Comparison of Q-estimation methods: an update

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SUMMARY

In this article, three methods for Q estimation are compared: a complex spectral ratio method, the centroid frequency-shift method, and a time-domain match-filter method. Their performance for Q estimation is evaluated using synthetic data and real data in terms of accuracy and robustness to noise. Testing results shows that the complex spectral-ratio method, with phase information employed, can obtain improved estimation results. The centroid frequency-shift method is robust to noise and gives stable estimations, while the accuracy of estimated result is subject to the frequency band used to estimate centroid frequency and variance. The match-filter method is robust to noise and can give accurate estimation result for both VSP data and reflection data.

BASIC THEORY 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. As an extension to the classic spectral-ratio method, Cheng and Margrave (2008) propose a complex spectral ratio method for Q estimation, which use both amplitude spectra and phase spectra to estimate Q. When phase information is employed, a reference frequency should be chosen to model the phase difference for Q estimation.

The centroid frequency-shit method (Quan and Harris, 1997) computes the centroid frequencies from amplitude spectra of the two local wavelets, and estimates the Q attenuation from the downshift of centroid frequencies.

The match-filter method (Cheng and Margrave, 2012) 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

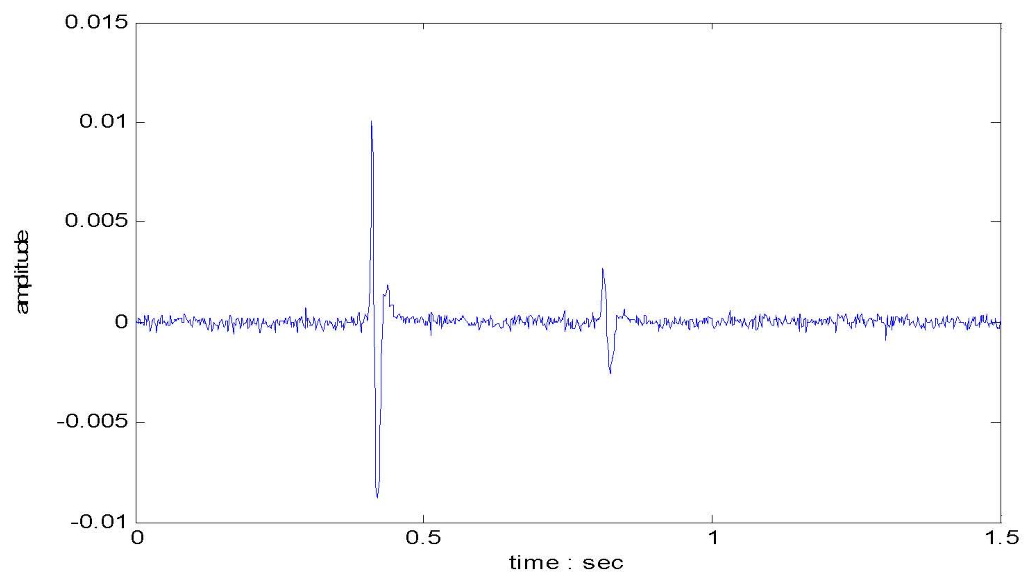

FIG. 1. Synthetic attenuated seismic trace created with two events, created using two isolated reflectors (Q=80, SNR=4). By maintaining the noise level at SNR=4, 200 synthetic trances with 200 different noise series can be obtained for Q estimation.

