Let there be light: illuminating physical models from the surface

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Abstract

A complex physical model (or any exploration prospect) should be illuminated by seismic energy over as wide an aperture as possible, in order to image all of its details***. Ideally, this aperture would be 360deg***, and the resulting image would then uniformly capture all model features. In the field, however, we can rarely illuminate a target over more than a fraction of the ideal aperture. Hence, we explore here what can be learned about a target using reflection data acquired over a restricted aperture; in this instance, data recorded only on the upper surface of a model, representing ***90deg or less of aperture***.

The model

The model shown in Figure 1 was installed in the CREWES physical modeling facility in order to explore various seismic ***acquisition techniques for illuminating the model***, which was intended to resemble a high-velocity salt body shielding deeper structural features. The model was extensively surveyed, not only from its top surface, but also using boreholes and subsurface sources.

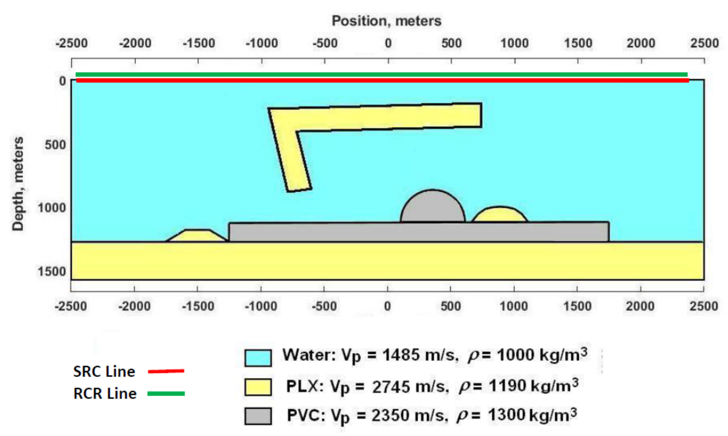

FIG. 1. Schematic of the physical model used to investigate seismic illumination

The objective

The purpose of our particular study, using this model, was to determine ***how much information we could obtain about the model using only data collected at the surface***, as in a conventional seismic survey. Hence, we used only two data sets from the collection of surveys: a conventional ***2D multi-offset CMP survey*** (101,000 traces), and a high-resolution ***zero-offset "sonar" type survey*** (only1000 traces).

Processing

Since the sonar survey is single-fold, we restricted our processing to coherent noise attenuation, Gabor deconvolution, demultiple, and FX deconvolution. Migration results were produced, but not considered helpful.

For the 2D CMP survey, the processing consisted of removing the direct wave from the source gathers, Gabor deconvolution, NMO correction with water velocity, removing coherent noise from common-offset gathers, and CMP stacking. We used the common-offset gathers, as well as the CMP stack image, in our analysis.

Results

Figure 2 shows the raw traces for the ***sonar survey*** with no processing except AGC, while Figure 3 shows the ***sonar survey*** after all processing.

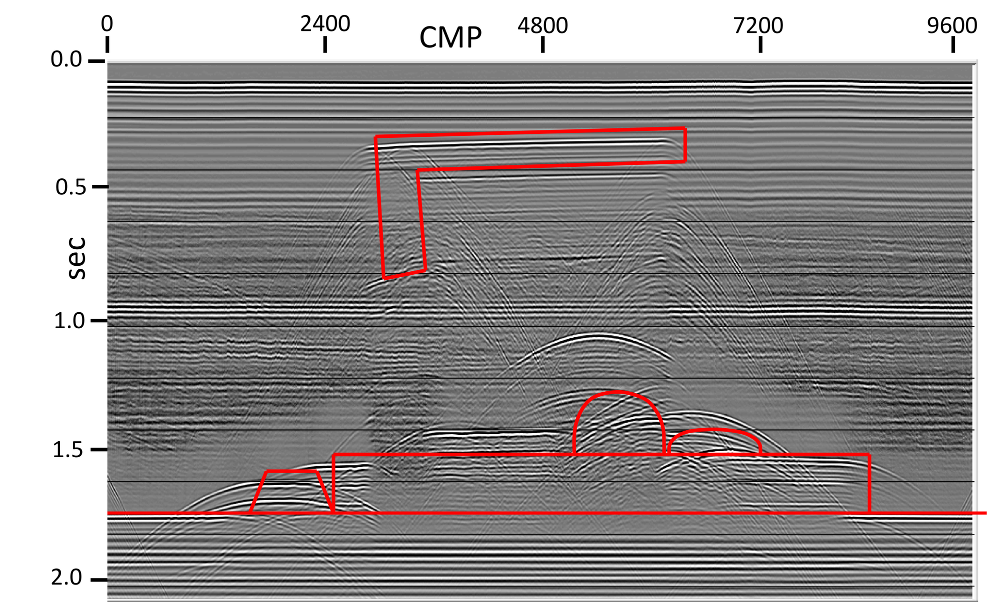

FIG. 2. Zero-offset "sonar" survey of model with schematic overlay—note distinct shadow.

