O12-3

Q IMAGING FROM FIRST BREAKS IN SHALLOW SEISMICS

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Seismic reflection and refraction techniques depend on the existence of the seismic wavelet itself. The information pertinent to absorption, however, is hidden within the seismic wavelet's shape. Unlike reflection and refraction, the absorption is a continuous phenomenon as seismic waves progress. Although there may not exist sufficient acoustic impedance contrasts among rock boundaries causing any reflection or refraction, still significant absorption information can accumulate on a progressing wavelet. The absorption information may be crucial as far as rock's consolidation, porosity, fractures, and fluid contents are concerned.

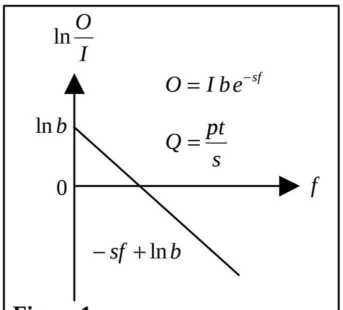

Figure 1

The absorption measurements are tedious and subject to noise. The imaging of the seismic quality factor, Q, is not common in every day use of engineering geophysics. In this presentation, we introduce a new methodology to rapidly compute and map the seismic Q.

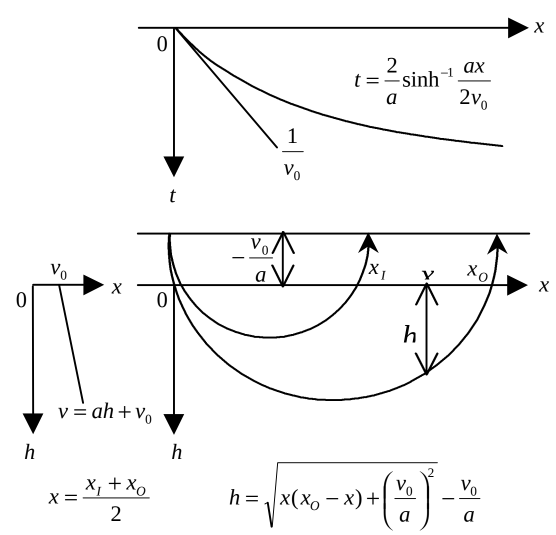

Figure 2

The absorption is frequency dependent, and in most dry rocks this frequency dependence is linear. Popular way to measure absorption is the spectral ratio technique. If the slope s is determined in least-squares sense, and the travel-time t is observed, then the seismic Q can be computed (Figure 1). In Figure 4, the input (I) and output (O) wavelets (picked from Figure 3) and their amplitude spectra are depicted. In case large wavelet amplitudes are clipped due to gain and dynamic range considerations, we encourage some method of wavelet shape reconstruction prior to seismic Q computations. The effective frequency band (say, 10-100 Hz in Figure 4) should be carefully selected to determine the slope s. Figure 5 shows how noisy the logarithm of the spectral ratio is. Filtering of the high frequency noise is very helpful (Figure 5, second line).

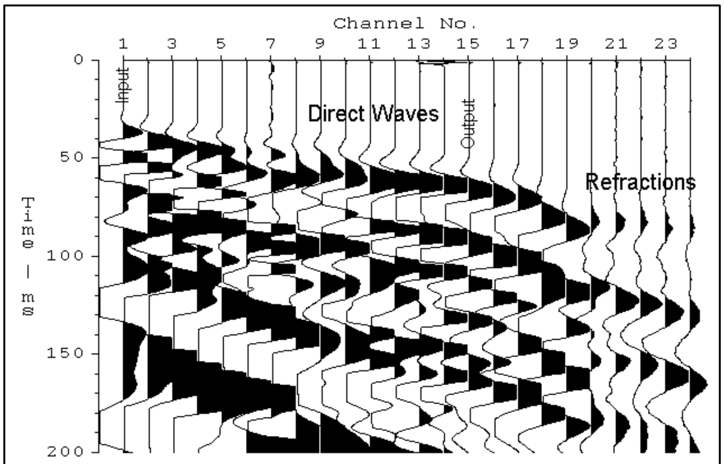

Figure 3

Once a seismic Q value is computed, our second task is to assign a subsurface position to it. In shallow seismics, at least for the first 100 meters, a linear increase of velocity with increasing depth may be a reasonable assumption. In such case, seismic ray's trajectory is an arc of a circle which centre lies v_0/a meters above the earth's surface (Slotnick, 1959). The direct wave and all the refracted waves are then considered as one seismic event: The first breaks. The velocity increase rate a, and the initial velocity v_0 are directly obtained from the data (Figure 2). In a sense, this approach is very similar to the depth penetration concept in electrical sounding (resistivity) methods. Whatever channel couples are selected for input (I) and output (O) wavelets, we consider the location of the computed Q be at the mid-point x of x_I and x_O (as in Common-Mid-Point of seismic reflection methods), and at the depth h on the circular ray path of x_O.

