Physically–modeled 3D survey over a channel structure

Joe Wong, Kevin Bertram, and Kevin Hall

ABSTRACT

We set up a physical model consisting of a PVC slab overlying an acrylic slab with a cut channel with both immersed in water. A 3D marine survey was conducted over an area with scaled X-Y dimensions of 5000m by 5000m. Both source and receiver lines were along the Y direction, with line separations of 100m. Source and receiver intervals along the lines were 50m. In this initial survey, the channel is water-filled. In possible subsequent surveys over this model, specific zones in the channel will be filled with tiny glass beads or fine sand, and 3D acquisition will be done with the sand zones saturated with water and air. Such an experiment would generate a physically-modeled dataset simulating a 4D survey over a gas injection project.

INTRODUCTION

We have set up a scaled seismic physical model consisting of a PVC slab overlying a Plexiglas slab with a channel structure machined into it. The two slabs were immersed in water, creating a three-layer water-PVC-acrylic assembly. Figure 1 is a photograph of the cut channel in the acrylic layer. Figure 2 is a side view of the physical model. Table 1 lists the seismic properties of the materials involved.

Table 1: Seismic properties of materials in the model.

Material	V_P, m/s	V_S, m/s	ρ, kg/m^3
Water	1485 ± 1%	0	1000
PVC	2350 ± 2%	1120 ± 2%	1300 ± 1%
PLX	2745 ± 2%	1380 ± 2%	1190 ± 1%

Using the University of Calgary Seismic Physical Modeling Facility (Wong et al., 2009), a 3D marine survey is being conducted over the channel model of Figure 2. The area with being surveyed has scaled X-Y dimensions of 5000m by 5000m. The plan is to occupy source lines (similar to the ones shown on Figure 1) separated by 50m. Currently, the survey is in the preliminary stages, and only about 20 of the planned 101 source lines have been occupied for recording data. At this time, we have only partial 3D coverage: every source line is associated with only one receiver line offset to the source line by 100m or 150m (the plan is to have 20 receivers lines associate with each source line). Source and receiver intervals along the lines were 50m. The number of distinct seismograms for the planned full 3D coverage is on the order of (101 x 101 x 101 x 20), i.e., more than 20 million.

OBSERVATIONS

Figures 3 to 6 show a selection of common-source and fixed-offset gathers of seismograms from the survey (the full seismograms are 2000ms long and are digitized at 1ms or 2ms intervals). The gathers indicate some of the features that are expected to be visible in the data cube formed from processing and migration of the final fully recorded 3D dataset. For example, the effect of the water-filled channel on reflections is very evident on the common-source gathers shown on Figure 3. In the absence of the channel in the near-offset seismograms, the reflection at about 1280ms from the bottom of the PLX layer with the cut channel is very clear. When the channel is present in t raypaths of the near-offset seismograms, the reflection from PLX bottom disappears (actually it has been pulled down to below 1400ms by the low-velocity water in the channel).

On Figure 4 to 6, the strong reflection above 8000ms is from the water-PVC interface. The reflection just below 900ms is from the bottom of the PVC layer. The reflection at about 1290-1300ms is from the bottom of the PLX layer with the channel. On figure 4, events and arrival pull-downs at profile positions between -350m and 50m reveal the presence of the channel. On Figure 5, the same events and pull-downs occur at positions between 800m and 1200m, while on Figure 6, they occur at positions between -800m and 400m. The two step-like features at about 1060ms and 110mm are reflections from the bottom boundary of the channel, and reflect the detailed structure within the channel that visible is on the photograph of Figure 1.

While the survey is incomplete, we can start to construct rough estimates of what the 3D data cube for the future full survey might look like. We have taken fixed offset gathers like those on Figures 4 to 6, and construct a time slice of amplitudes averaged over the time interval 1000ms to 1120ms. On Figure 7, the averaged amplitudes for seven source lines are overlain with their proper XY survey positions on the photograph of the channel. We can see that, in this very crude analysis of existing preliminary data, the high amplitudes for the time slice correspond with the location of the channel.

