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14. ABSTRACT

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We are beginning a new series of laboratory acoustic experiments that will examine the detailed physics of acoustic-elastic scattering. These experiments will measure up-scattered acoustic waves, down-scattered elastic waves, and scattered interface waves from edges and embedded objects using a variety of sensors. One of our goals is to verify a density-contrast hypothesis upon which the Wedge Assemblage numerical rough-interface scattering model is based and which is applicable to many seafloor acoustic environments. We are predicting some of these experimental results with calculations using finite difference (FD) codes that are designed for 2 and 3-D acoustic and 2-D elastic environments. We will use these FD calculations to predict the range of validity of the density-contrast approximation and then design laboratory experiments with properties throughout and beyond this predicted range to the point of failure. Our laboratory experiments will also provide a test of the accuracy of the elastic scattering calculations by the FD codes.

1. INTRODUCTION: WAVEFIELDS IN PENETRABLE SURFACES

The purpose of this component of the Physical Modelling Project at the Naval Research Lab has two parts. One: determine the relative importance of scattered elastic wave phases, clarifying the subcritical scattering problem. Two: validate the density contrast hypothesis upon which the Wedge Assemblage model is based. Our approach is to construct a suite of physical models in water in which multiple types of elastic waves will be excited and to measure the extent of these converted elastic waves. In order to get the most information out of a limited number of physical models, we have calculated the expected responses from possible model properties and instrument configurations using numerical finite difference wave propagation codes. There are many wave propagation models that are very accurate for planar interfaces but none have been evaluated for through-propagating rough-surface scattering. We are currently running calculations with two acoustic finite-difference programs and two elastic finite-difference codes with environments that will highlight the significance of the converted elastic waves and to test the limits, at least in a few cases, of the density contrast hypothesis. We present here some of these results.

In our physical model experiments we anticipate using blocks of homogeneous material placed in a water tank. We will use transducer-generated sound waves in the water and measure the scattered waves with hydrophones in the water and with accelerometers on the surfaces of the elastic blocks.

2. PREDICTED IMPORTANCE OF ELASTIC-CONVERTED SCATTERED WAVES.

Understanding rough surface scattering is critical for marine seafloor acoustics. The simplest element of rough surface scattering is from a single edge. We are using the classic problem of an elastic (or acoustic) quarter space within an acoustic media (Figure 1). The sound source is within the water and we calculate the wavefield in the entire space for both the elastic and acoustic quarter space. By using a quarter space, we avoid possible scattering from a stair-step interface due to the square grids. For these calculations we used the finite difference that comes with the Seismic Unix (SU) software package [1]. The *suea2df* program within SU was written by Chris Juhlin of Uppsala University based on the algorithms of Juhlin [2] and Levander [3].

In both the acoustic and the elastic quarter space calculations, the direct wave, the corner scattered wave, the transmitted pressure wave and a few other phases are clearly visible (Figure 1). The difference of the acoustic and the elastic calculation shows that there is not only considerable energy in the elastic converted waves but there is also a difference in the scattered and reflected acoustic waves in the water.

The scattered interface waves remain very near the quarter-space surface and are slower than the transmitted and scattered shear waves. A physical experiment designed to test these calculations will need to have accelerometers placed on these surfaces. These calculations also suggest that scattered converted waves can be important in a seafloor type of geometry where there are multiple corners along a rough surface which can scatter these elastic waves back as acoustic waves in the water.

