Multiple attenuation: strategy that addresses current challenges

A proposed plan recognizes real and prioritized open issues and defines and addresses challenges. (Part 1 of a two-part series)

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The demand for new and improved capability in removing multiples is driven by the portfolio of the petroleum industry and by current and anticipated future exploration trends. For example, the industry moved to deep water roughly 30 years ago. With that move, highly effective multiple-removal methods that were being applied industry-wide suddenly bumped up against their assumptions when applied to deepwater plays and failed. As an example, deconvolution is based on 1-D and on statistical assumptions, the latter not satisfied in deep water.

Since then, the overall industry trend to explore in progressively more complex and remote areas, with ill-defined and difficult-to-estimate subsurface properties and increasingly complex plays, is a constant that motivates the search for capabilities that will not require subsurface information. Methods that require various forms of subsurface information include F-K, radon, and feedback demultiple methods.

The inverse scattering series (ISS) provides the opportunity to achieve all processing objectives directly and without subsurface information. The current ISS internal multiple attenuation algorithm has a unique capability to predict the exact phase (time) and approximate amplitude of all internal multiples at once, automatically, and without subsurface information. These properties separate the ISS internal multiple attenuation algorithm from all other methods, make it the high-water mark of current internal multiple effectiveness, and explain its stand-alone capability. That is, those ISS properties and strengths are what all other current demultiple methods do not possess and cannot deliver.

Several researchers have developed ISS free surface multiple elimination algorithms and internal multiple attenuation algorithms. Field data applications have demonstrated their effectiveness.

However, at every period in the history of E&P, the arrival of new capability to address the latest set of challenges has encouraged industry to explore in yet more daunting circumstances – situations never previously imagined, let alone considered, and beyond current capability to accommodate. That will once again demand a new and fundamentally higher level of capability and effectiveness.

The petroleum industry's current worldwide portfolio of both conventional and unconventional onshore plays and of increasingly complex offshore plays with new and unforeseen challenges has returned and rejuvenated an interest in multiple removal (and a demand for substantially increased effectiveness). Multiple removal has come back to center stage, both for petroleum industry sponsors and as a key and fundamental research project for the Mission-Oriented Seismic Research Program (M-OSRP) at the University of Houston.

Marine

Early marine field data examples of the promise and delivery of ISS free surface multiple and internal multiple algorithms can be found in papers, abstracts, theses, and the Mississippi Canyon data tests in Weglein et al. (2003) pages R69 and R70.

Those algorithms were recently employed on data from offshore Brazil, and the results were reported (Figure 1). One of the conclusions in those field data tests at Petrobras was that "no other method was able to show similar effectiveness in attenuating the internal multiples generated by the salt layers."

Onshore

Several authors have described the motivation, evaluation, and comparison of different approaches to the removal of internal multiples on complex synthetic and onshore data. Fu et al. (2010) concluded, "[The ISS internal multiple algorithm] performance was demonstrated with complex synthetic and challenging land field datasets with encouraging results, where other internal multiple suppression methods were unable to demonstrate similar effectiveness."

Good news

At the 2013 post-convention Society of Exploration Geophysicists (SEG) Internal Multiple Workshop, nine of the 11 presentations described and exemplified the industry-wide impact and standalone capability (for complex offshore and onshore plays) of the ISS internal multiple attenuator. ISS internal multiple attenuation has become fully mainstream within the petroleum industry.

Remaining challenges

With all this "good news," what could be the problem? Industry's portfolio/trend and focus today (and for the foreseeable future) makes it clear that a large and significant gap exists between the current challenge for the removal of free-surface multiples and internal multiples and the collective capabilities of the worldwide seismic exploration community. The specific issues are that (1) the multiple generators and the subsurface properties are ill-defined and increasingly complex, and (2) too often the multiple is proximal to or interfering with the primaries. The latter serious and significant issue can occur in many marine environments and frequently occurs with onshore plays. That type of challenge of removing multiples proximal to and/or overlapping primaries (without damaging primaries) is well beyond the collective capability of the petroleum industry, service companies, and academic research groups and consortia to effectively address. It is not an issue that new and more complete data collection and acquisition will by itself address. The industry simply doesn't have the theory and fundamental concepts in place today that are needed for algorithm development, implementation, and application. That's the basic reason it is unable to address the challenge it currently faces. That's the bottom line.

To adequately address the current industry challenge, researchers will need to predict exactly the phase and amplitude of all internal multiples and thereby surgically remove the multiples at all offsets directly without subsurface information and without damaging primaries. No one today is able to provide that for marine applications, let alone for the even more challenging onshore plays.

There is a need for new basic concepts and fundamental theory development that must begin with a frank and forthright recognition of the problem, its economic moment and significance, and the current technical gap. New concepts and algorithms will need to be produced, followed by addressing the practical application and implementation issues.

