



Seismic imaging in gas obscured areas: Q anomaly detection and Q migration applied to broadband data.

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Summary

Seismic imaging in the North Sea is often hampered by gas clouds (low saturation gas zones generally characterized by low velocity and strong absorption). As results of these properties, seismic images in and below such anomalies are severely deteriorated by sags, shadow zones, amplitude attenuation and dispersive phase distortion, where these last two effects are quantified by the quality factor (Q). Furthermore, the recent trend for broadband processing of marine streamer data by employing deghosting techniques provides the opportunity for meaningfully extending the seismic bandwidth to the point where Q compensation becomes an issue. In this work, we discuss several techniques for estimating a Q model, and compare the corresponding visco-acoustic migration results with those obtained with more conventional acoustic imaging.

Introduction

Recent advances in spectral notch deghosting have facilitated the recovery of seismic broadband data with a frequency range typically between 2 – 150 Hz., either by deploying multi-sensor marine streamers or with a processing solution for single-sensor cables (e.g. Zhou et al. 2012). However, due to natural earth attenuation effects the higher frequency content is reduced for large propagation times (Futtermann 1962). A meaningful recovery of the attenuated signal requires both a good estimate of the Earth's Q structure and a migration algorithm capable of performing frequency-dependent phase and amplitude correction of the data during migration (e.g. Zhang et al. 2010; Jones 2013).

Here we consider a marine data example from the Tay Sandstone field in the North Sea, where broadband processing has been performed on single-sensor conventional marine streamer data using GXT's proprietary procedure. Once the spectral notches (caused by both the source and receiver ghosts) have been suppressed, the overall Q effects comprising both the scattering and intrinsic attenuation terms can be assessed from the spectral decay observed in the amplitude spectrum of the data.

There are two basic techniques for estimating Q, using either the spectral ratio methods (e.g. Jacobson et al. 1981) or the centre frequency method (Quan and Harris 1997; Wang 2008). Either method can be employed using spectral estimates made just for isolated picked horizons or for full-volume autopicked dense event segments. However, obtaining a reliable high-resolution estimate of the Q structure of the earth remains problematic for a number of reasons, the foremost being the availability of clean isolated waveforms from which to estimate a Fourier spectrum. Unfortunately, it is rare to find a reflection event that is not either contaminated with noise or interfering

with other close reflectors and/or remnant multiples, hence the spectral estimates are often corrupted.

The nature of the problem in this region can be seen in Figure 1, where a shallow depth slice (1a) through the pre-stack depth migrated (preSDM) data reveal a series of shallow channels, some of which have low-velocity sediment fill and are highly absorptive. The inline image (1b) clearly highlights the dimming and push-down associated with the absorptive channel fill.

Careful velocity model building and migration can help ameliorate the effects of the kinematic image distortion (e.g. Jones 2010, 2012), but the amplitude dimming and phase distortion are not addressed using conventional tomographic inversion of arrival time information and subsequent acoustic migration. In order to address the absorption-related effects, we would first need to estimate the effective-Q values associated with the near surface geobodies, and then migrate the data with a visco-acoustic algorithm to compensate for absorptive effects along individual ray-paths.

Results

Figure 2 shows a depth slice at 250m through a velocity model obtained using tomographic inversion based on CRP picking on a 50*50m grid followed by tomography with a cell size of 250*250*75m. The corresponding Q-tomography result is shown on the right, based on a spectral ratio approach, using a modelled source wavelet for the reference waveform and a few picked horizons to define the comparison intervals.

Figure 3 shows the associated vertical sections for the same inline displayed in Figure 1. In general with such Q estimation, we have relatively low spatial resolution as compared to the velocity tomogram. In velocity estimation, ray coverage is generated for very many small horizon facets and their associated moveout trajectories in the CRP gathers, but for a layer based Q estimate, we are estimating Q over a comparatively large interval.

