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Short Note

Nondestructive testing by migration

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INTRODUCTION

In the spring of 2005, engineers from Lawrence Livermore National Laboratories [2] contacted SEP to ask about the potential to use geophysical algorithms for nondestructive investigation of manufactured/machined parts. The conversation was sparked by emphasis from the LLNL management to search for existing solutions to their suite of current problems. Dr. Lehman presented SEP with a problem of investigating the interior of a layered manufactured product with a potential delamination or rugosity of an interior layer. As opposed to standard geophysical problems, the velocity/density structure of the target is completely determined.

The velocity model of the product is three two layers submerged in water. This makes the total 1D velocity model: 11mm of 1500m/s, 3mm of 4100m/s, and 30mm of 2670m/s. Data given to SEP was modeled with the elastic ED3D finite difference code from Livermore. Center frequency 2.25 MHz. First presented to our group was a data volume consisting of a single shot and 100 receiver locations over 80mm of the surface giving a receiver spacing of 0.8081mm. The target to identify was 1mm negative step in the center of the model. The zero-offset time to the anomaly is approximately 0.04 ms. However, the only shot modeled was at the extreme left of the model space.

The most obvious problem identifiable from a geophysical perspective was a strong multiple train generated from energy ringing within the high velocity middle layer. Secondly, from the standpoints of either multiple removal or imaging, the lack of redundant information from multiple shot locations were immediately identified as problematic. In all other respects, the laboratory conditions available to collect data with no velocity uncertainty promised highly successful application of conventional geophysical processing technology.

A full fold, $n_s = n_r$, data volume was modeled and delivered to SEP during the summer. Also modeled by LLNL was a similar data volume with a up/down double spoon/scallop anomaly at the base of the third layer. With standard migration algorithms, we were able to image both targets with resolution of 0.1mm vertically and about 0.40405mm horizontally. Intrabed multiples from the second layer were not time-coincident in the middle half of the offset range, so no multiple attenuation efforts were required after the far offset traces were

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removed before imaging. Source-receiver, shot-profile, and zero ray parameter planewave migrations were implemented. Given the simplicity and cleanliness of the data, zero-offset images from all approaches were practically identical.

DATA AND MIGRATION RESULTS

Figure 1 shows the data after the far offsets have been removed. A multiple train caused by the fast middle layer has died down over the inner offsets at the time of the anomaly. Therefor, removing the far offsets, we were able to create a nearly multiple free data volume for imaging purposes. The middle half of the total offset range was kept. Figure 2 is the image produced by shot-profile migration using all the available data. Figure 3 shows the image for the step anomaly and the scallop anomaly. Identical images were created by stacking all of the shots and migrating with a planar horizontal source function, and source-receiver migration (not shown).

