# GCMulticomponent Seismic: A Pragmatist's Primer*

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## General Statement

Among the many acronyms in the oil industry, we now have "3C" and "4C" and even "9C" seismic data. The "C" stands for "component." Onshore, three-component data have one vertical and two horizontal geophones and are used to record the entire seismic waveform, both compressional (P) wave particle motion and the less familiar shear (S) wave particle motion.

Offshore, a hydrophone is added to the three-component geophone to create a "4C" receiver. Here the hydrophone records accelerations while the geophones record velocity; the difference in response is used to stack out surface multiples.

The least common of the acronyms is "9C" seismic, which is available only onshore. Here a controlled polarization shear and compressional source and three-component geophones yield a three-by-three matrix of source-receiver orientation combinations.

## Recording, Processing, and Interpretation

Shear waves do not propagate through water; so at sea we must place the receivers on the seabed. We then rely on mode conversion from P-energy to S-energy at the water bottom and at other geological interfaces. These shear waves are then known as "converted shear waves."

Dramatic improvements in recording hardware and in data processing have brought multicomponent seismic from the domain of the research lab and academia to more wide-scale use by explorationists and development geoscientists:

- Most multicomponent receivers now in use exhibit good vector fidelity (they respond equally to motion in any direction) and broadband frequency response.
- Some receivers, such as I/O's VectorSeis and Sercel's DSU3, actually are solid-state accelerometers, where a digital signal is generated directly at the receiver, thereby eliminating analog instrument noise.
- Processing algorithms have matured to the point where prestack time migration of converted shear waves is part of a typical processing flow. This has made significant improvements to the quality of the final product.
- Commercial software (ProMC from Hampson Russell) is now available to help the interpreter with the task of correlating and measuring the relative responses from the different multicomponent modes.

## Gas Clouds

The primary application of multicomponent seismic has been imaging within gas clouds or beneath obscuring shallow gas zones. By reasonable estimate, approximately three-quarters of the industry's 4C surveys have targeted such geophysical problems. Gas strongly absorbs P-waves, which propagate through both the rock framework and the fluid. S-waves, on the other hand, pass almost undiminished, because they propagate only through the rigidity of the rock framework.

An example from Indonesia is shown in Figure 1; the deeper part of the P-wave section is badly degraded by a shallow gas reservoir, but the PS converted wave section gives a nice crisp image of the offending shallow gas layer, the local faults, and the underlying structure.

Geophysicists have had good success with imaging through gas clouds and shallow gas in cases all over the world. Indeed, a full consensus of multi-component experts at the 2000 SEG Summer Workshop deemed gas clouds to be the "slam-dunk" of multicomponent applications.

Table 1 shows that all 65 experts thought it "very likely" that a survey designed to image through gas would be successful. While some applications were still thought to be "research topics," several other applications are clearly mature or maturing technologies (and we've come quite some way in the four years since 2000).

## Low P-impedance Sands

The second most important application of multicomponent seismic is the imaging of low P-impedance sands (Class II AVO) -- and one of the most widely published examples is from Alba Field in the UK North Sea (Figure 2). In this case, the top of the oil-filled part of the reservoir has very low P-impedance contrast with the overlying shales. This hampered the mapping of the turbidite reservoir, which now is believed to be further complicated by a complex structure of injectite sands.

A 3-D 4C survey was able to take advantage of the strong shear impedance contrast at the top of the reservoir and provide a clear picture of the sand distribution. This had a profound impact on development drilling success rates and field economics in general.

This example is not an isolated success story -- several other turbidite plays have similar petrophysics and are similarly amenable to converted-wave imaging. This probably includes the Miocene deep gas play on the Gulf of Mexico Shelf.

