Muting Air-Wave Arrivals and Field Data from August 12, 2020

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Seismic Approach to Quality Management of HMA

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SUMMARY

- The importance of properly alleviating air wave energy existing in an acquired raw field record has been addressed multiple times in the previous work reports (e.g., April, May, and July progress reports). This report summarizes outcomes from one of those approaches when applied to a field data set acquired on August 12, 2020, on the same road previously surveyed (see here for previous survey results).
- Among multiple approaches, it is the "mute" approach summarized in this report that erases (i.e., zeros) all wavefields outside a designated mute window in a time-offset display of a raw field record. It turned out to be the most effective when constructing an accurate Lamb dispersion trend.
- It is also important to apply a pre-Lamb mute to reduce harmful influence from ambient noise. Therefore, both air-wave mute and pre-Lamb mute are simultaneously applied to the raw field record.
- Three (3) different types of mute have been tested. One is called "**MANUAL Mute**" that sets the mute window by visually inspecting the record to identify air-wave and Lamb-wave arrival times (msT0-air and msT0-Lamb) and propagating velocities (V-air and V-Lamb). With this approach, each record is manually muted one by one. The other type is called "**SURGICAL Mute**" that sets the mute window semi-automatically based on the presumptive values for msT0-air, msT0-Lamb, V-air, and V-Lamb. The arrival times (msT0-air and msT0-Lamb) can be approximately estimated based on the acquisition parameter of pre-trigger time (e.g., 1.0 ms), which is the length of previous time after air waves triggered the recording and therefore should be included in the acquired record. The velocity values (V-air and V-Lamb) can be set arbitrarily based on a common range of each type of waves (e.g., V-air = 340 m/s and V-Lamb = 1500 m/s). Once these values are set, then the "SURGICAL Mute" applies the same mute window to all records existing in the input file automatically. The last type is called "**AUTO Mute**" that tries to detect all four parameters (i.e., msT0-air, msT0-Lamb, V-air and V-Lamb) automatically through its own detecting algorithm. The algorithm is based on the Linear-Move-Out (LMO) stacking to detect different waves (e.g., air vs. Lamb) arriving with different velocities.

SUMMARY (Cont'd)

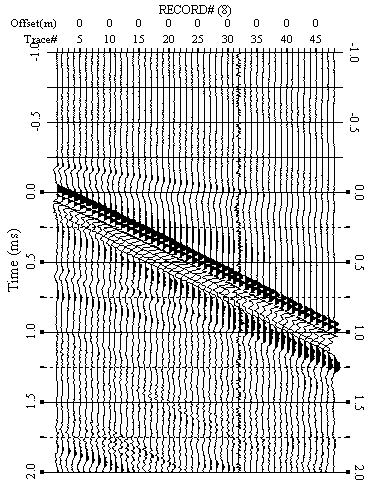
- The "AUTO Mute" includes additional algorithms that can detect other wave attributes that may exist in the raw field record such as reverberating air wave arrivals, air wave arrivals from the opposite end of the receiver array, too-low signal-to-noise (SN) ratio, etc. They are automatically applied whenever detected being necessary to improve the accuracy in the evaluation of the mute window and also to improve the overall SN ratio of the recorded Lamb waves.
- All three (3) approaches are applied to a data set acquired on August 12, 2020, on the same road previously surveyed on July 22, 2020. Results of time-domain records and corresponding dispersion images are displayed for various comparison purposes in this report.
- Results from all three approaches are comparable to each other in seismic data and dispersion image qualities. However, the "AUTO Mute" provided slightly superior quality. The comparison will continue to be made on further future data sets to confirm the superiority.
- Advantage of pre-Lamb mute is illustrated by using a field record that shows dispersion image trend at high frequencies (e.g., > 20 kHz) is improved due to the attenuation of ambient noise in the corresponding high frequency range.
- Importance of using a "proper" mute window is illustrated by using a field record.
- All (20) field records acquired on August 12, 2020, are displayed in raw data format as well as processed dispersion image format for the purpose of evaluating Lamb wave quality. They were obtained by using both forward (FWRD) and reverse (REVS) impact sources attached at forward (i.e., #1 channel side) and reverse (i.e., #48 channel side) side of the receiver array, respectively. All reverse-shot records, however, are purposely flipped to look like forward-shot records by the software at the time of data import, which is necessary to apply all mute approaches properly. In consequence, those reverse-shot records are separately marked by (*) to indicate so.