Method to decrease time to do a complete high-resolution 3D survey

At this point in time, our acquisition has completed only a fraction of the full planned 3D coverage. We plan to finally occupy 101 source lines at intervals of 50m in the X-direction. Presently, we have data for only about 20 source lines, and each is associated with only a single receiver line offset in the X-direction from the source line by 100m or 150m. Continued acquisition will add 20 more receiver lines with distance from the source line increasing in steps of 50m. The planned high-resolution survey over the channel model likely will take several hundred hours to complete if we continue to use a single source transducer (Wong, 2013). The most direct way to decrease survey time is to increase some of the following survey parameters: source interval, source line interval, receiver interval, receiver line interval. For example, if in our survey we increase the source interval and the source line interval to 100m from 50m, we would decrease survey time by a factor of 4. We also could limit the number of far source-receiver offset measurements. However, any of these actions would decrease data fold and image resolution.

It is possible to do the surveys using an array of four or eight source transducers running simultaneously (Wong, 2013). Such an array of four source transducers is shown on Figure 8. By acquiring data with four simultaneous sources, we would decrease the time to complete a 3D survey by a factor of four. However, the recorded signals would be sums of the signals from the individual sources, and these summed data must be separated or deblended to obtain ordinary common-source gathers before standard processing and imaging techniques can be applied.

Figure 9 displays an example of a gather of summed traces, where we see that the signals from the individual source transducers show very different time moveouts... On the basis of the different time moveouts, techniques such as shifted apex radon transforms (Trad et al., 2012) and generalized deconvolution (Sacchi et al., 1998) can be used to separate the blended gather into individual common-source gathers. The effectiveness of deblending processes depends on the degree of difference in the time moveouts. These in turn depend on the separation between the sources in the array.

CONCLUSIONS

The purpose was to image a water-filled channel cut into the acrylic layer. In this initial survey, the channel is water-filled. In possible subsequent surveys over this model, specific zones in the channel will be filled with tiny glass beads or fine sand, and 3D acquisition will be done with the sand zones saturated with water and air. Such an experiment would generate a physically-modeled dataset simulating a 4D survey over a gas injection project. It is possible to continue this modeling project by doing a repeat survey after creating water-saturated zones in the channel filled with very small glass beads or very fine grain sand with average diameters much less that the acoustic wavelength in water ($\lambda_w \sim 3.7$ mm). A third survey could be done after using compressed air to force water out of the glass-bead-filled zones. If the reflection data from these two latter surveys are of sufficient quality, then we would have a physically-modeled dataset simulating a 4D (time-lapse) seismic survey over a gas injection project.

ACKNOWLEDGEMENTS

We thank the industrial sponsors of CREWES and the Natural Sciences and Engineering Research Council of Canada for supporting this research.

REFERENCES

Sacchi, M.D., Verschuur, D.J., Zwartjes, P.M., 2004, Data reconstruction by generalized deconvolution, 74th Annual International Meeting, SEG, Expanded Abstracts, pp. 1989-1992.

Trad, D., Siliqi, R., Poole, G., and Boelle, J.L., 2012, Fast and robust deblending using apex shifted Radon transform, 82nd Annual International Meeting, SEG, Expanded Abstracts, DOI http://dx.doi.org/10.1190/segam2012-0703.1.

Wong, J., Hall, K., Gallant, E., Maier, R., and Bertram, M., 2009, Seismic physical modeling at the University of Calgary, CSEG Recorder, 36, 25-32.

Wong, J., 2013, Seismic physical modeling I: acquisition of 2D and 3D surveys involving HTI targets, CREWES Research Report 25, 83.1-83.14.

