Imaging workflow for compensating attenuation due to shallow gas

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The presence of gas, both as shallow pockets and as commercial reservoirs, have long been recognized as a significant problem in imaging seismic data. It has been seen to be so serious an issue in places like the North Sea that efforts to see through the gas has involved expensive acquisition solutions such as ocean bottom shear wave recording. This problem is also becoming increasingly recognized as an issue in Southeast Asia as gas receives increasing exploration and development attention. Conventionally processed data cannot be used for inversion when these problems remain uncorrected; mapping of the structures within the gas field become problematic; auditing of reserves is less reliable.

The propagation of seismic wave through viscoacoustic media is affected by the attenuation that is caused by the quality factor Q, resulting in significant loss of signal strength and bandwidth. Gas trapped in sediment is an extreme example of these media. Seismic images of geological structures underneath shallow gas often suffer from resolution degradation and the effect of amplitude dimming, making their identification and interpretation difficult. This in turn affects the ability to accurately predict reservoir properties. The deeper gas reservoir contributes additional attenuation such that the amplitudes are further strongly reduced. Thus, there is a need to compensate the attenuation due to Q.

Complete Q compensation involves two steps – first, the estimation of Q and; second, using the resultant Q volume to correct the amplitude and phase effects through migration. We have recently developed a ray based tomographic method for estimating Q that takes into account the actual dips of the 3D structure because the analysis is performed on the depth migrated data. Its implementation involves the use of amplitude-preserved depth migrated common image gathers (CIGs). By separating the CIGs into different offsets and frequency bands, amplitudes are measured along the picked horizons. Rays are then shot from the picked points along the horizons to the surface. Through ray-tracing, the attenuation effect that causes the change in amplitude at different horizons is then accumulated along the ray-paths. By repeating the process for other frequencies and offsets, a Q volume can be estimated through tomographic inversion (Q-Tomography) (Xin and Hung, 2009).

The resulting Q volume can then be used for mitigating the attenuation effects on amplitude, frequency and phase of the affected seismic signal through migration. This can be done in our Q prestack depth migration (Q-PSDM) in which the velocity of the attenuation medium is treated as a complex number that is a function of Q. With this complex velocity, an anti-dissipation term can be included in the migration operator for restoring the seismic response (Xie et al., 2009). Thus, the procedures involve the computation of the conventional traveltime and the complex dissipation time that accumulates the Q effect along the raypath. Since anisotropy as a result of rock properties is easily to be incorporated in the conventional traveltime calculation, our method is capable of performing anisotropic Q-PSDM not only to compensate the attenuation effects, but also to image the subsurface structures at the correct locations.

Base on Q-Tomography and Q-PSDM, we propose a workflow for imaging below shallow gas. We demonstrate, with synthetic and real data examples, how we include the estimated Q volume in the depth migration process to mitigate amplitude attenuation and frequency-dependent dispersion so that reservoirs can be better imaged and characterized.