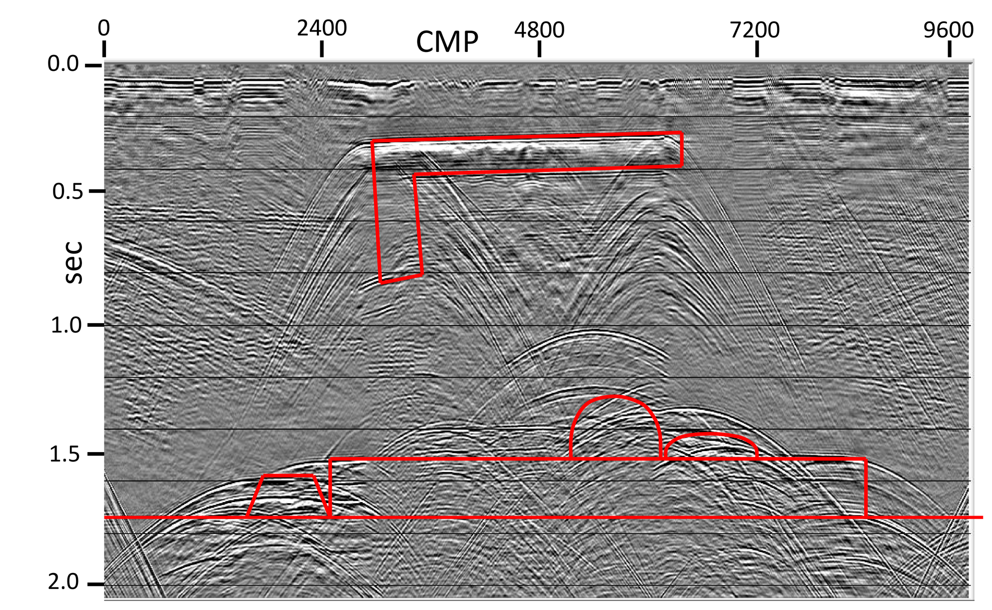

FIG. 3. Processed "sonar" survey of model with overlay—shadow visible, as are many diffractions.

Figure 4 shows the CMP stack of the ***multi-fold survey*** with a ***"mystery event"*** flagged, while Figure 5 shows the ***common-offset gather for zero offset***, extracted from these data, clearly resembling a coarsely sampled ***sonar survey*** (Figure 3) .

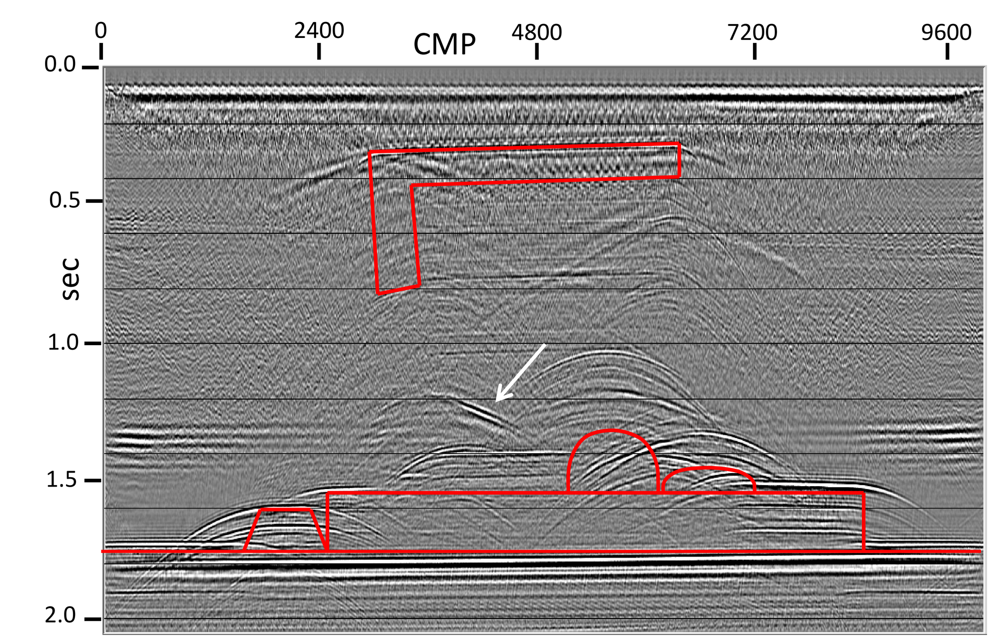

FIG. 4. CMP stack of 2D multi-fold survey with overlay. Arrow indicates mystery event.