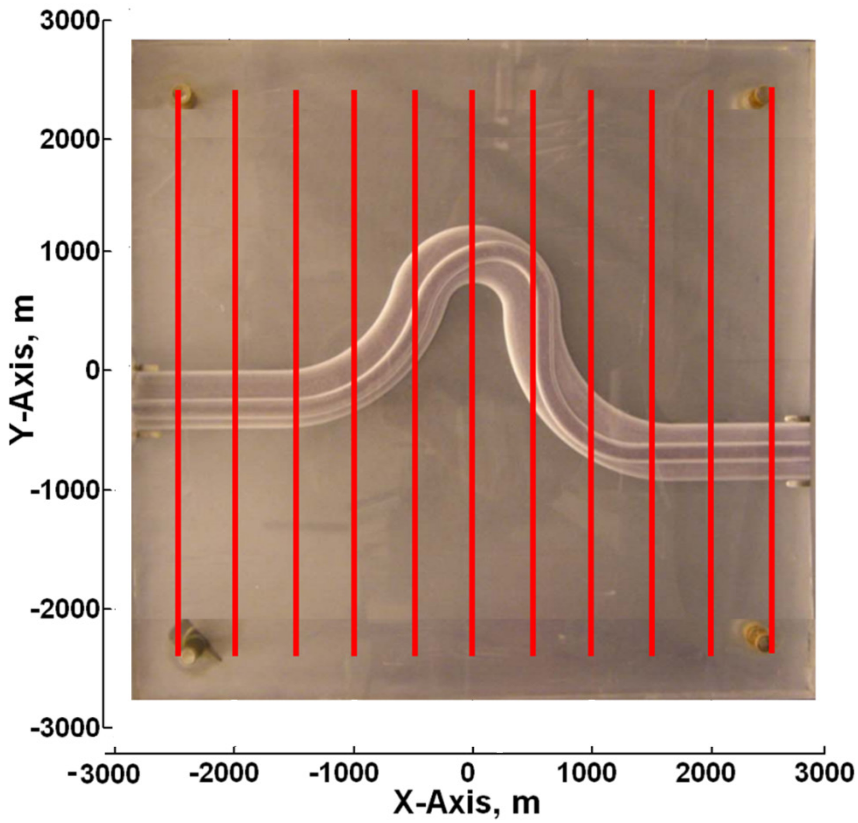

FIG. 1: Photograph and plan view of the PLX-channel slab with a few survey lines shown in red.

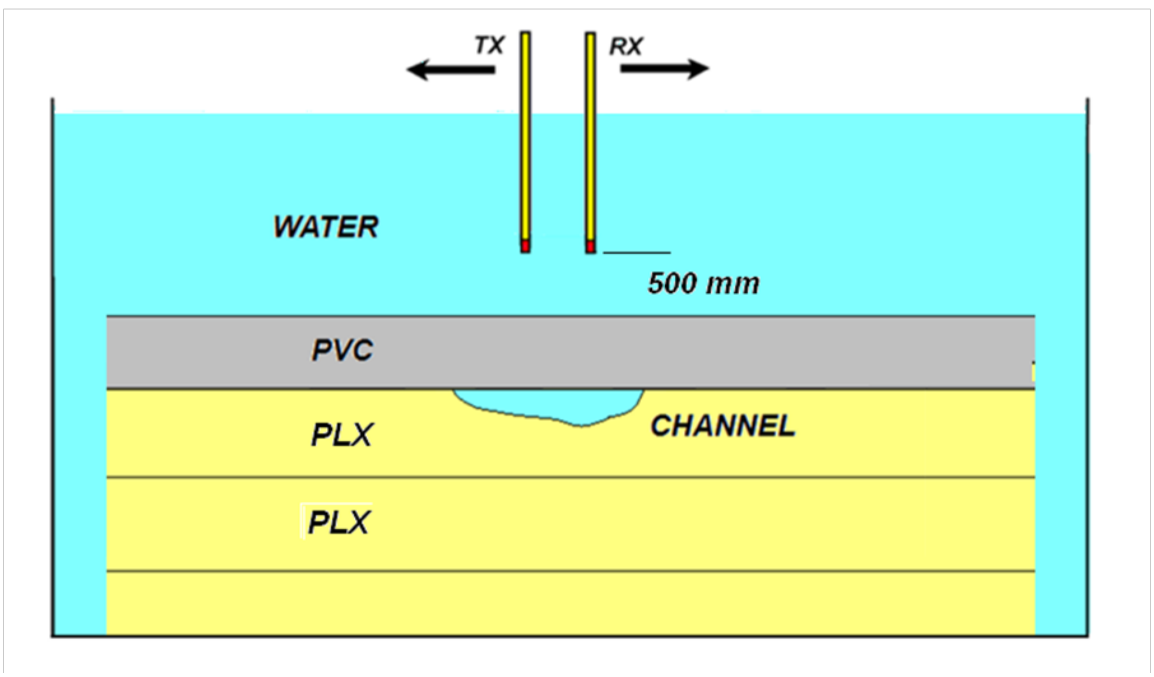

FIG. 2: Schematic side view of water-PVC-channel physical model, looking in the X-direction. See Table1 for the seismic properties of each layer.

