Multiple attenuation: The status and a strategy that identifies and addresses current challenges

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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 deep water plays, and failed. (As an example, deconvolution is based on 1D 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, *e.g.*, F-K, Radon, and Feedback demultiple methods.

The inverse scattering series provides the opportunity to achieve all processing objectives directly and without subsurface information. The current inverse-scattering-series (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, and make it the high-water mark of current internal-multiple effectiveness and explains its stand-alone capability. That is, those ISS properties and strengths are what all other current demultiple methods (*e.g.*, Feedback loop methods, modeling and subtracting multiples, and filter methods) do not possess and cannot deliver (Weglein and Dragoset, 2005).

Carvalho (1992), Carvalho and Weglein (1994), Araújo (1994), Araújo et al. (1994), Weglein et al. (1997), and Weglein et al. (2003) developed ISS free-surface-multiple elimination algorithms and internal-multiple attenuation algorithms. Field-data applications demonstrated their effectiveness. Several marine and onshore data examples are noted below.

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. In this article, we describe how that's the state of affairs for multiple attenuation today.

The petroleum industry's current worldwide portfolio of both conventional and unconventional onshore plays, and of increasingly complex offshore plays — with new and unforeseen daunting 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 our petroleum-industry sponsors and concomitantly as a key and fundamental research project for the Mission-Oriented Seismic Research Program (M-OSRP) at the University of Houston.

1 Marine

Early marine field-data examples of the promise and delivery of ISS free-surface-multiple and internal-multiple algorithms can be found in the above-cited papers, SEG Abstracts, theses, and, *e.g.*, in 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 in Ferreira (2011) (see 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."

2 Onshore

Fu et al. (2010), Terenghi et al. (2011), and Luo et al. (2011) describe 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 that "Their (ISS internal multiple algorithm) performance was demonstrated with complex synthetic and challenging land field data sets with encouraging results, where other internal multiple suppression methods were unable to demonstrate similar effectiveness."

Goodway (2013), Mackidd (2013) and Griffiths et al. (2013) were among those that came to the same conclusion. A recent paper by Kelamis et al. (2013) presented at the International Petroleum Technology Conference in Beijing, China was entitled "Strategies of Land Internal Multiple Elimination based on Inverse Scattering Series."

3 Good news

At the 2013 post-convention SEG Internal Multiple Workshop (Thursday, September 26, 2013) it was positive and encouraging to see nine of the eleven presentations describe and exemplify the industry-wide impact and stand-alone capability (for complex offshore and onshore plays) of the inverse-scattering-series (ISS) internal-multiple-attenuator. ISS internal-multiple attenuation has become fully mainstream within the petroleum industry.

4 Challenge we face

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 world-wide seismic exploration community (including, of course, M-OSRP). 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 circumstances (*e.g.*, in the North Sea) and frequently occurs with onshore plays. **That type of challenge of removing multiples proximal to, and/or overlapping with, 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. We simply don't have the theory and fundamental concepts in place today that are needed for algorithm development, implementation and application. That's the basic reason we are unable to address the level of challenge we currently face worldwide in the petroleum industry. That's the bottom line. To adequately address the current industry challenge, we will need to be able to predict exactly the phase and amplitude of all internal multiples and thereby surgically remove (eliminate) the multiples at all offsets, directly, and 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. We must recognize the problem we face today and our collective inability to address it. New concepts and algorithms will need to be produced, and then will be followed by addressing the practical application and implementation issues.

5 The plan

At the 2013 SEG International Conference (Recent Advances and the Road Ahead Session), we proposed and described a three-pronged strategy (please see the link and slides below) that M-OSRP will pursue as a direct response to that challenge. It will have the potential to provide the necessary step-change increase in capability, and thereby to respond effectively to this current and 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 our 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 within M-OSRP. We feel that our background and experience gives us a good chance to develop, and to deliver, the next level of required capability.

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

(1) Develop the ISS prerequisites for predicting the reference wave field (wavelet and radiation pattern) and producing de-ghosted data (in particular, for on-shore and ocean bottom acquisition) that are direct and do not require subsurface information;

(2) Develop internal-multiple-elimination algorithms from the inverse scattering series;

(3) Develop a replacement for the energy-minimization criteria for adaptive subtraction, that derives from, and always aligns with and serves, the inverse-scattering-series free-surface and internal-multiple algorithms.

This three-pronged 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.

The plan is first to progress and deliver items (2) and (3) for marine applications (since item (1) is in relatively good shape for marine application), and simultaneously to progress item (1) for onshore plays. Then, we will return to onshore exploration with the full suite of (1), (2) and (3) ingredients in place. Our plan is to deliver in stages, with offshore delivery coming before onshore delivery.

Below please find links for the SEG abstracts/posters/presentations and slides that relate to this communication.

http://mosrp.uh.edu/events/event-news/seg-annual-meeting-2013

http://mosrp.uh.edu/news/seg-annual-meeting-2013

http://mosrp.uh.edu/

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6 Summary

Today, the ISS internal-multiple attenuator combined with an energy-minimization adaptive subtraction is the most capable method for removing internal multiples. However, the current ISS attenuator-plus-adaptive-subtraction method will fail under the pressing and prioritized challenge of removing internal multiples that are proximal to and/or interfering with primaries. In this note, we describe a three-pronged strategy for providing an effective response to this pressing and prioritized challenge while retaining and adding to the strengths of the current ISS attenuator.

7 Acknowledgments

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8 References

References cited in this article can be found in: http://mosrp.uh.edu/research/publications/ep-magazine-2014

9 Figure captions

Figure 1: Stack before (a) and after (b) free-surface-multiple removal; common offset sections before (c) and after (d) internal-multiple attenuation (Ferreira, 2011).