

Q_P and Q_S estimation from multicomponent VSP data

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Summary

VSP data give us direct access to the wavelet at different receiver depths without having to include reflections. The direct down-going wavefield has always been the key to estimate Q and correct the effects of seismic attenuation on the data. In this study we demonstrate that we can also use the up-going wavefield to estimate Q , particularly for the shallow, near-surface layers. We estimated Q from field VSP data by using the spectral-ratio method (Vista software). We found that Q estimation for shallow layers is better using the up-going wavefield than the down-going wavefield. Combining both estimations provides the optimum understanding of Q variation with depth. From the up-going wavefield, we obtained that Q_P values range from 20-28 from 66-250m depth. For the deeper layers, using down-going wavefield, the estimated Q_P values range from 51-61 from 250-500m depth. On the other hand, using the direct down-going shear wavefield for the estimation, Q_S values range from 21-34 from 200-420 depth.

Introduction

Estimating Q on the shallow down-going wavefield has been always a difficult task because the receivers are close to the source and this causes an oversaturation in the amplitudes (Figure 1a). Also, the wavefield has propagated for a short period of time and we may not see significant attenuation when we process our seismic data. However, shallow layers are expected to show low Q values because poorly consolidated rocks are usually present. One way to approach this problem is using the up-going wavefield to estimate Q in the shallow zone. By assuming that the source is at the reflecting interface, the receivers located in the shallow zone will be far from it (Figure 1b) and more reliable estimations could be obtained.

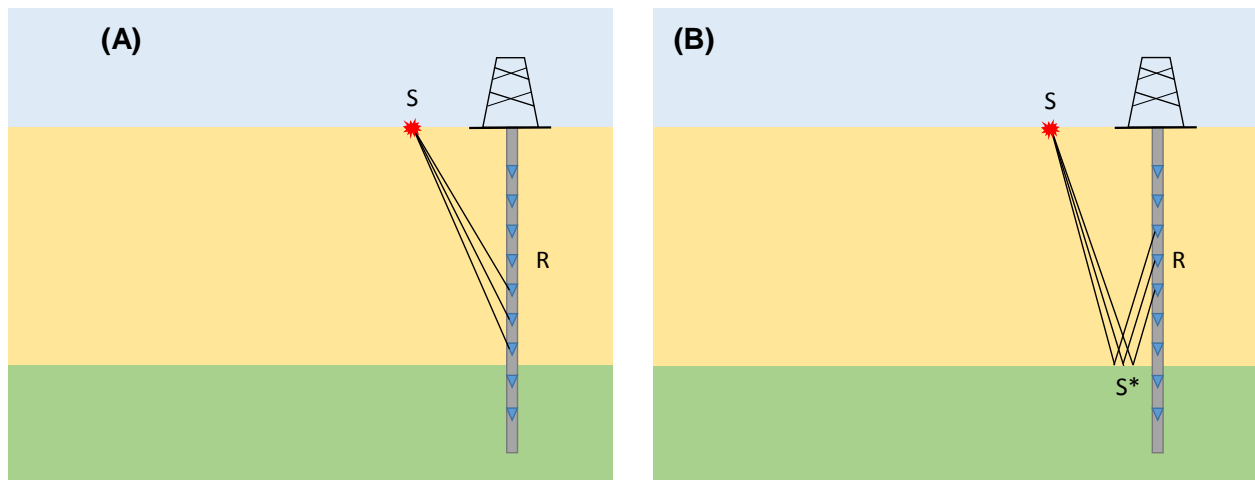


Figure 1. (a) Down-going waves and (b) up-going waves propagating to the borehole receivers.

The spectral-ratio method for Q estimation

If we consider two wavelets at times t_1 and t_2 , in which $t_1 < t_2$, their amplitude spectra will be the following:

$$|\hat{w}(t_1, f)| = |\hat{w}(f)| e^{-\frac{\pi f t_1}{Q}} \quad (1)$$

$$|\hat{w}(t_2, f)| = |\hat{w}(f)| e^{-\frac{\pi f t_2}{Q}} \quad (2)$$

Then, the log spectral-ratio or lsr is the ratio of equations 1 and 2 (Margrave, 2013),

$$lsr(Q, \Delta t, f) = \ln \frac{|\hat{w}(t_2, f)|}{|\hat{w}(t_1, f)|} = -\frac{\pi f \Delta t}{Q}, \quad (3)$$

where $\Delta t = t_2 - t_1$. Equation 3 shows that lsr has a linear relationship with frequency. The interval Q between t_1 and t_2 can be computed by a least square fit of a first order polynomial. Note that, noise and also notches can be a problem for the spectral division.

