Pitfalls in 3D seismic interpretation

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Today's geophysical workstations are splendid tools but they are only tools. Unfortunately too many interpreters are expecting to find the solution to their problem in the workstation! The skill remains the thoughtful geological interpretation of geophysical data. As a consultant, I am often in a position to review seismic interpretations by others. It gives me the opportunity to reflect on how geoscientists can improve interpretations and avoid pitfalls. All too often I am in contact with seismic interpreters who have misidentified a horizon, failed to understand the phase and polarity of their data, distorted the result with a poor use of color, used an inappropriate attribute, failed to recognize a significant data defect, or are still frightened by machine autotracking.

On one occasion I was invited to listen to a presentation on seismic attributes and my opinion was sought. We were shown a map of attribute 1, then we were shown a map of attribute 2, then we were shown a map of attribute 3. At this point I interjected: "What is the objective of this study and how do these maps relate to that objective?" "I am gathering all the evidence for the study of this reservoir" was the response. We were then shown attribute 4, attribute 5, and attribute 6.

I could not contain myself any longer: "Could you please explain how you selected these particular attributes?" "Oh, they are all very important!" Then the show continued with attribute 7, attribute 8, attribute 9 .... He was selecting attributes because they existed on his workstation. Sadly, too many workstation users today are button pushers seeking the silver bullet rather than analytical thinkers using the workstation as a tool.

On another occasion I was shown some rather elaborate AVO and converted-wave work, and the optimum drilling location for this sand was being determined on this basis. I then discovered that the sand was 5-m thick at a depth of 5000 m. I did some quick calculations and determined that the sand thickness was about one fortieth of a wavelength! Experience dictates that a fortieth of a wavelength is never seismically visible. For Tertiary gas sands with large impedance contrasts, the limit of visibility can, at best, be one thirtieth of a wavelength! We cannot benefit from the more advanced techniques available today until some basic issues of seismic resolution have been well understood.

The precision of machine autotrackers is typically around one-quarter of a millisecond. In good data this precision represents geology and must be exploited. Thus autotrackers are indispensable tools of modern interpretation. Yet some interpreters are frightened of them, feeling that the human must stay in direct control of the placement of the horizon. Others have not figured out how to parameterize the tracker in moderate quality data. Manual tracking is not only time consuming but it introduces imprecision that can obscure detailed geology. Derivatives of autotracked time maps, such as residual, dip, and azimuth can yield vital structural detail not visible in any other way.

Data phase and polarity critically determine seismic character. Character is more important than amplitude in directly identifying hydrocarbons with seismic data. Figure 1 shows the four principal phase and polarity expressions (zero phase American polarity, zero phase European polarity, and ±90° phase) of a low-impedance hydrocarbon sand. Two intermediate characters are also shown. Once data phase and polarity are determined, hydrocarbon character can be predicted, and this is of major importance in analyzing prospectivity in younger sediments. Regrettably I observe interpreters extracting amplitude and locating wells on the resultant map without regard for the detailed character on the vertical section.

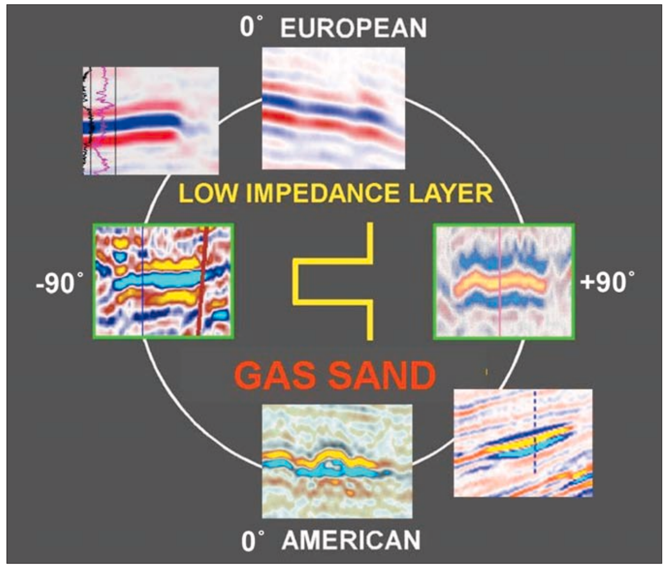

Figure 1.

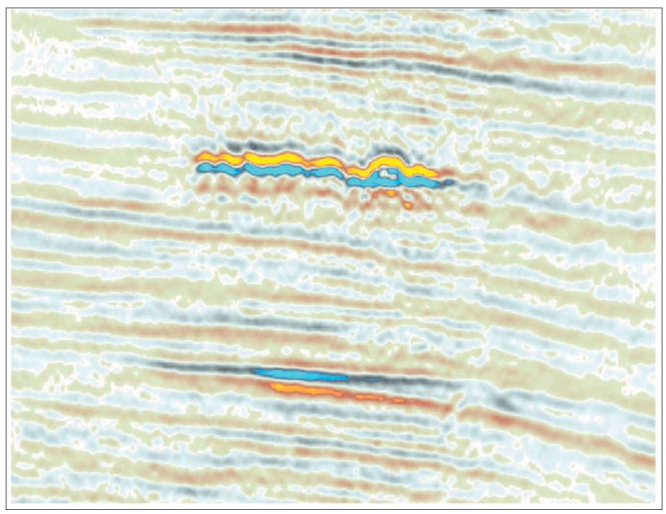

***Figure 2.** Two high-amplitude reflection pairs targeted by the same well. Note the different characters.*

Character is also key in making an effective well tie and thus correctly identifying seismic horizons. Too many interpreters take a well top (measured in depth) and a velocity (to convert to time) and locate the horizon at that exact point on the seismic section. So why do interpreters not think more deeply about phase and polarity, and about tuning effects? I believe that every seismic interpreter, particularly with an objective beyond structure, has the responsibility to determine or verify the phase and polarity of his or her

