Multiple attenuation techniques suitable for varying water depths.

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Introduction

In recent years, there has been considerable seismic exploration activity offshore astern Canada. Much of this data are plagued with strong and frequently complex multiples.

The characteristics of the multiples are governed mainly by water depth, the complexity of the sea floor immediately below the water. Water depths in the East Coast exploration zone can range from a few tens of meters to 5000m. No single multiple attenuation technique is suitable for all ranges of water depth.

In this paper, the problem is subdivided into two principal zones based upon water depth. For each zone, the most effective method or combination of methods is presented. For the purposes of this paper, water depths less than 150 meters are classified as "shallow water", whilst those deeper than 150 meters are classified as deep water. The quality of the attenuation, for each of the tested methods, was examined on both zero and non-zero offset gathers, stacks and migrations.

Shallow water characteristics

The Shallow water areas to the east of Canada are usually accompanied with a hard but generally flat water bottom. Typically there can be as many as four or five "direct" sea bottom multiples, and a multitude of "peg-leg" multiples accompanying major reflectors. "Inter-bed" multiples, although present, are usually a second order problem.

Other complicating factors are that, when water is very shallow, a true sea bottom reflector may be absent altogether. In addition, seismic data is often low fold and poorly sampled, spatially, at shallow depths. This may limit the effectiveness of some attenuation methods.

Deep water characteristics

The transition from shallow to deep water in areas is abrupt, with a steep shelf slope. The deep water areas offshore Nova Scotia also have a "hard" water bottom, resulting in high amplitude multiple reflections relative to primary energy. Scouring, channel formation and extreme rugosity are common features of the outer slope. Diffracted and "out-of-plane" multiples present extreme challenges. Depending upon acquisition geometry, multiples are frequently aliased at far source-receiver offsets.

Shallow water multiple attenuation

Typically, periodicity and predictability are the properties which are exploited for effective multiple attenuation in shallow water. Due to limited differential move-out, shallow water peg-legs are difficult to attenuate with methods such as Parabolic Radon De-multiple.

It has become clear after extensive testing that "direct" multiples are best attenuated using the surface related multiple elimination (SRME) technique (Verschuur 1992). However, correct parameterization is critical for success. Predictive Deconvolution (Peacock 1969), Parabolic Radon (Hampson,1986) and TauP Deconvolution (Yilmaz 1987) all fail to adequately attenuate direct water bottom multiples.

Whilst SRME performs well on the "direct" water bottom multiples, TauP deconvolution is the most effective in attenuating the "peg-leg" multiples. As before, good parameterization and data preparation are critical for success. In this case, a non iterative, Hi-Resolution transform (Sacchi 1995) was used along with careful data preparation.

One negative with TauP Deconvolution, is that the entire ensemble passes through the transform. As a consequence, transform artifacts may be embedded in the data. Many multiple attenuation techniques (e.g. Parabolic Radon and SRME) model the multiple and subtract from the original. This helps minimize process-induced artifact.

A modified TauP deconvolution method is used, which allows multiples to be modeled and subtracted. The final shallow water scheme consisted of a blended, cascade of pure SRME and the modified TauP approach.

Deep water multiple attenuation

Traditionally, differential velocity based methods such as Parabolic Radon have been used in deep water. These methods tend to fail on near offsets where there is little move-out difference between primaries and multiples. This problem becomes more serious with dip or where the multiple generators become more complex. Additionally, aliasing of the multiples on far offsets can lead to inadequate separation of primaries and multiples in transform space. This requires an additional de-alias step or a transform capable of handling aliased data.

In recent years, the SRME technique has become popular in deep water. Near offset multiples in particular, are better attenuated than those with Parabolic Radon. Although there is active research into 3D SRME, current industry available techniques are strictly 2D and assume all recorded data to be "in- the-plane" of the section.

Cascading SRME and Radon has become an industry standard approach. However, the complexity of the multiple generator and "out-of-plane" effects can severely limit even this combination. For this reason, a third level of attenuation is added.

Many of the residual multiples fall into a category of "Apex shifted hyperbolas" i.e. when viewed in common mid-point gathers the apex of the multiple is observed, not at zero offset, but at an offset shifted towards the mid offset range. Intuitively one would expect parabolic or hyperbolic radon to fail on these as they rely entirely on assumption that the apex is at zero offset.

A method described by Trad (2003) was suggested as a way to suppress this category of multiple. This method has been improved and is presented in this paper as Apex Shifted Multiple Attenuation (ASMA).

Summary & Conclusion

The methods presented deal effectively with the unique and challenging characteristics associated with the shallow and deep water multiple problems found in the marine exploration areas to the east of Canada.

For shallow water, a combination of SRME and a modified Hi-Resolution TauP deconvolution was found to be most effective. In deep water a combination of SRME, Hi-Resolution de-aliasing Parabolic radon filtering and Apex Shifted Multiple Attenuation achieved good results.

The data used in this evaluation was acquired by GX Technology as part of their regional 2D exploration program "Nova-Span".

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