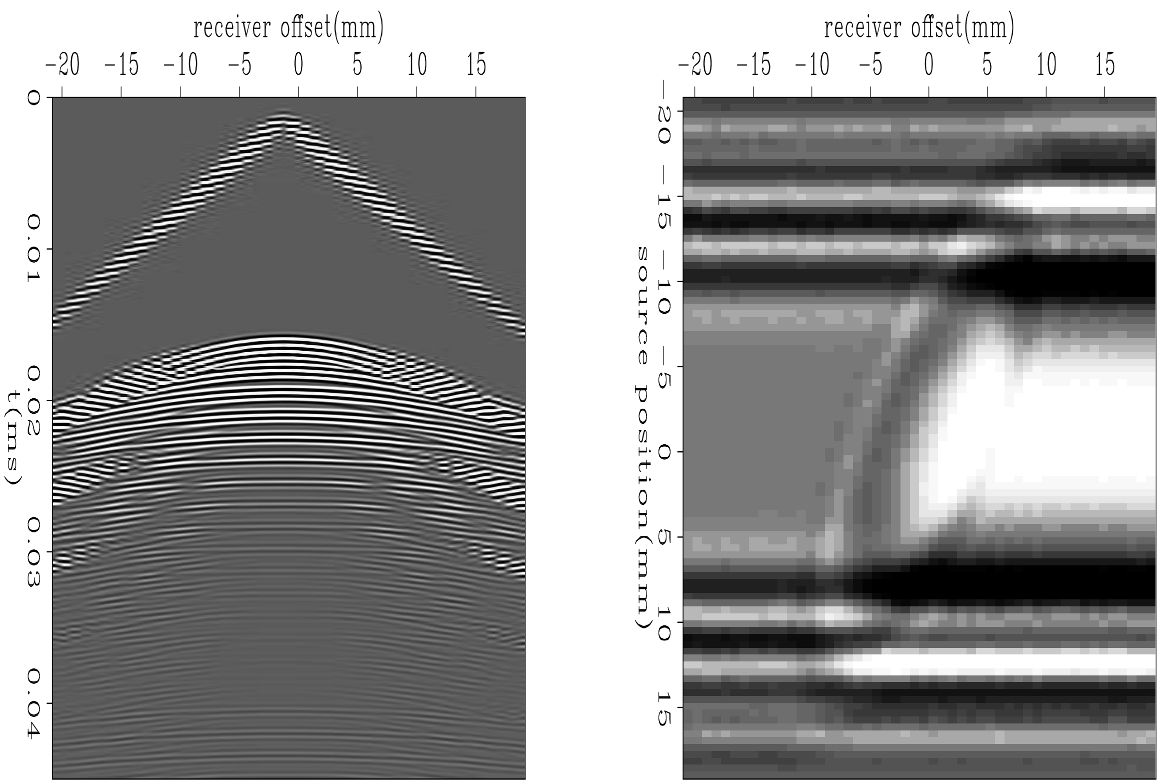

Figure 1: Shot record and time slice of the inner offsets of modeled data. The time slice shows the anomaly. brad2-data [CR]

To understand the importance of multiple shots, two single shot data volumes were migrated with shot-profile migration. Figures 4 is the image from a shot located at the left edge of the model space. The bottom reflector is very poorly imaged, and their is no indication of the anomaly. If the shot were located directly over the anomaly, as in Figure 5, the anomaly is noticeable though the quality of the image is poor.

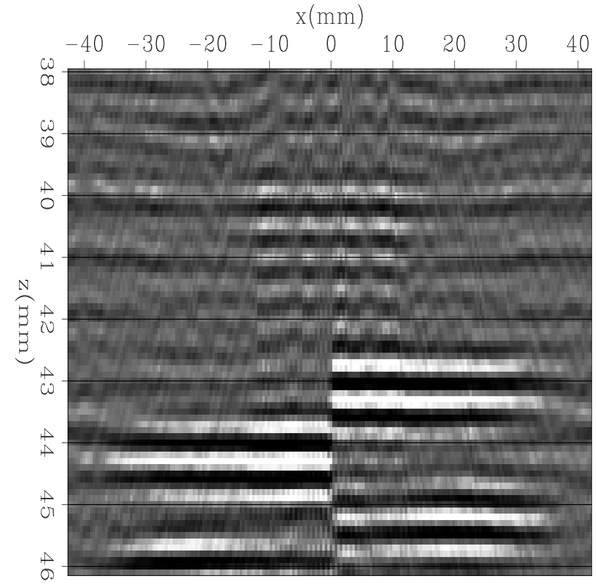

Figure 2: Shot-profile migration using all available data. Interference from intrabed multiples from middle layer decreases image quality. brad2-alloffsmig [CR]

