[GC]Occurrence of P-Wave Wipeout Zones*

By
Bob Hardage[1], Michael DeAngelo[1], and Diana Sava[1]

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[1]Bureau of Economic Geology, The University of Texas at Austin (hardageb@beg.utexas.edu)

General Statement

One hydrocarbon exploration application that has caused multicomponent seismic data to be acquired across several offshore areas is the ability of the converted-S mode 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. Numerous examples of P-wave and S-wave images across P-wave wipeout zones have been published, but the rock physics cause of the P-P imaging problem usually is not discussed.

Example

One example of differences between P-P and P-SV images of stratigraphy and structure inside gas-charged sediment is shown in Figure 1. The P-wave wipeout zone shown here extends about two kilometers (from CDP 10,000 to CDP 10,150) and is small compared with some P-wave wipeout zones, which may span several tens of kilometers.

Visual inspection of these images shows that 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 between coordinates 10,000 and 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 provides an image that is sufficient for structural mapping, as well as for analyzing seismic sequences and seismic facies. These increased interpretation options are obvious advantages of multi-component seismic data and elastic wavefield stratigraphy over single-component seismic data and conventional P-wave seismic stratigraphy in regions where gas-charged sediments are common.

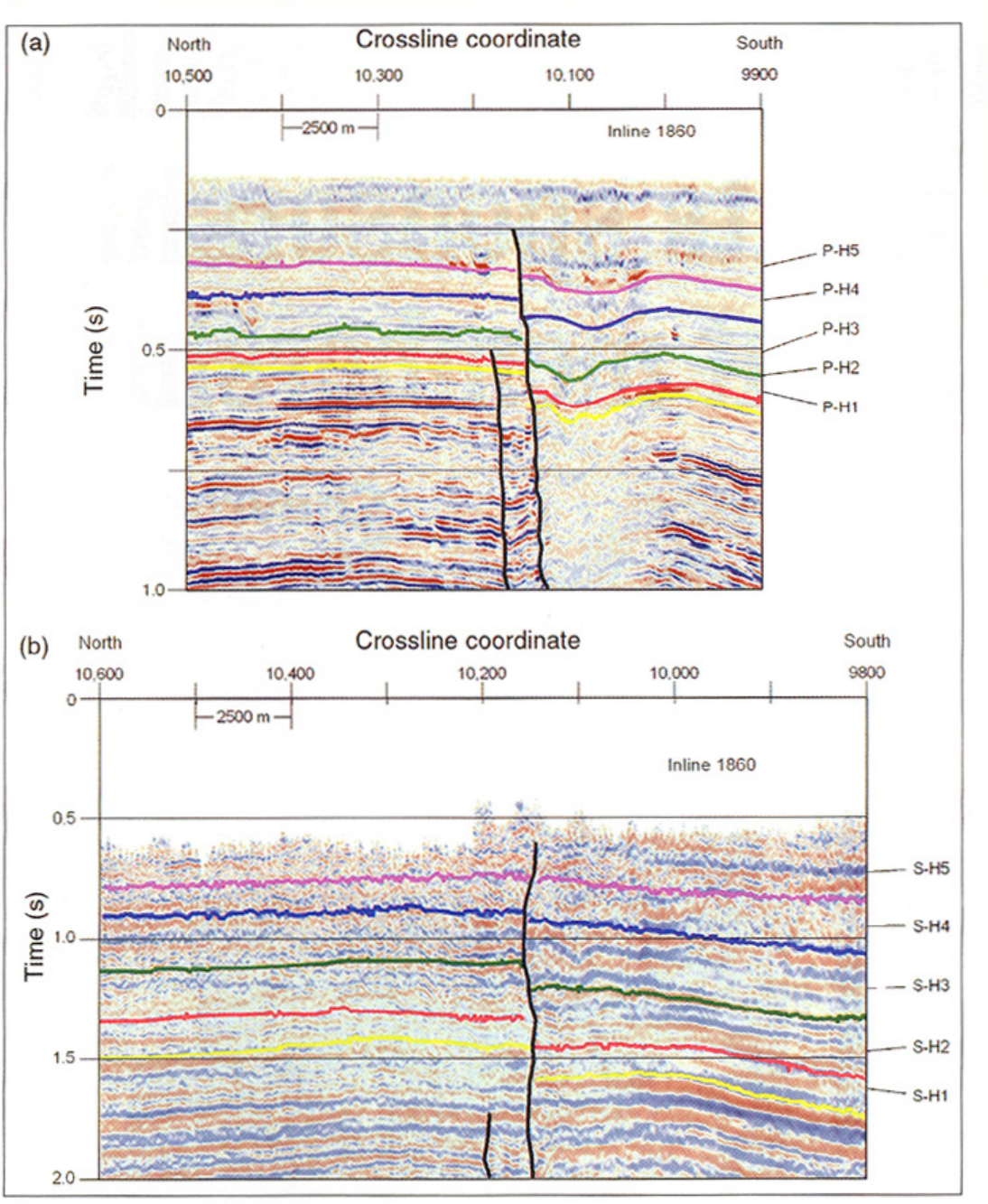

Figure 1. P-P image (a) and P-SV image (b) across gas-charged Gulf of Mexico sediments that are lithified and stratified. P-P horizons P-H1 through P-H5 are interpreted to be depth equivalent to P-SV horizons S-H1 through S-H5. A P-wave wipeout zone extends from CDP coordinates 10,000 to 10,150. P-SV data (b) image geology quite well inside this zone.