SUMMARY (Cont'd)

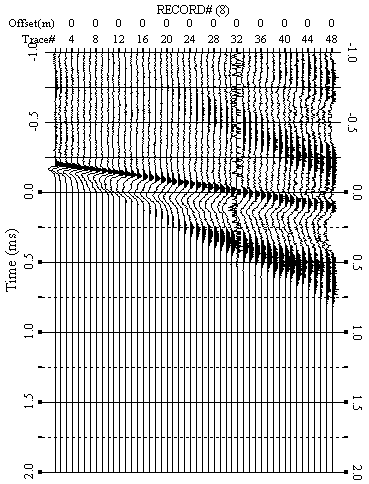
- Comparing dispersion images from forward- and reverse-shot records, those from the reverse shots did not have proper Lamb dispersion trend. This seems to be related to a short pre-trigger time (0.5 ms) that was not long enough to catch the Lamb waves that arrived earlier than air waves by more than 0.5 ms (e.g., 1.0 ms) due to the extended distance between the array center and the impact point of the reverse shot. This will be verified from a next field survey with a longer pre-trigger time (e.g., 1.5 ms). This hypothesis was tested in two slides by using rough estimation of impact distances for both shots (i.e., FWARD and REVE) from the receiver array by using a configuration shown on a photo.
- Amplitudes of forward and reverse shots are compared by displaying peak amplitudes of all (48) traces in each record. The display indicates that, in general, the reverse shots were more powerful than the forward shots.
- Decimation of channels (i.e., from 48 to 16 channels) was tested for each record from surveys performed during July and August for the purpose of evaluating any possible degrade of data quality in Lamb dispersion image. The results show there is little difference, indicating that a 16-channel array will be able to provide an equally good quality.

Muting Air and Pre-Lamb Wavefiels

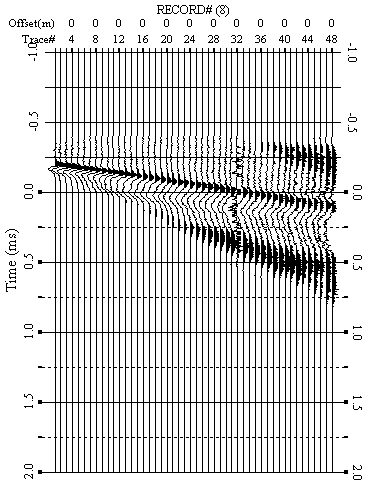
This shows that muting air waves and later arrivals and pre-Lamb arrivals consistently improves the quality of dispersion image.



