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Shadow imaging: attenuation tomography without arrival picking for physical model data from a circular array

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ABSTRACT

The CREWES physical modeling system is very versatile, in that it can be used for modeling a large variety of situations, not only for earth imaging, but also for medical and/or engineering applications. Recently, the system has been used to explore the use of circular arrays of transducers immersed in a fluid, to locate and image objects included within the transducer aperture. The first phase of the study uses first arrival waveforms and attempts to use them to provide a low-order estimate of shape and location of objects within the circular aperture. We demonstrate two potential methods, one of which uses anomalous time picks of the arrival wavelets to create ‘artificial shadows’ of objects, the other of which estimates the attenuation of acoustic energy along each raypath and creates ‘attenuation shadows’ of the objects. In either case, the shadows are properly oriented in image space and stacked to provide a ‘shadow image’ of objects within the circular aperture.

THE EXPERIMENT

Figure 1a shows the geometry used for the physical modeling, with coincident rings of source and receiver positions, while Figure 1b shows the possible raypaths for acoustic transmission, except for apparatus interference.

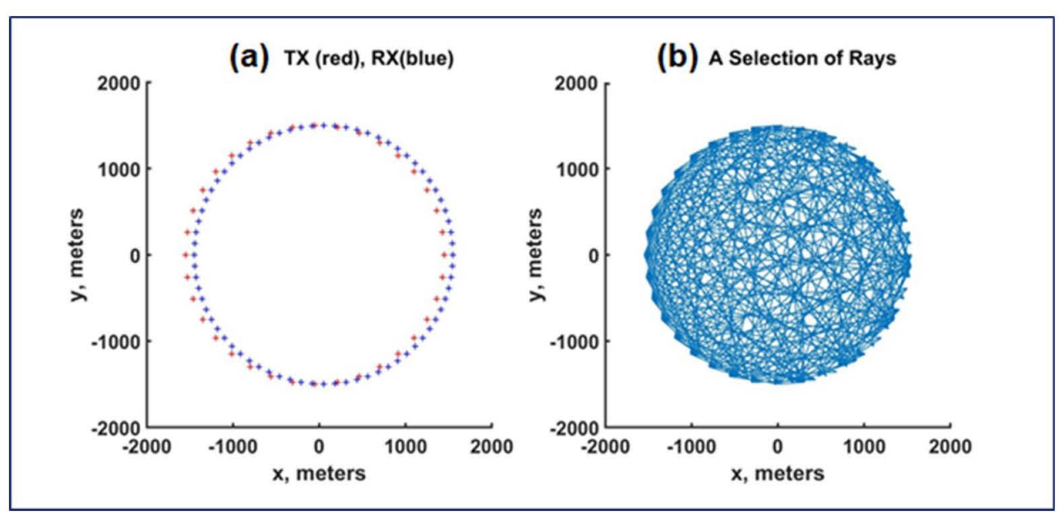

FIG. 1. a). The concentric transducer arrays for the experiment—72 receiver positions (blue), and 35 source positions (red). b). Possible transmission raypaths for the experiment (about 50% are not allowed because of mechanical equipment constraints.

Figure 2 shows a group of 5 source gathers from a complete survey with an unknown object inside the circular acquisition aperture.

