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Short Note

Cross-equalization of a very shallow seismic experiment

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INTRODUCTION

Cross-equalization is catch-all term for the removal of systematic non-fluid related differences between reservoir monitoring surveys. It is an important step in the processing of time-lapse seismic data as it allows interpretation of difference images in terms of fluid parameters. In this paper we apply a post-stack cross-equalization algorithm to detect differences between two high-resolution seismic surveys caused by the addition of 20 liters of honey in the near-surface. It follows the cross-equalization work on synthetic data presented in the previous paper (Rickett, 1997).

FIELD DATA

The surveys were completed on a sandy beach in Monterey Bay, California. The same geometry and acquisition parameters were used for both surveys to minimize differences unrelated to fluid changes. The source was a 0.25 kg hammer, and geophone spacing was 20 cm. These acquisition parameters coupled with the homogeneous nature of the sand allowed significant energy above 800 Hz to be recorded in the shot records. Figure 1 shows a typical shot record before and after high-pass filtering to remove the ground-roll. Despite the narrow bandwidth of the signal, at least two distinct hyperbolic events are visible in the filtered gather.

Since the honey was added to the top 2 m of the subsurface, we were not able to image it directly. Instead we looked for changes in the response of the water-table below. Theory predicted that the primary effect of the honey would be one of attenuation.

The surveys had been designed to see if it was possible to detect 20 liters of honey

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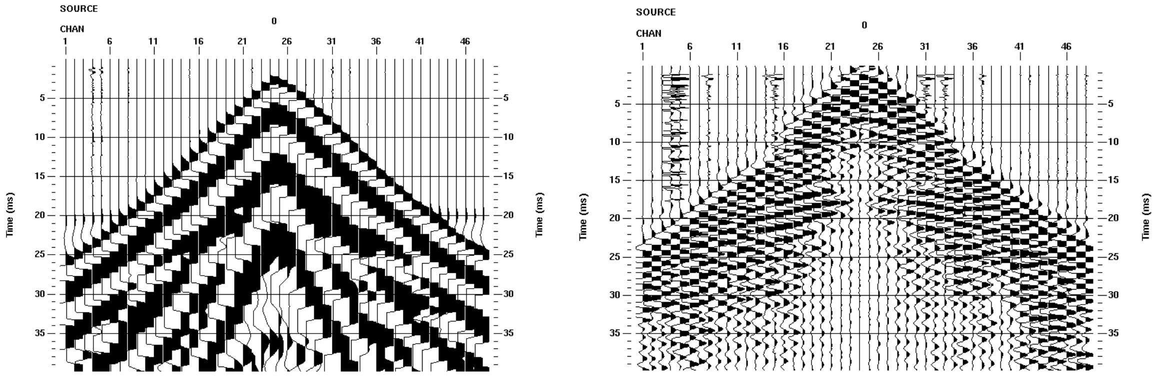

Figure 1: Typical shot record before and after high-pass filtering. The water-table reflector can be seen at 18 ms, and there is another hyperbolic reflection event visible in the near offsets at 10 ms. james2-shot [NR]

that had been mixed with 200 liters of sand at one location along the survey line, giving approximately 25% pore-space saturation.

In this paper, we are concerned only with the problem of cross-equalizing the datasets. We will cover the motivation and rock physics fully in later papers. However, in summary, the experiment follows up on earlier shallow seismic experiments described in Bachrach and Nur (1997) and Bachrach et al. (1997), and theoretical work concerning partial saturations (Bachrach and Dvorkin, 1997).

PROCESSING

The processing flow applied to the data was as simple as possible to preserve amplitude information. It consisted of trace-edits, muting, bandpass filtering, normal move-out correction and stack.

The cross-equalization algorithm was applied to stacked sections with two different frequency contents. These correspond to different bandpass filters used on the shot-gathers to remove the ground-roll. Figures 2 and 3 show the stacked sections with different frequency contents, and their raw differences.

The honey was located between 5 m and 6 m on the CMP axis, and the water table reflector is clearly visible at 20 ms. However, any changes in the raw differences in the area where the honey was added are well below the signal-to-noise level on both sets of stacked sections.