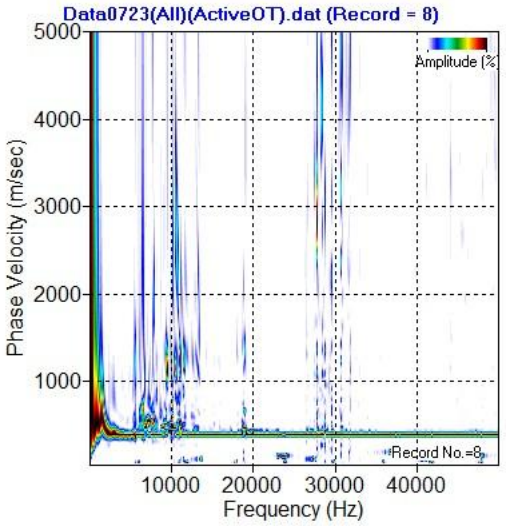
RAW

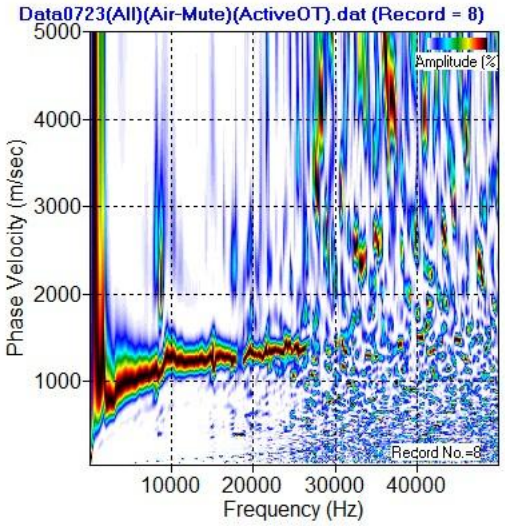


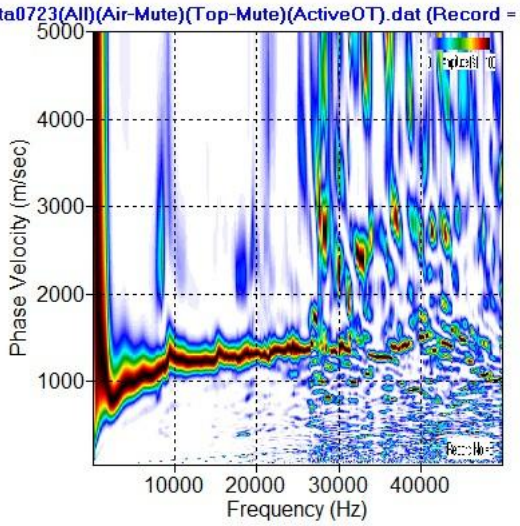
AIR MUTE



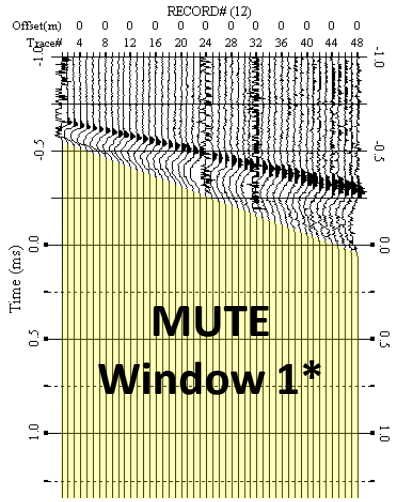
AIR + Pre-Lamb MUTE



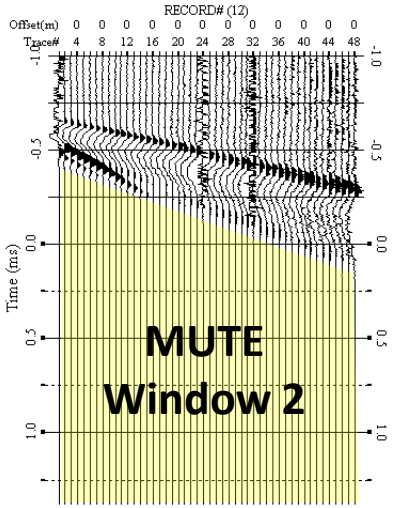