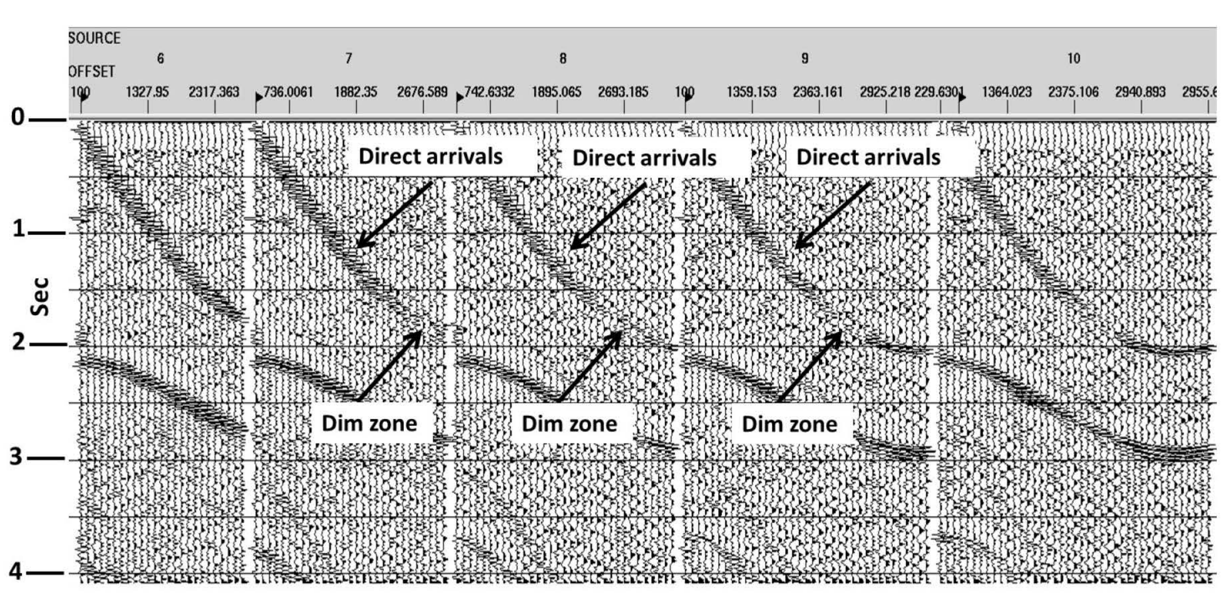

FIG. 2. Five source gathers from a complete survey with an unknown object inside the circular acquisition array. Note the prominent ‘dim zones’ in the first arrival trains that denote energy absorbed by an object between source and receiver transducers.

PROCESSING

To remove the effects of acquisition geometry, we align all the direct arrivals by applying a ‘water’ static shift to each trace corresponding to the transit time for acoustic energy along the particular raypath corresponding to the trace, assuming a known water velocity. We refine the alignment using trim statics computed using the entire acquisition set of traces as the learning set. Trace amplitudes are scaled for spherical spreading, using the corresponding raypath lengths, and the traces are deconvolved to equalize amplitudes and phases of the arrivals. Figure 3 shows a group of 3 source gathers after these operations.

