Estimation of Q: a comparison of different computational methods

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SUMMARY

In this article, four methods of Q estimation are investigated: the spectral-ratio method, a match-technique method, a spectrum modeling method and a time-domain match-filter method. Their accuracy and the reliability of Q estimation is evaluated using synthetic data. Testing results demonstrate that the time-domain match-filter method is more robust to noise and more suitable for application to reflection data than the other three methods..

BASIC IDEAS OF Q ESTIMATION METHODS

Q estimation is usually estimated from two local reference wavelets, which are at a deep zone and a shallow zone respectively. For spectral-ratio method (Bath, 1974), Q is estimated by fitting a straight line to the logarithmic spectral ratio over a finite frequency range.

The spectrum modeling method (Blias, 2011) compares the amplitude spectra of the local wavelets. The amplitude spectrum for the wavelet in shallow zone is modified by varying Q until an optimum approximation to the one for the wavelet in deep zone is obtained.

The match-technique method (Raikes and White, 1984) estimates a forward prediction filter by matching the wavelet in shallow zone to that in deep zone and a backward prediction filter by matching the wavelet in deep zone to that in shallow zone. Then, transfer functions correspond to the prediction filters are computed, from which the spectral power ratio is obtained to give Q estimation by spectral-ratio method.

The match-filter method (Cheng and Margrave, 2011) estimates the smoothed amplitude spectra for the two local wavelets, and then computes the apparent minimum-phase wavelets corresponding to the smoothed amplitude spectra. Finally, Q is estimated by matching the two apparent minimum-phase wavelets with optimal forward Q attenuation filter.

NUMERICAL EXAMPLE

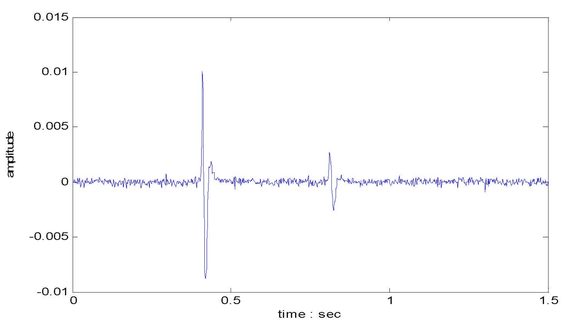

FIG. 1. Synthetic attenuated seismic trace created with two events, created using two isolated reflectors (Q=80, SNR=4). By maintaining the noise level at SNR=4, 200 synthetic trances with 200 different noise series can be obtained for Q estimation.

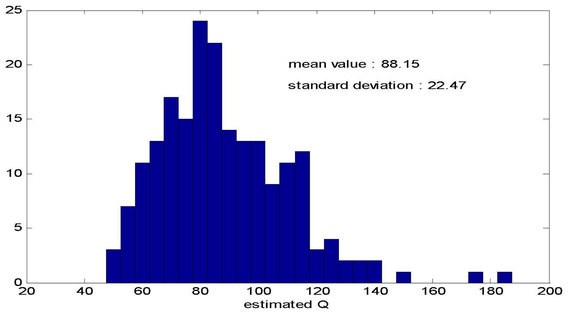

FIG. 2. Histogram of the Q values estimated by spectral-ratio method using 200 seismic traces (similar to the one shown in figure 1) with noise level of SNR=4.

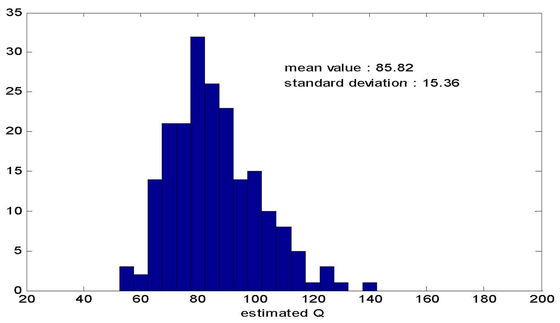

FIG. 3. Histogram of the Q values estimated by spectrum-modeling method using 200 seismic traces (similar to the one shown in figure 1) with noise level of SNR=4.

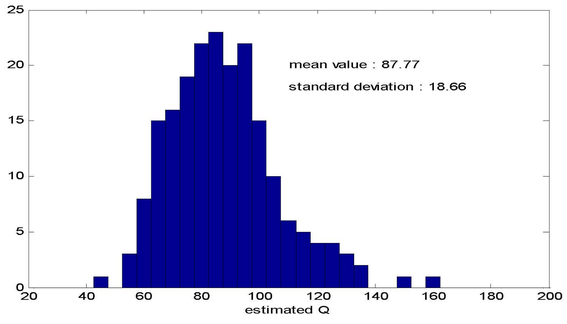

FIG. 4. Histogram of the Q values estimated by match-technique method using 200 seismic traces (similar to the one shown in figure 1) with noise level of SNR=4.

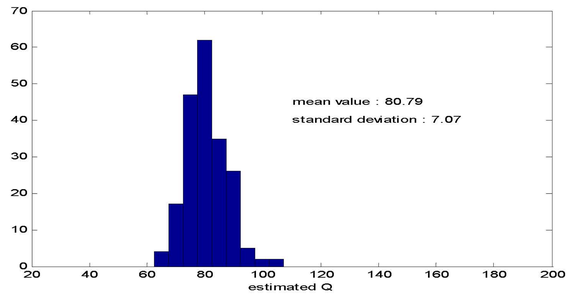

FIG. 5. Histogram of the Q values estimated by match-filter method using 200 seismic traces (similar to the one shown in figure 1) with noise level of SNR=4.

