GC P-Wave Wipeout Zones Caused by Low Gas Saturation Strata*

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General Statement

A hydrocarbon exploration application that has caused multicomponent seismic data to be acquired across several offshore areas is the ability of S-wave modes to image geology inside broad, thick intervals of gas-charged sediment where P-P seismic data show no usable reflections. The term "P-wave wipeout zone" is often used to describe this imaging problem.

Example

An example of P-P and converted-shear (P-SV) imaging across an area of shallow, gas-charged sediments of the Gulf of Mexico is displayed as Figure 1. Visual inspection of these images shows the P-P mode provides poor, limited information about geological structure, depositional sequences and sedimentary facies inside the image space dominated by gas-charged sediment (CDP coordinates 10,000 to 10,150). Conventional seismic stratigraphy (P-P mode only) would have little success in analyzing geological conditions within this poor-quality P-P image area.

In contrast, the P-SV mode (Figure 1b) provides an image that is sufficient for structural mapping, as well as for analyzing seismic sequences and seismic facies. Both of these interpretation options are obvious advantages of elastic wavefield stratigraphy over conventional seismic stratigraphy in areas having gas-charged sediment.

A simple Earth model consisting of a shale layer atop a sand layer can be used to evaluate P-P and P-SV reflectivity behaviors associated with P-wave wipeout zones. Two pore-fluid situations are defined on table 1:

1) A condition where both layers have 100% brine saturation.

2) A second condition where both layers have a mixed pore fluid of 80% brine and 20% gas.

P-P and P-SV reflectivity curves for these two pore-fluid conditions are shown as Figure 2.

When pore fluid is 100% brine, P-P and P-SV reflectivities have opposite algebraic signs but approximately the same average magnitude (about 5%) for incidence angles ranging from 0 to 25% (Panel a). When pore fluid changes to 20% gas (Panel b), P-SV reflectivity is unchanged, but P-P reflectivity decreases in magnitude and undergoes a phase reversal at an incident angle of approximately 18%.

The gas-charged sediment, thus, does not affect P-SV imaging – but P-P imaging is seriously degraded. The negative reflectivity for incident angles between 0 and 18 degrees essentially cancel the positive reflectivities for incident angles greater than 18%, resulting in "wipeout" P-wave reflections. The effect would be similar to that exhibited by the data on Figure 1.

Conclusion

There is logical rock physics evidence why P-wave wipeout zones occur in strata having low gas saturation and why S-mode data are insensitive to low gas saturation.

