PETEX 2010
From Volatility to Value

AMPLITUDE PRESERVING DEMULTIPLE IN THE BARENTS SEA OVER THE HOOP FAULT COMPLEX: DECONSTRUCTING SRME AND A NEW ALTERNATIVE METHOD FOR STACKING THE NEAR OFFSETS

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Introduction

In 2009 TGS acquired 2,770 km^2 of multi-client seismic data in the southwestern Barents Sea across the Hoop Fault Complex covering acreage nominated in the recent Norwegian 21st licence round. The Hoop Fault Complex (HFC) derives its name from the vessel “de Hoop” used by Dutch explorer Willem Barentsz and is a swarm of northeast-southwest trending normal faults with a strike-slip component cutting across the Loppa High and the Bjarneland Platform (Gabrielsen *et al*. 1990). The survey (figure 1) images the northernmost part of the Maud Basin and the greater part of the platform immediately to the northeast. The area was subject to significant uplift in late Jurassic/early Cretaceous times resulting in late Cenozoic glacial erosion estimated to be in the region of 1900 metres (Løseth *et al*. 1992). Across the survey a strong unconformable Base Quaternary reflector (BQU) follows the water bottom at an interval of ~ 60 milliseconds strongly attenuating primary energy.

The interaction of multiples, both surface related and internal, generated within the water-bottom – BQU layer compromise the ability of 2-D SRME (Berkhout 1982, Verschuur *et al*., 1992) specifically, to correctly predict multiple and preserve amplitudes within the potentially prospective underlying Triassic-Permian sequence. An alternative, de-aliased demultiple method, seen to preserve amplitudes, is presented in the following sections, termed *Stepwise Multiple Elimination using Linear Transforms* (SMELT), capable of removing multiple on the near-mid offsets.

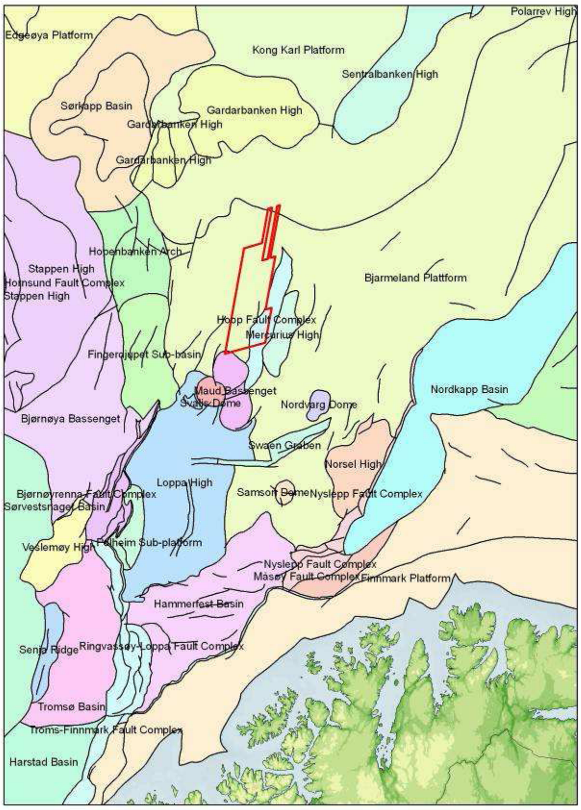

Figure 1: Structural elements of the western Barents Sea (after Gabrielsen et al. 1990) and outline of the HFC09 multi-client survey (shown in red).

Defining the Problem

SRME involves two stages, multiple prediction and primary-multiple separation. Despite major advances, amplitude errors and imperfections in the predicted multiple model remain a challenge in the second separation stage. Conventional least-squares (L-2) adaptive match-filtering techniques can lead to residual multiple energy and deterioration of the primaries in such instances. Abma *et al*. (2005) show that L-1 adaptive subtraction fairs little better and recent implementations such as curvelet-domain separation (Herrmann *et al*., 2007) still deteriorates in the presence of significant amplitude errors.

In the HFC area amplitude errors in the predicted multiple model are clearly apparent (figure 2(b)). The amplitude error worsens as the BQU-water layer becomes more extensive and a short period reverberation dominates the multiple model through the Triassic and Permian, not present in the input data (figure 2(a)).

