Some 2D results from the U of C Seismic Physical Modelling Facility

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ABSTRACT

We have made progress in upgrading the Physical Seismic Scale Modelling Facility at the University of Calgary and bringing it back on line. Linear electric motors and motion tracks from Parker/Daedal and Parker Motion Control have been assembled and wired to provide precise movement and positioning of mm-sized piezoelectric transmitters and receivers. We use vendor-supplied hardware and software installed on PC computers to control the motors moving transmitter and receiver transducers in the x, y, and z directions. We have updated circuitry for producing high-voltage pulses to drive transmitting transducers and for amplifying receiver signals in the 50 kHz to 900 kHz range. We present examples of 2D seismic gathers recently recorded using the Physical Modelling Facility operating in a semi-automatic mode.

INTRODUCTION

Seismic scale modelling has been done at the University of Calgary Seismic Physical Modelling Facility for many years (Cheadle et al., 1985; Lawton et al., 1989). Recently, the facility has undergone extensive upgrading to take advantage of precision positioning systems made possible by finely controlled motors (Bland et al., 2006). Linear electric motors and motion tracks from Parker/Daedal and Parker Motion Control enable us to locate transmitting and receiving piezoelectric transducers to within at least 0.1 mm. New, more robust high-voltage circuits have been designed to drive the transmitting transducers and generate source wavelets with dominant frequencies in the range 100 kHz to 1.0 MHz. Received signals are amplified, digitized, and recorded using a data acquisition board (GageScope model 1450), or a digital oscilloscope (Tektronix. model 2014).

At present, these basic functions are working and can be controlled by computer individually. However, integrating them into a single master control program for fully automated operation remains to be done. Hence, the upgrading is not yet complete, and the facility is operational only on a semi-automatic basis. Nevertheless, after an interruption of several years, we now have the ability to collect model seismograms. As evidence of this progress, we present gathers of seismograms from two model experiments simulating marine seismic surveys.