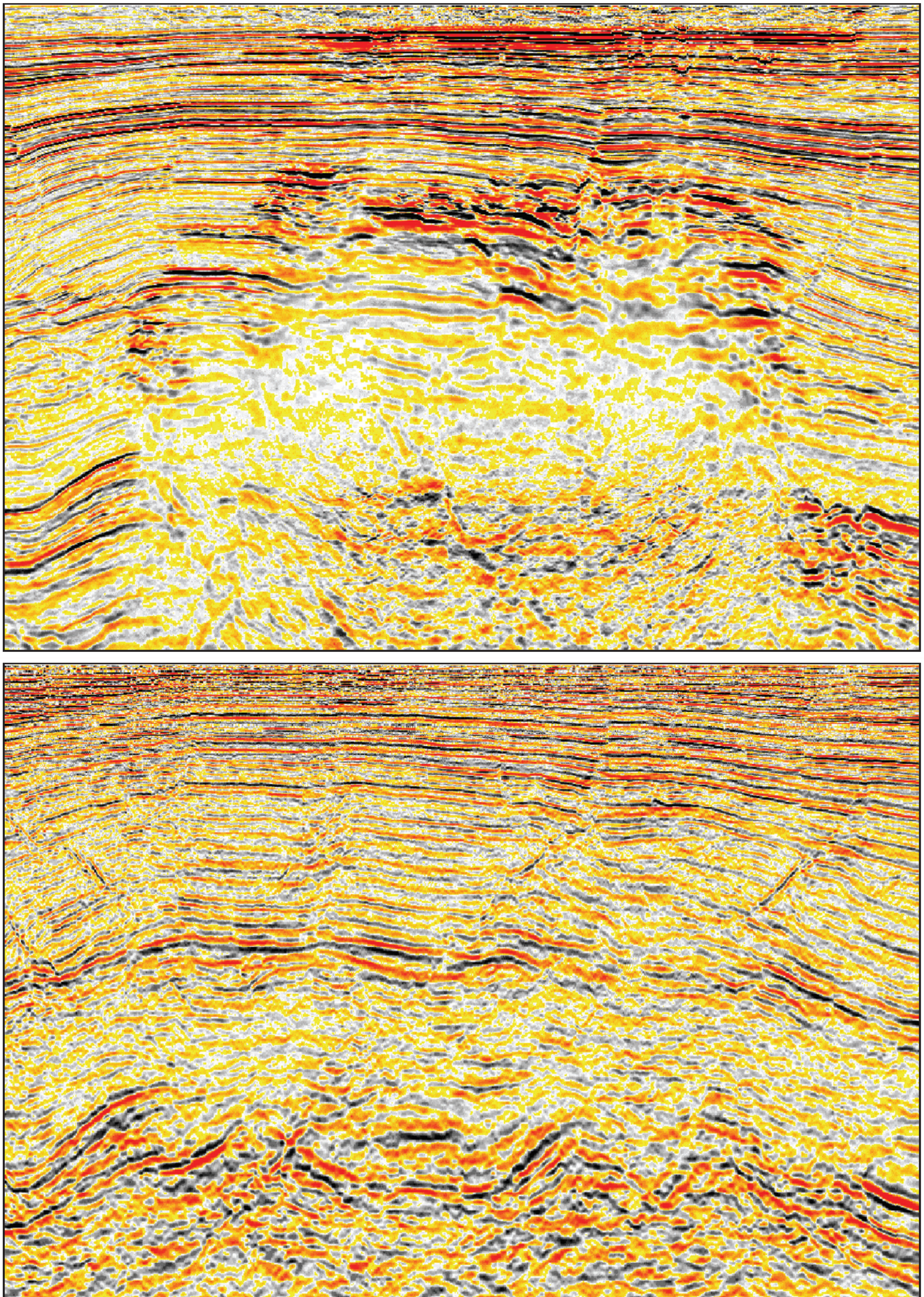

**Figure 1. Imaging through gas clouds. Normal 3-D streamer data (<u>top</u>) from a deepwater field in Indonesia is badly distorted by shallow gas. The converted wave section (<u>bottom</u>) from the 4C survey successfully imaged the shallow gas reservoir and the underlying structure. (Image from Battie et al., 2000.)**