Model

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 for the types of siliciclastic rocks that occur across the Gulf of Mexico, where P-wave wipeout zones are common.

Two pore-fluid situations will be considered:

1) Both layers have 100 percent brine saturation.

2) Both layers have a mixed pore fluid of 80 percent brine, and 20 percent gas.

Well-established rock physics theory can be used to determine seismic propagation velocities and bulk densities for these fluid-sediment conditions.

P-P and P-SV reflectivity curves calculated for typical pore-fluid conditions are shown in Figure 2. When the pore fluid is 100 percent brine, P-P and P-SV reflectivities have opposite algebraic signs but are approximately the same average magnitude (about 5 percent) for incidence angles ranging from 0 to 25 degrees (Figure 2a). When the pore fluid changes to 20 percent gas (Figure 2b), P-SV reflectivity is unchanged, but P-P reflectivity has a smaller magnitude and undergoes a phase reversal that essentially eliminates the P-P response across the first 30 degrees of the incidence-angle range.

P-SV imaging, thus, is not affected by the gas-charged sediment, but P-P imaging is seriously degraded. The effect on P-P and P-SV images would be similar to that exhibited by the data in Figure 1.

Conclusion

Simple reflectivity analysis, thus, often explains much of the reason for degradation of P-P signal inside regions of gas-charged sediment and for the lack of negative impact of gas-charged sediment on P-SV signal. One conclusion is that multi-component seismic data and elastic wavefield stratigraphy are not just helpful for studying geological conditions across P-wave wipeout zones; they are essential.

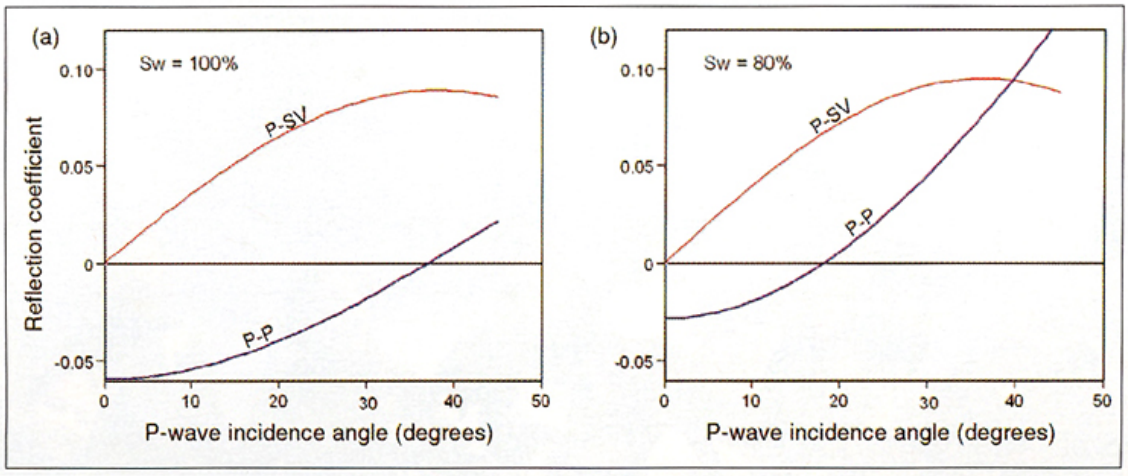

Figure 2. P-P and P-SV reflectivities for (a) brine-filled and (b) gas-charged sediment.