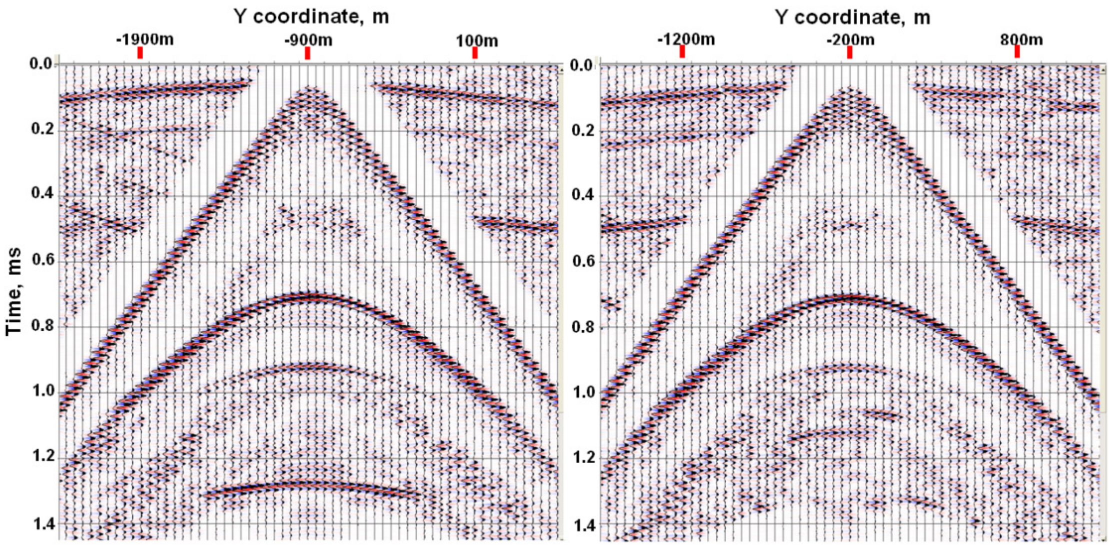

FIG. 3: Two common source gathers, for line with X = -1500m. Left: source is at Y = -900m, well away from the centre of the channel. Right: source is at Y = -200m, almost at the centre of the channel. On the AGC plots, the energy seen at times above the direct water arrivals are reverberations in the water column, produced by repeated periodic firing of the source transducer.