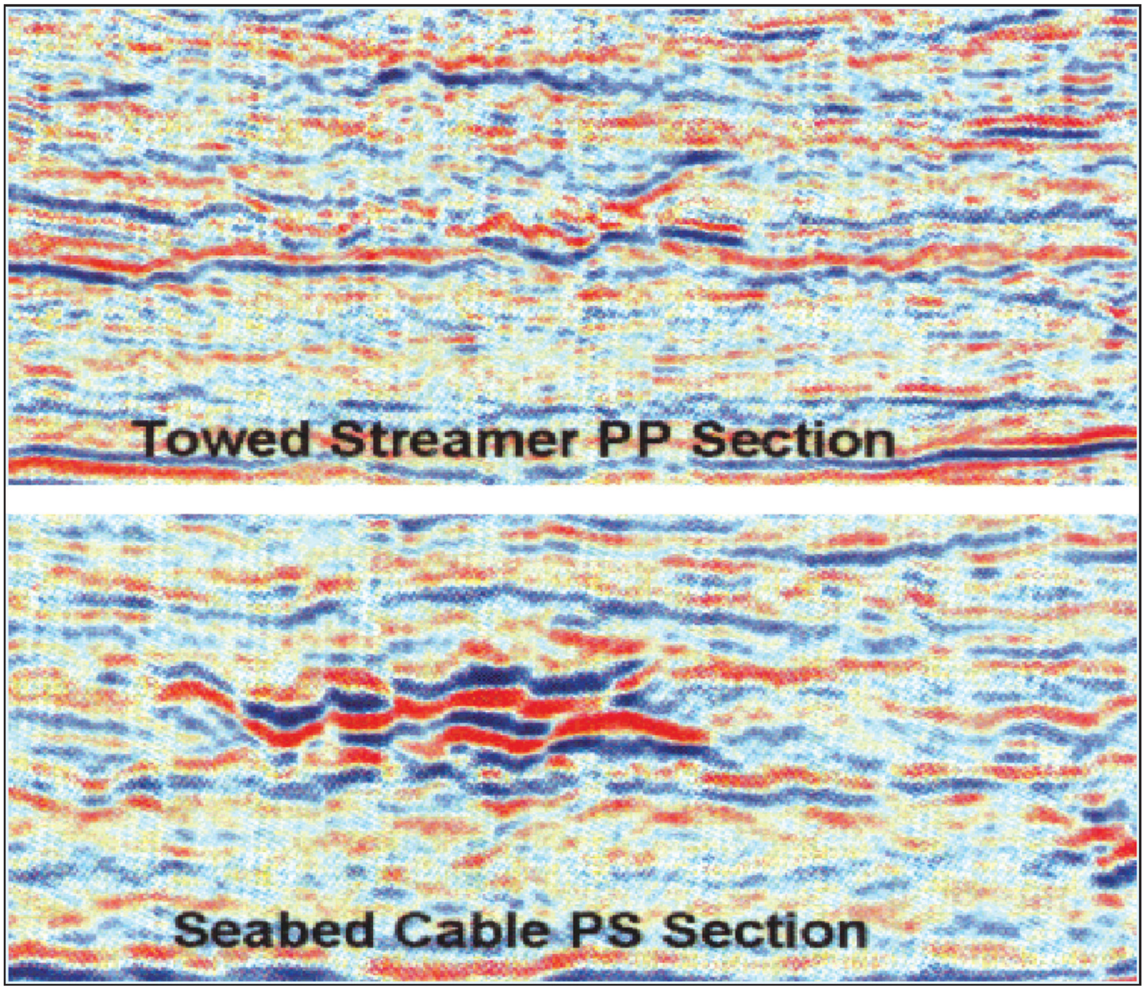


**Figure 2. Low P-wave contrast sands. The normal P-wave section (top) shows almost no reflections from the Alba Field reservoir. The converted wave section (bottom) shows clear high amplitude reflections from the same sands. (Image from MacLeod et al., 1999a,b.)**