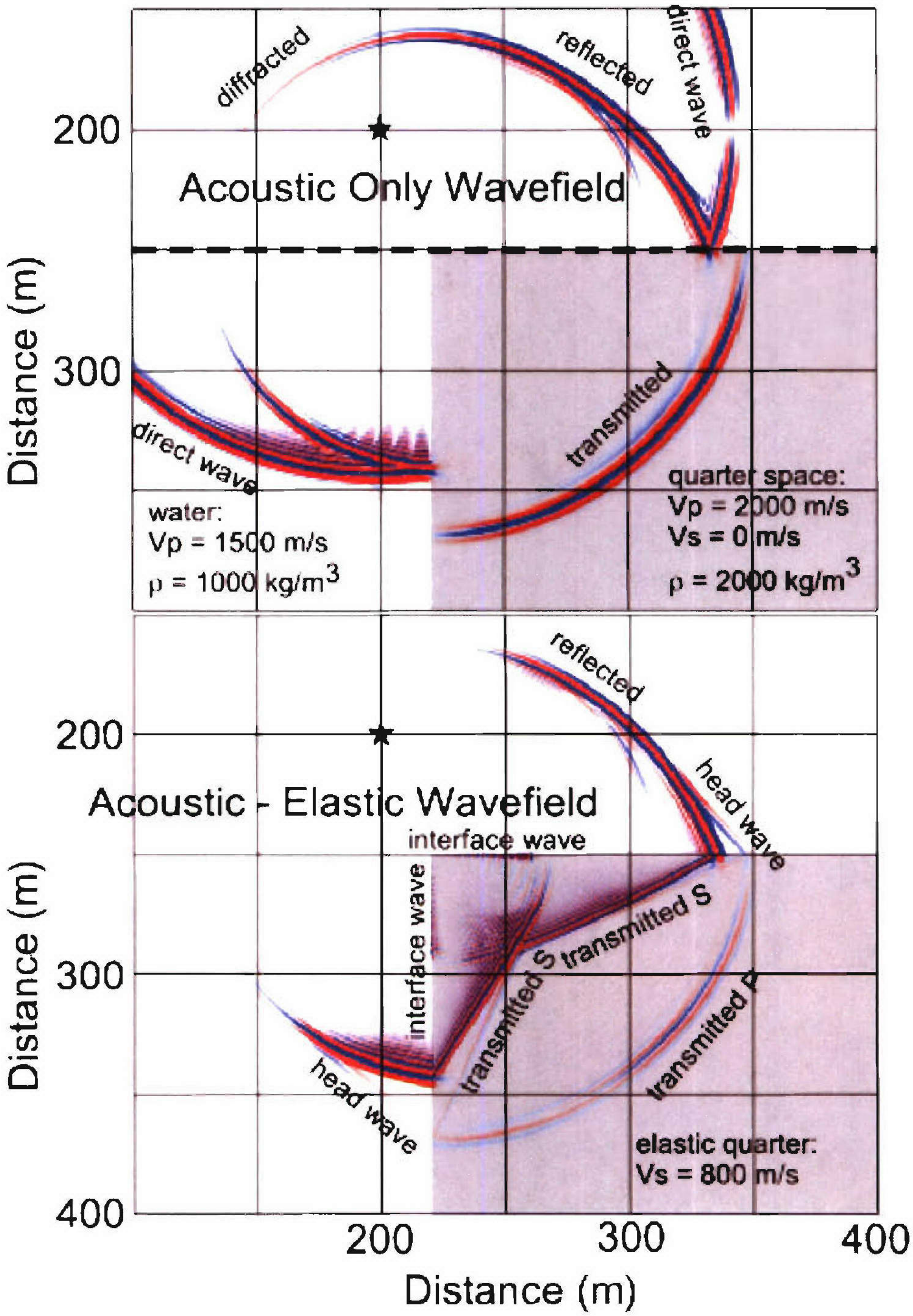

Fig. 1: Acoustic and elastic wavefield snapshots (at 0.1 seconds) as calculated by the vertical displacement. The source is at the black star. Positive and negative amplitudes are represented as blue and red. The lower pane shows the difference between the acoustic and the elastic calculations with strong interface waves and diffracted and refracted shear waves within the elastic body. The interface waves, although small in volume filled, have large amplitudes.