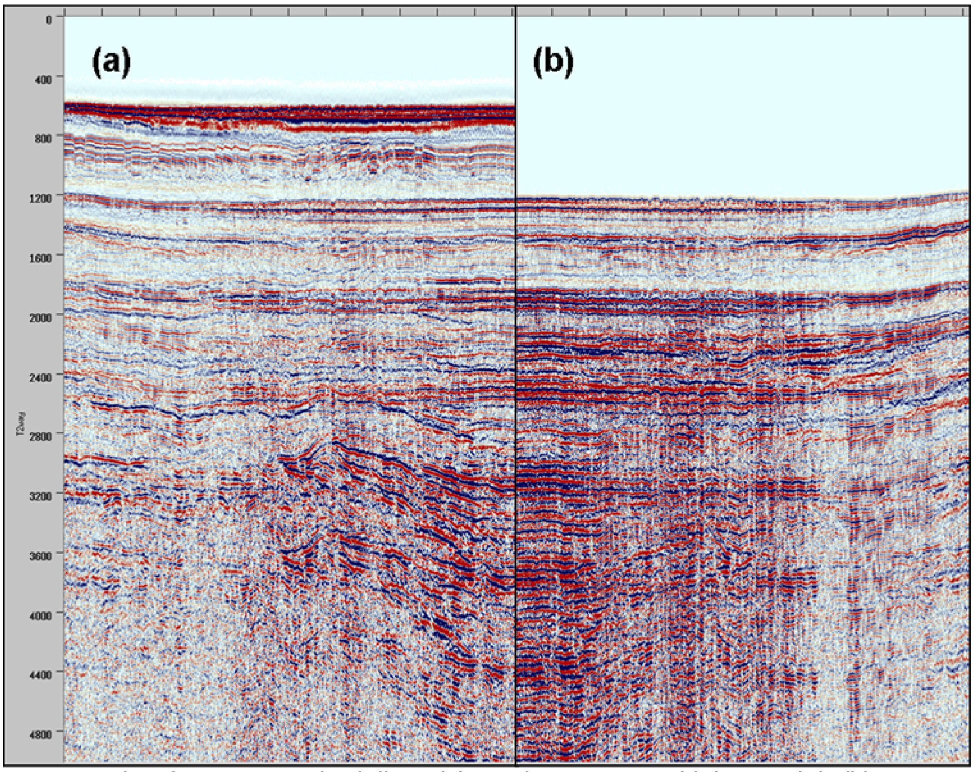

Figure 2: Stack of an example inline (a) and SRME multiple model (b) reversed for comparison. Note the amplitude error in the predicted multiple decreases as the BQU-water bottom layer thins and amplitude of the BQU weakens on the right hand side.

Stepwise Multiple Elimination using Linear Transforms (SMELT)

The local failure of 2-D SRME to preserve amplitudes related to the strong BQU reflection creates a challenge to stack multiple-free near offsets. The new process we term SMELT addresses this problem. The SMELT "multiple model" (figure 3) is gradually built up by a series of linear transforms in the CMP domain after flattening with a constant normal moveout correction (NMO) in steps between water and maximum peg-leg velocity. For a zero offset intercept τ and apparent slowness p, the amplitude $F(\tau, p)$ in the tau-p domain is described discretely by

$$F(\tau, p) = \sum_{i=1}^{n} F(x_i, \tau + p x_i) \tag{1}$$

(Turner, 1990), where n is the number of traces used in the transform and x the offset of the trace on the input CMP gather. If the CMP gather is perfectly flattened prior to transformation, then the velocity $v \rightarrow \infty$, so the apparent slowness

$$p = \frac{x}{tv^2} \to 0\,, \tag{2}$$

where t is time on the input CMP gather. In the limit, equation (1) therefore reduces to

$$F(\tau, p) = \sum_{i=1}^{n} F(x_i, \tau)\,. \tag{3}$$

In the SMELT process only multiples flattened with a constant NMO are passed through the forward-inverse tau-*p* transform pair with the correct amplitude reconstructed. As a zero *p*-range cannot be transformed in practice, the actual range is related to the velocity step Δv centred around p=0. As we want to account for slight under- and over-correction as well as non-hyperbolic/anisotropic effects, following on from equation (2) the effective *p*-range transformed is

$$\pm\frac{1}{2}\left[\frac{x}{t\left(v_{const}-\frac{\Delta v}{2}\right)^2}-\frac{x}{t\left(v_{const}+\frac{\Delta v}{2}\right)^2}\right], \tag{4}$$

where v_{const} is between water velocity and maximum peg-leg velocity of interest. At each step the true multiple is subtracted from the input data in the CMP domain within a window. As the multiple is flattened in each velocity step prior to transformation the process is de-aliased. Only a very small number of *p*-traces are required under normal aliasing criteria in the tau-*p* domain, making the process extremely cost-effective.