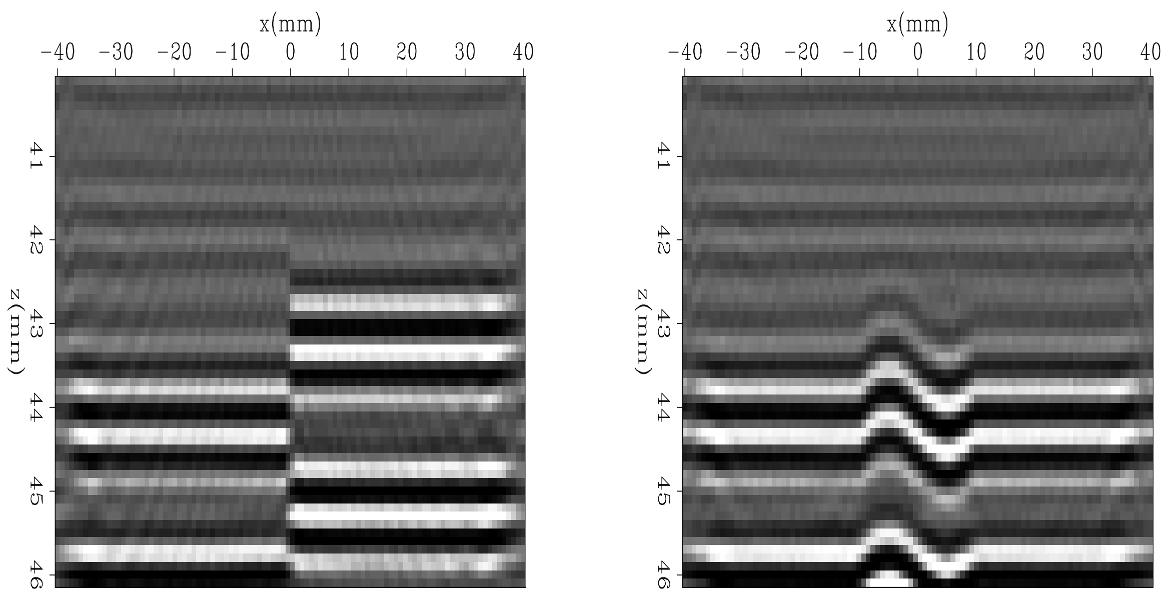

Figure 3: Both data sets produce very clean images when only near offset traces are migrated. Image produced with shot-profile migration. brad2-shotmig [CR]

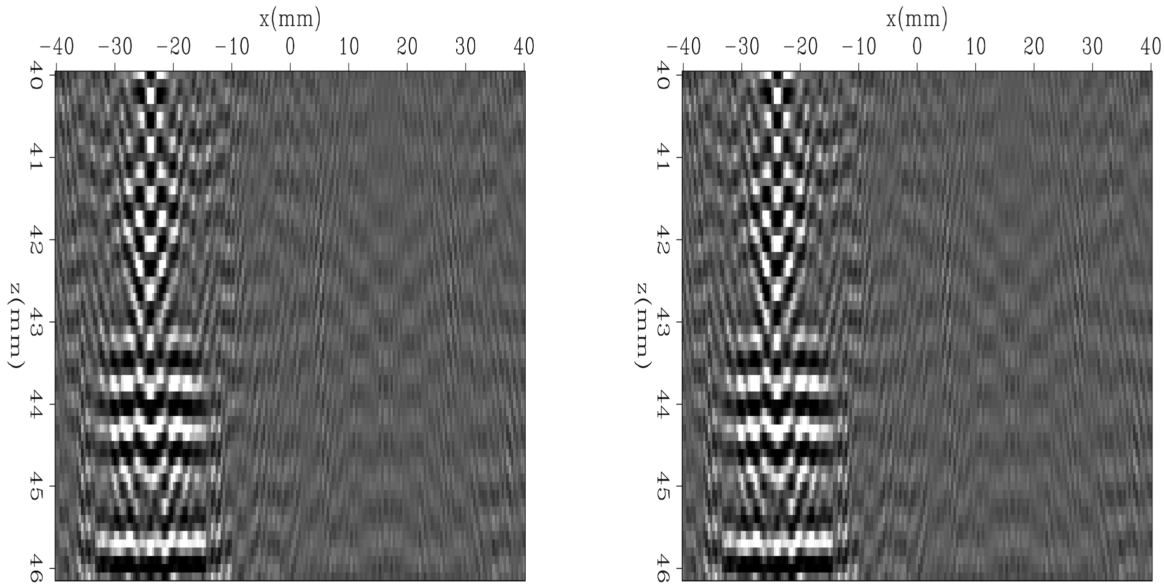

Figure 4: Image from a single shot at the far left edge of the model. brad2-oneshot [CR]