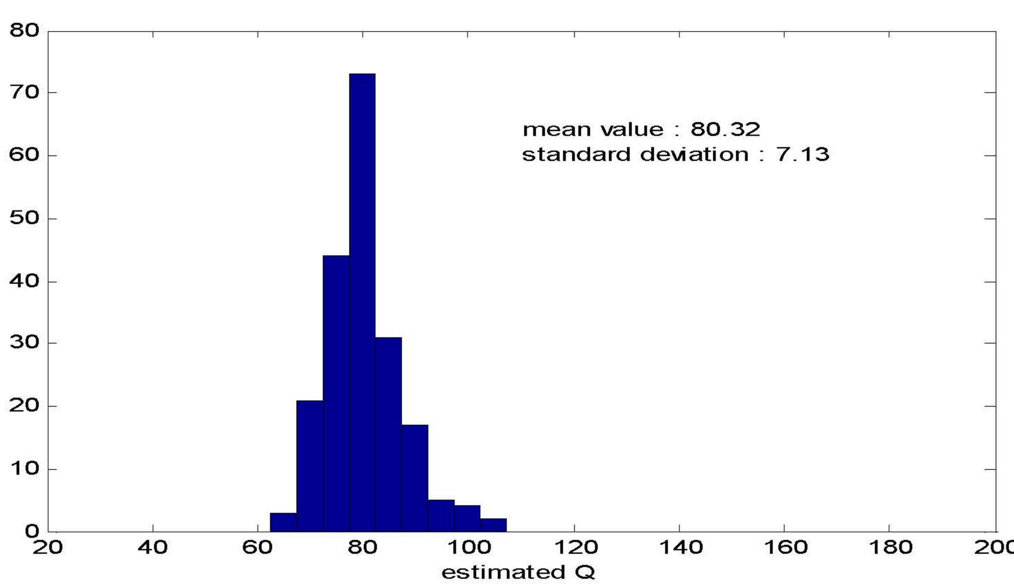

FIG. 2. Histogram of the Q values estimated by complex spectral-ratio method (only phase information is employed) using 200 seismic traces that are similar to the one shown in figure 1 with noise level of SNR=4.

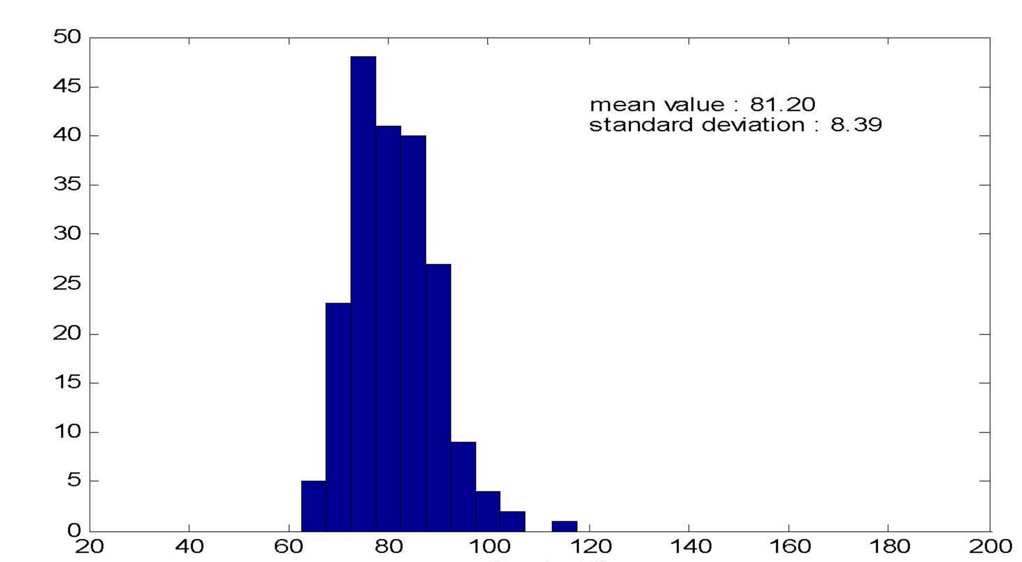

FIG. 3. Histogram of the Q values estimated by centroid frequency-shift method using 200 seismic traces that are similar to the one shown in figure 1 with noise level of SNR=4.