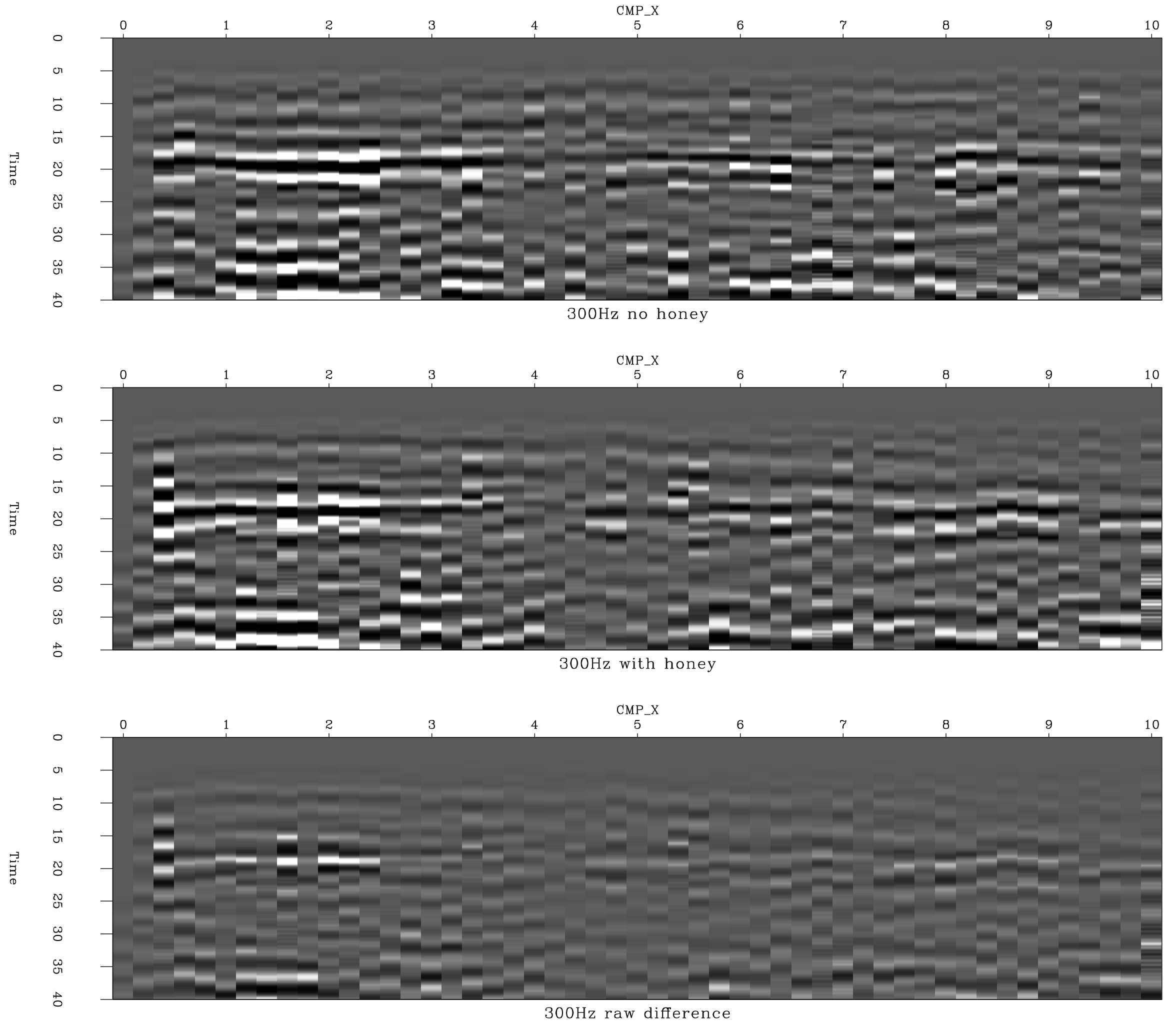

Figure 2: Stacked sections with high-pass filter (300 Hz) in processing flow. Left is no honey, center is with honey and right is raw-difference. james2-honey.raw.300Hz [ER]