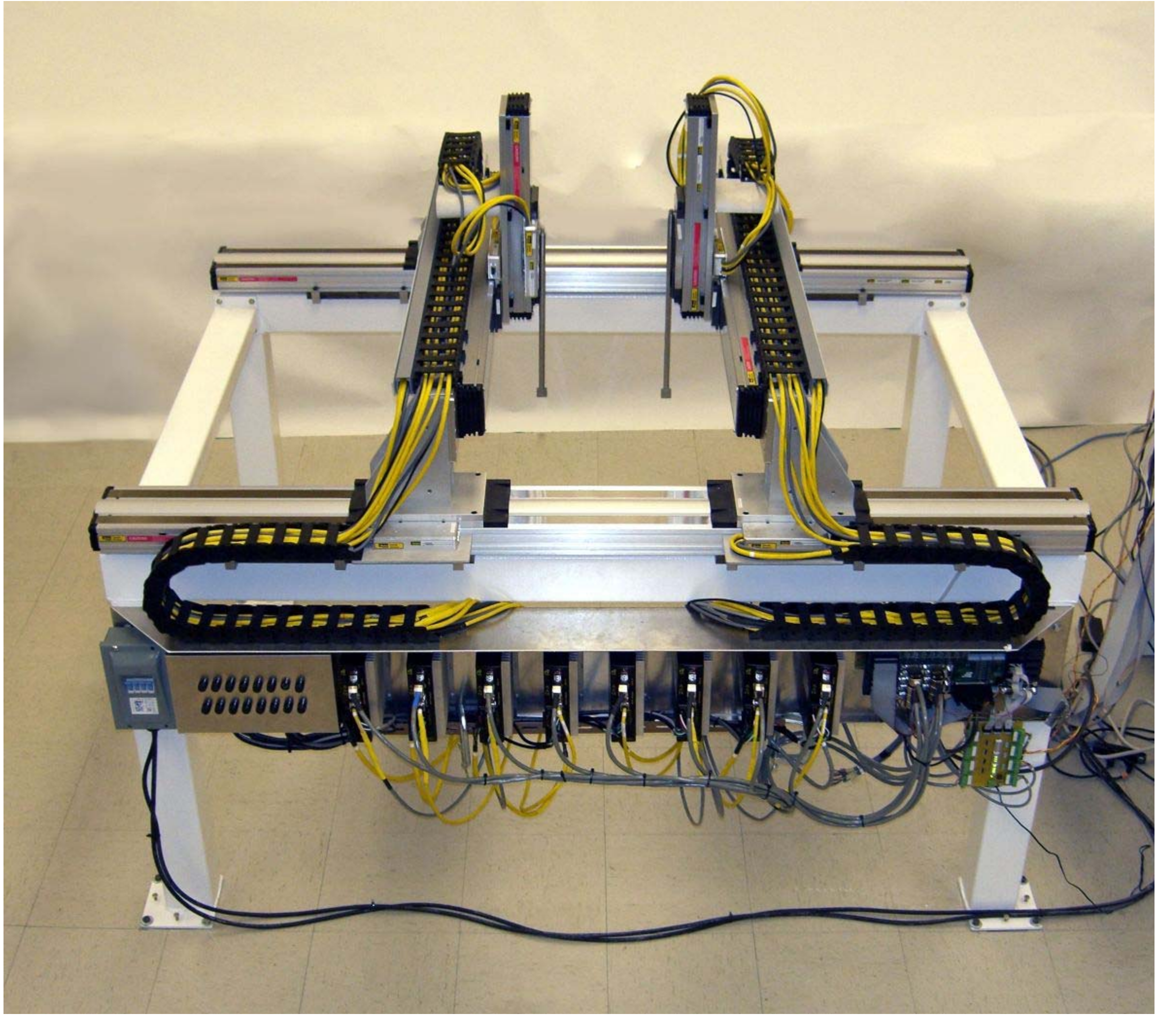

FIG. 1. Positioning system with 8 linear motors for the Physical Seismic Modelling Facility (From Bland et al., 2006).

THE POSITIONING SYSTEM

Figure 1 shows the positioning system. The ends of two beams rest on two tracks. Each beam is moved along these tracks in the x direction (left to right on the photograph) by two linear motors. On each beam is mounted a track with one linear motor that moves in the y direction. On each of these y motors is attached a short vertical track with another motor that moves up and down in the z direction. A carriage for holding transmitting and receiver piezoelectric transducers is bolted to each of the two z motors. This configuration of tracks and linear motors enables the positioning system to move and locate transmitters and receivers independently with 0.1 mm accuracy. The flexibility and precision of the positioning system will be crucial for modelling 3D surveys. The motors span about 800 mm in the x direction, 1180 mm in the y direction, and 160 mm in the z direction. When a scale factor of 10,000 is applied, the x-y dimensions represent a real-world survey area of about 8.0 km by 11.8 km.