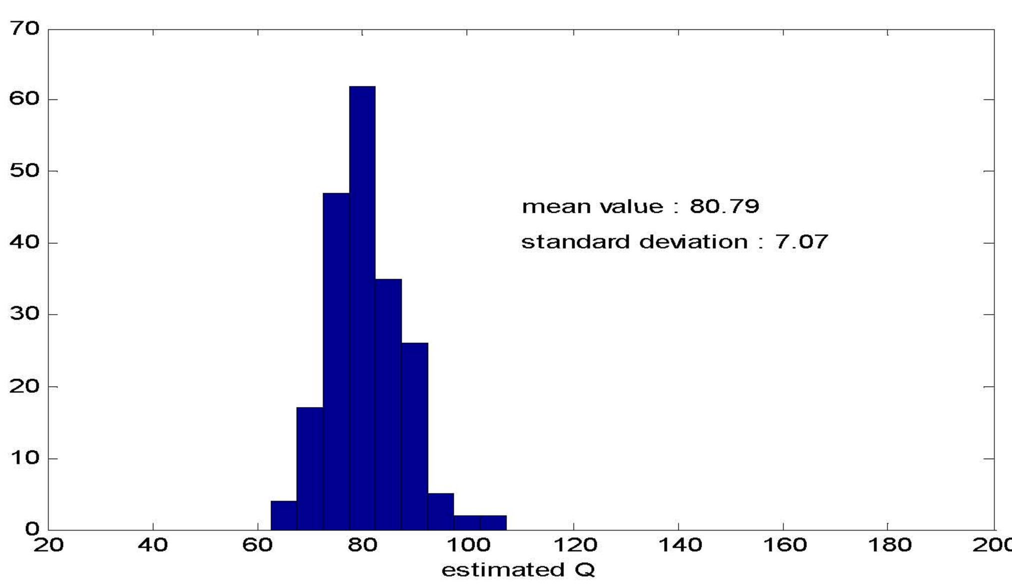

FIG. 4. Histogram of the Q values estimated by match-filter method using 200 seismic traces that are similar to the one shown in figure 1 with noise level of SNR=4.

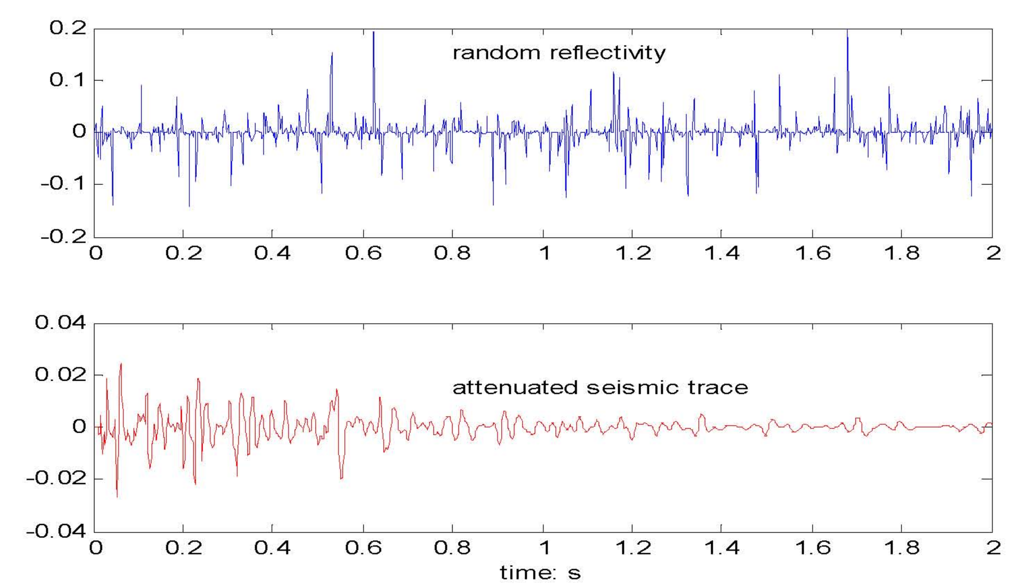

FIG. 5. An attenuated seismic trace (red) created from a random reflectivity series (blue) with a constant Q of 80.

