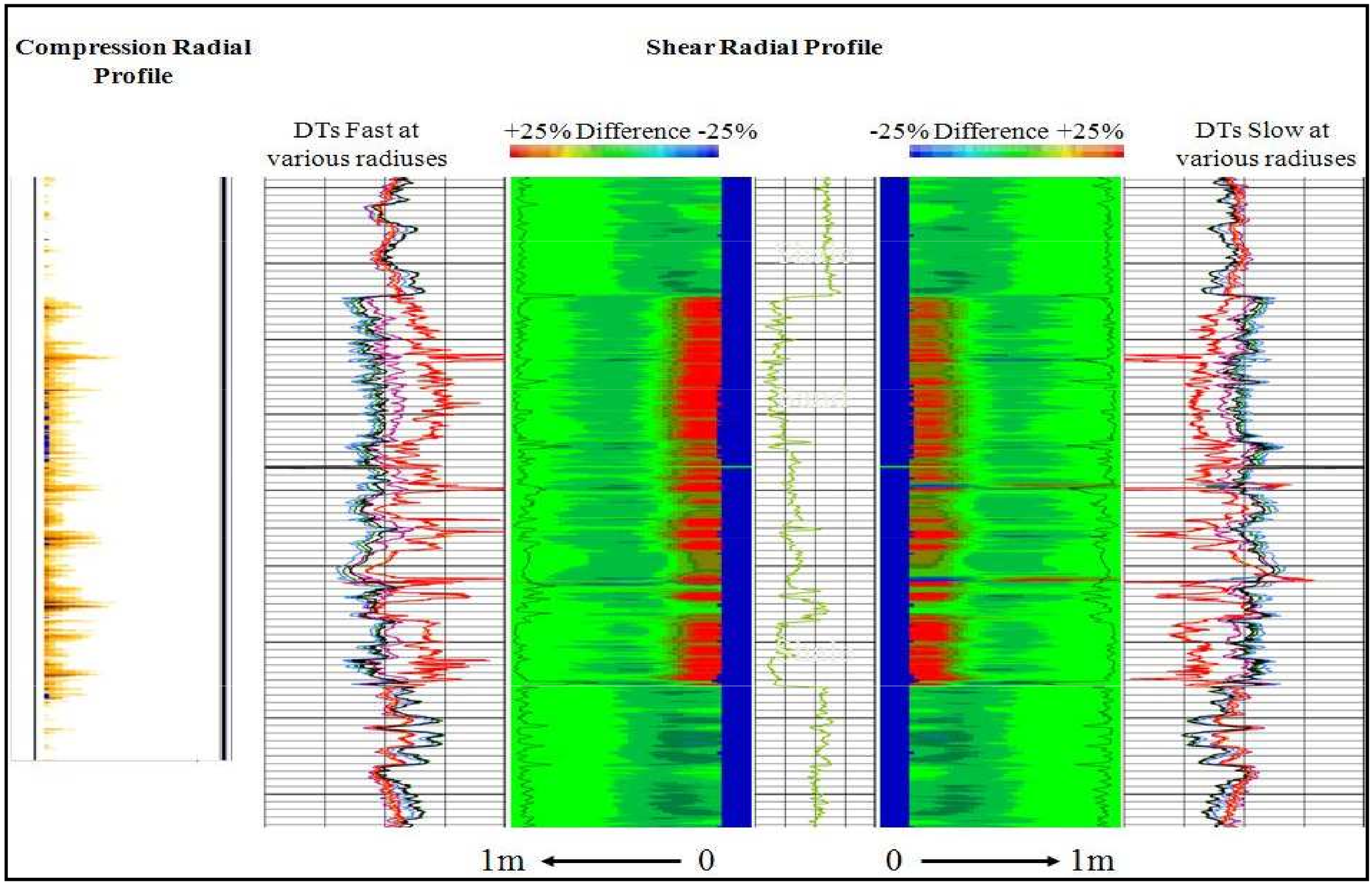

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High-Resolution Seismic Images (BARS)

- Advance technology provides high-resolution seismic images (BARS) within the wellbore.
- Resolution if two to three orders of magnitude higher than borehole seismic images.
- Potential applications are:
  - Well Placement
  - Reservoir structural analysis
  - identifying sub-seismic interbeds