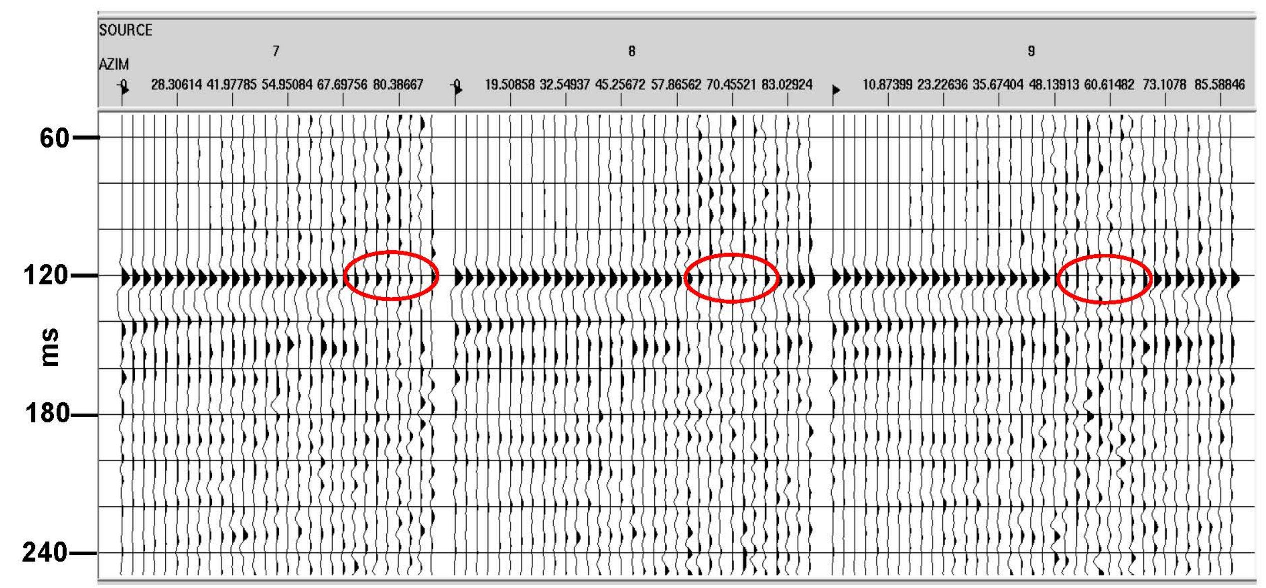

FIG. 3. Three source gathers after being aligned with water statics and trim statics, scaled for spherical spreading, and deconvolved. Note that the dim zones are easily seen in these arrivals.

1). Artificial shadows from dim zones

In our first attempt at shadow imaging, we examined all 35 source gathers, like those shown in Figure 3, and flagged the edges of the dim zones (requiring arrival picking). Sample values within these zones were set to a constant, while samples outside were zeroed, as in Figure 4.

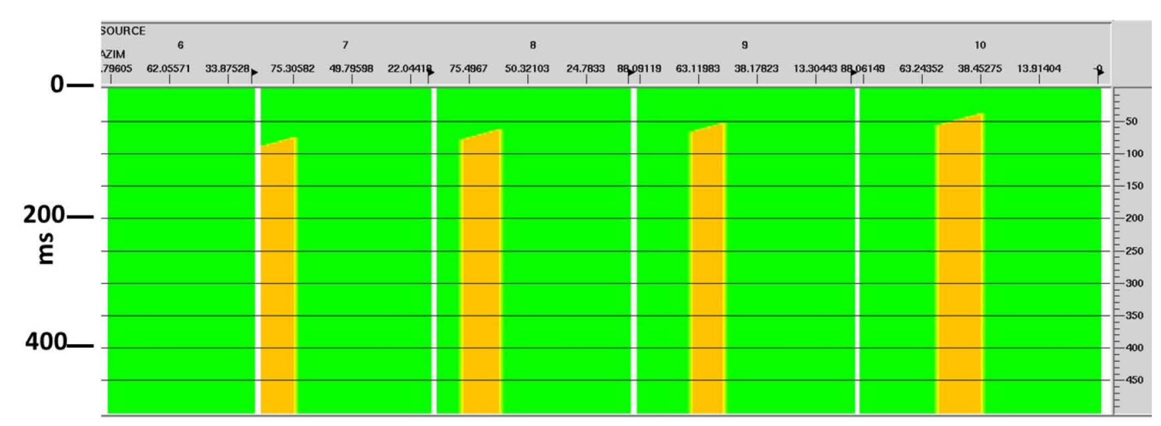

FIG. 4. Five source gathers showing artificial shadows within the dim zones flagged on the processed and aligned direct arrivals.

The gathers in Figure 4 show shadows as a function of source-receiver azimuth. These shadow gathers are tilted and rotated, then stacked, as in Figure 5.