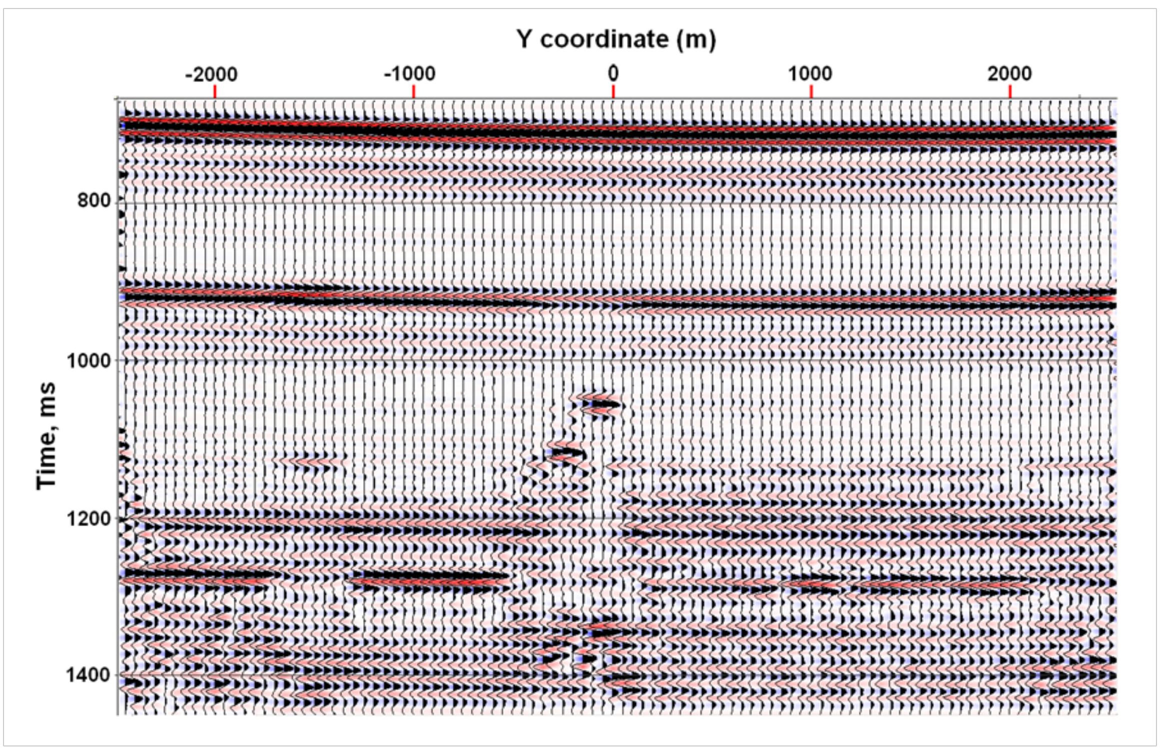

FIG. 4: AGC plot of fixed-offset seismograms, with source at X = -1500m and receiver at X = -1350m. Events and arrival pull-downs at profile positions between -350m and 50m reveal the presence of the channel.