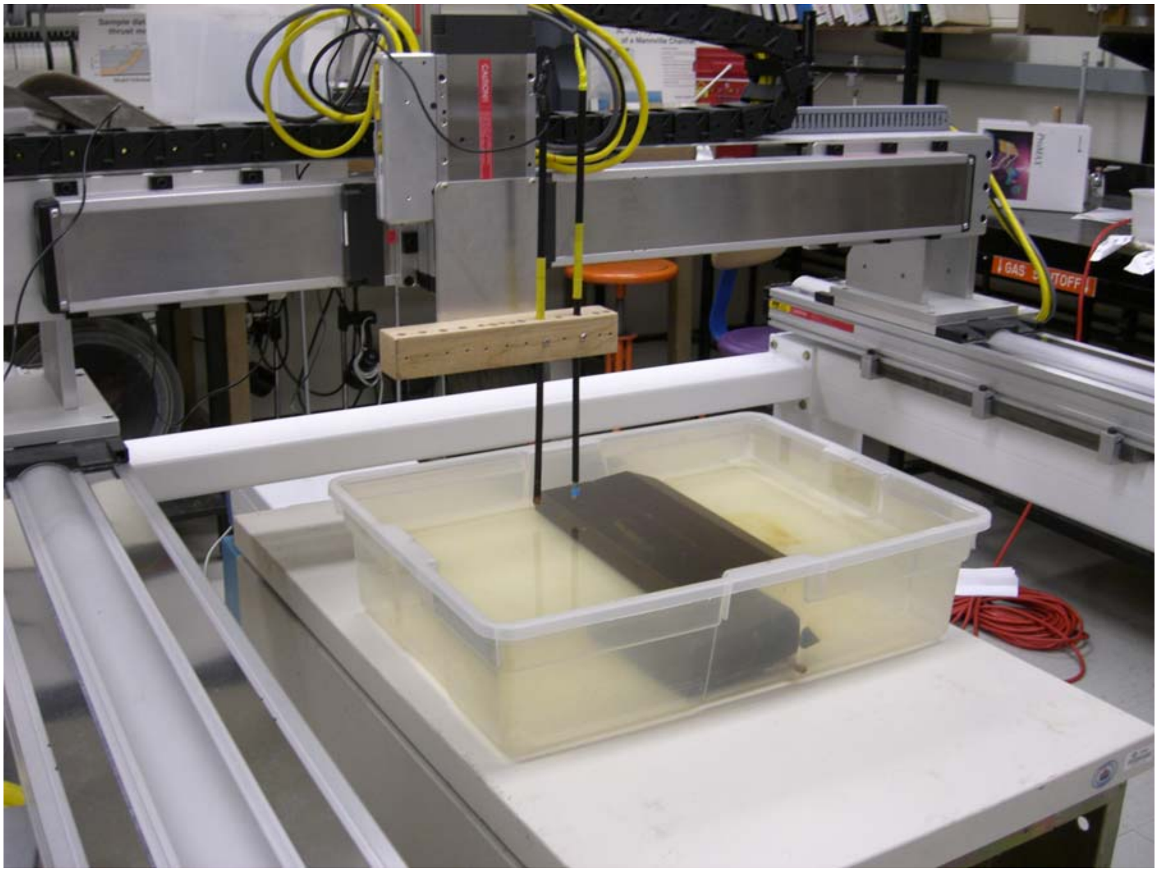

FIG. 2. Rx and Tx transducers mounted over a phenolic model in water.

MODEL MEASUREMENTS

We made test measurements using the current capability of the modeling facility. Figure 2 is a photograph of a pair of receiver (Rx) and transmitter (Tx) piezoelectric transducers attached to the carriage on one of the beams. The figure also shows a phenolic body immersed in a plastic container of water. This was Model #1 for our test measurements, and represents a reflecting target in an acoustic medium.

The particular transducers shown in the photograph have peak responses at about 310 kHz. For a scale factor of 10,000, this would be equivalent to a dominant frequency of about 31 Hz for a real-world survey. In the test surveys, the Rx-Tx offset was kept fixed at 38 mm. The hemispheric transducers (6.0 mm diameter with about 0.6 mm wall thickness) were immersed approximately 3 mm into the water using attachment rods. The transmitting transducer was driven with 150V pulses, and received signals were sent through a preamplifier with gain of 1000 to the Tektronix 2014 oscilloscope for digitizing. We recorded seismograms with a sampling time of 2μs and trace lengths of 2500 points. Profiles were recorded in the y direction (into the page in Figure 1) with a spatial sampling interval of 2 mm. Profile lengths were restricted to about 450 mm by the size of the plastic container.

Model #1

Figure 3(a) is a close-up photograph of Model #1, and Figure 3(b) shows the cross-section view schematically. The gross dimensions of the body are about 280 mm long by 160 mm wide by 55 mm high. The depth of the water to the bottom of the plastic was about 139 mm. The depth to the top of the phenolic body varied from 68 mm to 84 mm. The depth to the bottom of the body is about 139 mm but rises to 112 mm at the raised tip on the right side of the body.

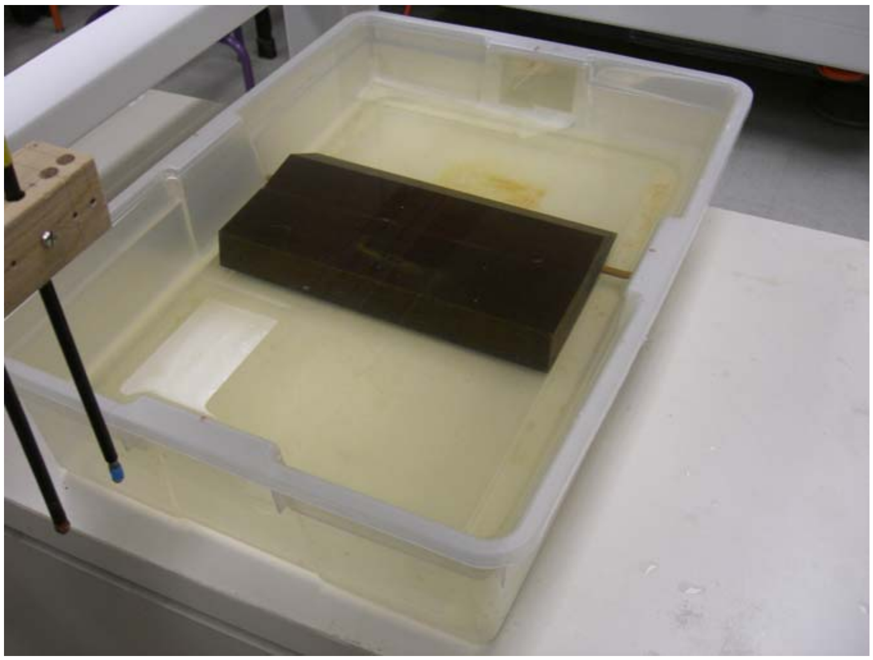

FIG. 3a. Close-up photograph of Model #1 (phenolic body in water).