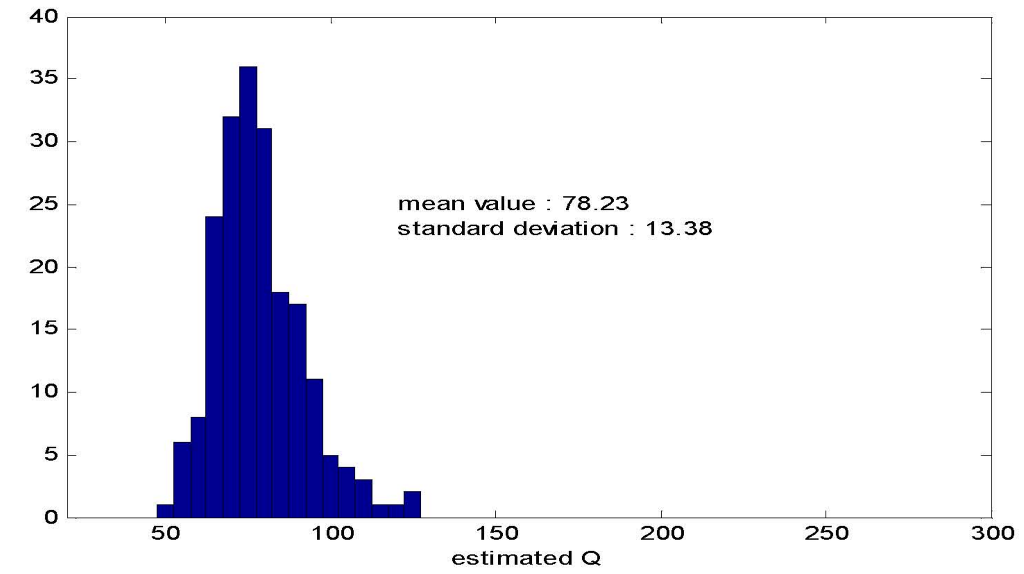

FIG. 6. Histogram of the Q values estimated by centroid frequency-shift method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 5 (SNR=2).

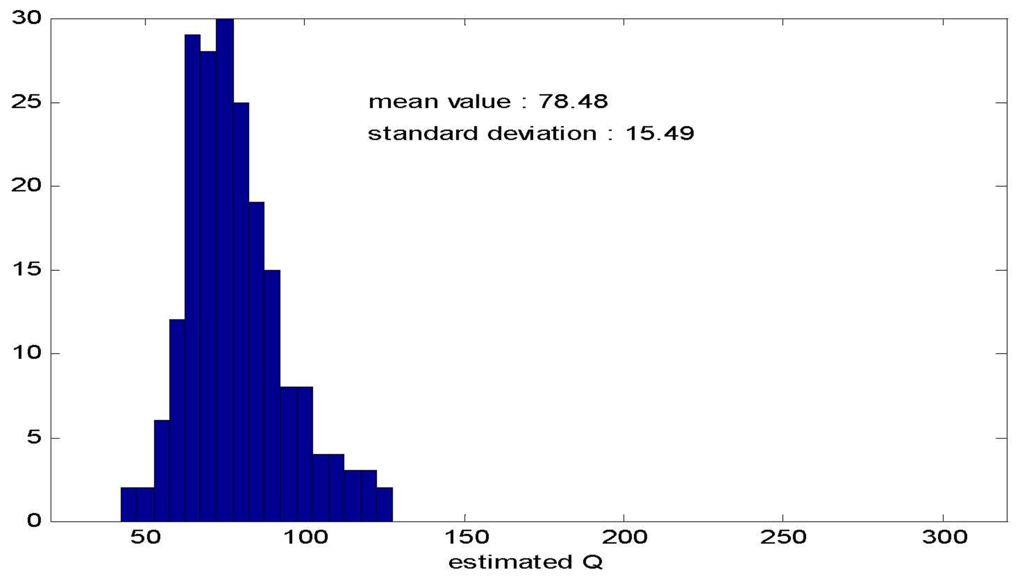

FIG. 7. Histogram of the Q values estimated by match-filter method using the 100ms-500ms and 900ms-1300ms parts of 200 seismic traces similar to the one shown in figure 5 (SNR=2).