Results

Figure 4 shows the application of SMELT on a CMP gather after tau-*p* processing in the shot and receiver domain, prior to radon demultiple. Not only does SMELT perform better than 2-D SRME on the near offsets in this local example, difference displays (figure 4(d)) reveal no deterioration of primary. The superior result provided by SMELT is also apparent on a full offset stack out to 55° angle of incidence with no inn er trace muting applied (figure 5(b)).

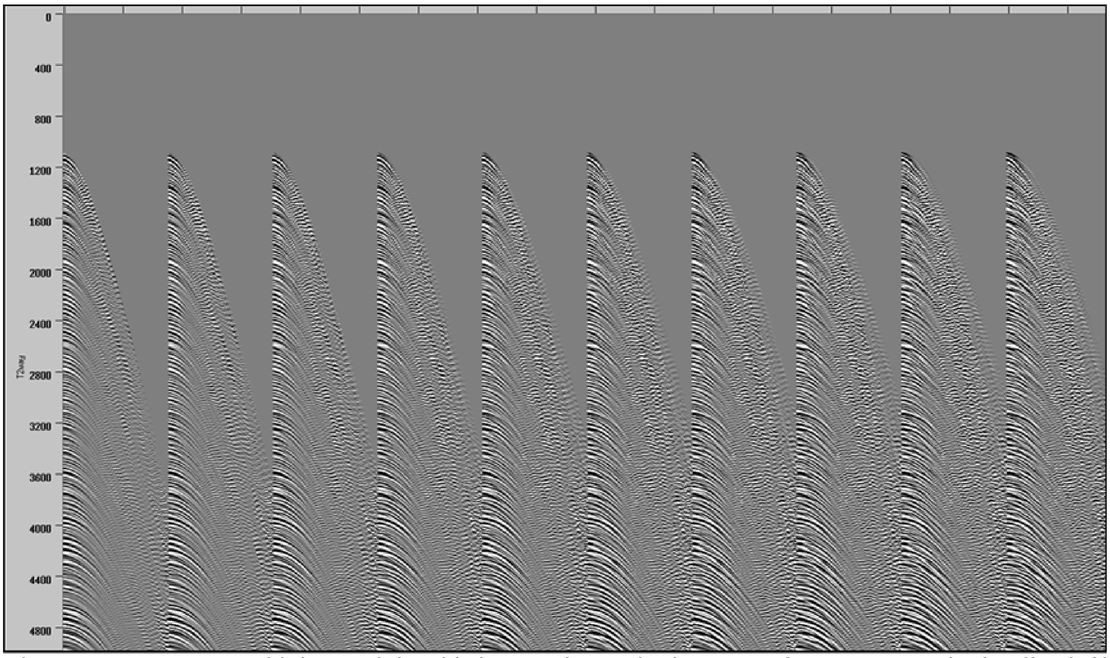

Figure 3: SMELT "multiple model" with increasing velocity steps from water velocity (far left) to Top Jurassic peg-leg velocity (far right).

Conclusions

The locally strong Base Quaternary reflector in the HFC area associated with uplift and subsequent widespread glacial erosion generates significant amplitude discrepancies in the SRME model. Deterioration of primary energy in the prospective underlying Triassic-Permian sequence is inevitable with 2-D adaptive subtraction methods. SMELT provides a very effective, de-aliased and cost-efficient alternative to stacking the near offsets with good preservation of primary amplitudes.