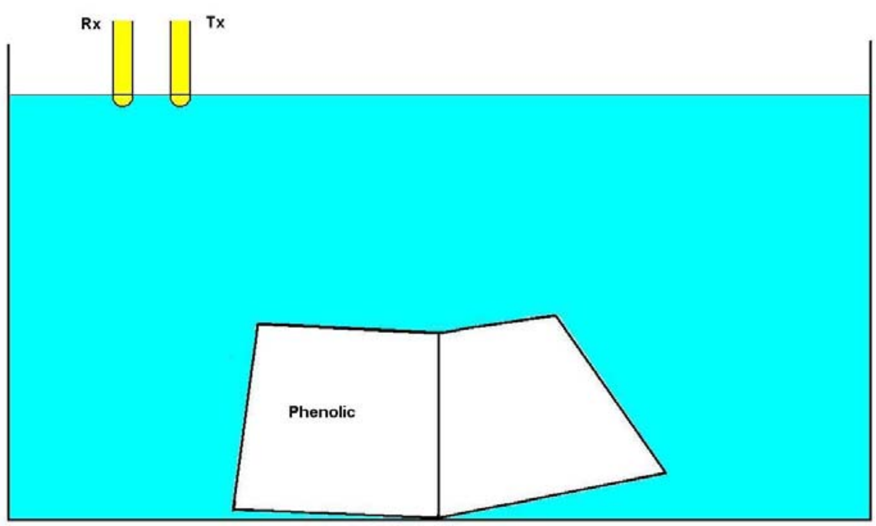

FIG. 3b. Schematic diagram showing the geometry of the 2D survey over Model #1.

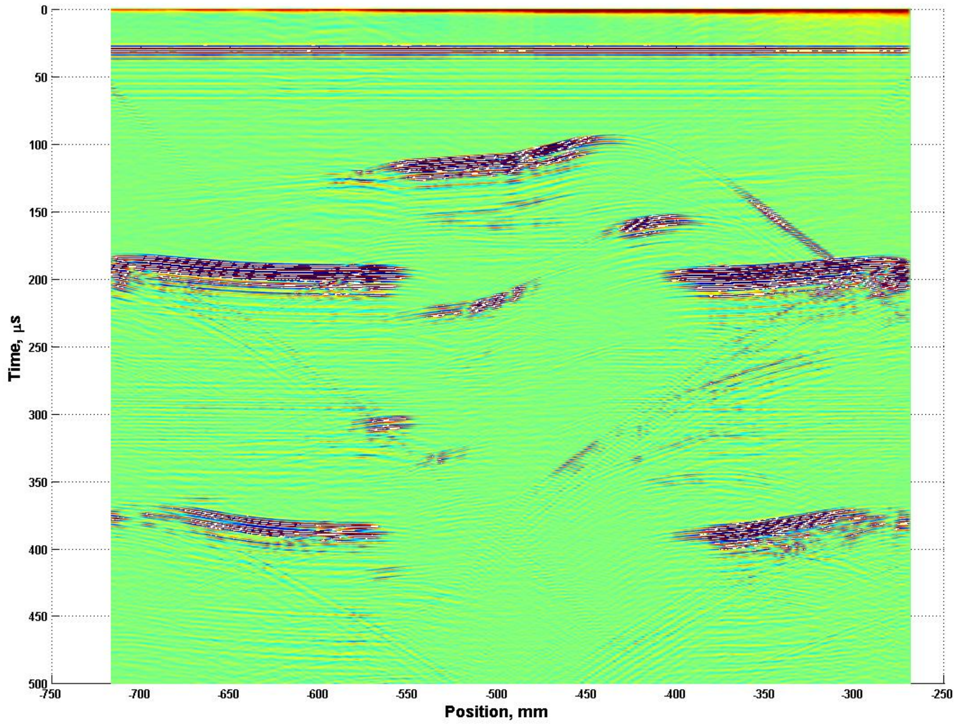

FIG. 4a. Common offset gather for Model #1. Note the presence of multiples.