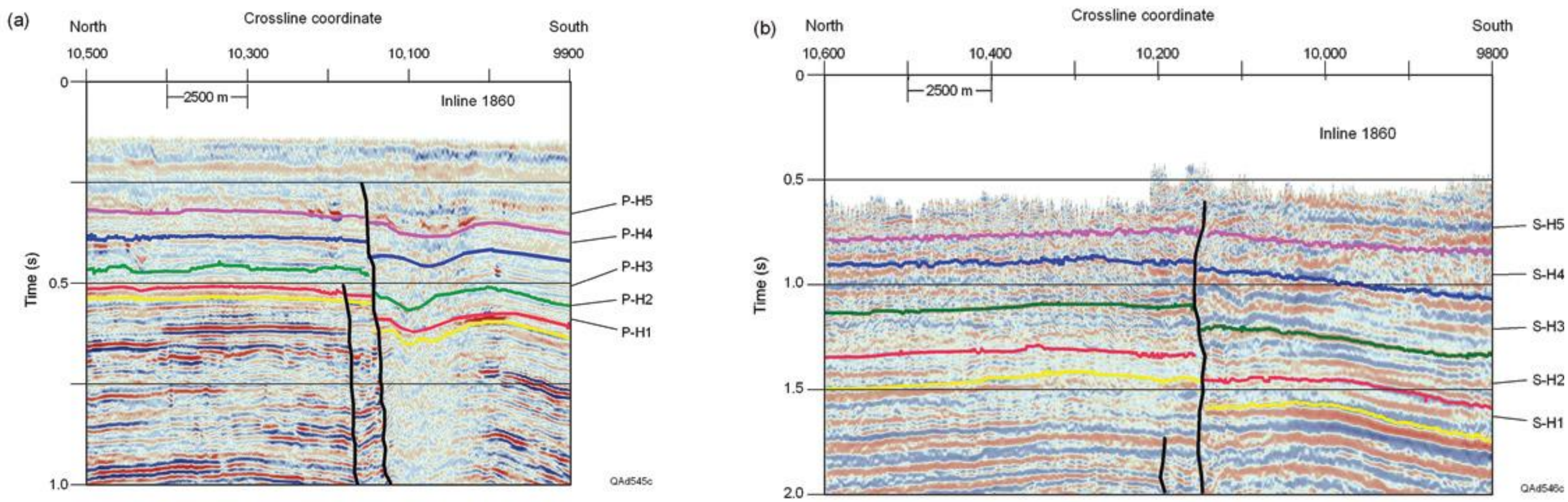

Figure 1. (a) P-P image, and (b) P-SV image across shallow, gas-charged sediments in the Gulf of Mexico. P-P horizons P-H1 through P-H5 are interpreted to be depth equivalent to P-SV horizons S-H1 through S-H5. The P-SV data image stratigraphy inside the P-wave wipeout zone extending from CDP coordinates 10,000 to 10,150.

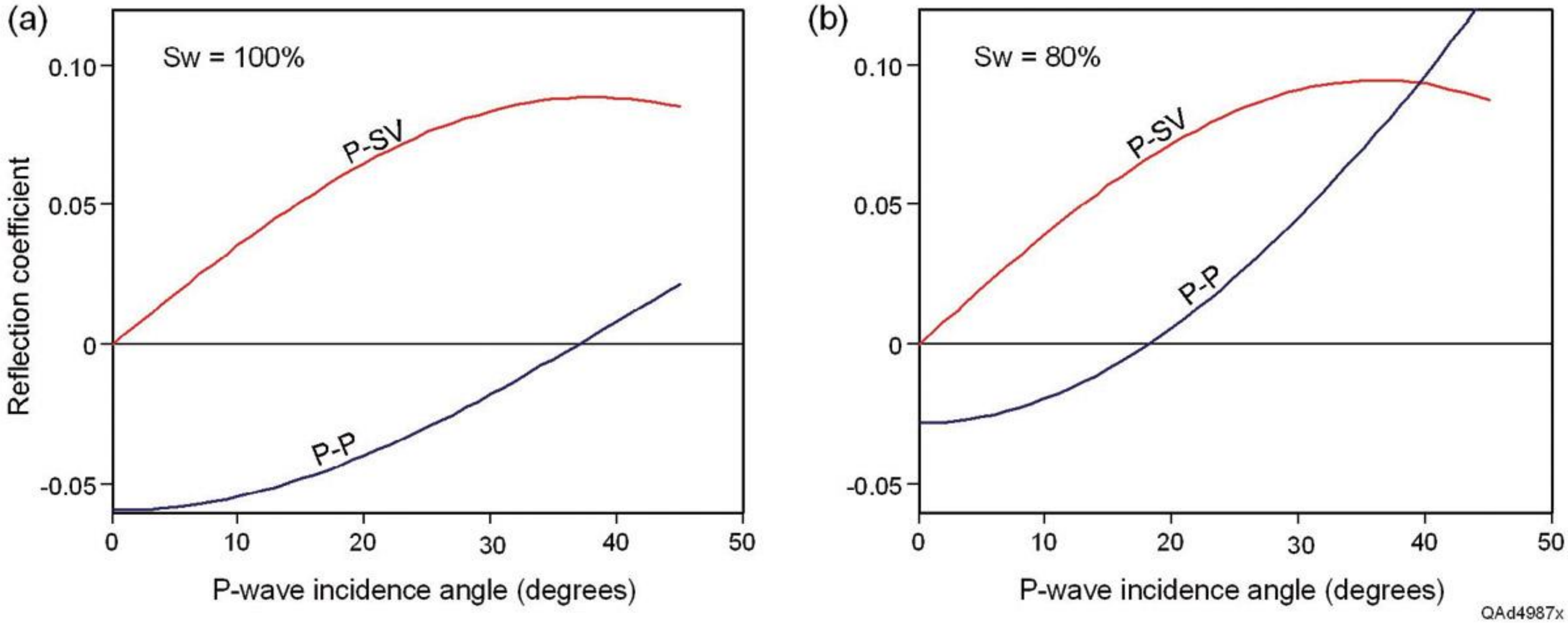

Figure 2. P-P and P-SV reflectivities for (a) brine-filled, and (b) gas-charged sediments.