Figure 4 compares the final results obtained from using an acoustic Kirchhoff and visco-acoustic (Q) Kirchhoff migration scheme. In the visco-acoustic scheme, frequencies of up to 200Hz have been preserved, and the phase distortion due to attenuation-related dispersion has been addressed.

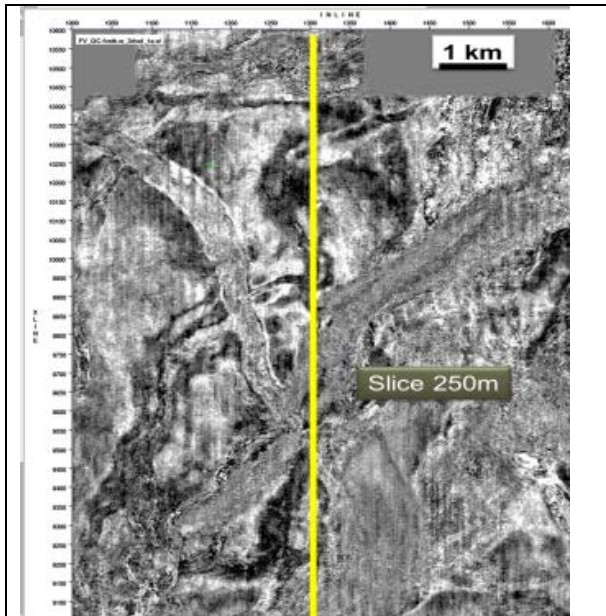


Figure 1a: A shallow depth slice (250m) through the acoustic preSDM image reveals various channel geobody features.

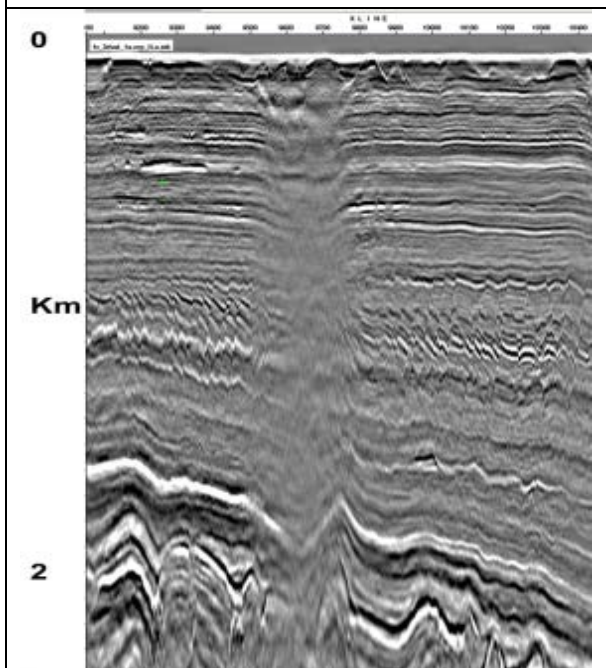


Figure 1b: The associated inline shows the push-down image distortion and dimming, resulting from these geobodies. The inline is taken along the yellow line shown in the depth slice.