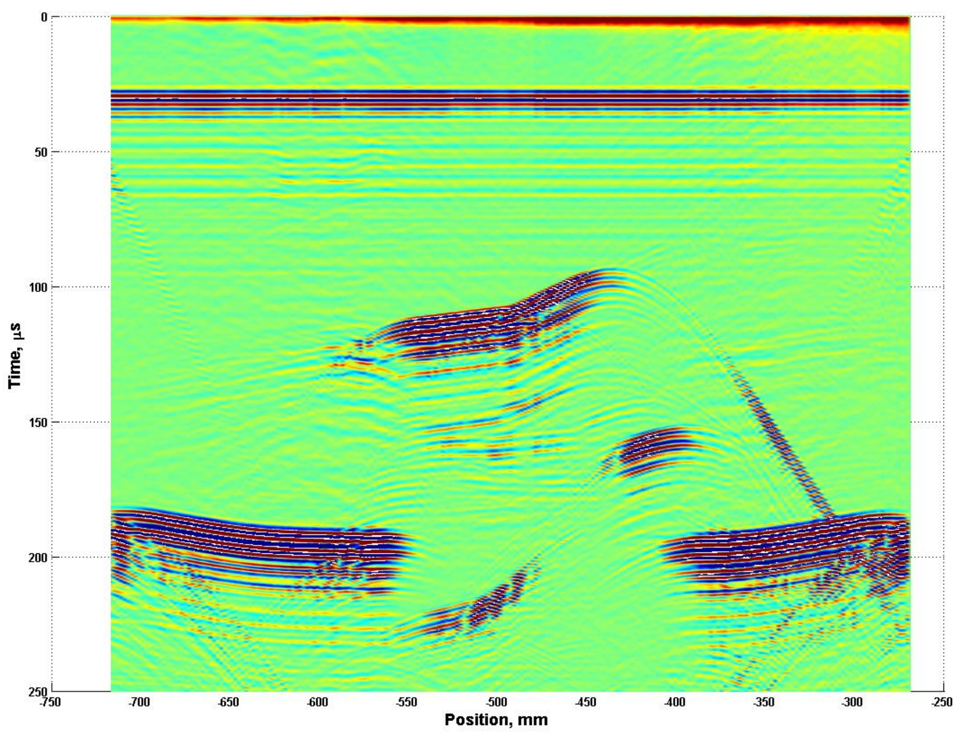

FIG. 4b. Common offset gather for Model #1 with expanded time scale.

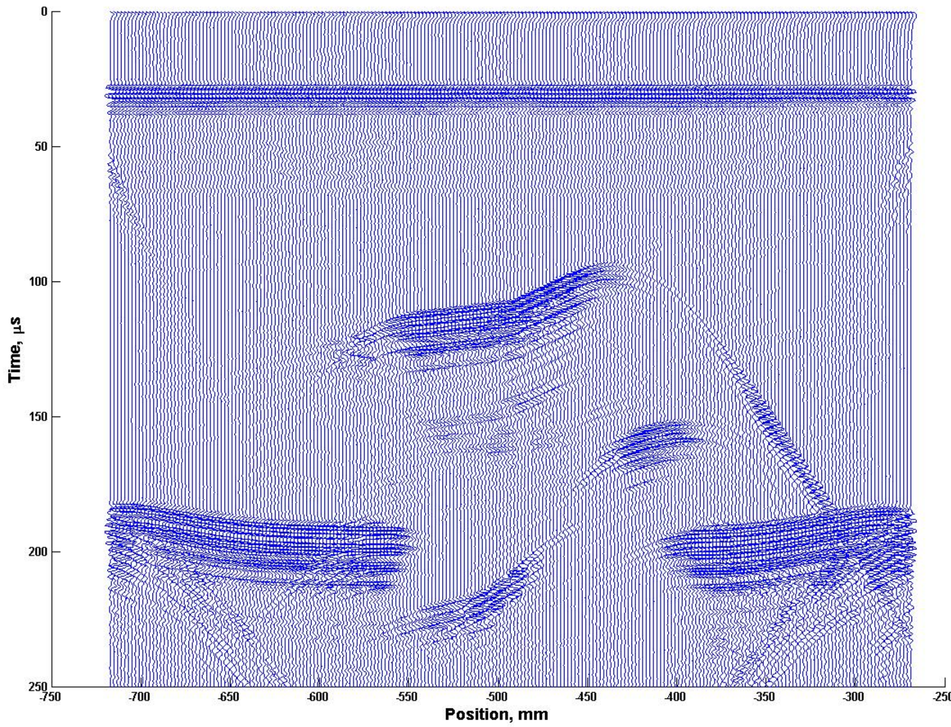

FIG. 4c. Common offset gather for Model #1 in wriggle trace format.

