S-wave and P-wave velocity model estimation from surface waves

Abstract

Seismic surveys are the leading tools for oil and gas exploration. Although their target is the deep imaging, near-surface characterization is yet very important, since the complexity and heterogeneity of the unconsolidated near-surface significantly affects the propagation of the body waves, resulting in inconsistent images of the deep reflections. As a solution, the static correction step is applied in oil and gas seismic data processing. An additional challenge is that the surface waves (ground-roll) which travel near the free surface are usually dominant in the recordings, blurring the reflection data. The successful elimination of the surface waves and the estimation of static corrections require the knowledge of the near-surface S-wave and P-wave velocity (VS and VP) models. Here, we focus on developing surface wave methods that allow estimating both VS and VP models.

The surface wave dispersion curves, which are considered mainly sensitive to VS , are usually inverted to estimate the VS model. To estimate VP, a new concept, the wavelength-depth (W/D) relationship, is introduced. The W/D relationship exploits the strong correlation between the phase velocity of surface wave and the time-average VS (VSZ) and is sensitive to both VS and VP (Poisson's ratio). We develop a W/D workflow that estimates VS and VP models and is suitable for sites with strong lateral heterogeneity. The method directly transforms the dispersion curves into 1D VS and VP models, without the need to perform extensive inversions. We assemble the estimated models from many local DCs to construct quasi 2D or 3D velocity models. We show the application of the method to data sets from sites with diverse geological properties and acquired with various acquisition techniques.

We also develop a Monte Carlo joint inversion algorithm that uses both the W/D relationship and the dispersion curve in the formulation of the misfit function. The method provides high-resolution VS and VP models. We apply the algorithm to two synthetic examples which simulate loose unsaturated and saturated (high Poisson's ratio) environments, as well as to the data set from a site with known properties and compare the estimated models with the benchmarks.

The laterally constrained inversion (LCI) and surface wave tomography (SWT) are well-known methods for estimating VS. We use the W/D method to estimate the a priori Poisson's ratios, required by these methods. We then transform the estimated

VS of the LCI and SWT into the VP model using the same Poisson's ratio. In scheme of SWT, we develop a two-station dispersion curve estimation workflow that enables the estimation of multi-modal curves. Including the higher modes in SWT enhances the investigation depth and leads to improved resolution of the deepest layers of the model.

The application of the W/D, LCI, and SWT methods to a data set from a stiff site estimates VS and VP models which are, respectively, more than 95.3 % and 94.6 % similar among the methods, all in agreement with the geological information on the site.