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Interpretation of passive seismic data obtained during active source surveys with nodal arrays: A case study from Western Colorado

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The advent of cable-free nodal arrays for conventional reflection and refraction experiments has changed the acquisition style for active source surveys. Instead triggering short recording windows for each shot at limited offset ranges, the nodes are continuously recording the entire spread and over the entire acquisition period . Depending on the total duration of the survey, a significant amount of continuous data might be collected. These data can be analyzed with passive seismic methods and therefore offer the possibility to complement subsurface characterization at little to no additional cost.

Among passive seismic methods, interferometry is becoming a well-established technique for imaging and monitoring the subsurface. It aims at mimicking active source data from long-term passive recordings without the need for knowing the temporal and spatial distribution of contributing seismic energy. Due to its simple principle, interferometry can be automatized to a high degree with little need for interaction. Depending on the distribution, type, and strength of the contributing energy sources, a few days or even hours of recording might be sufficient to synthesize seismic waves traveling between the receivers.

In 2017, seismic reflection data have been acquired along 2.5 km long profile in the Unaweep Canyon in Western Colorado with the aim to characterize structure and thickness of its sedimentary infill. 120 Fairfield ZLand 3C nodes and 385 Reftek RT125 data loggers (‘Texans’) equipped with 1C Geophones have been deployed at 5 m spacing. The instruments recorded continuously for ca. 30 hours, and during that time an accelerated drop weight was used as source.

We apply seismic interferometry to the continuous data. Due to the large number of stations, a substantial set of virtual source gathers is obtained. Rayleigh surface waves in the frequency range 1 – 20 Hz are observed at offsets up to 1.5 kilometers. Contributing energy sources are the active shots and traffic noise. The dispersion curves show lateral variation and correlate with the sedimentary structure.

Combined inversion and interpretation of the active and passive seismic data offers several benefits. Active data provide P-wave structure, while inversion of dispersive Rayleigh waves adds information on the S-wave velocities. Body-wave travel time tomography has little sensitivity to velocity inversion zones, which show up more clearly in the dispersion curves. Rayleigh wave inversion for S-wave velocities can make advantage of existing P-wave velocity models. We discuss these benefits, and also the limitations of passive seismic data acquired during active source surveys with nodal arrays.