Figure 4(a) shows the raw common offset gather over Model #1. The horizontal event at 25 µs is the direct arrival through water from the transmitter to the receiver. The reflection near 180 µs is from the bottom of the plastic container. It is not flat because the bottom is pushed down by the weight of the water. The primary reflections are very clear, but the first multiples from the bottom of the plastic container and the top of the reflecting target are also very strong. The gather is plotted with expanded time scale on Figures 4(b) and 4(c) to show more detail associated with primary reflections and diffractions. On the wriggle trace format, it is apparent that the source wavelet is ringing, and deconvolution is an obvious first step in future processing of this data. Most of the events on Figure 4 can be tied easily to the various reflecting surfaces on Model #1.

Model #2

Model #2 is the same as Model #1, except that a length of round steel tube (155 mm long with a diameter of 38 mm and wall thickness of 2 mm) and a short piece of square steel tubing (65 mm long and 13 mm with wall thickness of 2 mm) were placed on top of the phenolic body to act as extra reflectors. Figure 4(a) is a close-up photograph of Model #2, and Figure 4(b) is a schematic diagram representing a cross-section in the profile direction. The depth to the top of the round steel tube was about 40 mm.

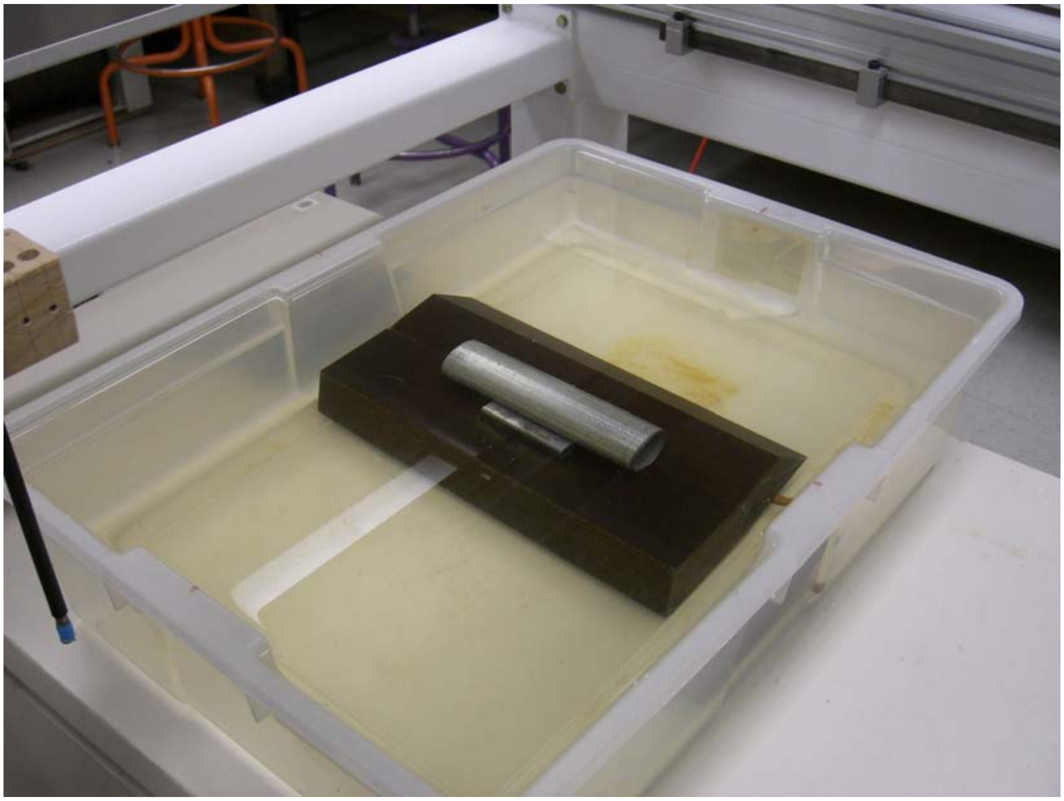

FIG. 5a. Close-up photograph of Model #2 (phenolic body and steel tubes in water).

