Presented at: Exploration Geodynamics Chapman Conference.
Dunsborough, Western Australia, 19-24 August, 2001.

Study of spatial variability of surficial shallow water sediment properties with wavelet correlation analysis using synthetic data

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Abstract

Seismic waves traveling in the water/sediment or sub-bottom sediment interface have been the subject of considerable interest in underwater acoustics in recent years. Some progress has been made in understanding the propagation and attenuation characteristics of interface waves in different geological environments. However, the generating mechanisms are poorly understood. In particular, what is the acoustic-seismic energy conversion process? As seismic waves involve both time and space parameters it should be able to relate directly the propagation characteristics of the ocean bottom interface waves to the shear properties of the sediments over the propagation area. To address these problems we have applied the wavelet correlation method to examine the variations of bottom characteristics and their role in coupling waterborne sound into the sea bottom. To confirm the validity of the developed modeling technique, we created synthetic seismograms and applied wavelet correlation analysis for synthetic seismograms. We present images of the first and second shear modes and the Scholte wave (interface wave) component as a function of arrival time and frequency.

Introduction

Physical properties of surficial sediments play a prominent role in the geosciences and underwater acoustics. Near surface sediments affect acoustic wave fields in shallow water waveguides and govern conditions for operation of active sonar. Examination of the seabed acoustical properties, including the density and sound speed of the top sediment layers and sub-bottom of the sound field has shown [*Jin-Yan Lui et al., 2000*] that the variation in the acoustic properties inside the layer give rise to many characteristics that potentially allow for acoustic inversion of the physical properties of the sea-bed, which are important factors in geophysical exploration.

Wavelet transform has become a standard tool or software kit in identification of flow structure of turbulence and eddy analysis. Wavelet correlation analysis provides unique capability for extracting the most essential scales governing features of structures that change both in time and space. The wavelet method is successfully used in studies of turbulent flows and convection processes in air to identify possible coherent structures [*D. A. Yuen, et al., 2000*]. However, wavelet analysis has not been much used in seismo-acoustics. A multiple filter technique developed by Dziewonski [*1969*] introduces, probably, the only known successful application of wavelet transform (1-D wavelet transform) to visualize seismic signal in terms of their arrival times (group velocities) and frequencies.

Motivation and Objectives

The major motivation and objective of this study is to apply wavelet analysis to study near surface sediments and develop a new diagnostic technique for extracting physical properties from seismic data. The proposed diagnostic technique will overcome limitations of the traditional methods, such as Fourier analysis and correlation analysis which only describe signals in terms of frequencies and time delay. The new technique will offer the potential of extracting the essence of various structures from any type of seismo-acoustic fields, which are normally lost when using traditional analysis.

The main outcomes are expected in two categories: 1) development of the near surface sediments structure from the wavelet correlation analysis of simulation and experimental data 2) development of numerical methods, algorithms, and software based on wavelet correlation bases, allowing inversion of physical properties of sediments from standard seismic data.

Methodology

Synthetic time series of pulse modeling were done by Fourier synthetics from wave-number integration. The results of the propagation modeling from the sea bottom hydrophone perform first and second shear modes (at about 3 and 4 Hz) and the Scholte wave (interface wave) component centered at 2 Hz. The aim was to construct an environment that would lead to dispersion characteristics in agreement with the experimental results we have from out shallow water trial in May, 2001 (Rottnest Island). Using explosives as sound sources, a shallow water experiment was carried out in which the propagation along different interface paths was measured by an array of three receivers located in the middle water and on the sea bottom. To obtain realistic input data for the propagation models, continuos seismic profiles were run along the propagation path.
Results of the wavelet cross correlation analysis applied to the experimental and synthetic data were used to develop a geoacoustical model of the near top sediments along the trial profiles.

Summary

We have presented results of applying the wavelet correlation analysis to study the shear properties of marine sediments. Developed technique applied to synthetic data gives a performance of different modes and types of seismic waves (first and second shear modes and Scholte waves) in terms of their arrival times (group velocities) and frequencies (Figure 1, 2, 3).