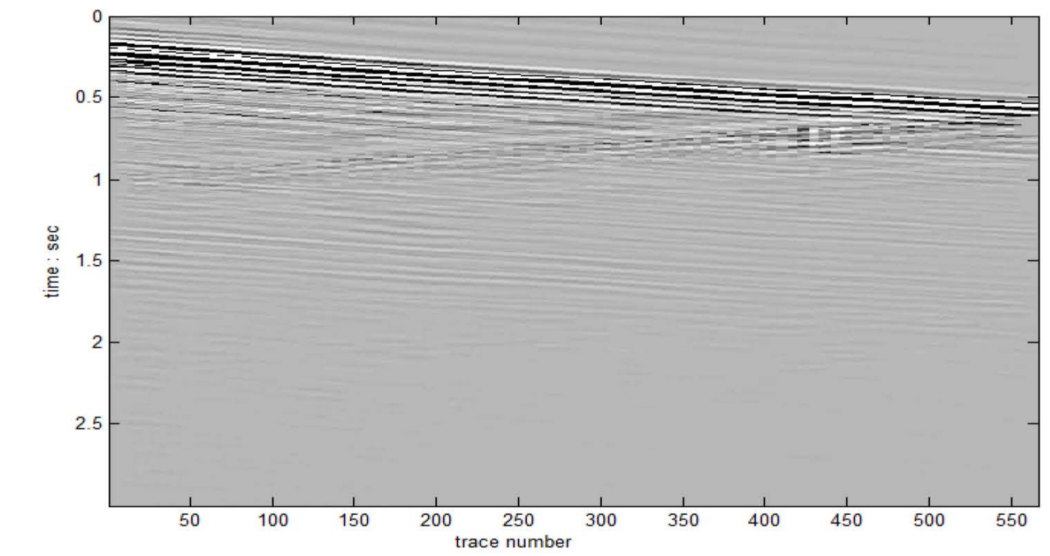

FIG. 8. Ross Lake VSP data with upgoing wave suppression (vertical component P-wave).