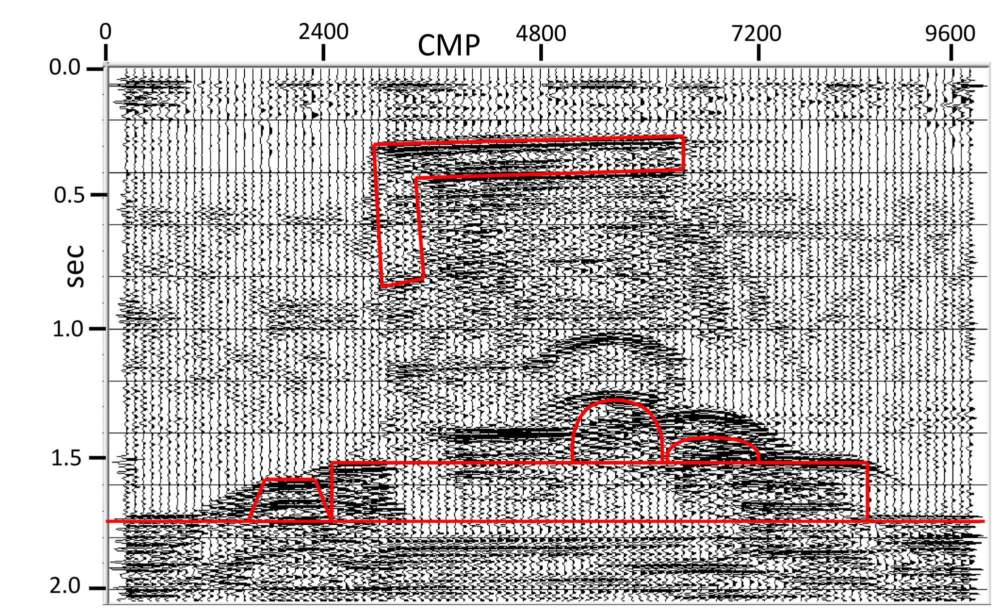

FIG. 5. Common-offset gather for zero offset

Identifying the mystery event

We determined that the ***"mystery" event*** seen on the CMP stack image was present only for a particular range of offsets. By studying individual common-offset gathers using schematic raypath overlays, we identified the event as a ***segment of the reflection*** from the top of the ***slab at the bottom of the model***, pulled up by the presence of the high velocity ***dike structure***. Figure 6 shows our analysis on the common-offset gather for offset = -850m (left), and for offset = -425m and offset = 0m (right). Arrows indicate the ***pulled-up segments*** of the slab reflection for each position of the schematic raypaths. Because the pulled-up events appear for a range of offsets, each having a slightly different pull-up, ***the CMP stack exhibits a tilted linear event***.

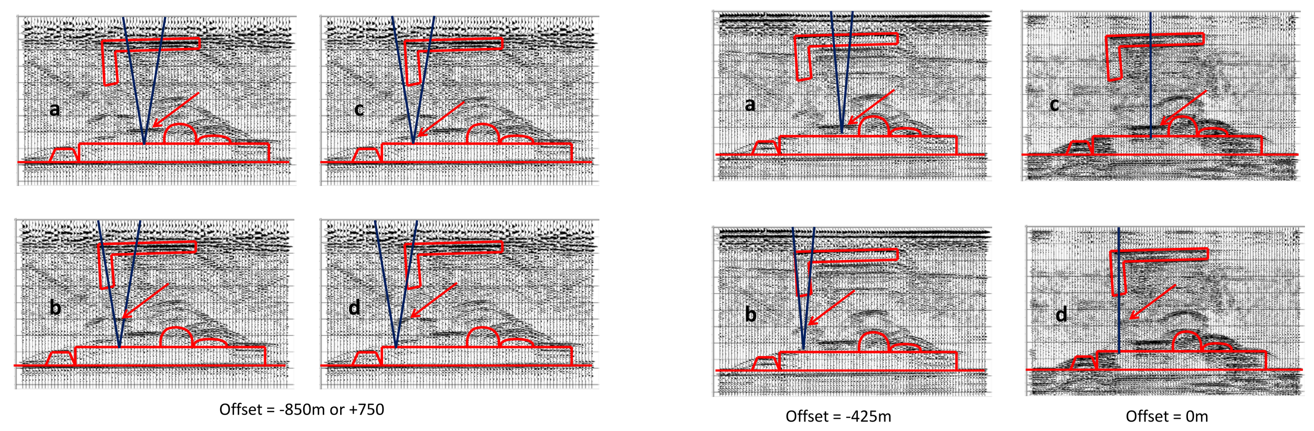

FIG. 6. Schematic raypaths explain the segments of the reflection from the model slab being pulled up by different amounts depending upon which portions of the dike and sill structure they traverse. The four images on the left show the event pull-ups for offset = +/- 850m, while the four images on the right show the situation for offset = +/- 425m and offset = 0m.