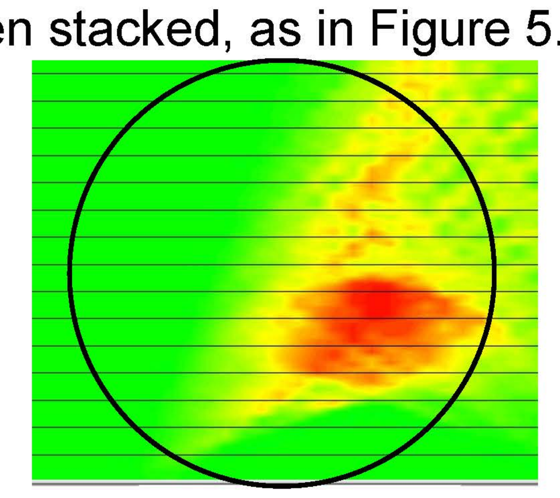

FIG. 5. Trial stack of artificial shadows from dim zones on direct arrivals. Dimensions are unresolved.

2). Shadows from trace attenuation

Instead of trying to detect the edges of shadows on aligned direct arrival source gathers, which requires direct arrival picks, we also explored a method in which wavelet magnitude, derived from an envelope function, becomes an analog for inverse energy attenuation, or ‘shadow intensity’.

Figure 6 shows the reciprocal envelope magnitude (smoothed perigram), normalized by the trace envelope maximum in the vicinity of the direct arrival, for 5 source gathers.

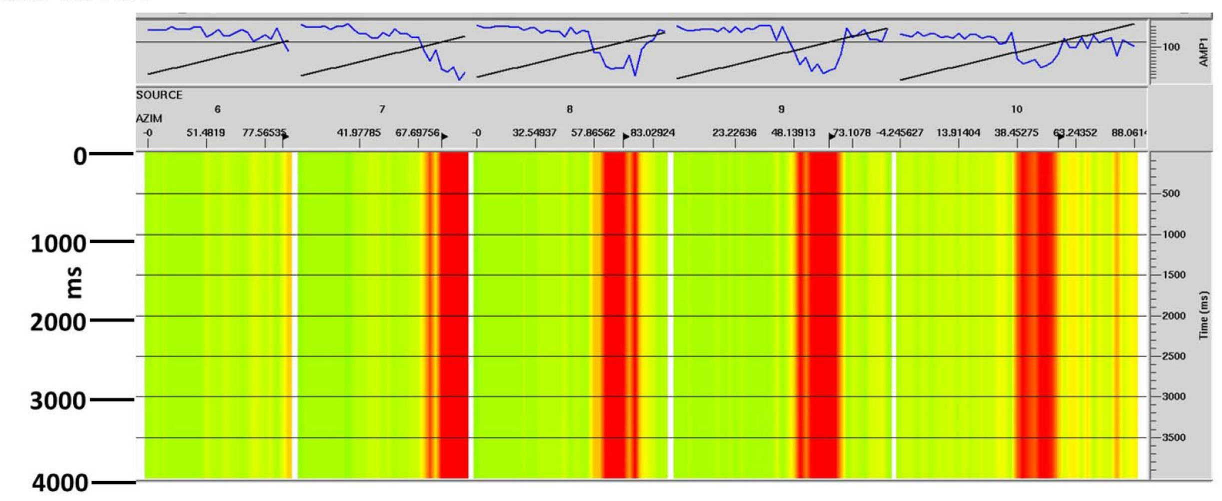

FIG. 6. Normalized reciprocal of smoothed envelope magnitude for 5 source gathers, as a function of source-receiver azimuth.

Figure 7 shows all 35 source gathers after conversion to angular beam gathers as a function of offset and depth, then rotated and positioned around an image aperture corresponding to the circular acquisition aperture.