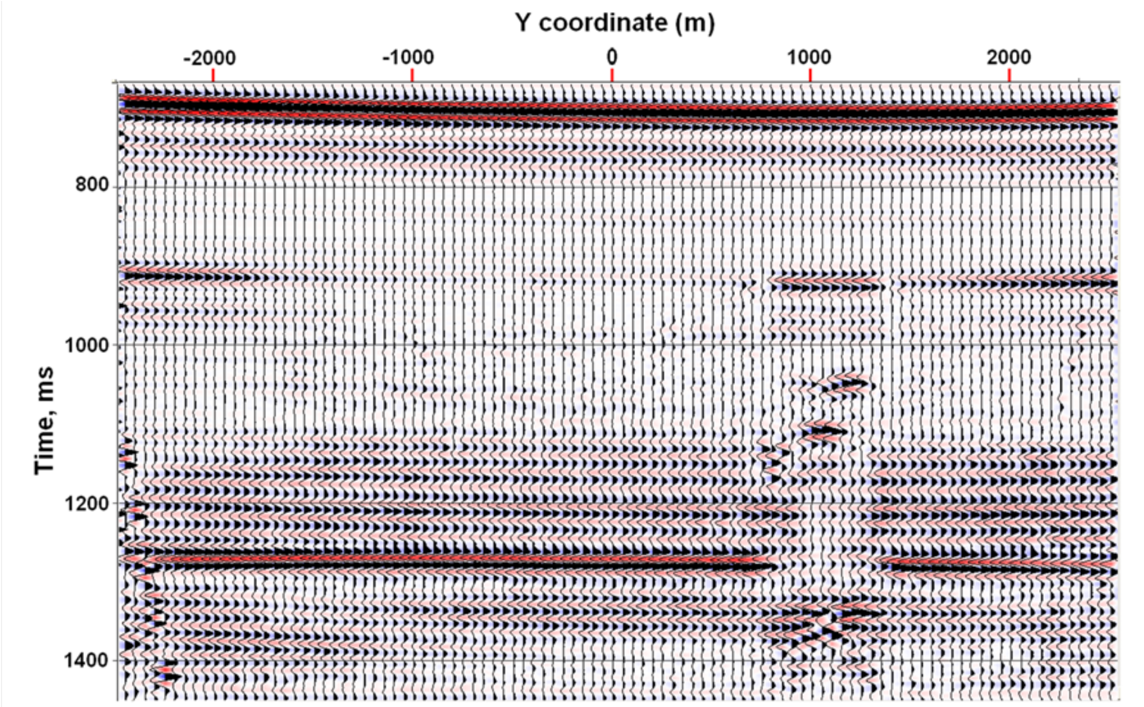

FIG. 5: AGC plot of fixed-offset seismograms, with source at X = 0m and receiver at X = 150m. On this profile, the channel is located at positions between 800m and 1300m.

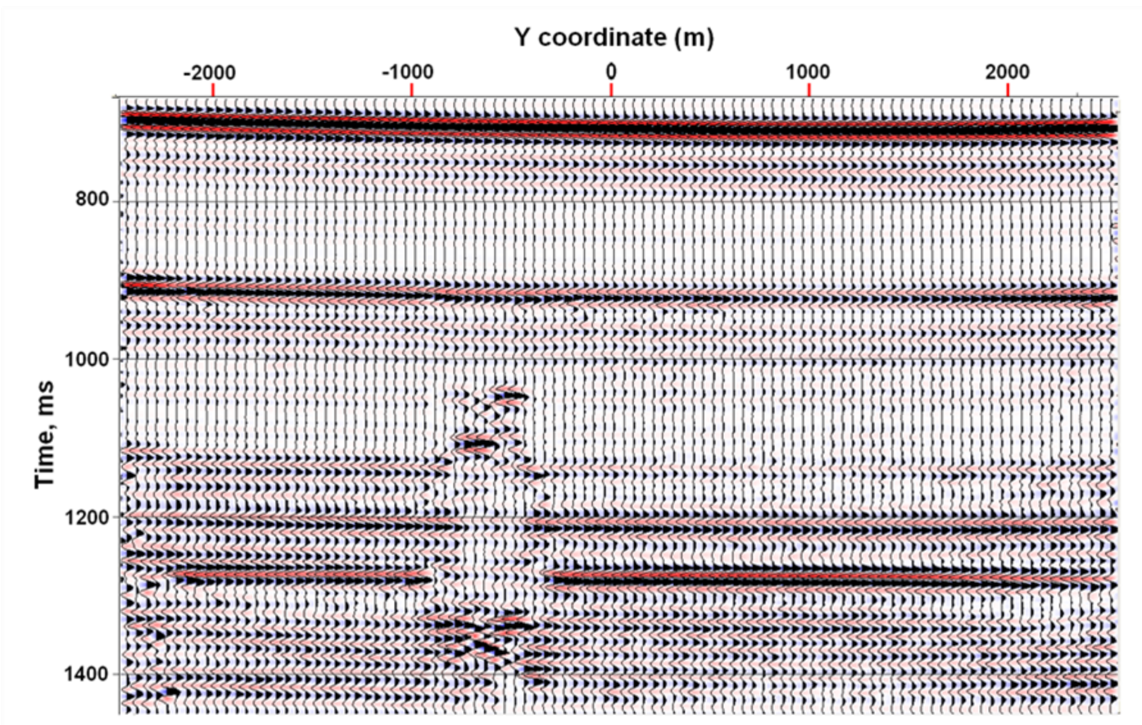

FIG 6: Plot of fixed-offset seismograms, with source at X =1500m and receiver at X = 1650m. On this profile, the channel is located at positions between -800m and -400m.