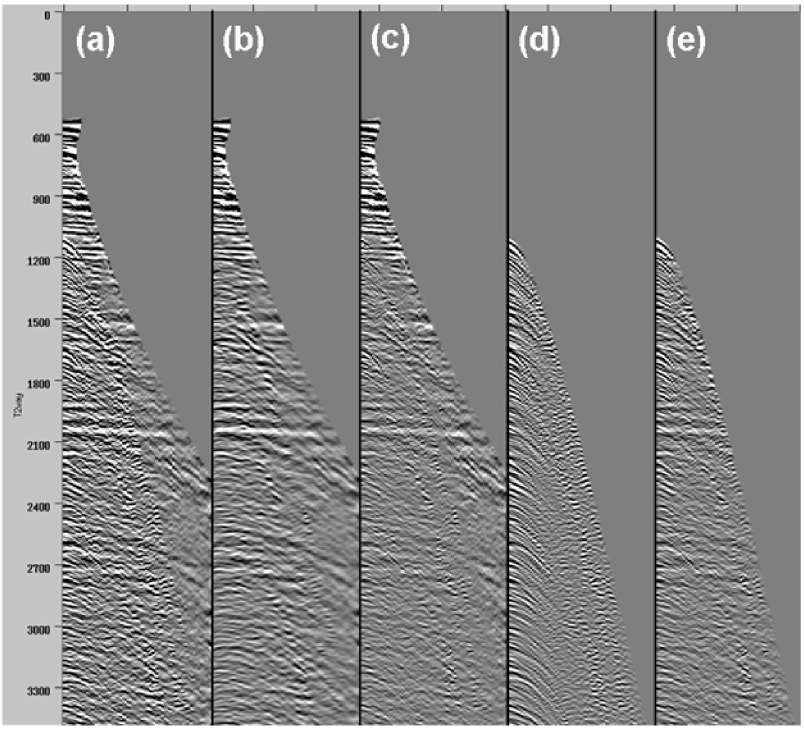

Figure 4: (a) Input CMP gather after tau-p domain processing; (b) SMELT; (c) 2-D SRME with frequency-split adaptive subtraction in the CMP domain; (d) Input-SMELT difference; (e) Input-SRME difference. Note the removal of primary energy after adaptive subtraction in (e).

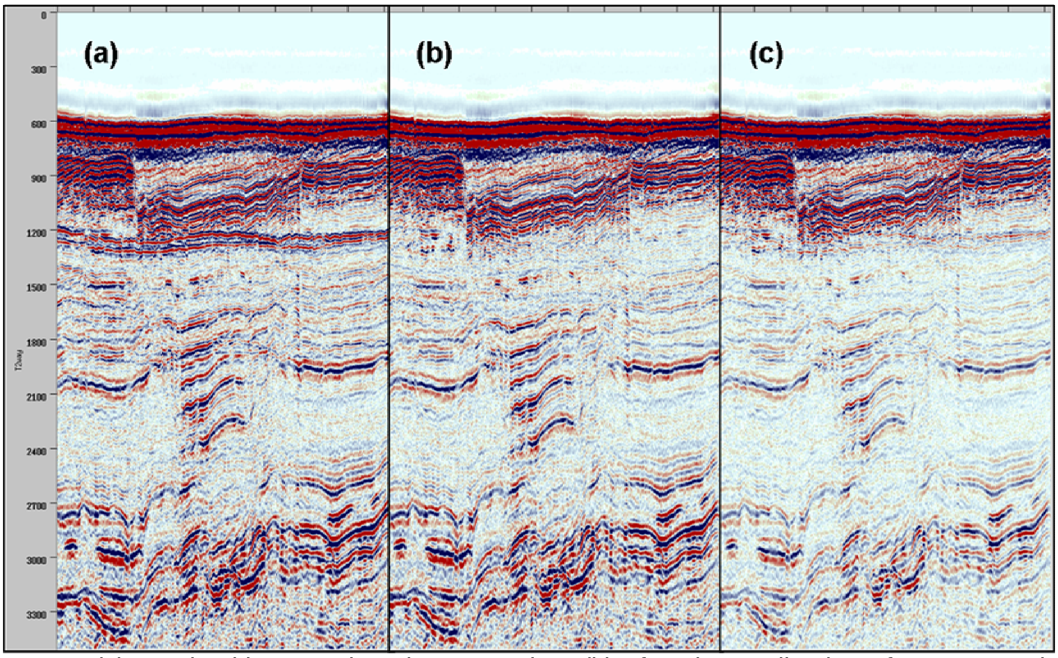

Figure 5: (a) Stack with tau-p domain processing; (b) after the application of SMELT and (c) after 2-D SRME.

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