The plan

At the 2013 SEG International Conference Recent

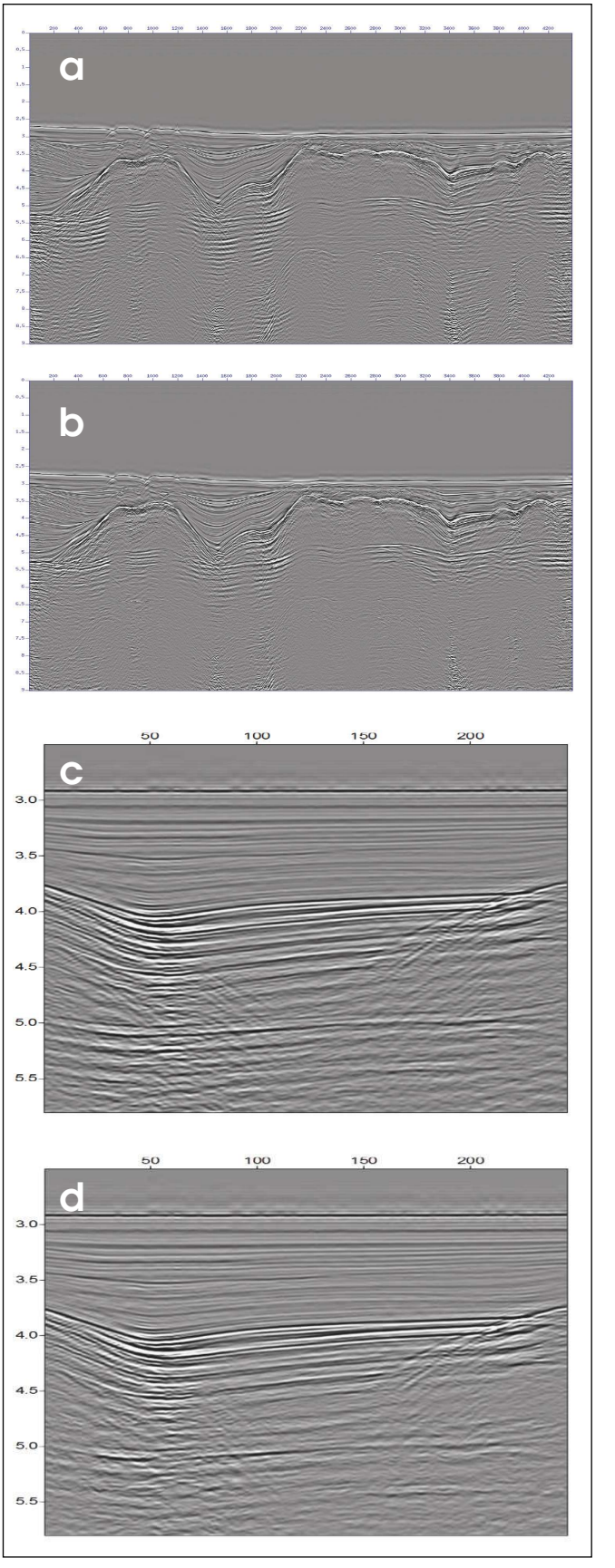

FIGURE 1. Stack before (a) and after (b) free surface multiple removal; common offset sections before (c) and after (d) internal multiple attenuation. (Data from Ferreira, 2011; image courtesy of M-OSRP)

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Advances and the Road Ahead Session, M-OSRP proposed and described a three-pronged strategy it will pursue as a direct response to that challenge. It will have the potential to provide the necessary step-change increase in capability and respond effectively to this pressing problem. The level and magnitude of the challenge and the potential for opening and delineating new petroleum reserves and achieving improved drilling success rates all underlie the commitment to developing and delivering fundamental new concepts and algorithms that offer a step-change increase in capability. Multiple removal has returned from being viewed as a relatively mature subject and project that helped M-OSRP "pay the rent" and is back to occupying center stage as a major research project and focus.

The three-pronged strategy to respond to the current open issues and pressing challenges in removing multiples is as follows:

- Develop preprocessing methods for predicting the reference wavefield (wavelet and radiation pattern) and producing deghosting data (in particular for onshore and ocean-bottom acquisition) that are direct and do not require subsurface information;
- Develop internal multiple elimination algorithms from the inverse scattering series; and
- Develop a replacement for the energy minimization criteria for adaptive subtraction that derives from, always aligns with, and serves the inverse scattering series free surface and internal multiple algorithms.

This strategy represents a consistent and aligned processing chain with one single objective: providing a direct and practical solution to the removal of all multiples without requiring any subsurface information and without damaging primaries. E&P

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References are available on request.