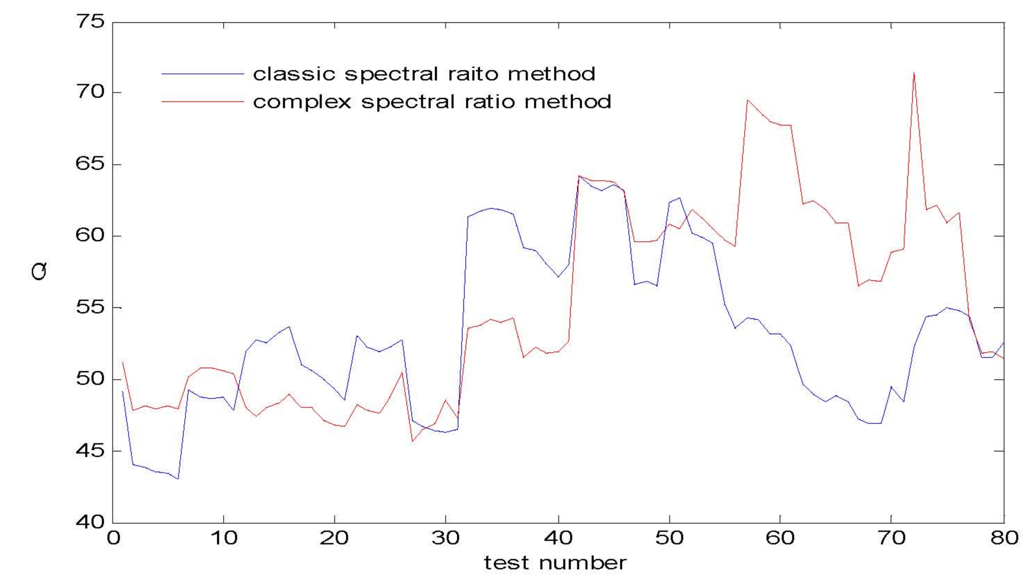

FIG. 9. Q estimation by classic spectral-ratio method and complex spectral –ratio method using 80 pairs of VSP traces shown in figure 8 (Each pair has a fixed trace interval of 250; the first pair are the VSP trace 101 and trace 351, and the last pair are VSP trace 180 and trace 430).

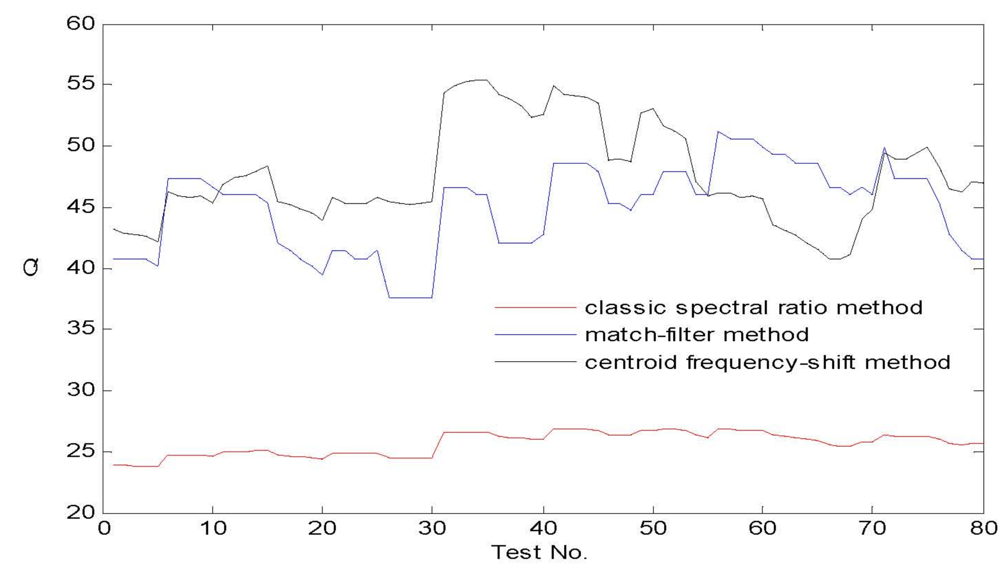

FIG. 10. Q estimation by centroid frequency-shift method and match-filter method using 80 pairs of VSP traces shown in figure 8 (Each pair has a fixed trace interval of 250; the first pair are the VSP trace 101 and trace 351, and the last pair are VSP trace 180 and trace 430).

CONCLUSION

The performances of complex spectral-ratio method, centroid frequency-shift method and match-filter method are evaluated. With the employment of phase information, the complex spectral-ratio method can obtain better estimation result than the classic spectral-method. To apply the complex spectral-ratio method to real data, minimum-phase equivalent wavelet transformation can be conducted before *Q* estimation, and the reference frequency for modeling phase difference can be chosen with the calibration of other methods.

The centroid frequency-shift method is robust to noise and gives stable estimation results. The accuracy of estimation results is subject to the frequency bands used for the calculation of centroid frequencies and variances. It seems that there is no convenient way to determine frequency bands to give accurate estimation in practice.

The match-filter method gives accurate and stable estimation results for both VSP data and reflection data. The associated frequency bands for random noise attenuation can be conveniently determined by evaluating the SNR level of local wavelets