DISCUSSIONS ON 3D3C SEISMIC MULTICOMPONENT

Multicomponent seismic concerns the acquisition of P and S waves (compressional (P) and shear (S) wave modes).
This adds new inputs in a system of equations aiming to solve for dynamic elastic attributes.
As far as wave velocities is concerned, P-waves are dependent on three bulk rock properties (compressibility K, rigidity μ and density ρ) while S-waves are only influenced by two of them: rigidity μ and density ρ.
In Rock Physics and seismic reservoir characterization three attibutes are particularly important:

E → Young Modulus , σ → Poisson Ratio , ***K*** → Bulk Modulus

$$E = \frac{\mu(3\lambda + 2\mu)}{(\lambda + \mu)}$$

$$\sigma = \frac{\lambda}{2(\lambda + \mu)}$$

$$k = \frac{3\lambda + 2\mu}{3}$$

These are here expressed as a funktion of the Lame' constants (λ, μ).
By recording both compressional (P) and shear (S) wave modes and their combination it is possible to captures more information related to rock properties and fluids.
Multicomponent or 3D3C data will also add substantial quantitative attributes in the reservoir characterization, and critical interpretation processes for fracture analysis.
3D3C data increases resolution for lithology identification, fluid discrimination, imaging through gas, fracture, stress-field characterization and density estimation.
The method is the extended alternative to conventional P-wave images and AVO results and provides important complementary seismic information.
After AVO Attributes calculation, additional derivation of key elastic attribues through 3D3C inversion can reinforce the interpretation process.
Advent of 4C ocean bottom recording 1999 Processed industry's first time-lapse 4C survey.
Introduction of MEMS digital sensors pioneered the acquisition and processing of 3C data
P-wave data alone requires the use of long offsets and AVO techniques to derive S-wave impedances and velocities. Joint PP and PS inversion provides S-wave properties directly.
A key step towards successful inversion is ensuring the S-wave image is of the highest possible resolution.
Crossplot of V_P and V_S properties is one of the most efficient rock physical interpretation tools.

This has for instance important applications in heavy oil. Computation of V_P/V_S ratios, decrease uncertainty and aid quantitative identiion of Shale Volume through better density estimation.
As we know Shale volume can crirically affect the heavy oil recovery process since it can act as barrier to steam movements.
In Gas-Shales exploration brittle Frac behaviour can be defined through Young Modulus and Poisson Ratio.
These two properties can be determined with more accuracy with the seismic multicomponent data. By crossplotting the two elastic parameters, caracteristic fields of brilltle behaviour can be identified. By further crossplotting in the 3 to n-dimentional field with other seismic or petrophysical attributes the interpretation can be further developed for specific facies discrimination.

The list of seismic attributes derived in PP - PS mode.
List of seismic attributes
Elastic parameters:
V_P : compressional wave velocity
V_S : shear wave velocity
ρ : density
from them, parameters more familiar to people working on samples or well data can be derived:
λ,μ : Lamé's constant
σ : Poisson's ratio
E : Young's modulus
λ/μ : Fluid factor

Anisotropy parameters:
As of now, only azimuthal parameters are delivered (VTI parameters are ignored)
Orientation of the fast velocity axis (generally along fracture orientation)
Percentage of azimuthal anisotropy (generally linked to fracture intensity)
When derived from P mode (conventional 3D) these parameters are based on the analysis of seismic amplitudes.
When derived from P+PS modes (3D3C) these parameters are based on the analysis of seismic amplitudes, time differences and wave polarizations, they are more reliable and of more better resolution.

Observations of the 3D3C processing.

PP/PS seismic inversion can be derived in different ways.
An essential distinction is between pre-stack or post-stack inversions.
The post-stack principle assumes that amplitudes of stacked PP or PS data respectively represent P or S impedance relative differences. Then the ratio of P to PS impedances is Vp/Vs.
This kind of inversion has two weak points:
- PS stacked amplitude is only an approximation of S impedance
- Density derivation is not possible from stacked P and PS data

The pre-stack inversion combines PP and PS AVO attributes, generally two PP and one PS or, more refined, 3 PP and 2 PS in order to better define the density and optionnally the TTI anisotropy attributes in addition with Vp/Vs.
A key point of these options remains the accuracy of the association of combined PP and PS attributes that is valid only when these PP and PS attributes are taken exactly at the same depth. Most procedures tie PP and PS propagation times with well data then propagate their association by interpretative pickings. Another possibility consists in ensuring
the maximum compatibility of the Vp/Vs ratio values issued from AVO with the ratio of the time difference between P and PS samples.

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