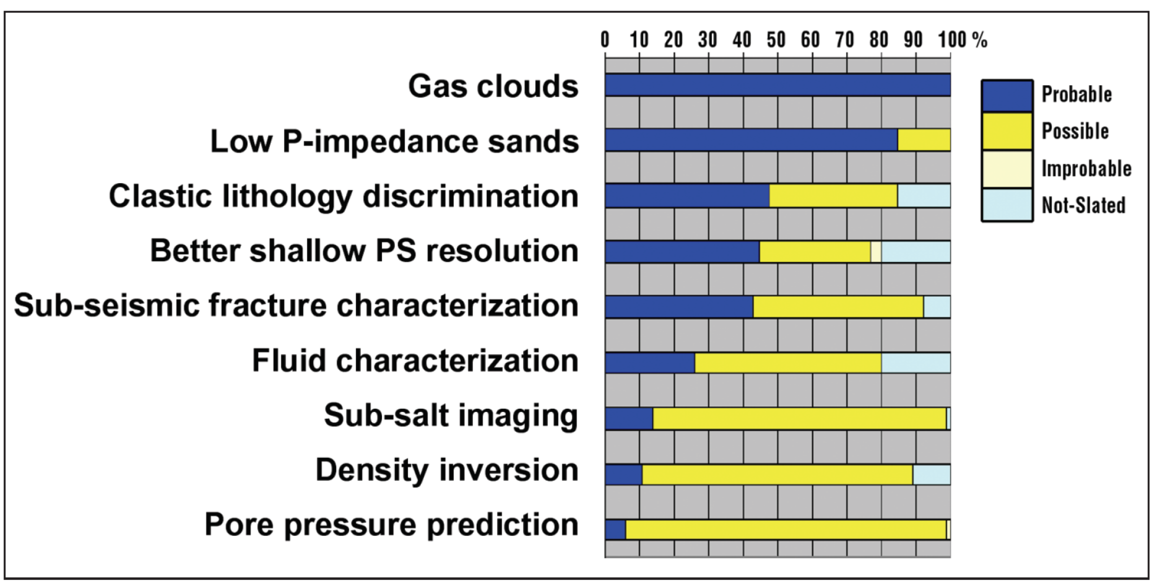


**Table 1. Maturity of multicomponent applications. A group of experts at the 2000 SEG Summer Workshop indicated the likelihood of technical success of a multicomponent survey designed for each of several applications. The most mature applications are gas clouds and low P-impedance sands.**

## Economics

So the enabling technologies are mature and available. The question then is an economic one -- does the risked value of the multi-component data exceed the cost of the survey?

Very often, the answer is yes. There are several capable crews available, and competition is generally a good thing. Onshore, a 3-D 3C survey need not be much more expensive than a normal 3-D survey; given the costs and uncertainties of permitting, it is often wise to collect the best data in the initial survey.

Nine-C surveys require costly oriented-shear sources, which tend to drive the price up relative to normal 3-D, but the expense may be justified in some cases. Offshore, a seabed receiver survey will be considerably more expensive than 3-D streamer, often 5-10 times as much.

However, for many surveys the expense is well worth it, particularly when the prize is large. In an area congested by facilities, it may not even be possible to collect a high quality long-offset streamer survey. A seabed survey may be necessary for multiple attenuation, or for full azimuths and long offsets. If two components on the seabed are to be recorded, one should almost certainly record all four.

## References

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MacLeod, M.K., R.A. Hanson, and C.R. Bell, 1999b, The Alba Field ocean bottom cable seismic survey: impact on development: The Leading Edge, v. 18, p. 1306–1312.