Q analysis from field VSP data

A zero-offset VSP was acquired with 0.125kg of dynamite at 9m depth (Hall et al., 2012). The Q_P values estimated from the direct down-going wavefield using spectral-ratio method in Vista software are shown in Figure 2. We obtained a high Q_P value for the shallow layer, $Q_P=138$, from 100-200m depth. Then, these values gradually increase from 51 to 62. This higher Q_P value in the shallow layer may be due to the short distance between the source and the top receivers, and we suspect this values to be erroneous. Q_P values were then estimated from up-going wavefield that comes from the deepest interface (Figure 3). For this case, Q_P values range between 20 and 28, in the shallow intervals from 66-266m depth. We consider these values more reliable for shallow layers.

The zero-offset VSP was also acquired with an EnviroVibe source. It is well known that even vertical vibrators can produce direct shear waves. Q_S values were estimated from the direct down-going shear wavefield. The results obtained are: $Q_S=100$ from 100-200m depth, $Q_S=21$ from 200-350m depth, $Q_S=34$ from 350-420m depth, and $Q_S=10$ from 420-500m depth (Figure 4). These Q_S values are lower than the Q_P values obtained before (Figure 2).

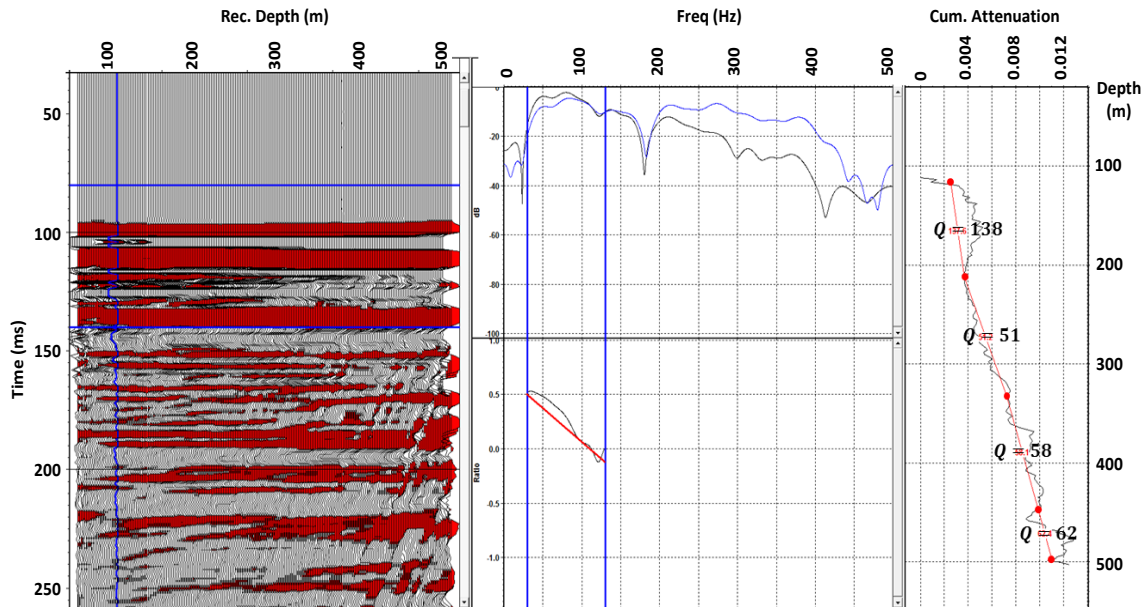


Figure 2. Q_P estimation from down-going wavefield using spectral-ratio method (Vista software).