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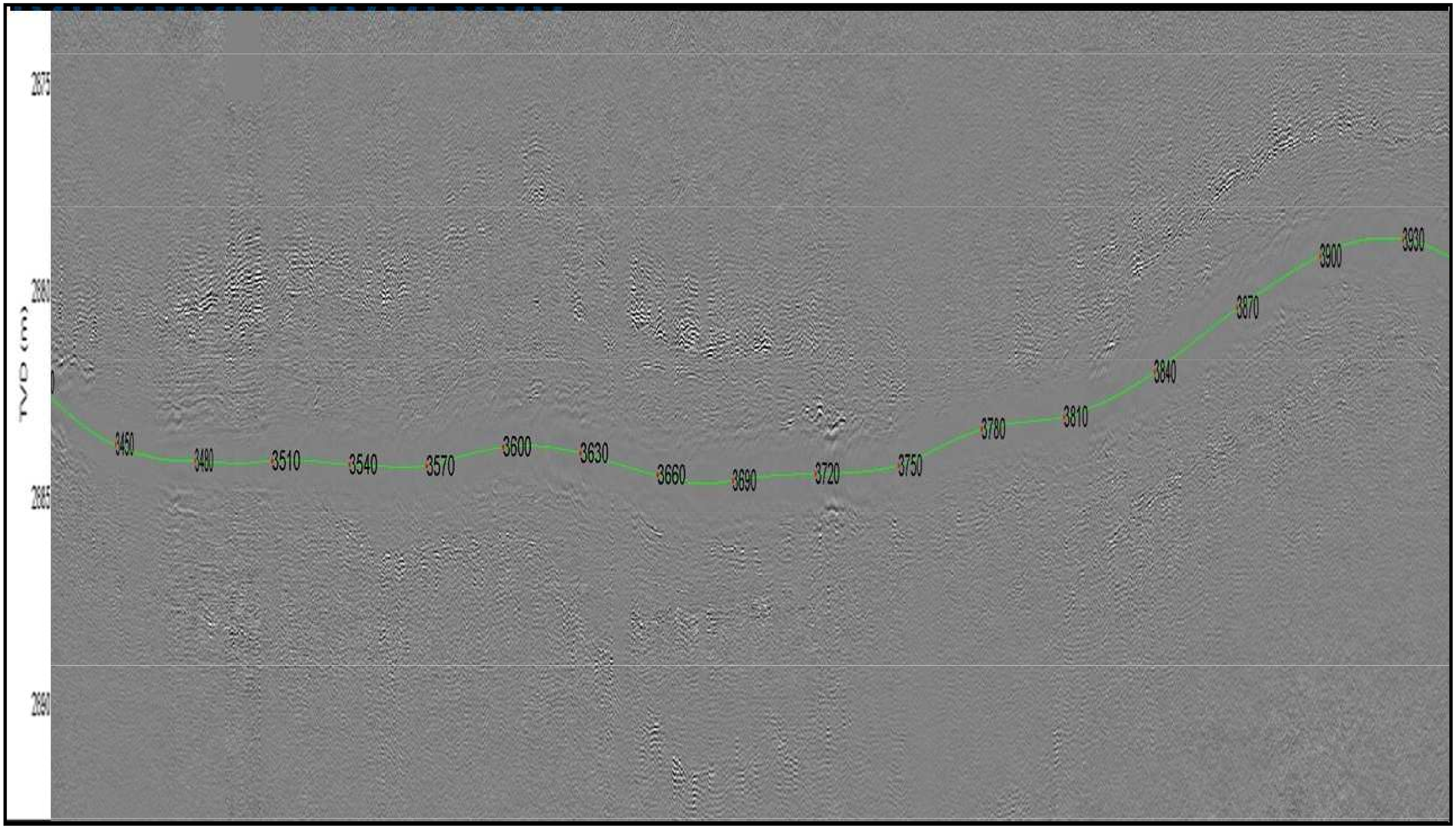
High-Resolution Seismic Images (BARS)



