New workflow for estimating seismic wave attenuation from 3D seismic data

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Saturated media such as reservoir zones are a favorable environments for attenuation mechanisms which causes a dissipation in the energy of seismic waves. The main mechanisms of seismic wave attenuation are scattering and fluid related mechanisms. Scattering is due to the subsurface heterogeneities which cause a wave energy redistribution in all possible directions with conservation of the integrated energy in the total wavefield (Wu and Aki, 1988). Fluid-related mechanisms such as wave induced fluid flow (WIFF) (e.g., Pride et al., 2004; Müller et al., 2010), are caused by the frictional movement between pore fluids and solid grains induced by wave passage. Therefore, seismic wave attenuation might be a good parameter for investigating fractured reservoirs.

The most commonly used methods to estimate seismic wave attenuation, , such as spectral ratio (Båth, 2012; McDonal et al., 1958) and frequency shift (Quan and Harris, 1997) methods are suitable for zero-offset seismic data such as zero-offset vertical seismic profiling (VSP) data. This is because the acquisition geometry of such data enables sampling of the downgoing wavefield at various known depths and provide direct observations of the changing nature of the source wavelet as it propagates through the earth. Such constraint makes the estimation of from 3D surface seismic data challenging. This explains the limited number of attenuation studies on 3D surface seismic data, even though with such data we have a good lateral coverage.

In this study, we established a new workflow to estimate from 3D OBC (Ocean Bottom Cable) seismic data acquired in an oilfield located in Abu Dhabi. We applied Gabor transform (Gabor, 1946), which is a short time Fourier transform with a Gaussian filter. After that we performed a time to depth conversion. The 3D VSP data recorded in the same area were used to optimize the parameters of Gabor transform. Thereby, we sampled the data at various known depths before applying the Centroid frequency shift (CFS) method. Distinct attenuation anomalies were observed in highly heterogeneous and saturated zones, such as the reservoir zones. Attenuation anomalies in the reservoir zones are most likely a result of scattering and fluid-related attenuation mechanisms, which are important due to the high fracture density and fluid content in the reservoir. The attenuation profiles show minor lateral variation which is in agreement with the slight lateral heterogeneity of the subsurface stratigraphy of the oilfield subsurface. Our results demonstrate the potential of seismic wave attenuation for detecting highly heterogeneous and highly saturated zones such as reservoirs and aquifers. Nevertheless, this study remains qualitative due to some challenges in the methodology such as the offset. This latter induces a lateral separation between the ray path of the waves from which the attenuation is estimated. This separation is inversely proportional to the depth which leads to a higher uncertainty on attenuation estimate at shallower depths. Furthermore, fluid effect on the attenuation is coupled with other effects such as lithology and close fractures. This is because the separation between scattering and intrinsic attenuation is very challenging in the case 3D seismic data.

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