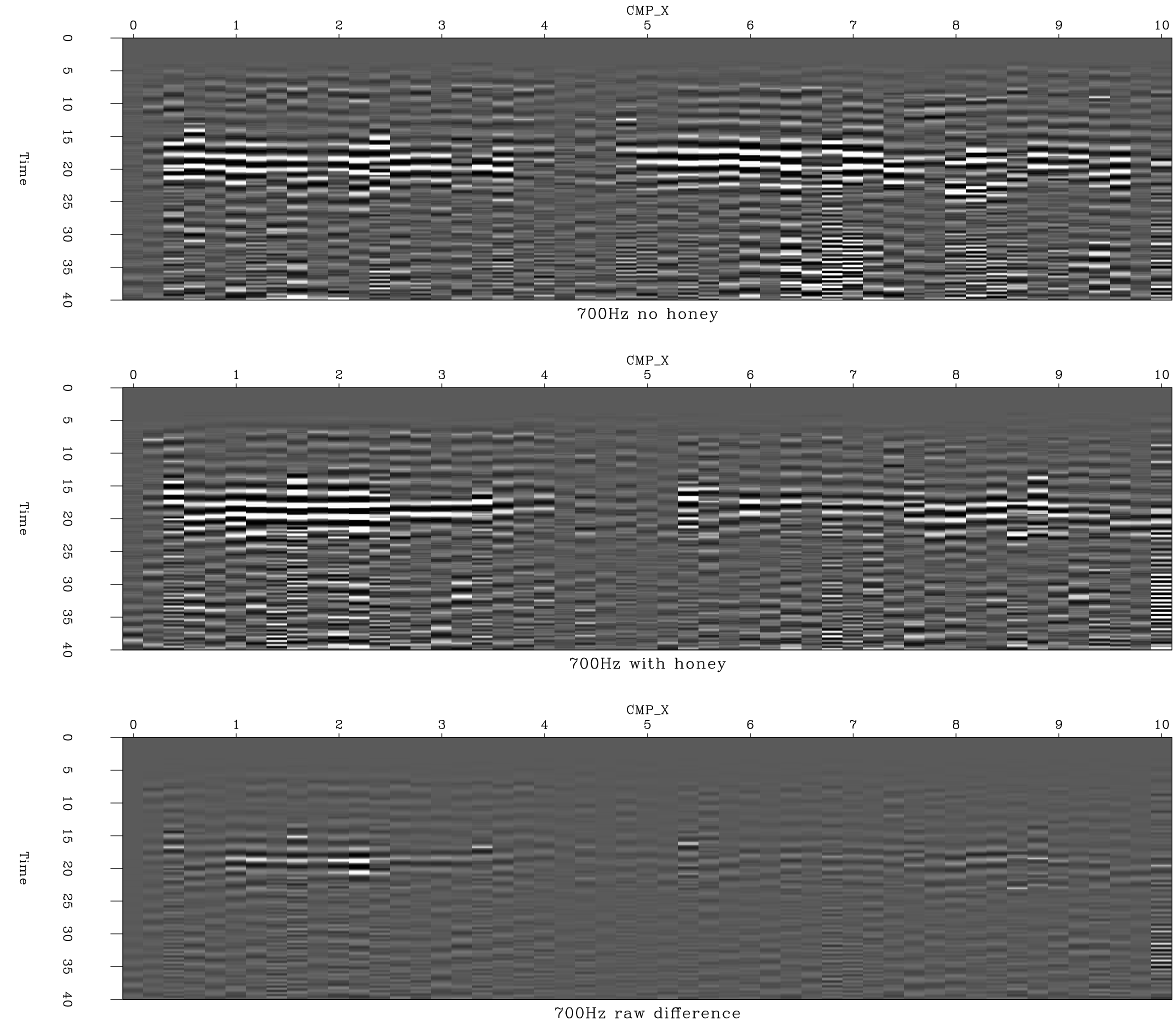

Figure 3: Stacked sections with high-pass filter (700 Hz) in processing flow. Left is no honey, center is with honey and right is raw-difference. james2-honey.raw.700Hz [ER]

CROSS-EQUALIZATION

Since the two experiments were conducted with very similar acquisition parameters, none of the 'optimal' cross-equalizing methods that I discussed in my earlier paper were useful. The simple time domain match-filtering approach was used instead.

