Applying Seismic Noise Interferometry to extract high-resolution P-wave reflectivity from hydraulic fracturing data.

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Abstract

This study utilizes passive seismic interferometry, focused explicitly on calculating the auto-correlation function, on extracting reflections of P-waves centered on each receiver. Stacking these reflections allows for the construction of seismic sections at zero offsets. Typically, this technique uses data based on environmental noise or earthquakes. However, in this study, measurements taken during the hydraulic fracturing process in the vicinity of the Potiguar basin located in northeastern Brazil were used. Although this acquisition was not intended for a passive seismic interferometry experiment, an advantage was taken of its design and location concerning the fracturing point to evaluate the ability to construct seismic images from induced ambient noise. This geometry is composed of three main lines with three different azimuth angles, which intersect precisely at the point of fracturing located at a depth greater than 400 meters. To extract the best body wave component from Green's function, we apply a novel variation to the commonly used processing flow. This includes the Gaussian smoothing filter, which allows a smoothed amplitude spectrum to be obtained. This spectrum may still be affected by high-energy point events that need to be further treated, for which the whitening process is considered using the division between the natural spectrum of the data versus the smoothed spectrum. After applying the inverse Fourier transform to each trace obtained for each station, they are complemented to form the resulting seismic sections, which are compared to active source seismic lines acquired close to the study area and interpreted with available geological information. Seismic images were built in 2D and projected in 3D, taking advantage of the peculiar geometry arranged for monitoring the hydraulic fracturing process. This allowed analyzing the consistency between each of the acquired lines, also considering the point of intersection between them. Within this context, we can define a result of seismic sections that have well-defined reflectors of high resolution, continuity, and a satisfactory reproduction of the limits of the different geological formations typical of the Potiguar basin, such as the Jandaira, Açu formation, and the basement top. The estimated depth in time reached up to 2 seconds. The obtained information can generally be compared with all available geophysical and geological data, except for the shallowest lithologic bodies. For these, the cross-correlation between stations with the longest available offset was calculated to obtain a velocity model and determine the maximum possible penetration of investigation with the available acquisition geometry. Our work demonstrates the potential of passive seismic interferometry to generate high-resolution seismic images with highly efficient processes, considering the low relative investment level, very low environmental impact, and high-quality results.