GC Reflection Response of Class Two Reservoirs*

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General Statement

Geophysicists define gas reservoirs as Class 1, 2, 3 or 4, depending on their P-P amplitude-versus-angle (AVA) response. The P-P AVA behaviors on which this classification scheme is based are shown as generalized curves in Figure 1. Although this reservoir terminology originated in the Gulf of Mexico and was applied initially only to sandstone reservoirs, the nomenclature is now used across basins worldwide and is applied to reservoirs other than gas-bearing sandstones.

Response of Reservoir Classes

Inspection of Figure 1 shows that:

1) A Class 1 reservoir exhibits a strong, positive P-P reflection response at normal incidence, and that response then decreases as the angle of incidence increases.
2) A Class 2 reservoir has a small P-P response (either positive [Class 2A] or negative [Class 2B] polarity) at normal incidence, and its P-P response becomes more negative as the angle of incidence increases.
3) A Class 3 reservoir has a strong, negative P-P response at normal incidence that becomes more negative as the angle of incidence increases.
4) A Class 4 reservoir has a strong, negative response at normal incidence, just as does a Class 3 reservoir, but its P-P response decreases (becomes less negative) with increasing angle of incidence.

Only Class 2 reservoirs are considered in this article because Class 2 reservoirs are faint, low-amplitude P-P events and sometimes are almost invisible in P-P seismic data. The reason for this invisibility is explained by the Class 2 reflectivity curves in Figure 1, which show that a Class 2 target does not generate an appreciable amount of common-phase reflection signal over the first third or half of the incidence-angle range used in most seismic data-acquisition programs.

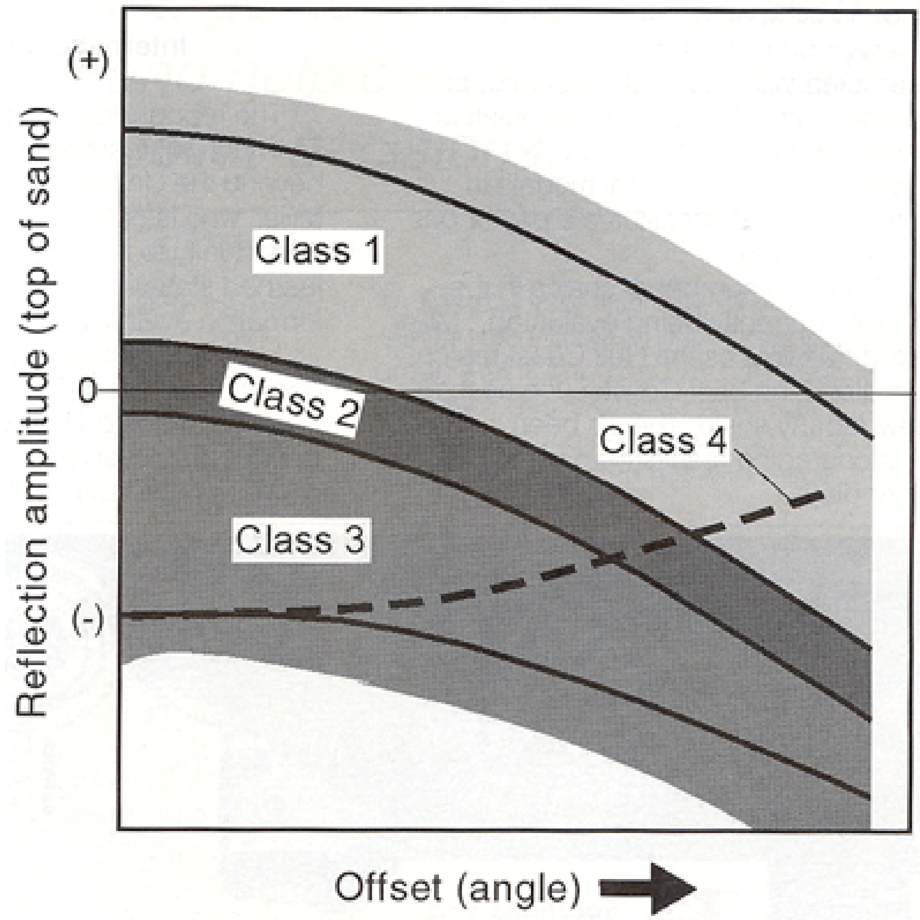

Figure 1. Domains of P-P AV responses for Class 1, 2, 3 and 4 reservoirs. Typical P-P reflectivity curves are drawn for each P-wave AVA reservoir class.