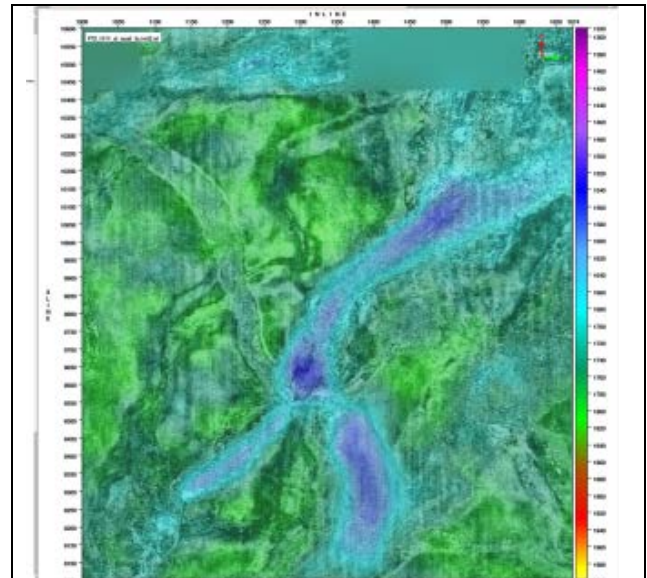


Figure 2a: Depth slice at 250m through velocity model showing low-velocity geobodies. For the tomographic inversion, the autopicking was performed at 50*50m and the tomographic cell size was 250*250*75m.

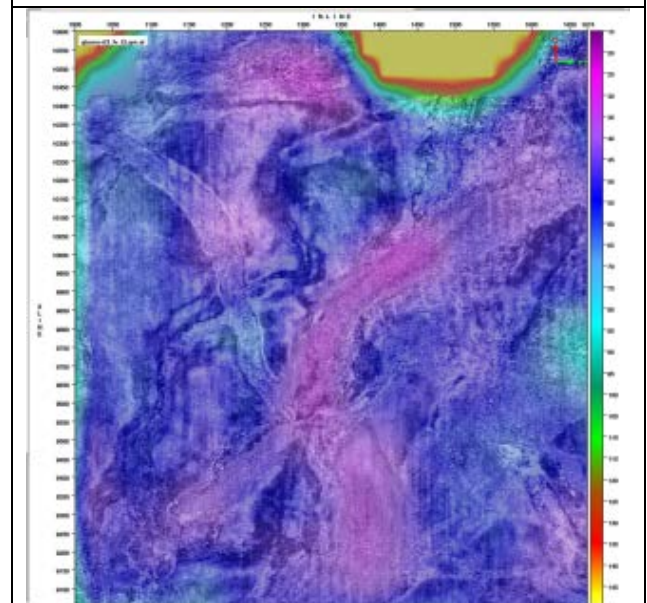


Figure 2b: corresponding tomographic Q model (obtained using an horizon-based spectral ratio method). A minimum Q value of about 25 is found in the channels.

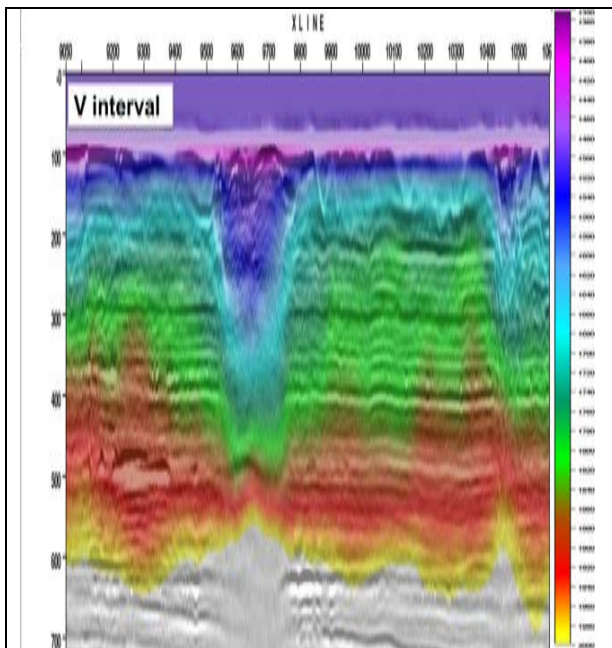


Figure 3a: Vertical slice from the interval velocity model obtained using ray-based tomographic inversion.