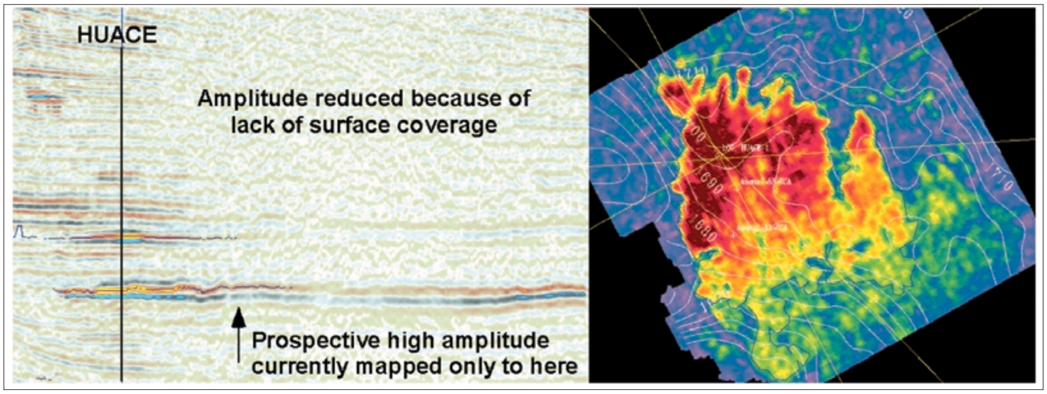

Figure 3. *High-amplitude prospective reflection pair affected by reduced surface coverage, and corresponding horizon slice.*

data. Many dry holes have been drilled by those who failed to do so!

The choice between horizon amplitude and windowed amplitude is another common pitfall. Windowed amplitude is more modern, but this doesn't mean that we use it to the exclusion of horizon amplitude that has been available for 20 years. The rms (root mean square) amplitude seems to be the most popular type of windowed amplitude. This has splendid application for various reconnaissance endeavors. The squaring of the amplitude values within the window gives the high amplitudes maximum opportunity to stand out above the background contamination. The rms amplitude over a large flat or structured time window can be used to identify many small bright spots at different levels within a formation.

Horizon amplitude, extracted along the high-precision autotrack, is preferable for studying a single reservoir. Most workstations use curve fitting to interpolate a high-precision amplitude value at the exact crest of the reflection. Horizon amplitude suffers no contamination but requires that the horizon has been correctly identified and tracked. This also requires that phase and polarity have been properly understood so that the well tie can be correctly made using character. Horizon slices thus remain the best amplitude displays for selecting the optimum drilling location or measuring the area of a reservoir. We should make every effort to consider the amplitude on the top reflection and the amplitude on the base reflection.

Figure 2 shows two high amplitudes targeted by an exploratory well. These data are American polarity, so red-over-blue (trough-over-peak) is the character of low impedance prospective sand. The upper high amplitude has this character and has also high amplitude-over-background. Both amplitudes were originally drilling objectives but, on the basis of character, we can observe that the lower amplitude is blue-over-red indicating that it is a hard bed and thus most probably unprospective.

Seismic data can contain defects caused by the acquisition and processing, and interpreters must attempt to understand these. Amplitude is full of geologic information, so amplitude must be preserved as thoroughly as possible in data processing. The presence of surface obstacles or the lack of access (no permit) causes reduced and variable seismic coverage. This tends to be the principal acquisition-induced problem facing interpreters of land surveys. Amplitude changes and pseudofaults can both result from this type of defect. Figure 3 shows a high amplitude considered to be very prospective and its corresponding horizon slice on the top sand (red) reflection. The reduction in amplitude to the south had been interpreted as the limit of the hydrocarbon. In fact data disruption caused by reduced surface coverage is the reason for the reduction in amplitude. Compensating for this effect makes the prospect twice the previous size.

3D seismic data should be collected and processed in a regular manner. Irregularities in coverage can easily introduce effects that can be confused with geology. Today's interpreter must appreciate the defects in his data and understand what effect they have on his interpretation.

Recommendations to help today's interpreter get more geology out of 3D seismic data in a reasonable period of time are outlined below. These will also help avoid common interpretation pitfalls. Seismic interpretation today involves a delicate balance between geophysics, geology, and computer science. As interpreters we must be continuously learning to improve our understanding of geophysics, of geology and of the workstation.

- Expect detailed subsurface information
- Don't rely on the workstation to find the answer
- Use all the data
- Understand the data and appreciate its defects
- Use time (or depth) slices/horizontal sections
- Visualize subsurface structure
- Use machine autotracking and snapping
- Select the color scheme with care
- Question data phase and polarity
- Tie seismic data to well data on character
- Try to believe seismic amplitude
- Understand the seismic attributes you use
- Prefer horizon attributes to windowed attributes for detailed work
- Use techniques that maximize signal-to-noise ratio TLE

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