Example

One Class 2 reservoir that has been widely publicized is the Alba Field reservoir in the UK sector of the North Sea. P-P and P-SV seismic images across this particular reservoir have become classic data examples of multi-component seismic reflectivity behavior for Class 2 reservoirs among the geoscience community and will be used in this discussion.

Among the published P-P and P-SV profiles across the Alba Field are those displayed as Figure 2, which show that the Alba target produces a minor response in P-P image space, but a bold reflection package in P-SV image space. This image comparison illustrates that Class 2 reservoir interpretation can be difficult in a conventional seismic stratigraphy study that uses only P-P seismic data, but can be on a more rigorous foundation when both P-wave and S-wave data are available and elastic wavefield stratigraphy is utilized for prospect evaluation.

To illustrate the P-P and P-SV reflectivities associated with the Alba Field reservoir, we represented the target as a simple, two-layer Earth model defined by averaging published log data across the reservoir and its bounding units. Resulting reflectivity responses for the target interface are shown in Figure 3. The P-SV and the P-P reflectivity curves have zero and near-zero values, respectively, at normal incidence and then slope toward negative values. As the incidence angle increases, P-SV reflectivity reaches a magnitude of –5 percent quickly at an incidence angle of ~8 degrees and continues to increase to almost –15 percent at an incidence angle of ~30 degrees.

In the seismic reflectivity world, these reflection coefficients are huge. In contrast, P-P reflectivity does not reach a magnitude of –5 percent until the incidence angle is almost 30 degrees. The implication is that P-SV reflections from the Alba reservoir (and from all Class 2 reservoirs in general) are much more robust than P-P reflections at all angles of incidence.