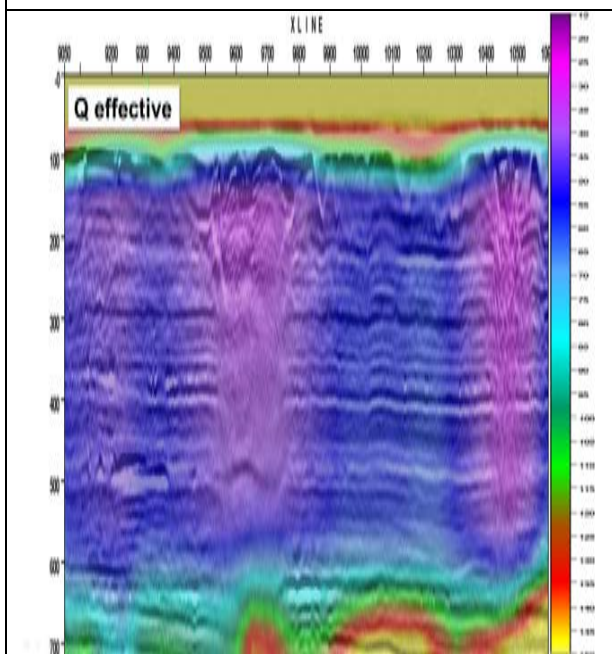


Figure 3b: Vertical slice from the effective Q model also obtained using ray-based tomographic inversion. The velocity model has higher spatial resolution as it has more ray-hits per cell.

Conclusions

The advent of broadband processing has facilitated the extension of the usable bandwidth of conventional seismic data. However, to profit from this recovered information, we also need to compensate for the attenuation effects of the Earth. This requires high resolution estimation of the effective Q structure of the subsurface, used in conjunction with a visco-acoustic migration scheme. Here, we have shown one such combination of Q estimation and migration to recover information hitherto obscured beneath a highly absorptive geobody. The approach helps restore both the amplitude and phase character of the data.

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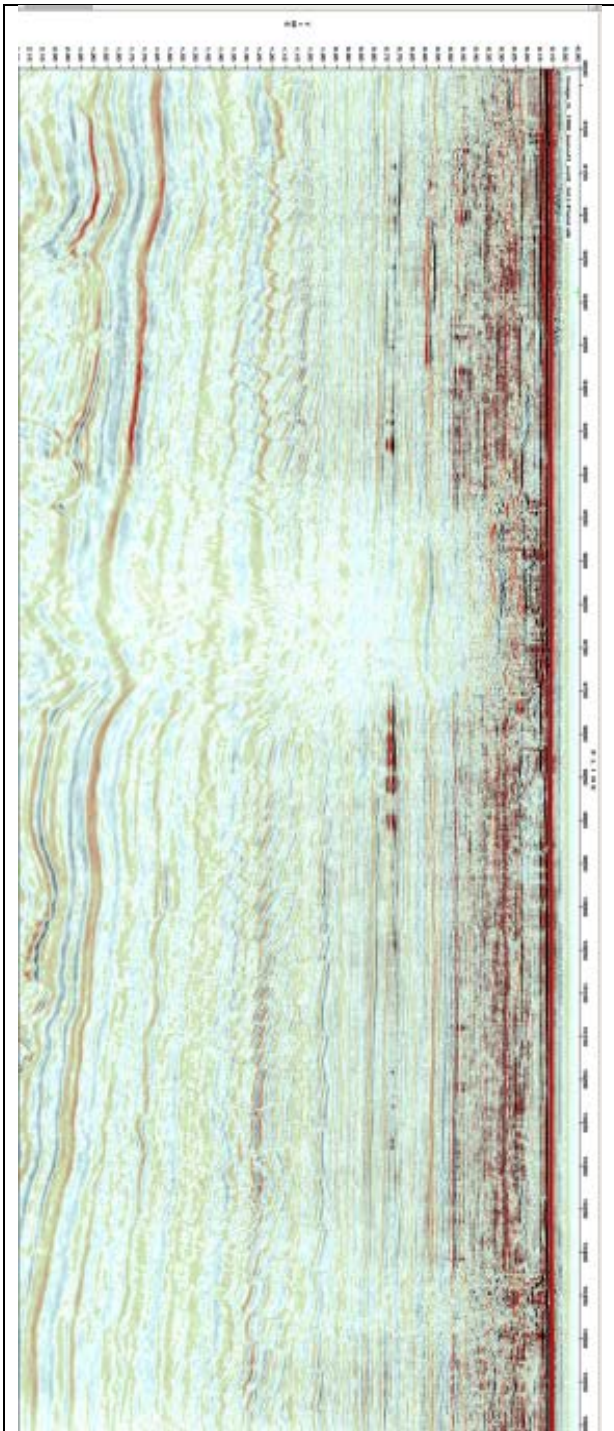


