What to expect from Vector Wavefields?

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Introduction

Multi-component experimentations started around forty years ago, using primitive acquisition or processing tools, when compared to the complexity of the shear mode propagation. Slow but substantial advances of the field techniques and digital processing now open the way to the real potential of multi-component technology provided the process respects all necessary conditions. Pure shear mode surveys are rare, multi-component technology presently considers PS mode in addition to the P mode.

1) Are we doing everything we should do?

1-1) Multi-component acquisition.

Number of multi-component surveys imply replaces the single component receiver by 3 or 4 components. Such surveys do not take into account the particulars of PS mode propagation.

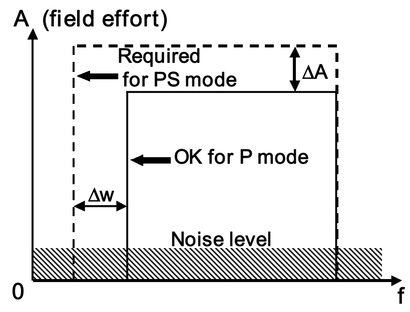

Figure 1: Compared necessary field efforts

Because the reflectivity of PS mode is globally weaker and absorption is globally stronger than P mode ones, the field effort of MC surveys should be increased (ΔA in Fig 1).

Because the conversion from P to S mode involves a wavelength shift towards short wavelengths from P mode to PS mode, PS mode signal does not include long wavelengths; when a source is producing satisfactory low wavelengths in the P mode, it should be modified to provide frequencies in the (Vs/Vp) ratio in order to obtain the same wavelength content in the PS mode (ΔW Fig 1).

Because of the small horizontal scale and the strong size of the shear static correction anomalies, MC receiver groups should be shortened.

Because splitting effects have to be removed from PS mode data even when they are not the aim of the survey, acquisition design, source and receiver groups should be isotropic.

1-2) MC processing.

It is very difficult to separate long wavelength statics and lateral velocity variations within medium depth layers. The overall quality of a CDP stack is not really affected by inaccurate separation; however, the velocity field is disturbed then the imaging of PS data.

When azimuthal anisotropy is not the aim of the survey, birefringence compensation is generally not considered causing a loss of resolution of PS mode results.

2) What benefit can we expect?

2-1) Already recognized benefits of MC

Disturbances caused by shallow gas in P mode are definitely reduced in PS mode; this application of MC surveys is certainly the most popular.

Sand/shale impedance contrast may be stronger in PS mode than in P mode. Examples of clearly improved results exist but are not very common.

Higher resolution of PS mode data in the shallow domain is commonly observed.

2-2) Potential improvements

The achievement of the seismic process should be a full seismic inversion including accurate depth imaging and the definition of the physical rock parameters within each geological domain. MC technology improves the chances to reach these two goals.

Depth imaging is submitted to uncertainties due to the difficulty to produce accurate velocity fields and to estimate the anisotropy parameters. Producing P and PS images that must be compatible instead of P image alone is certainly a plus.

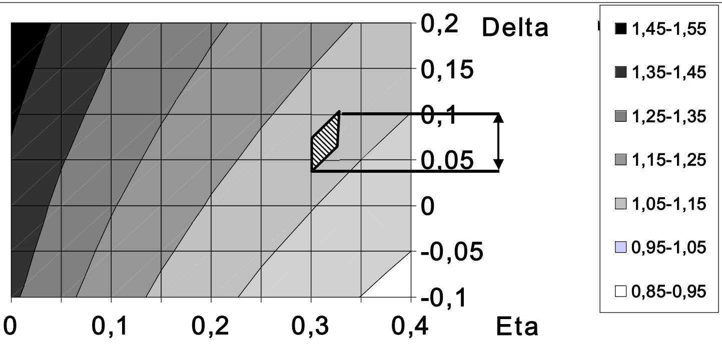

Figure 2: (Vpnmo/Vpsnmo) appears the Eta and Delta coordinates, uncertainty on Delta can be defined (hashed area)

More precisely, once the Eta parameter is derived from the observation of long offset NMO, the depthing parameter Delta, including its uncertainty range, is obtained by considering the ratio between P and PS short spread NMO velocities (Fig 2).

The definition of the elastic parameters in the general case means defining 21 elastic constants. Less ambitious, the actual practice considers 3 particular schematic cases: isotropic, transversely isotropic and orthorhombic.

In the isotropic case, 2 elastic constants in addition with the density are enough.

P mode elastic inversion provides acoustic impedance and Vp/Vs ratio, does not separate Vp, Vs or density while MC inversion does it, thus provides any attribute related to the elastic constants.

Formally, it can be established that considering MC data in P and PS modes can deliver the necessary 5 or 9 elastic parameters corresponding to polar or orthorhombic anisotropy, while P mode alone cannot. In practice, combining P and PS modes in polar anisotropic conditions delivers Vp, Vs, density, Eta and Delta (SH mode should be considered to reach 5 elastic constants).

In the orthorhombic case, MC technology benefits of 3 wave modes, P, PS1 and PS2 instead of only one. P mode alone may deliver azimuthal information by considering amplitude versus azimuth. With MC acquisition, two more accesses exist to azimuthal investigation: PS amplitudes and shear propagation times.

No doubt that the definition of the elastic constants is much better through S1 and S2 polarizations, propagation times and amplitudes than from the P mode amplitudes alone.

Conclusion

Even when not considering pure shear modes, MC technology has real potential in exploration. It can supply some failures of the conventional P mode surveys as gas clouds or weak impedance contrasts. Offering the observation of two additional propagation modes, it is a way to decrease the uncertainties of P mode imaging, to deliver more lithology indicators or either exploration attributes and to improve their accuracy.