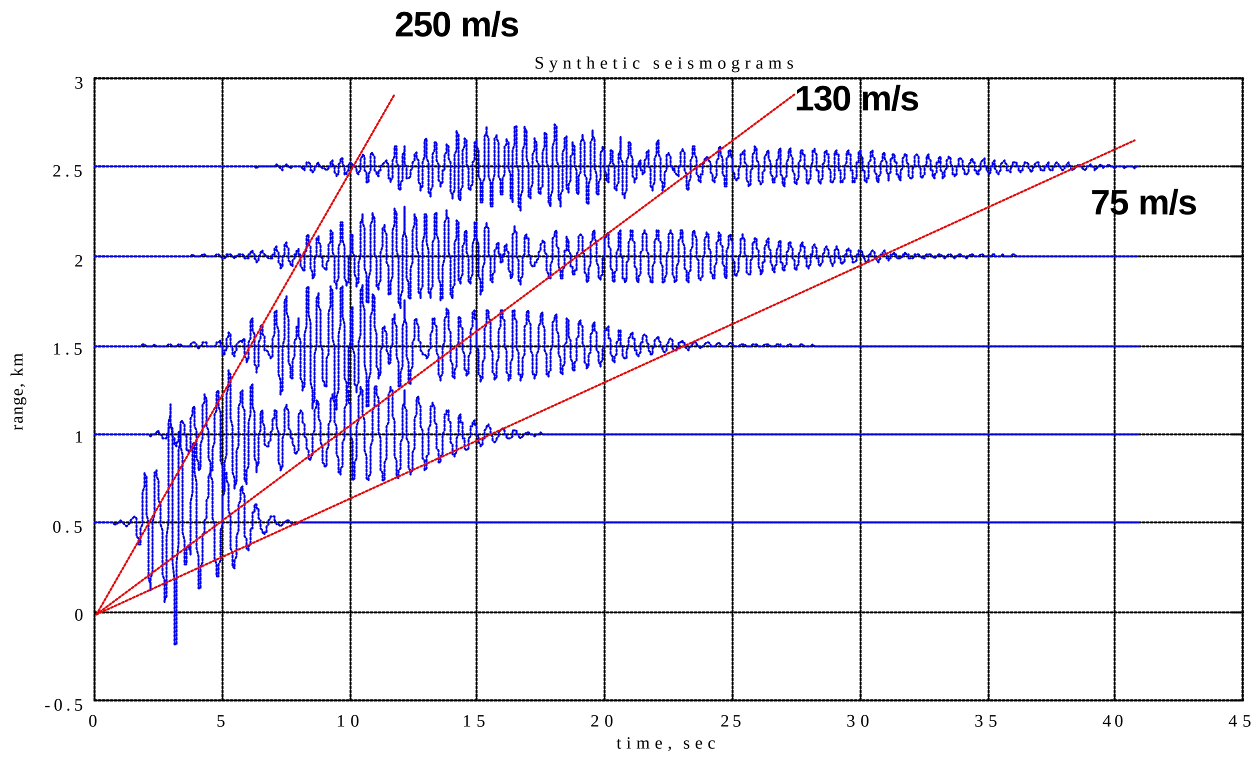

Figure 1. Synthetic data (receivers are distanced at 0.5, 1.0, 1.5, 2.0, and 2.5 km from the source).

