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地震波インターフェロメトリを用いたVSP測定配置変換と減衰評価
Q estimation by transforming VSP measurement configuration with seismic interferometry

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Although seismic attenuation measurements have great potential to enhance our knowledge of physical conditions and rock properties, their application is limited because robust methods for obtaining reliable attenuation estimates have not yet been established. The combined use of velocity and attenuation data reduces the uncertainty in characterizing such conditions and properties. Although Vertical seismic profile (VSP) measurement is considered to be best suited for attenuation studies and the spectral ratio method is a popular means of measuring seismic attenuation, this method is not stable because it is strongly subject to the variation of the S/N in the spectra. In the present paper, we propose attenuation estimation methods for VSP data by combining seismic interferometry and a robust attenuation estimation method developed for sonic waveform data. Seismic interferometry allows VSP data to be converted from the VSP configuration to the sonic logging measurement configuration. Then, we can apply the robust attenuation estimation method developed for sonic waveform data to the converted VSP data. We adopt two different types of seismic interferometry, one based on deconvolution interferometry and one based on cross-correlation interferometry. By applying the proposed methods to synthetic and field VSP data, we demonstrate the advantages of the proposed methods over the conventional spectral ratio method. For the case without noise, we demonstrate the applicability of deconvolution interferometry and the incompleteness of cross-correlation interferometry for attenuation estimation. The application of cross-correlation interferometry cannot provide absolute attenuation but can provide relative attenuation from the slope information of the attenuation results curve. The bias of cross-correlation interferometry is due to the incorrectness of the amplitude information, that is, the phase information estimated from cross-correlation interferometry is correct, whereas the amplitude information is not adequate for attenuation estimation. In the case of the application of cross-correlation interferometry, we have also pointed out the relationship between the magnitude of attenuation and the biased attenuation results. For the case with random noise, deconvolution interferometry does not have an advantage over the conventional spectral ratio, whereas cross-correlation interferometry is less sensitive to random noise than the application of deconvolution interferometry and the conventional spectral ratio method. This is because a cross-correlation operation improves the S/N ratio, i.e., not only the cross-correlation between random noises but also the cross-correlation between signal events and random noise is ideally zero, whereas the cross-correlation between signal events is enhanced. Sensitivity tests on borehole irregularities, such as unnecessary residual events after wavefield separation, also reveal the advantage of the proposed methods using deconvolution interferometry over the conventional spectral ratio method. The inverted attenuation results from field data obtained by deconvolution interferometry do not completely correlate with those obtained by the spectral ratio method, except for the high-attenuation zone. The difference between these inverted attenuation results might be the difference in sensitivity to borehole irregularities, such as unnecessary residual events after wavefield separation. Furthermore, the difference in quality and resolution among the inverted attenuation results obtained by cross-correlation interferometry is relatively small compared to the two other cases. This might be due to the lower sensitivity of cross-correlation interferometry to noise.

キーワード: 地震波インターフェロメトリ, 地震波減衰評価, VSP データ
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