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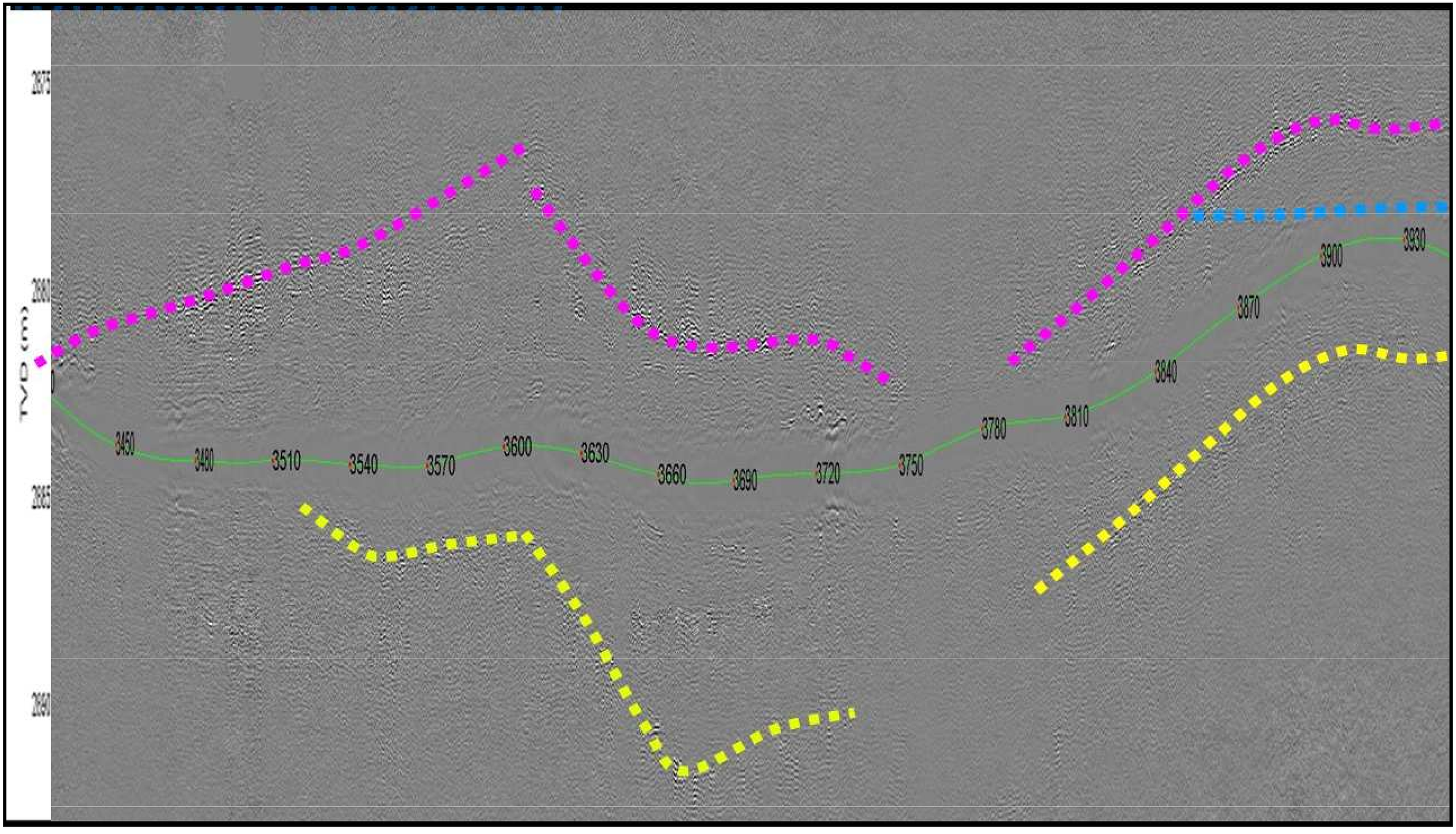
High-Resolution Seismic Images (BARS)



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Cement Evaluation

- Cement evaluation in same logging run as acquiring other acoustic data (compression, shear, Stoneley).
- Large number of receivers help correct attenuation for casing and cement.
- Multitude of receivers also compensate for eccentralization up to one-third of an inch.

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Summary

- Improved measurements in open hole and cased hole.
- Fracture identification through Stoneley and shear-wave analysis
- Determination of stresses and their directions
- Use in mechanical earth modeling (MEM)
- Formation alteration detection, which helps in completion designs
- Better positioning of the formation tops by incorporating anisotropy in improved seismic processing
- Processing high-resolution seismic images for proper structural interpretation and well placement
- Advanced cement evaluation combined with compression, shear and Stoneley acquisition

Acknowledgement

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