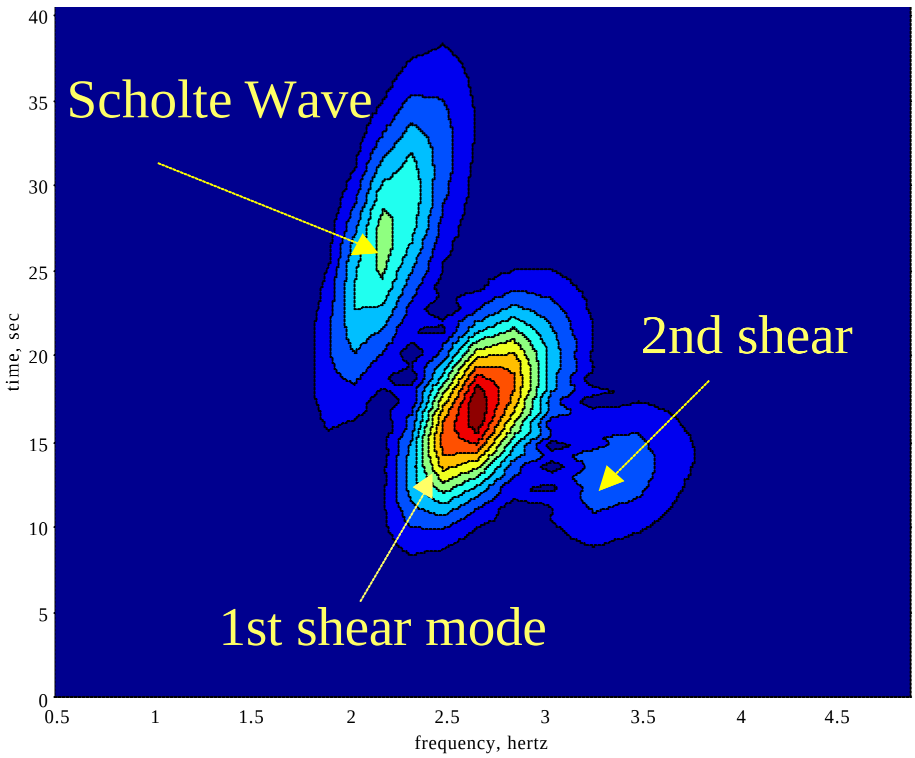

Figure 2. Result of applying of the wavelet method for the synthetic data (for the receiver distanced at 2.5 km from the source).

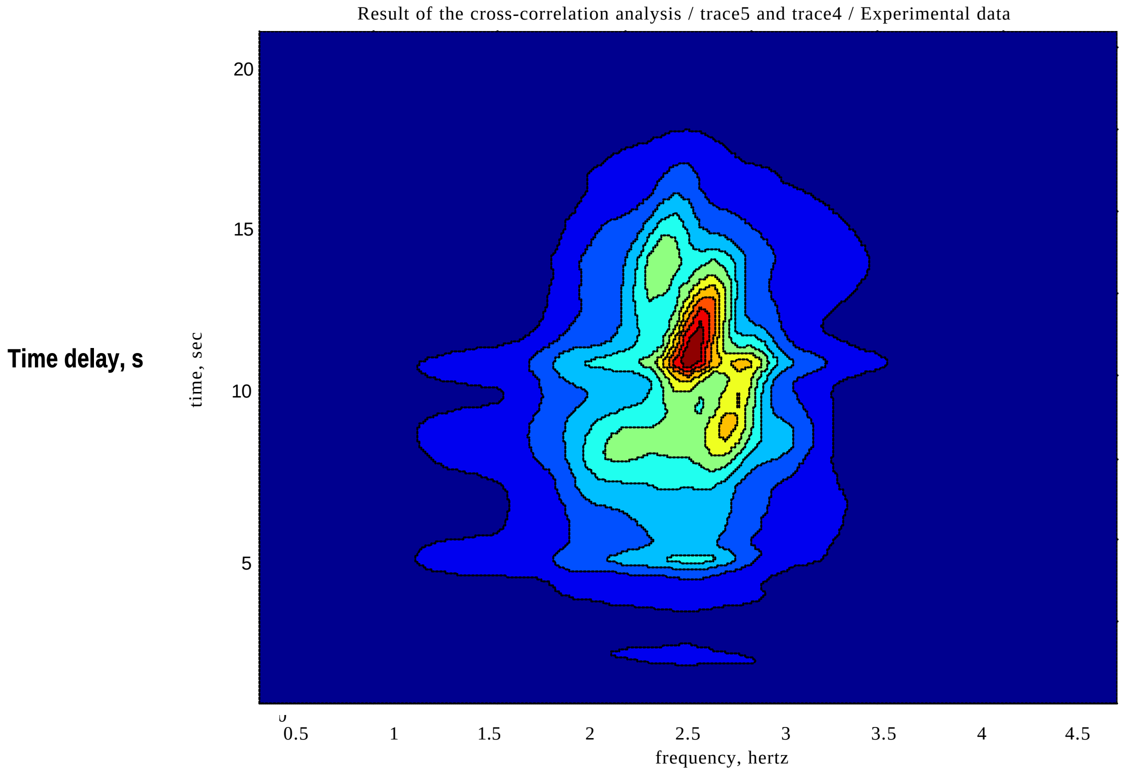

Figure 3. Results of the wavelet cross-correlation analysis (bottom hydrophone, experimental data) for receivers distanced at 2.5 km and 2 km from the source.

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