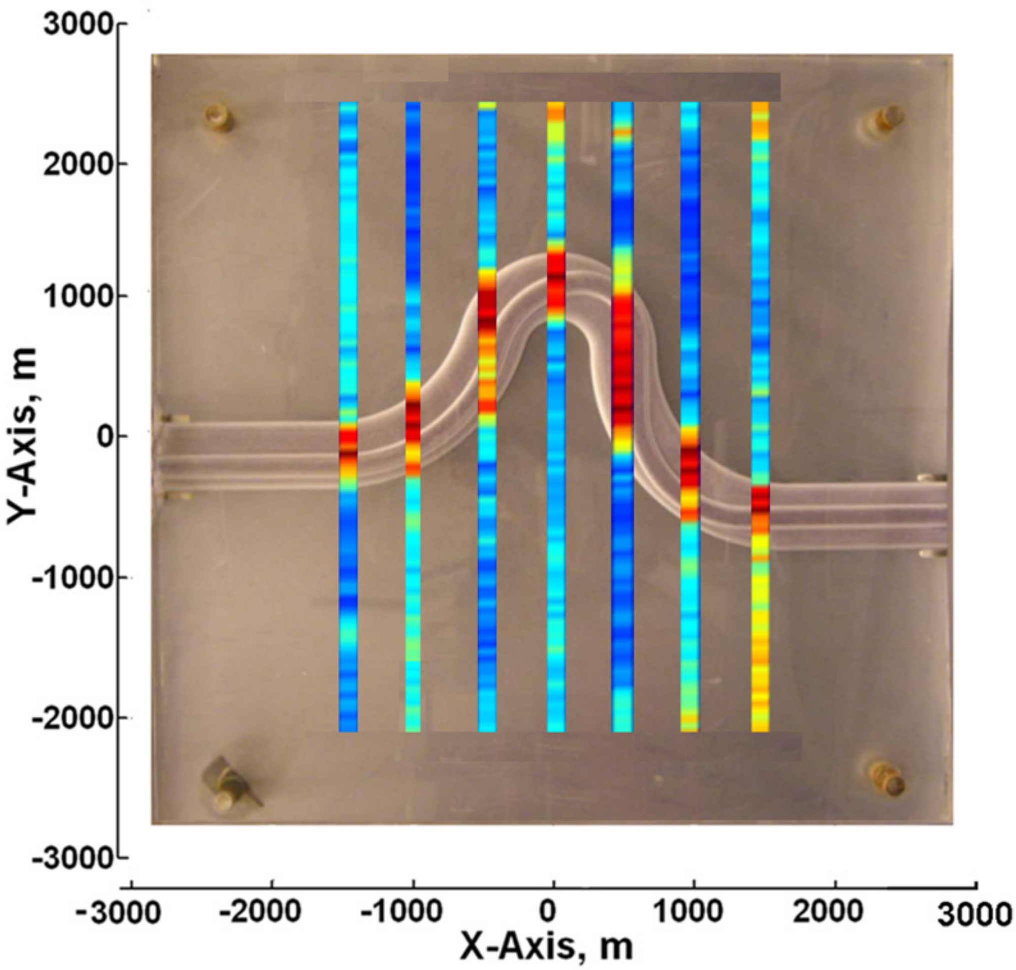

FIG 7: Time slice amplitudes for seven source lines, averaged over the interval 1000ms to 1160ms for fixed-offset gathers similar to those on Figures 4 to 6. High amplitudes (orange-red colors) coincide with channel locations.