In this approach, a filter, $\mathbf{A}$, is designed on a training window to map one survey, $\mathbf{s_1}$, onto the other, $\mathbf{s_2}$, minimizing the regression:

$$\mathbf{A s_1} - \mathbf{s_2} \approx \mathbf{0} \tag{1}$$

The training window should be a subset of the survey in which it is expected that all the changes are acquisition related. For this dataset the training window that was used are shown in Figures 4 and 5.

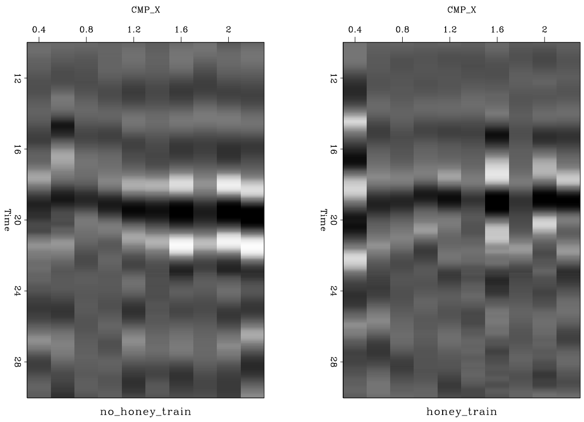

Figure 4: Training window for 300 Hz section. Left is without honey and right is with honey. james2-htrain.300Hz [ER]

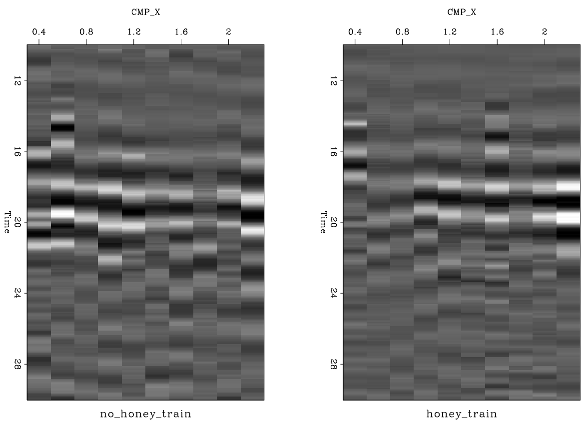

Figure 5: Training window for 700 Hz section. Left is without honey and right is with honey. james2-htrain.700Hz [ER]

RESULTS

The results of cross-equalization are displayed in Figures 7 and 6. The differences in the 700 Hz section (Figure 7) after cross-equalization show that the water-table reflection on the left of the section is attenuated by the cross-equalization process. However below 6 m, the reflector remains clear and un-equalized.

In the 300 Hz section (Figure 6), the water-table reflection is poorly attenuated along throughout the section. There is a difference where the honey is located, but this difference is no greater or more coherent than the the differences on the water-table elsewhere.

In the 700 Hz section (Figure 7), the differences on the left of the section are incoherent, however the differences at CDP X between 5 and 6 m are larger and more coherent.

CONCLUSIONS

The conclusions that can be drawn from these preliminary results are limited, since the cross-equalization was applied to the stacked data only. Further work with the pre-stack data, including surface consistent amplitude balancing, will enable us to better understand the repeatability of the acquisition and the causes of the systematic differences between surveys.

However, the differences we saw at CDP X between 5 and 6 m on water-table in the 700 Hz section fits with the hypothesis that the honey at that location causes attenuation and/or velocity changes which impact the seismic signature of the water-table. Any differences in the 300 Hz section fall below the signal-to-noise ratio.