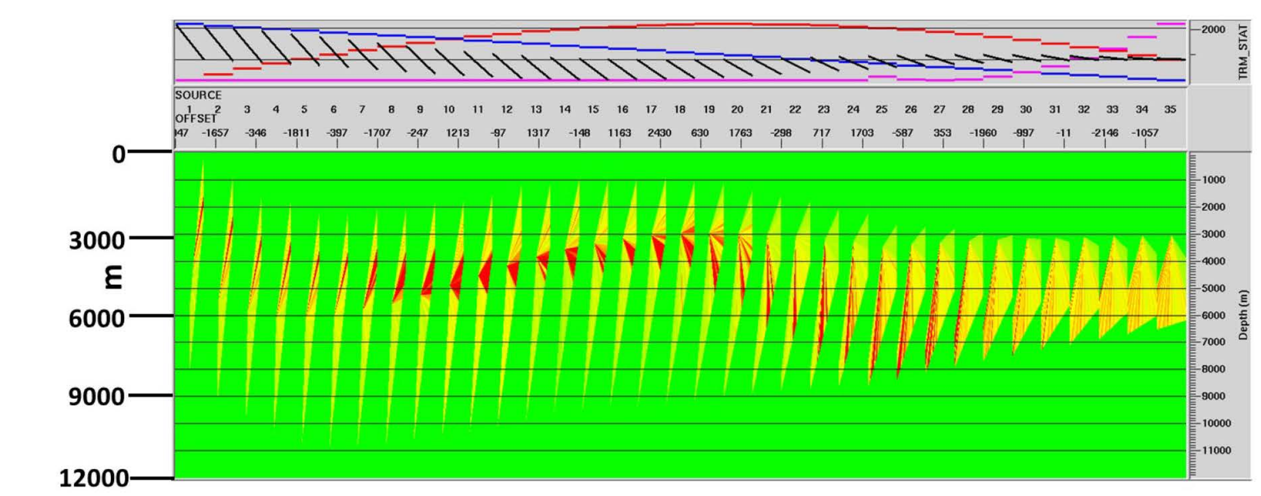

FIG. 7. All 35 source gathers converted to angular beam gathers via the inverse radial trace (RT) transform. The gathers are then positioned around the circumference of an image circle, rotated according to their source position and offset. Header plots show corrections applied as statics to the traces in the gathers.

When the source shadow gathers have been transformed to angular beam gathers, positioned around an image circle, and rotated and otherwise corrected, they may be stacked over image coordinates, as shown in Figure 8.

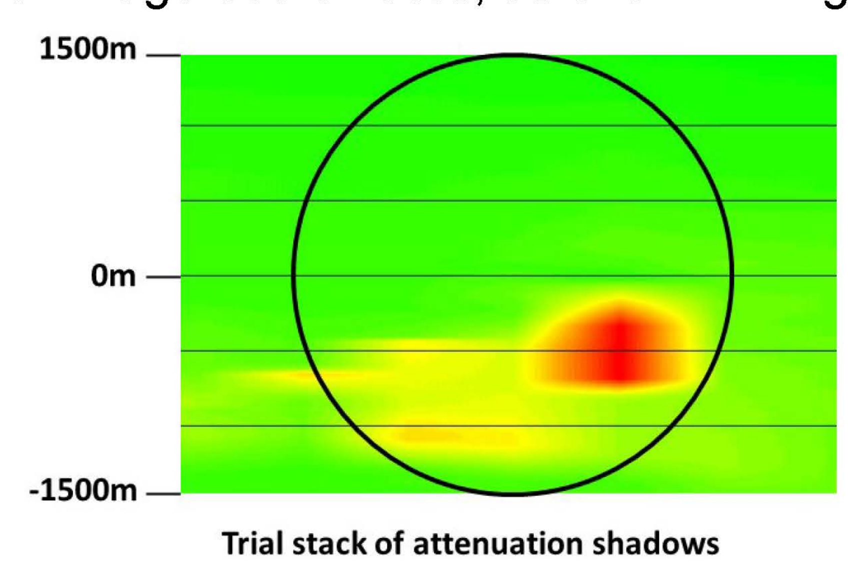

FIG. 8. Stack of attenuation intensity shadows, over image coordinates, of the rotated and adjusted beam gathers in Figure 7.

Comparison

Figures 5 and 7 are not actually comparable because of the attributes they image, but they are ‘suggestively similar’.

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