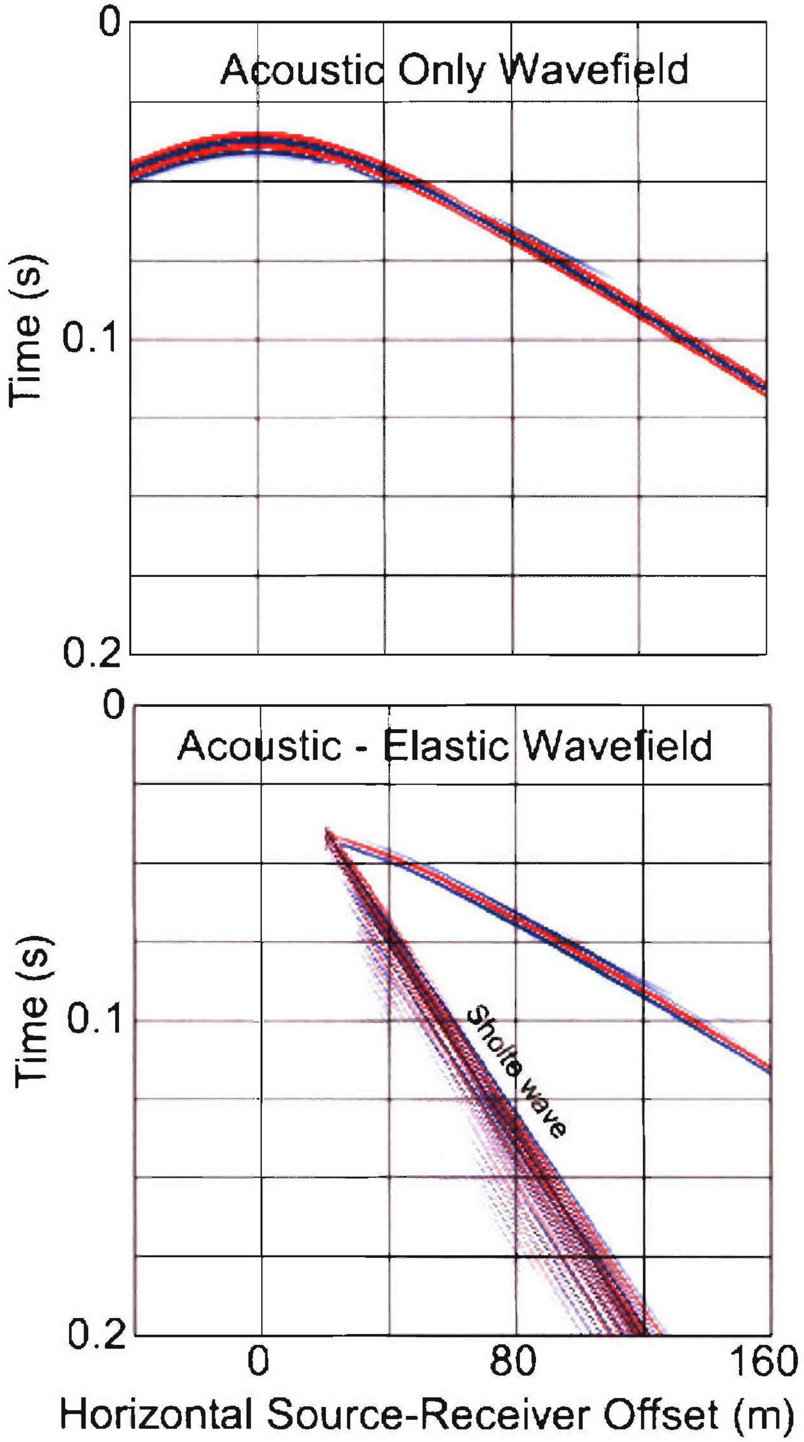

Fig. 2: The response of a line of sensors at 250 m depth in Fig. 2 (along the surface of the block) displayed in the fashion of a seismic record with time increasing downward. Positive and negative amplitudes are represented as blue and red. These sensors are located to show the strength of the interface waves, in this case Sholte waves generated from the purely acoustic source.

3. TESTING THE DENSITY CONTRAST HYPOTHESIS

It has been pointed out in a number of papers, (e.g., Hamilton [4]) that for many marine sediments the acoustic impedance contrast at the water/seafloor interface is driven primarily by changes in density and secondarily by changes in sound speed. Unconsolidated sediments common in low-energy environments are usually silts and clays with densities ranging from 1.2 to 1.6 g/cc and compressional wave velocities between 1450 m/s and 1600 m/s. Even in coarse sands where the sound speed ratio (water/sediment) may reach 1.2, the change in density controls the variation in the impedance. The so-called "density-contrast hypotheses" proposes that acoustic scattering from rough marine sediments can accurately be predicted through consideration of the interface roughness and the changes in density at the interface.

In this preliminary study, a FDTD solution to the 2D acoustic wave equation was used to calculate the apex-diffracted signals from 90° wedges having different densities and compressional wave speeds. Three densities (1.5, 2.0, and 2.5 g/cc) and three compressional wave speeds (1500, 1575, and 1650 m/s) were used. The line source in this problem consisted emitted a Gaussian-tapered cosinusoidal signal centered at 300 Hz. Figure 3 shows the diffracted signals detected at a receiver located near the source for the case where the wedge density was 1.5 g/cc. Of all the cases studied, this was the example that showed the greatest sensitivity to changes in the compressional wave speed. Here, it can be seen that the diffracted signal is relatively unchanged by a 5% change in sound speed but a 10 % change in compressional velocity inside the wedge dramatically changes the magnitude of the diffracted signal.