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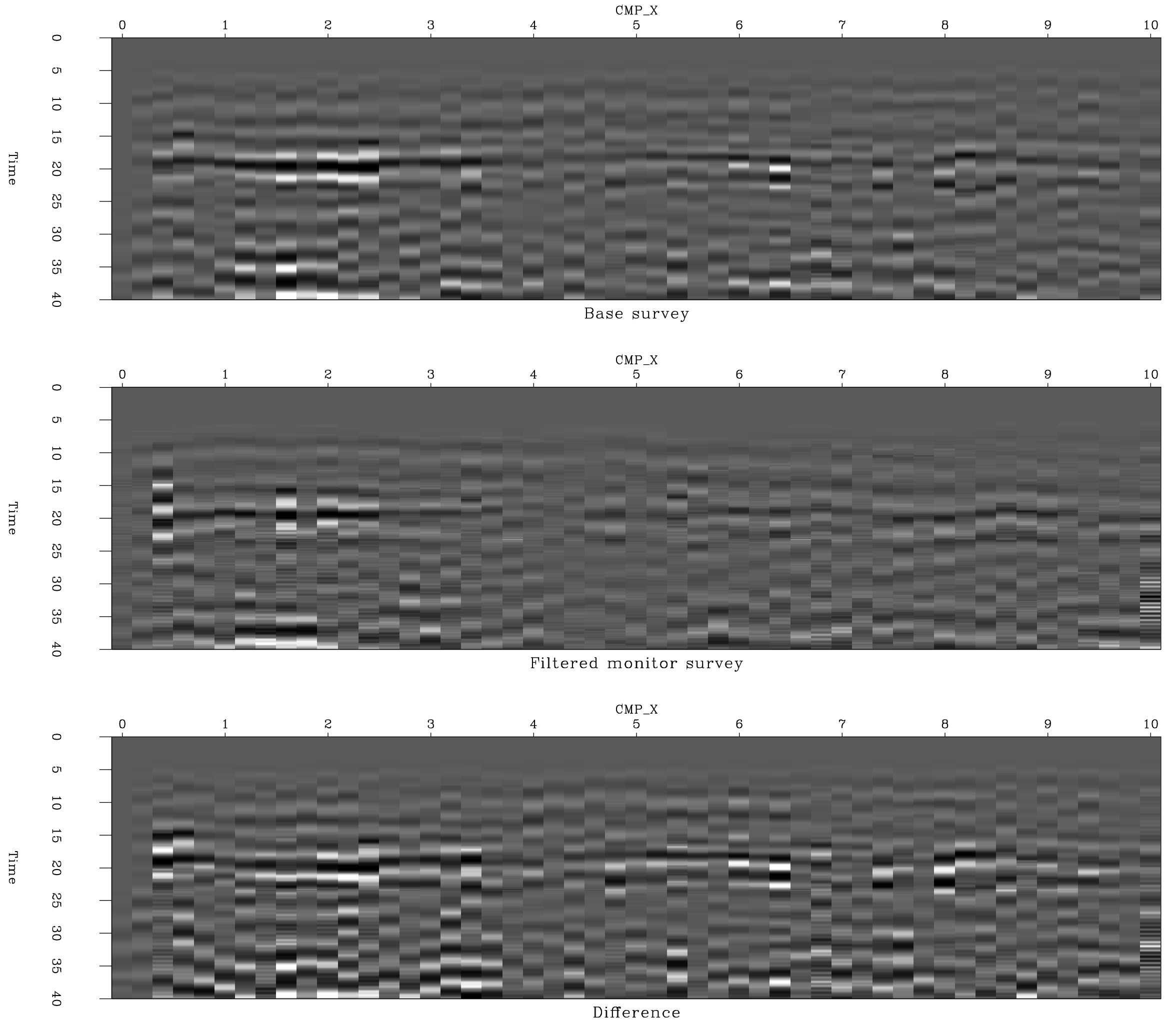

Figure 6: Cross-equalized stacked sections with high-pass filter (300 Hz) in processing flow. Top is no honey, center is with honey and bottom is difference. james2-inv.honey.300Hz [ER]