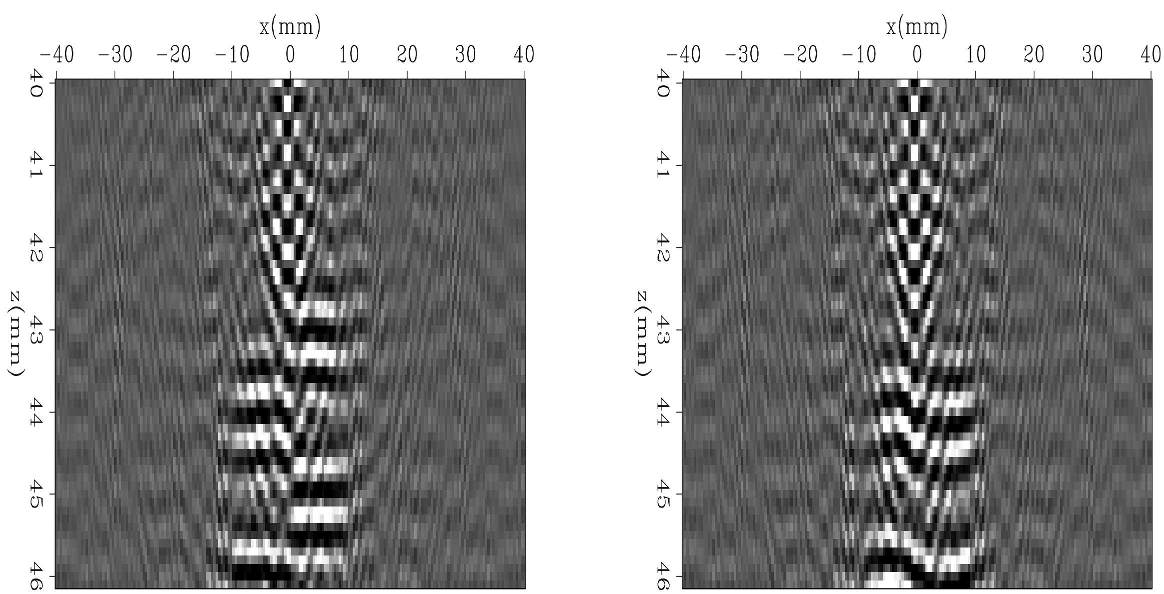

Figure 5: Image from a single shot directly over the anomaly. brad2-censhot [CR]

CONCLUSION

The modeled data given to SEP was produced to mimic a real manufactured product that the engineers at LLNL need to non-destructively test for potential defects. Laboratory apparatus will be used to collect data over a third dimension which also shares the same elastic properties. Simple geophysical migration techniques with acoustic depth algorithms were able to simply image both the step and scalloped anomalies in the modeled data. The various imaging algorithms tried (prestack source-receiver, prestack shot-profile, and zero ray parameter planewave) were all similarly successful.

Producing equivalent results, the least expensive solution is the best. Therefor, we can confidently advise the LLNL engineers that acquisition of a full fold multi-offset data volume is not required for this simple problem. However, many shot locations are imperative. Due to the intrabed multiple generator in the center of the product, the near offsets that are not contaminated with multiple energy are the most important. The most expedient method to collect the best and smallest data for their needs is to modify their laboratory equipment to allow the source piezoelectric element to record a zero offset trace after firing. This will allow for rapid data acquisition, over whatever third dimension may be required, and computationally inexpensive imaging.