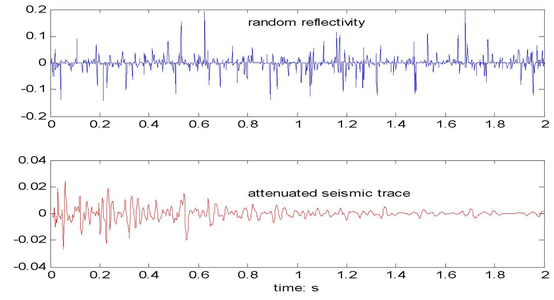

FIG. 6. An attenuated seismic trace (red) created from a random reflectivity series (blue) with a constant Q of 80.

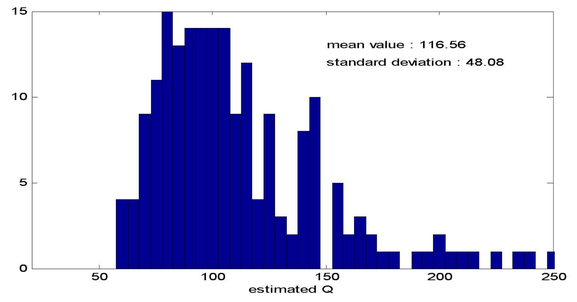

FIG. 7. Histogram of the Q values estimated by spectral-ratio method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 6 (SNR=4).

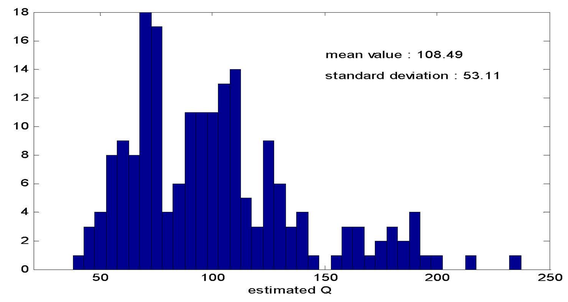

FIG. 8. Histogram of the Q values estimated by spectrum-modeling method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 6 (SNR=4).

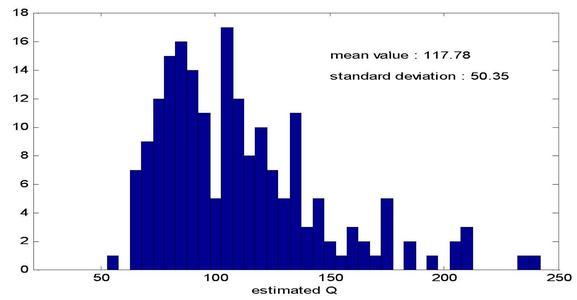

FIG. 9. Histogram of the Q values estimated by match-technique method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 6 (SNR=4).

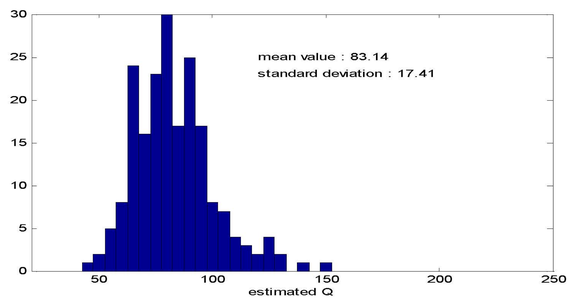

FIG. 10. Histogram of the Q values estimated by match-filter method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 6 (SNR=4).

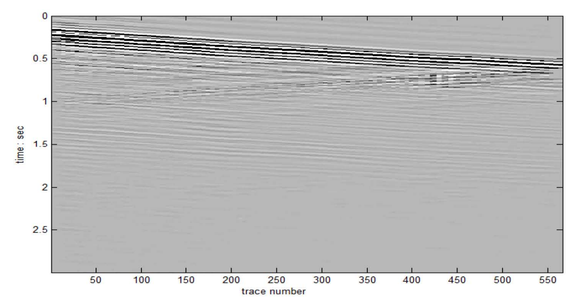

FIG. 11. Ross Lake VSP data with upgoing wave suppression (vertical component P-wave).
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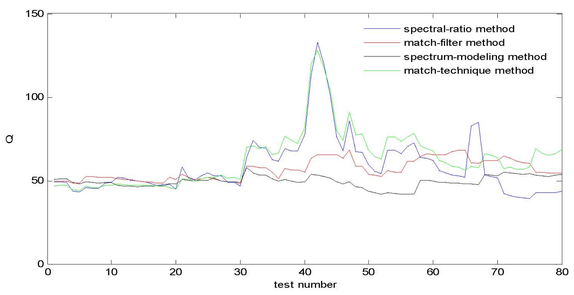

FIG. 12. Q estimation using 80 pairs of VSP traces shown in figure 11 (Each pair has a fixed trace interval of 250; the first pair are the VSP trace 101 and trace 351, and the last pair are VSP trace 180 and trace 430).

CONCLUSION

The relative performances of spectral-ratio method, spectrum-modeling method, match-technique method and match-filter method are evaluated. Testing on synthetic seismic traces shows that the match-filter method, compared to other three methods, is robust to noise and more suitable to be applied to reflection data. Testing on real data shows that all the four method can obtain similar results at most cases when VSP data with high SNR is used for Q estimation.