Figure 4a. conventional Kirchhoff acoustic migration using the final interval velocity model (as per Figures 2a and 3a)

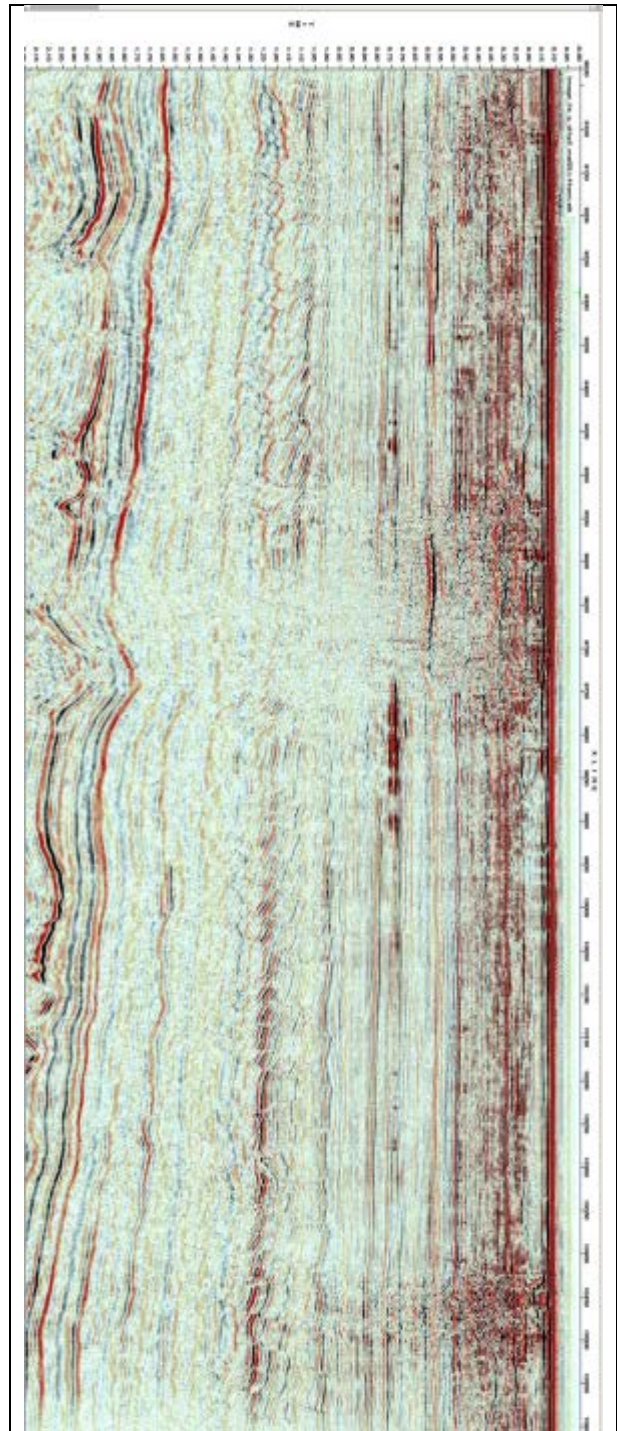


Figure 4b. visco-acoustic Kirchhoff migration with Q compensation up to 200 Hz using the same interval velocity model