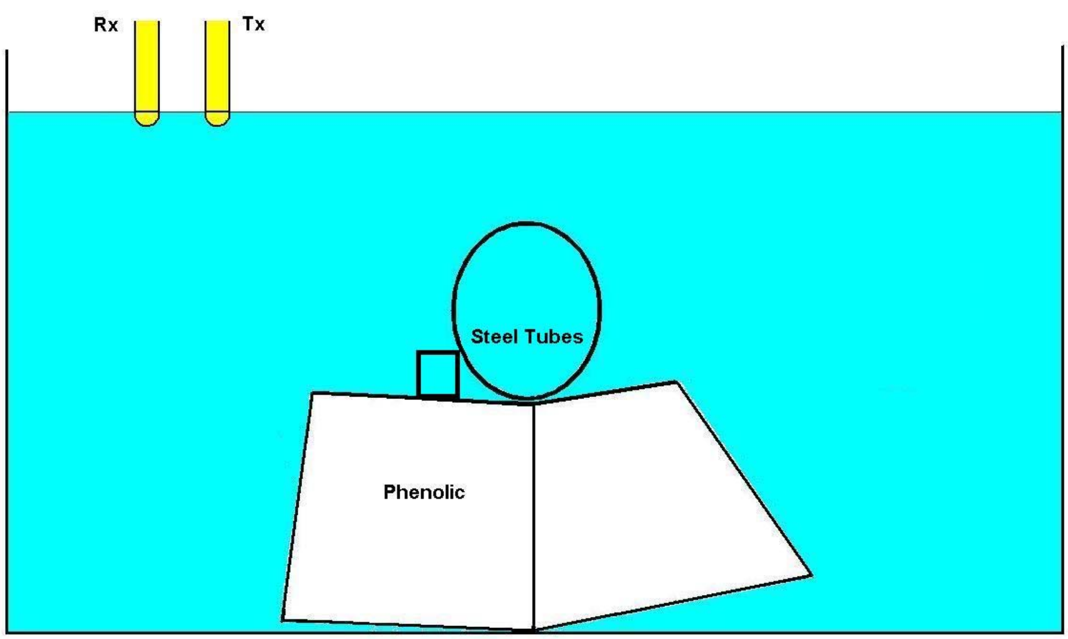

FIG 5b. Schematic diagram showing the geometry of the 2D survey over Model #2.

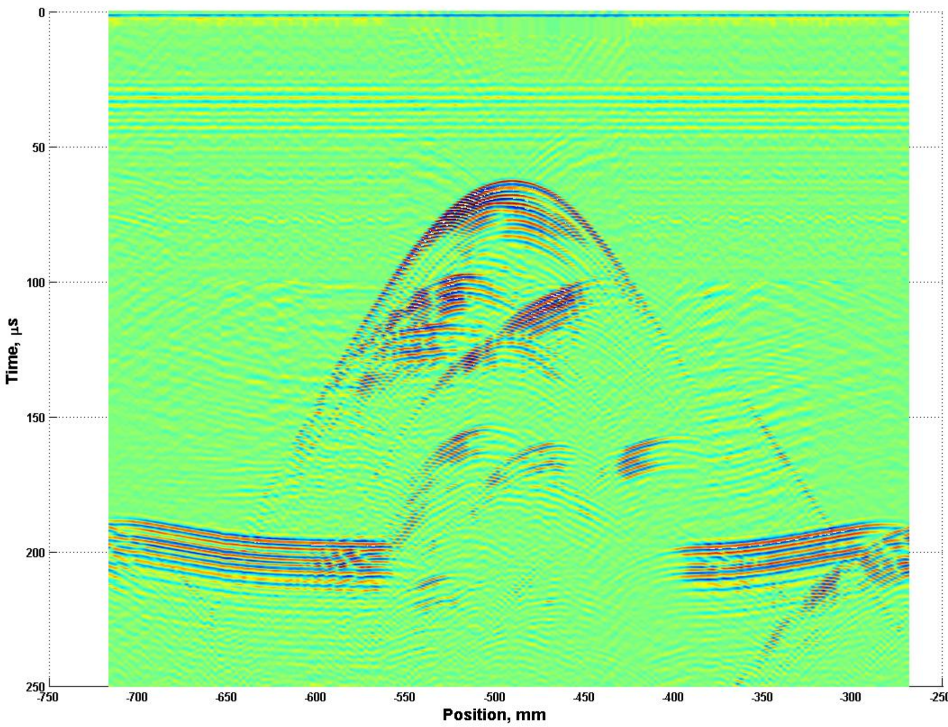

FIG. 6a. Common offset gather for Model #2.