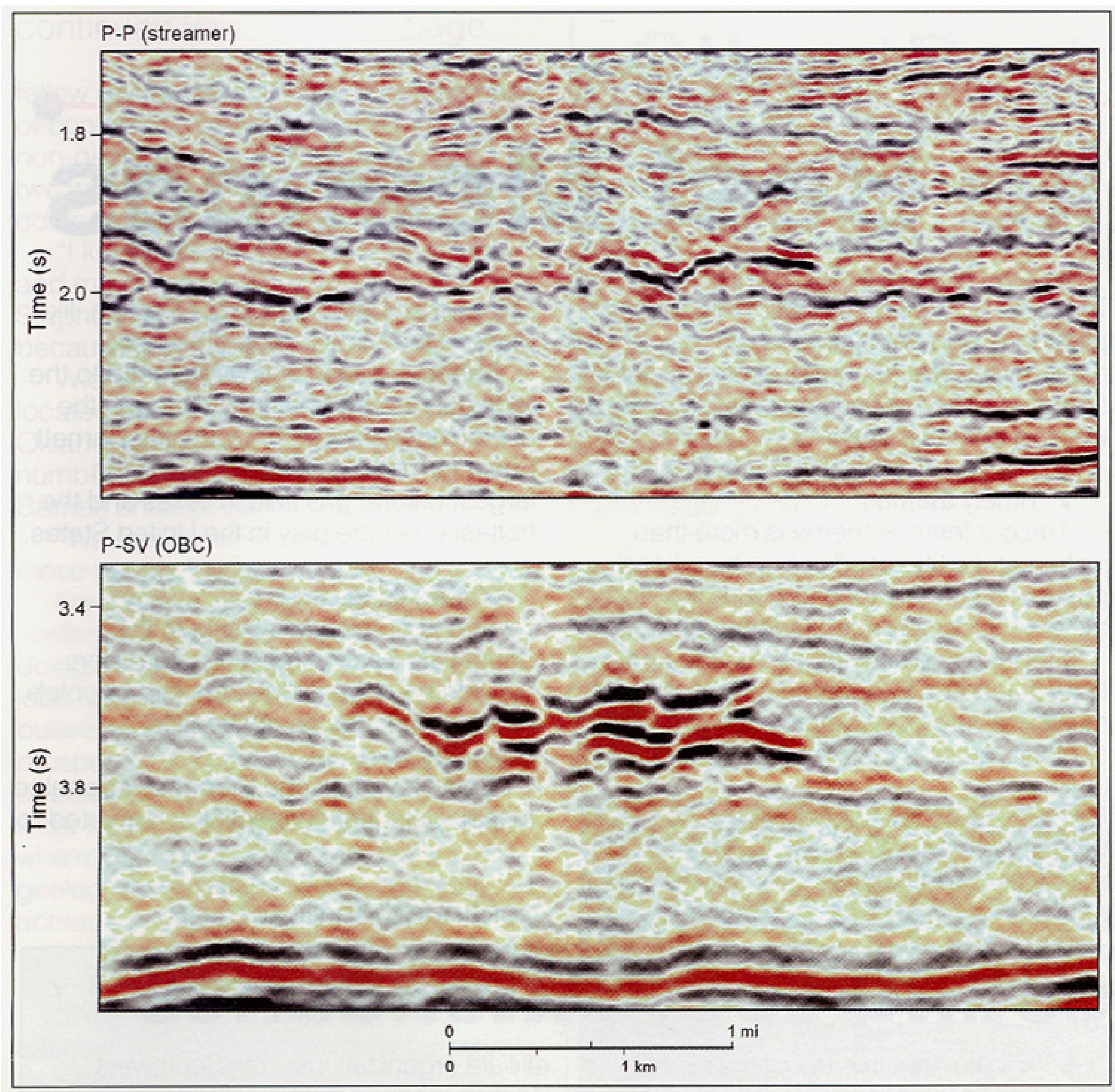

Figure 2. P-P towed-streamer profile (top) and P-SV profile constructed from 4C OBC seismic data (bottom) acquired across Alba field, North Sea (MacLeod et al., 1999).

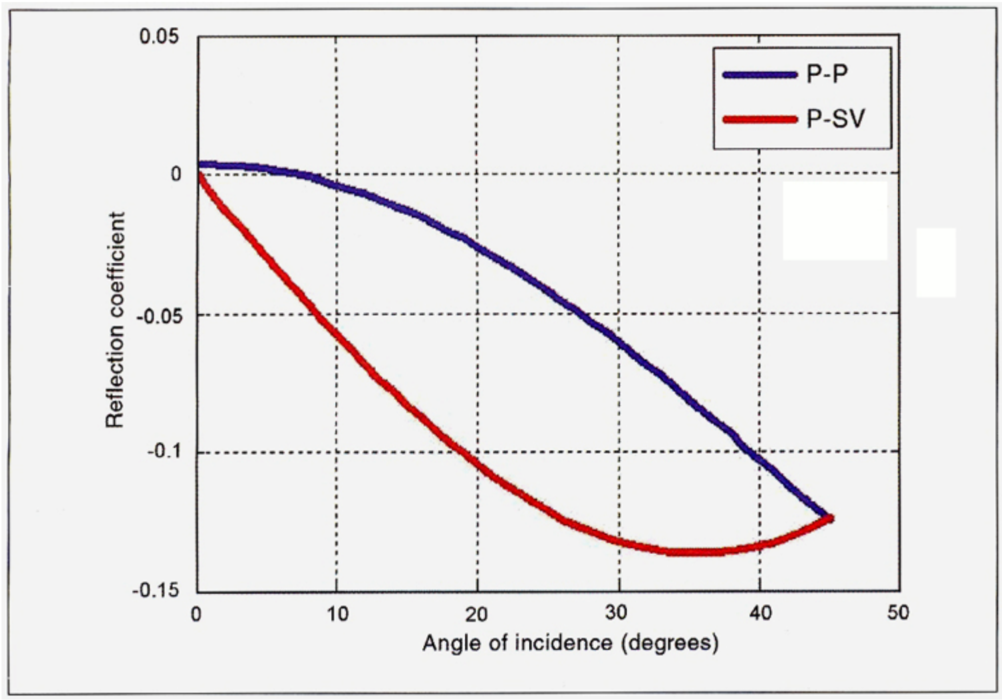

Figure 3. P-P and P-SV AVA responses across the top of the Alba reservoir.

Conclusion

An important conclusion is that multi-component seismic data and elastic wavefield stratigraphy allow exploitation of Class 2 reservoirs that cannot be properly interpreted with single-component data and conventional (P-P) seismic stratigraphy. Some explorationists are now learning that multi-component seismic data and elastic wavefield stratigraphy concepts are essential for imaging Class 2 reservoirs.

A recent example of such an application is the 4C seismic survey done by Petrobras across its deepwater Roncador field, in which P-SV data allowed an important Class 2 reservoir that could not be seen with P-P data to be exploited. This case history can be found in SEG's April 2006 *The Leading Edge* (Cafarelli et al., 2006).

References

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