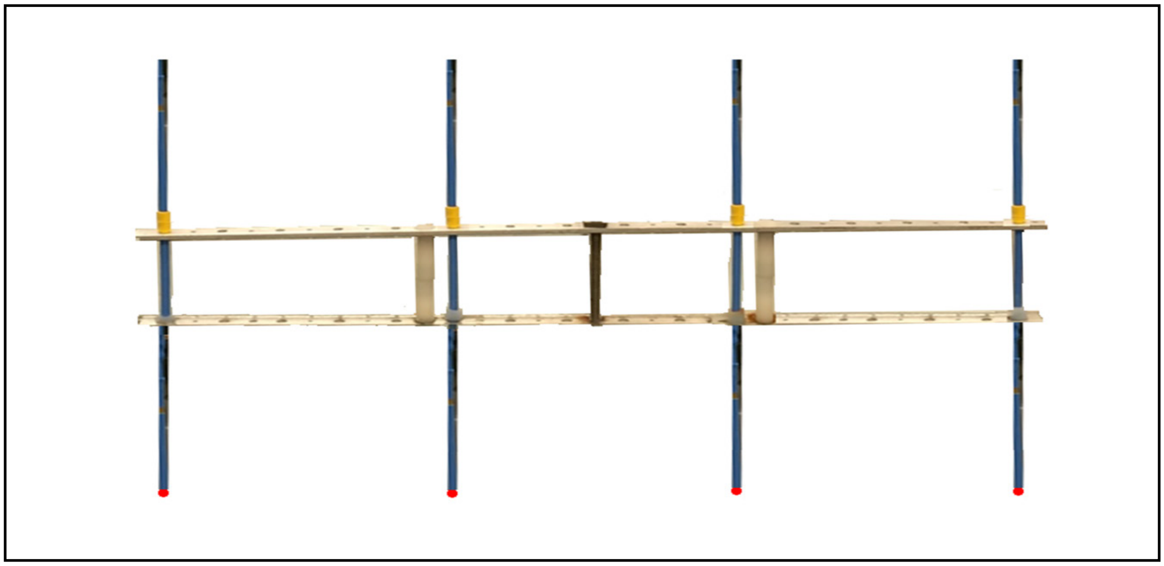

FIG. 8: An array of four source transducers to be used for efficiently conducting physically-modeled 3D seismic surveys. The separation between adjacent transducers is 100mm (scales up to a geological distance of 1000m).

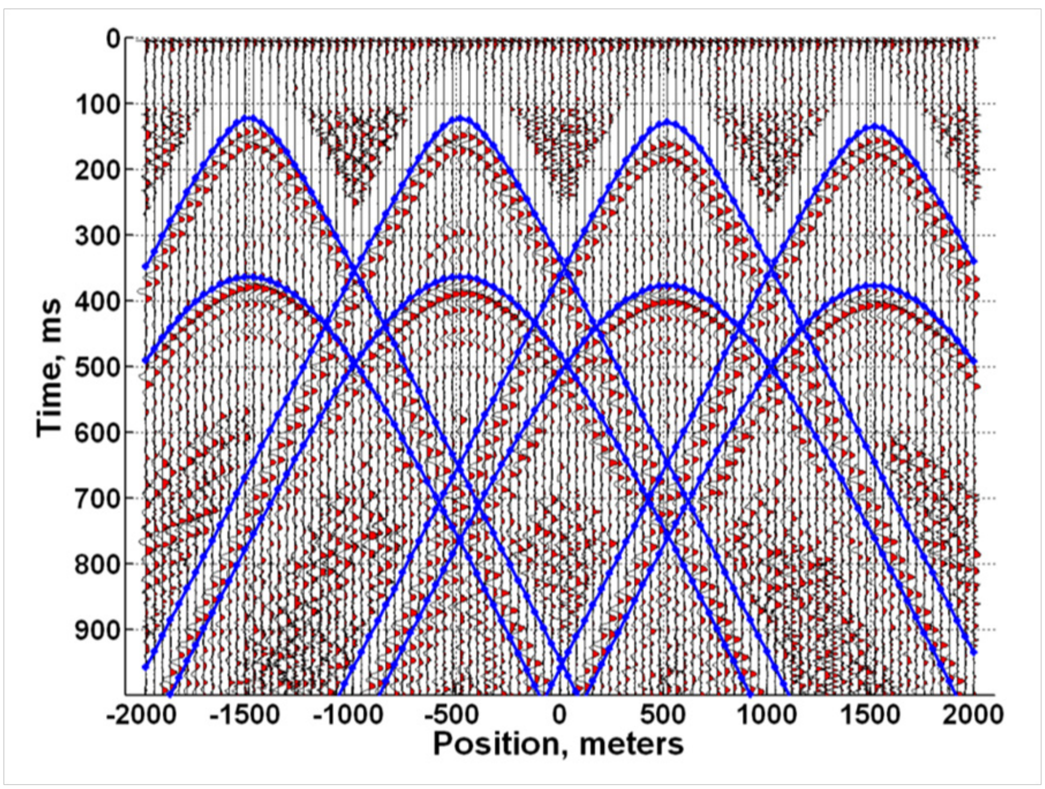

FIG. 9: Blended common-source gathers form the array of four source transducers.