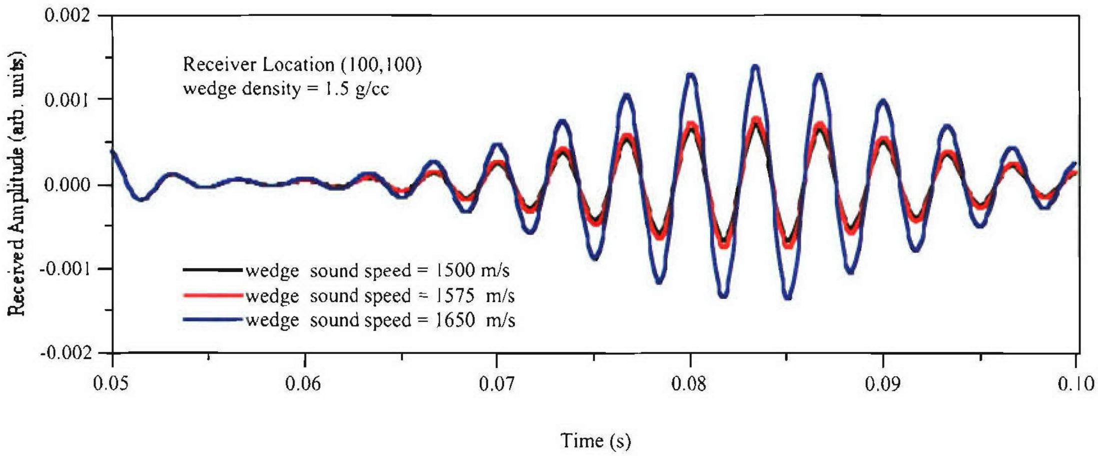

Fig. 3. Sensitivity of apex-diffracted signals to compressional wave speed contrast

Repeating this numerical experiment, that is using the same source and receiver location but now using a denser wedge material (now 2.5 g/cc) yielded results which were insensitive to variations in the compressional wave speed (Figure 4). These results suggest that the density contrast hypothesis is valid for a broader range of compressional wave speeds when the density is high (such as for a sandy seafloor) than for low densities (as for silty seafloors).

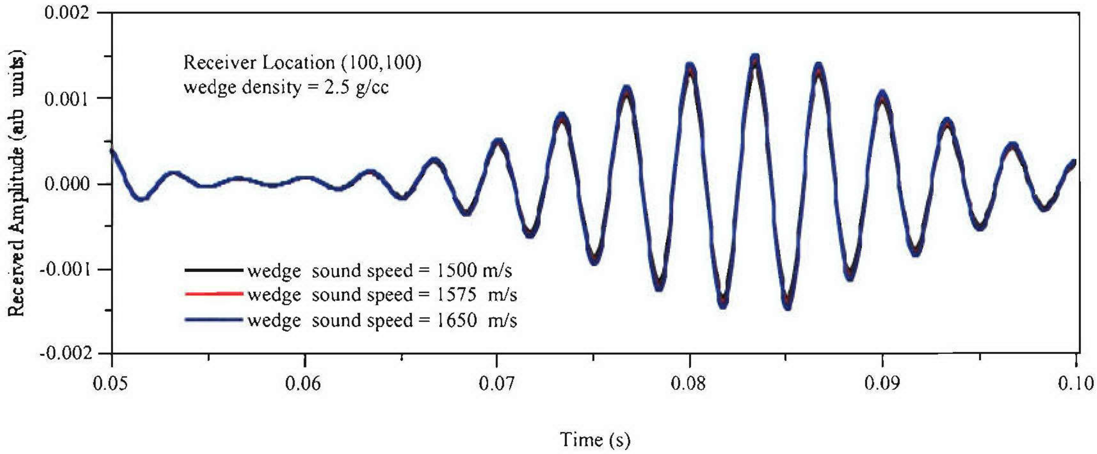

Fig. 4 Sensitivity of apex-diffracted signals to compressional wave speed contrast

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