Introduction

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In the geophysics of oil exploration and reservoir studies, the surface seismic method is the most commonly used method to obtain a subsurface model in 2 or 3 dimensions. This method plays an increasingly important role in soil investigations for geotechnical, hydrogeological and site characterization studies regarding seismic hazard issues.

This book is neither a basic introduction nor a theoretical study of seismic imaging. Its goal is to provide a practical guide, through the use of examples from the field, to the application of seismic methods to surface imaging.

After reviewing the current state of knowledge in seismic propagation, refraction and reflection seismic methods, the book aims to describe how seismic tomography and full waveform inversion methods can be used to obtain seismic images of the subsurface. The book highlights the benefit of combining different seismic methods through various synthetic and field examples.

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The tomographic approach is well adapted to seismic data imaging. The main focus of seismic tomography is to explore the sensitivity of selected seismic phases to different geological structures to obtain high quality depth or time images of the subsurface. Traditionally, depending on the input data, seismic tomographies fall into three main categories: transmission tomography, reflection tomography and diffraction tomography. The results of seismic tomography, known as tomograms, may even provide useful input data for further processing as pre or post-stack seismic migrations or inversion techniques. Here, the seismic tomography tools are efficiently used for processing multiple marine and land field datasets, acquired with different types of geometry: surface, cross-hole and vertical seismic profile (VSP). This diversity of field examples, in terms of scales and geometries, helps to show the application of seismic tomography in wide near-surface studies such as geotechnics, hydrogeology or site characterization.

Full Waveform Inversion (FWI) is an advanced seismic imaging method. The technique is simple: the objective is to obtain a model (velocity, density, and possibly anisotropy and attenuation) of the subsurface in which the synthetic shot gathers best fit the observed data. The results are quantitative in the sense that, for example, the velocity images are expressed in m/s. Beyond the apparent simplicity there are a number of challenges regarding the applicability of the method. The objectives of the chapter are (1) to provide the main elements of the formalism and (2) to indicate the applicability of the method as well as the strategy to be developed for successful results. The method is illustrated using 2D synthetic data in a geotechnical context, demonstrating that the practical aspects are essential. Two real data examples extracted from the literature are used to illustrate the value of the approach. We give particular attention to understanding the challenges raised by FWI.

With field data targeting shallow structures, we show how more accurate geophysical models can be obtained by combining different datasets: refracted waves with reflected waves, and body waves with surface waves. The proposed hybrid methods investigate the sensitivity of more than one type of wave to different geological structures or mechanical properties, benefiting from the advantage of several existing types of waves, in the same data set. This strategy is shown to be of interest, since it can be implemented without increasing the cost of seismic data acquisition, and the seismic data can be processed using standard procedures. A first example refers to a refraction-reflection imaging strategy with the capability to evaluate reflectivity information starting from the surface. One drawback of reflection processing is that the reflectivity model starts a few meters below the surface, depending on the first offset. The upper region can be modeled through the use of refraction data velocity models. A next step is to build continuous and accurate extended reflectivity information putting together both images. Thus, this hybrid tool is very useful for providing information about the reflectivity for targets located in the near and/or very near surface. A second field example proposes a strategy for imaging with refraction and surface waves. This hybrid seismic method combines knowledge about the P-wave velocity provided by the refraction arrivals and the S-wave velocity distribution through the surface wave data. The distributions of both velocities allow a better definition of a hydrothermal system, such as subsurface gas pathways consistent with degassing.

Finally, we show how the integration of seismic data (3D survey and VSP), logging data (acoustic logging) and core measurements, combined with a succession of specific and advanced processing techniques, enables the development of a 3D high resolution geological model in depth.