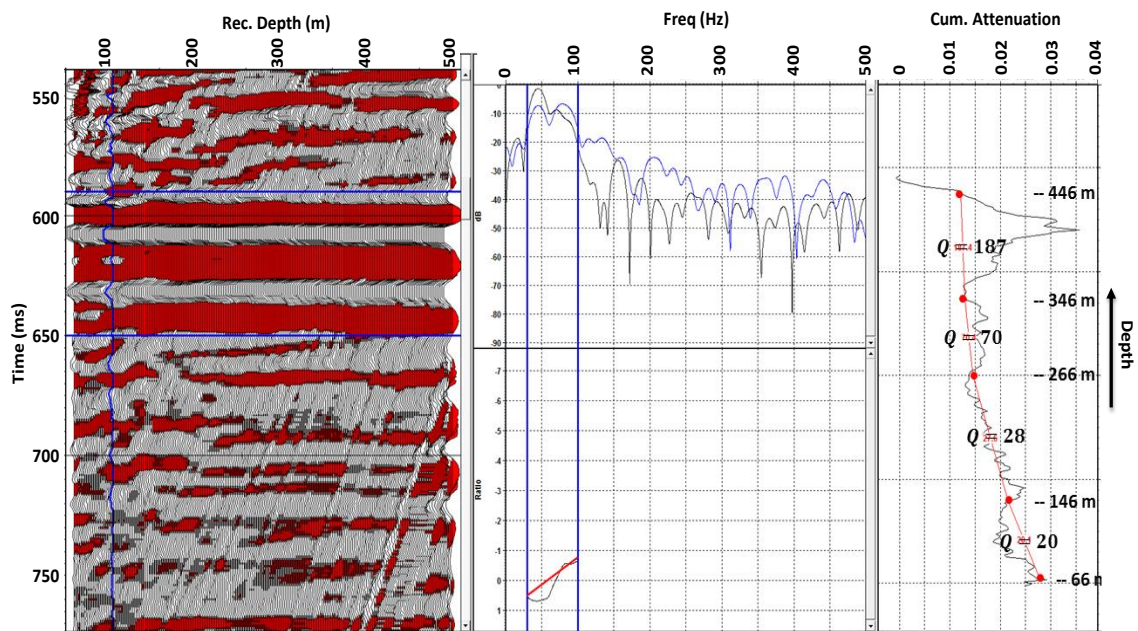


Figure 3. Q_p estimation from up-going wavefield using spectral-ratio method (Vista software).

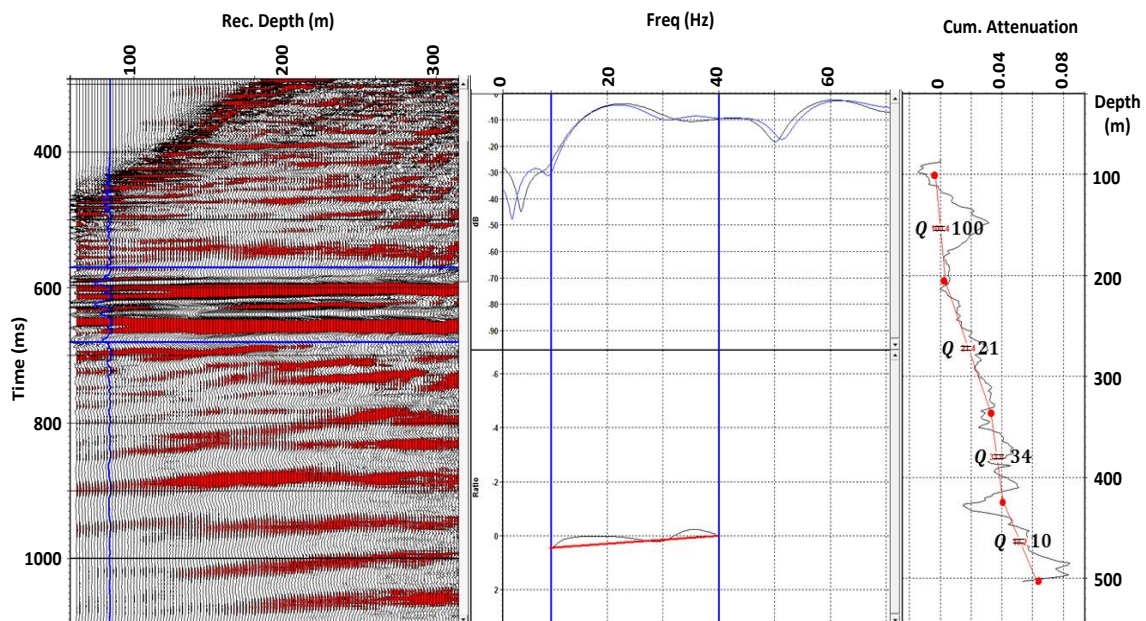


Figure 4. Q_s estimation from down-going wavefield using spectral-ratio method (Vista software).

Conclusions

Q_P values were estimated from the direct down-going wavefield with a dynamite source. The spectral-ratio method was used for the estimation. We obtained a high Q value for the shallow layer in which $Q_P=138$. After 200m depth, Q values gradually increase from 51-62. Q_P values were also estimated from the up-going wavefield where the main difference with the down-going wavefield is the result obtained in the shallow layer. There, the estimated Q_P value is lower since the wavefield has propagated a longer period of time at that zone. Then, we observe more significant attenuation when we process the data. Q_P values range from 20-28 from 66-266m depth.

The spectral-ratio method was also used to estimate Q_S values from the direct down-going shear wavefield with an EnviroVibe source. Results showed that shear waves attenuate faster than p-waves leading to lower Q_S values. In this case, Q_S values range from 21-34 from 200-420m depth.

Significant converted wave energy has also been seen in the data used in this research. In the future, we will estimate Q_S from the upgoing converted waves in order to confirm our results.

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