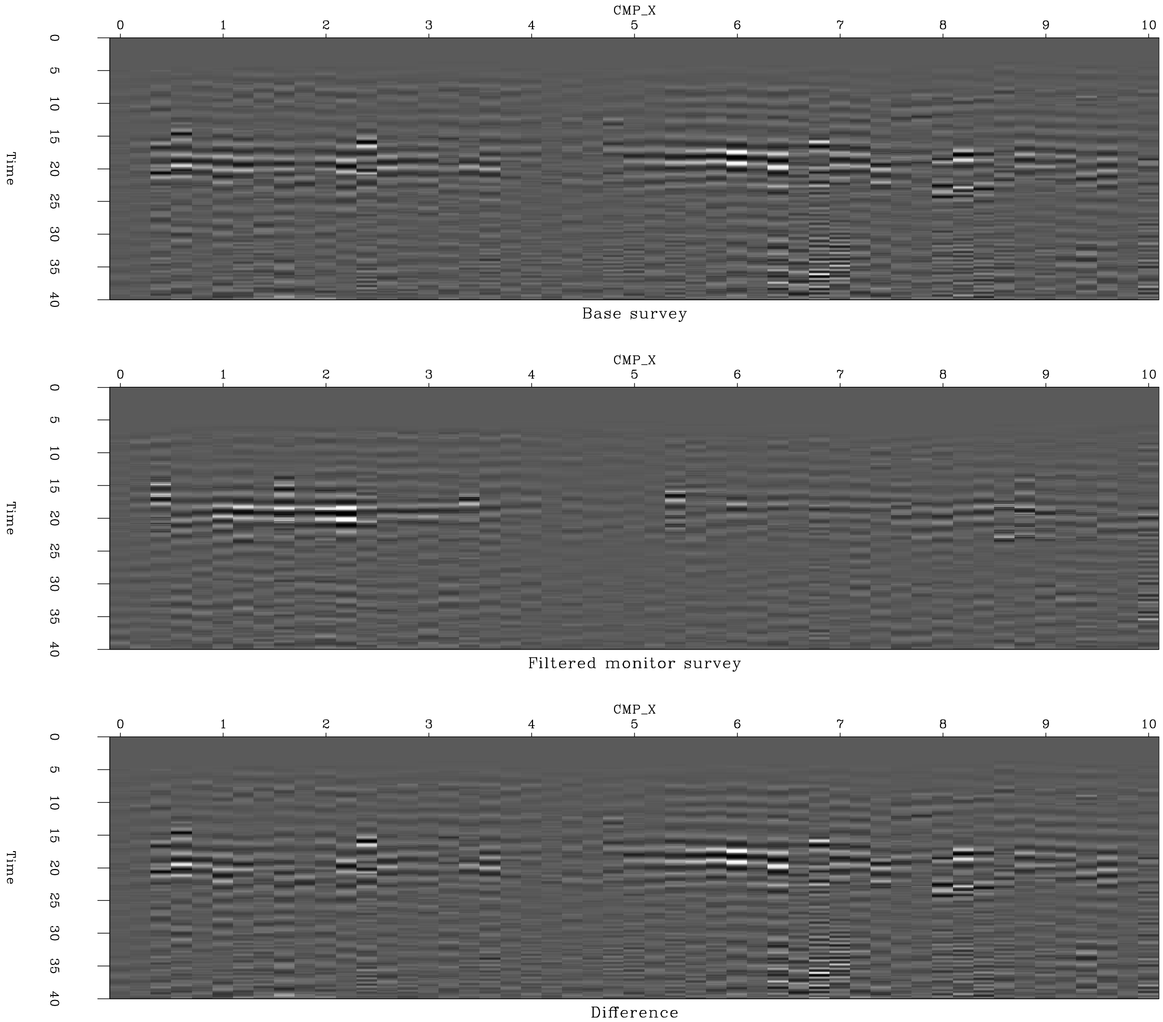

Figure 7: Cross-equalized stacked sections with high-pass filter (700 Hz) in processing flow. Top is no honey, center is with honey and bottom is difference. james2-inv.honey.700Hz [ER]