The verdict

Figure 7 shows the ***CMP stack*** image from the multi-fold survey, while Figure 8 shows the final ***"sonar"*** survey..

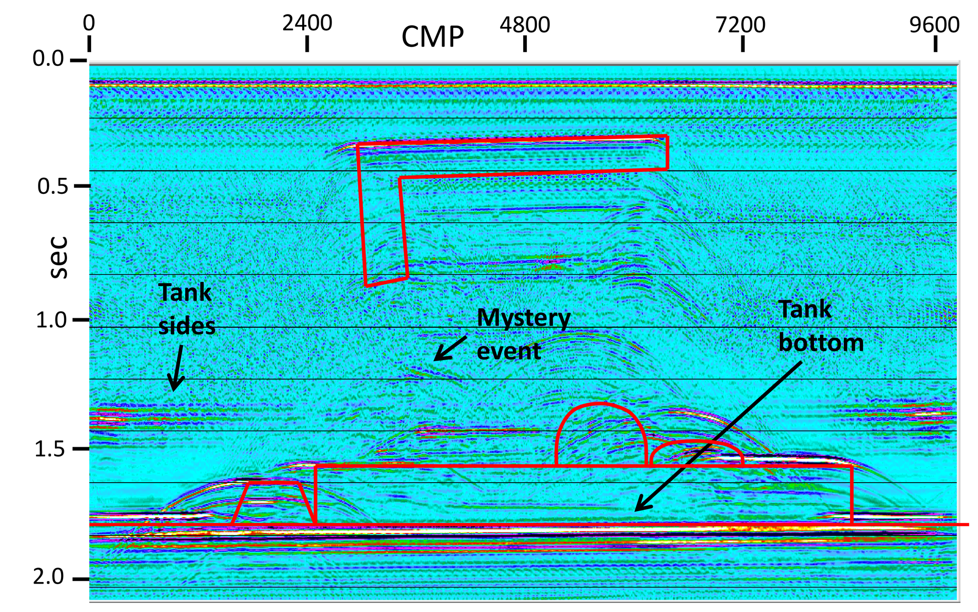

FIG. 7. CMP stack of 2D multi-fold survey

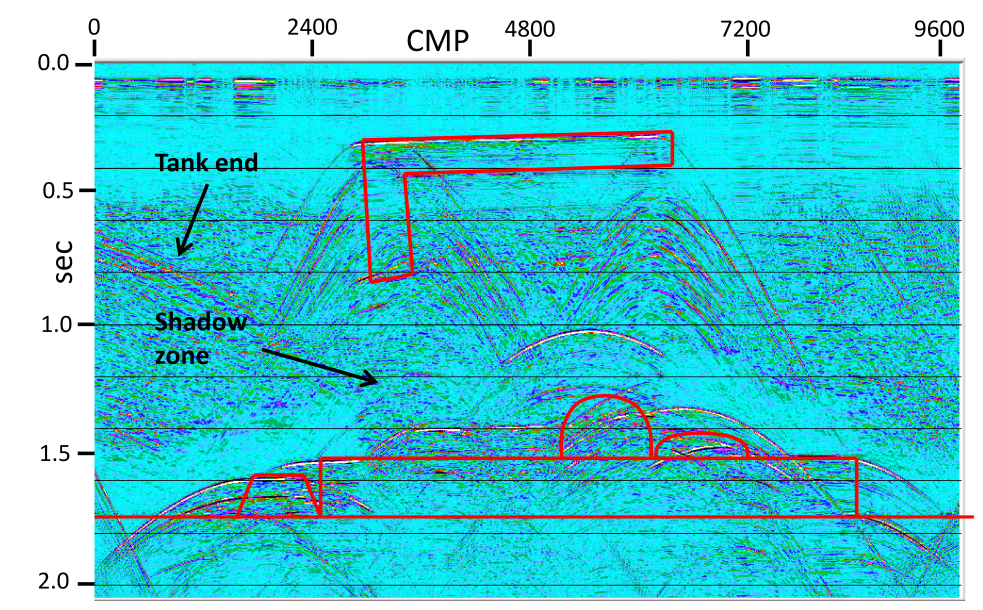

FIG. 8. "sonar" survey

Our preference, (in this instance of flat-lying structure) ***is the sonar survey*** for its ***absence of coherent noise, clear shadow zone (clues about dike and sill dimensions), and detailed diffractions (clues about edges and velocities).*** The CMP survey yields more information about velocities, but is also more affected by residual tank boundary reflections. The associated ***common-offset gathers can be useful diagnostics***, especially at zero offset, which is like a coarse sonar survey. ***The sonar survey only requires 1% of the acquisition effort, however!***

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