Figure 6 shows a subsurface Q image obtained from the data seen in Figure 3. The spatial distribution of the data contributing to contouring operations is also depicted in Figure 6. An effective Q anomaly of 20 is pointed out in the vicinity of 45 meters of depth.

Independently, we have also applied the conventional refraction interpretation for a horizontal double layer case (Figure 3). The results are extremely promising: First layer velocity 1967 m/s, second layer velocity 4262 m/s, intercept time 0.0414 s, resulting in 45 meters of depth for the refractor, the exact location we have found independently from seismic Q imaging. The high velocity and high effective seismic Q of the refractor is justified by both conventional refraction interpretation and seismic Q imaging. We have provided an interactive program to easily implement the method.

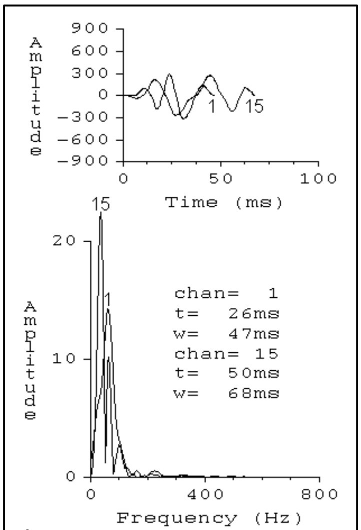

Figure 4

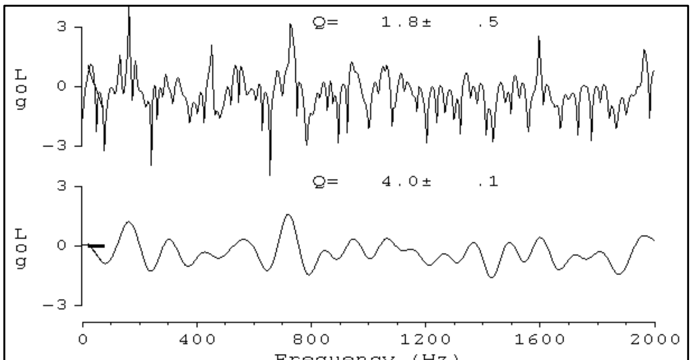

Figure 5

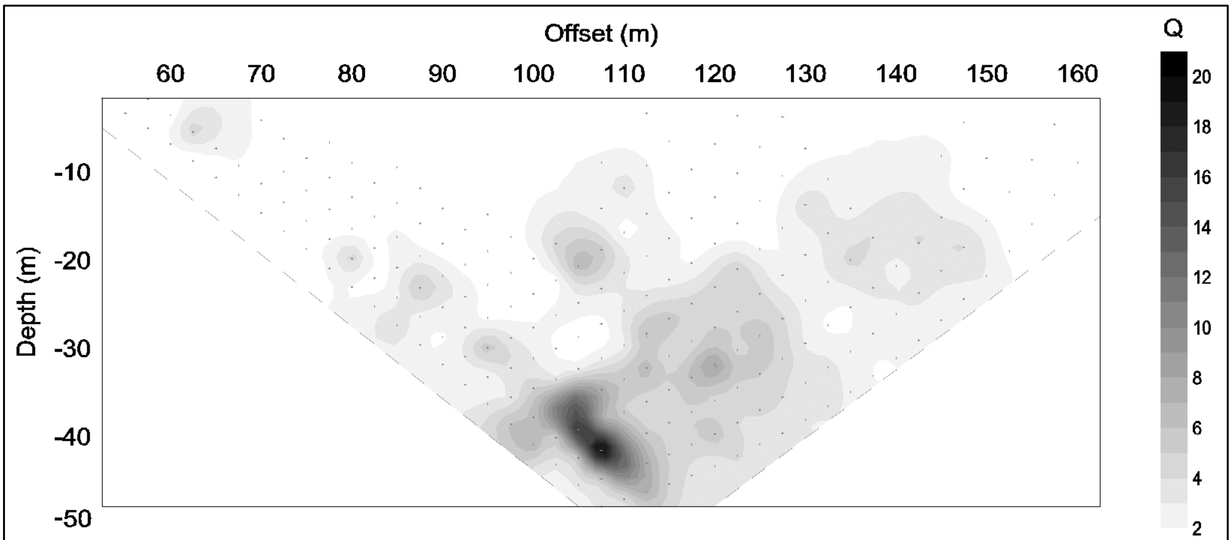

Figure 6

Reference

Slotnick, M. M., 1959, Lessons in Seismic Computing: The Society of Exploration Geophysicists, 268 p.