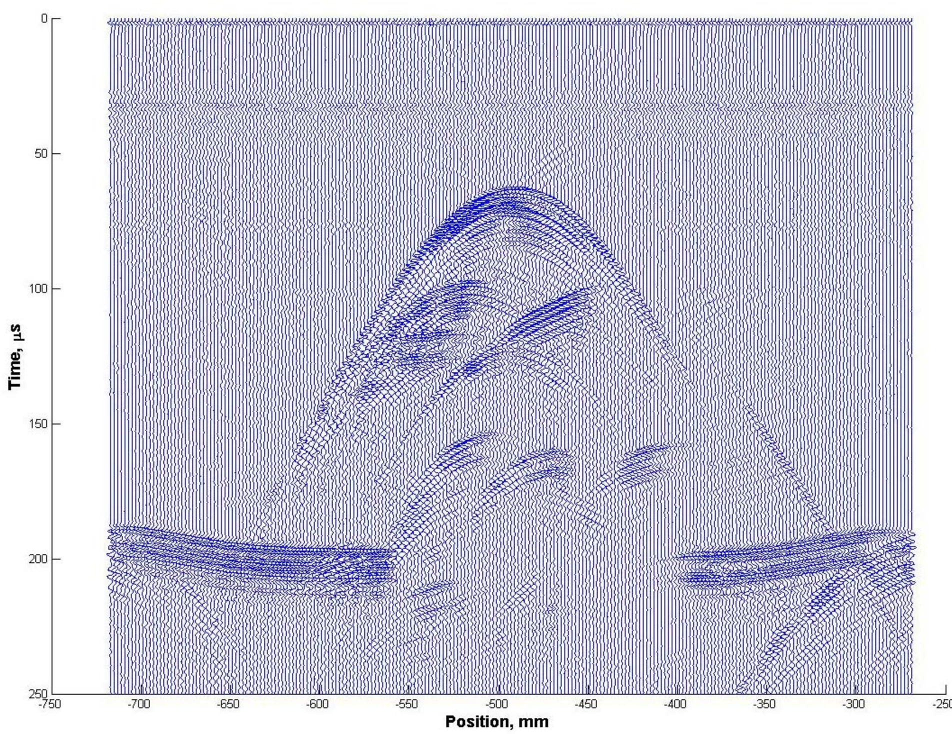

FIG. 6b. Common offset gather for Model #2 in wriggle trace format.

Figure 6(a) is the common offset gather over Model #2. There are many reflections and diffractions on this gather, indicating the complexity of the measured wavefields even for a relatively simple model. The primary reflections off the tops of the steel tubes and the phenolic can be identified quite easily. However, reflections off the bottoms are obscured by the first multiple events related to the top reflecting surfaces. We note again that the appearance of the gather would improve if deconvolution were to be applied to the ringing wavelets. Datasets such as these will serve as good benchmarks for researchers developing new processing and imaging algorithms.

DISCUSSION

After a long hiatus, the University of Calgary Physical Seismic Modelling Facility is again operational. At present, it functions only in a semi-automatic mode, and the acquisition electronics and control software are still in a developmental state. In spite of this, we have been able to collect seismograms for situations simulating marine seismic surveys. We will continue to work on optimizing the transmitter and receiver electronics. Our most immediate goal is to devise software to enable automated unattended acquisition procedures. Such a master control computer program is absolutely essential if we are to collect on the order of 100,000 seismograms for each model. We anticipate that, within the next six months or so, we will be able to efficiently simulate many different exploration scenarios on land and sea, employing either acoustic or elastic waves. Ultimately, the goal is to have a fully automated system capable of recording 3D-3C datasets of 10,000 to 100,000 seismograms efficiently and in reasonable time frames.

The construction of solid models with different seismic properties (density, P and S velocities, anisotropy, and attenuation) and complex geometries is expensive and time-consuming. For many situations, sufficient variations in at least some of the seismic properties can be achieved by using mixtures of sand (or glass beads), clay, and several choices of liquids. Fairly complex geometries can be achieved quickly and economically. Sherlock and Evans (2001) have exploited these ideas to perform a series of illuminating seismic experiments on what they termed as sandbox models. Although issues remain in controlling the seismic properties of unconsolidated mixtures, we intend to explore physical modeling with sand/clay/liquid mixtures, particularly in combination with solid reflecting targets.

ACKNOWLEDGEMENTS

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