Attenuation of P and S-waves in the near-surface using uphole data

Saul E. Guevara and Gary F. Margrave
seguevar@ucalgary.ca

INTRODUCTION

Attenuation of seismic waves in the near surface can be significant. Some authors attribute to this attenuation important effect on the resolution loss of the S-wave signal. Uphole surveys are oriented to obtain information about velocities of the near-surface layer and can contribute to the characterization of attenuation. Possible methods to find the parameter Q using uphole multicomponent data are analyzed in this work, focused on S-waves. Upholes appear easy to acquire, therefore an attenuation analysis method with this data can have practical benefits.

THEORY: ATTENUATION AND Q

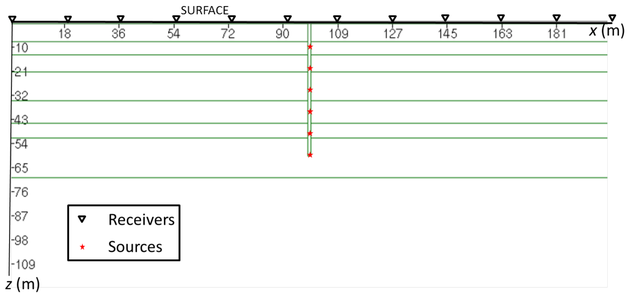
Attenuation causes amplitude decreasing, that affects more the higher frequencies.
An equation that describes the effect of attenuation is

$$|\widehat{w}_t(f)| = |\widehat{w}_0(f)|\, e^{-\pi f t/Q}$$

where f is frequency,, t is time, $\widehat{\omega}_t$ is the spectrum at the time t, and $\widehat{\omega}_0$ is the initial spectrum. The quality factor, Q, is the parameter most used to define the attenuation properties of Rocks. Spectral methods appear more convenient, since the amplitude is affected by many other factors different from attenuation. Three attenuation spectral estimation methods are available in the CREWES tools: *dominant frequency matching*, *spectral ratio*, and *spectral matching*. Dominant frequency matching is used in the following examples.

THE UPHOLE SURVEY

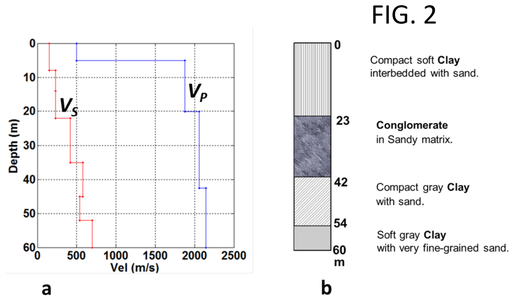
FIG. 1



Uphole design:

The sources of energy are inside the borehole and the sensors are on the surface. Energy sources are explosives separated by 5 m from each other. The receivers are separated by 5 m between them .

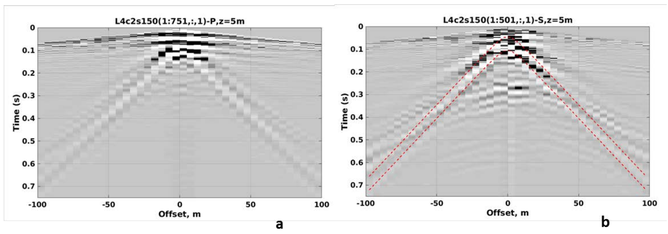
FIG. 2



(a) Velocity model at the uphole location, derived from the direct arrivals, (b) the corresponding lithological column obtained from the drilling cuttings.

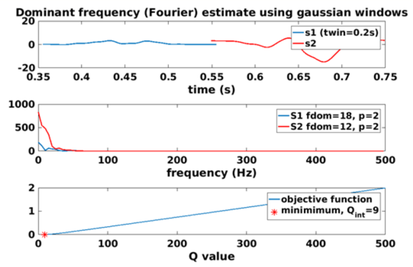
ESTIMATING HORIZONTALLY: THE 5 M DEPTH SHOT

FIG. 3



Shot gathers for the 5m depth shot, (a) vertical component, (b) horizontal component. The dashed lines in (b) show the estimated arrival time of direct S-waves generated by the source. Note the leakage between both components of P- and S-waves, and the presence of interfering events, specially in the horizontal component .

FIG. 4



S-wave attenuation for the shallow NSL, by the dominant frequency method using the 5 m depth shot, and the 10 m and 90 m offset traces. Wave mode separation was applied previously, to filter the S-wave.

ESTIMATING VERTICALLY: 25 AND 55 M DEPTH SHOTS

FIG. 5

The 25 m depth shot, (a) the vertical component, (b) the horizontal component.

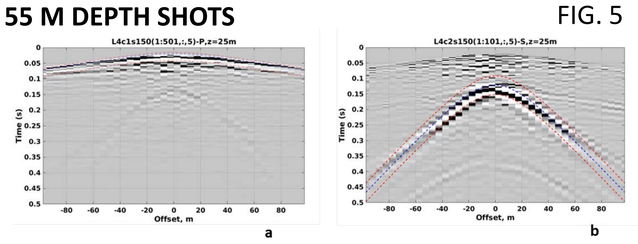
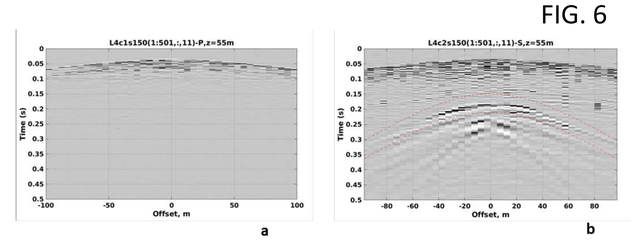


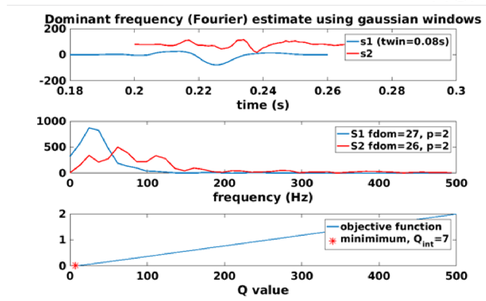
FIG. 6

The 55 m depth shot, (a) the vertical component, (b) the horizontal component. Note that there are differences in the radiation pattern compared with the 25 depth shot.



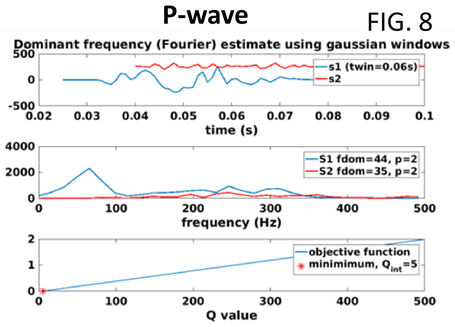
S-wave

FIG. 7



P-wave

FIG. 8



S-wave and P-wave attenuation resulting from the 25 and 55 m depth shots, using the dominant frequency estimation, applied to the -40 m offset traces. Both results are quite close, with apparently higher Q for the S-wave.

DISCUSSION

Estimation of near-surface attenuation from upholes appears possible, according to the experiment presented here. There are uncertainties about sources since each one can have different radiation patterns and frequency content, affected by the local characteristics of the borehole and the surrounding rocks. However, there is redundancy in the wave travel-paths , such that it is possible to consider inversion methods such as tomography. Comparison with other methods is also advisable. On the other hand, interference between different seismic events deserves additional analyses.

ACKNOWLEDGEMENTS

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