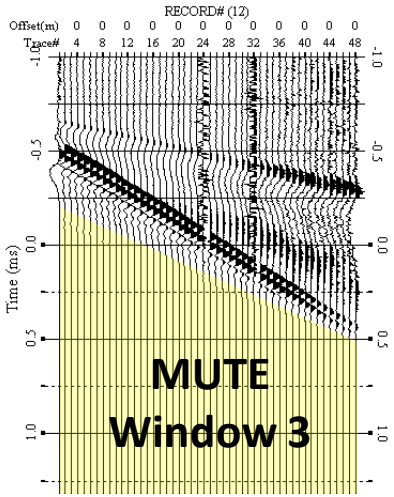


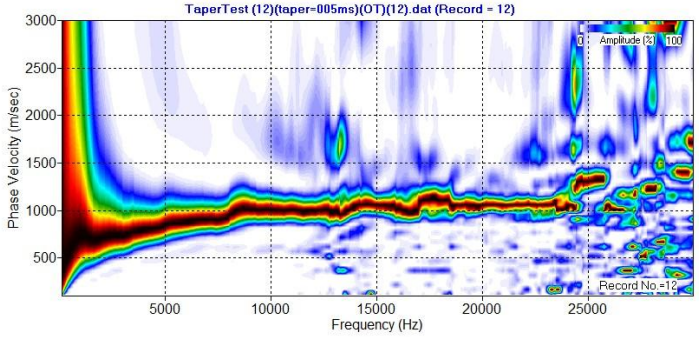
Optimum MUTE Window

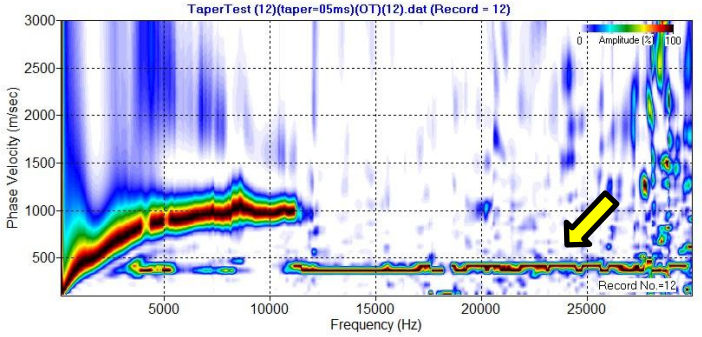


** Most optimum mute window applied*

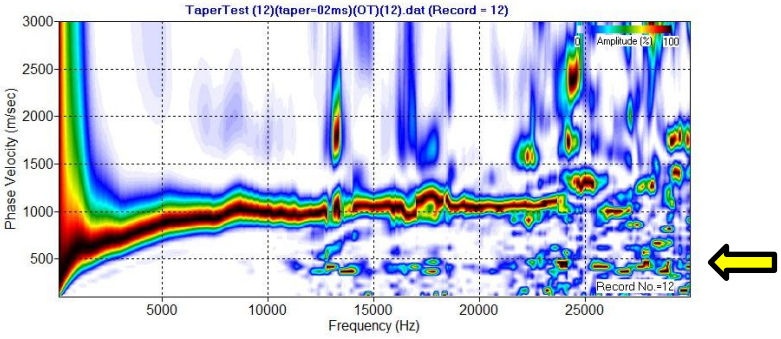


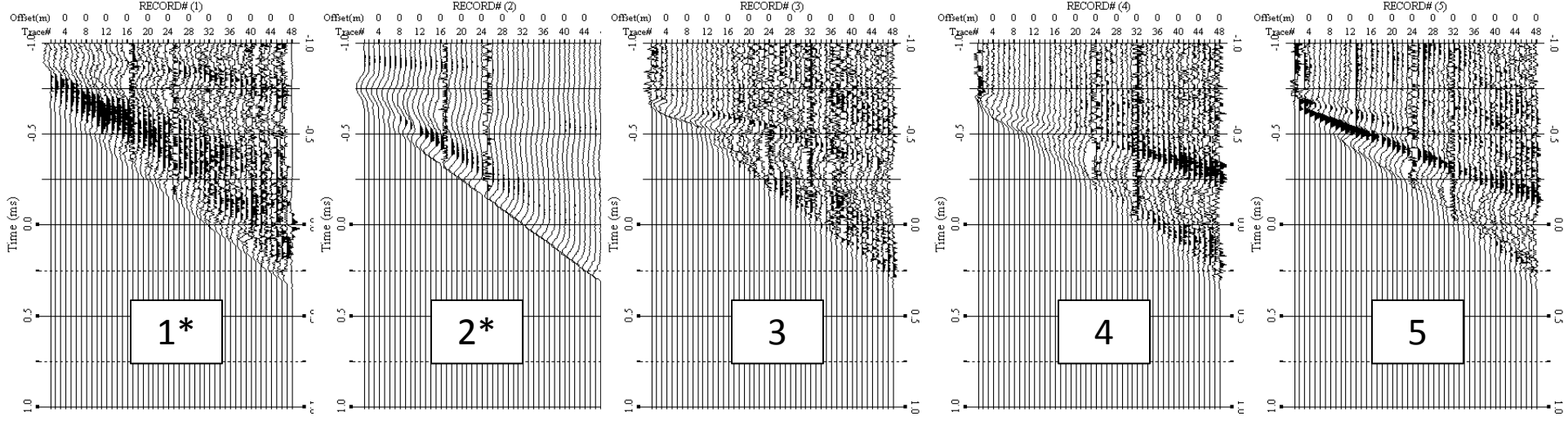


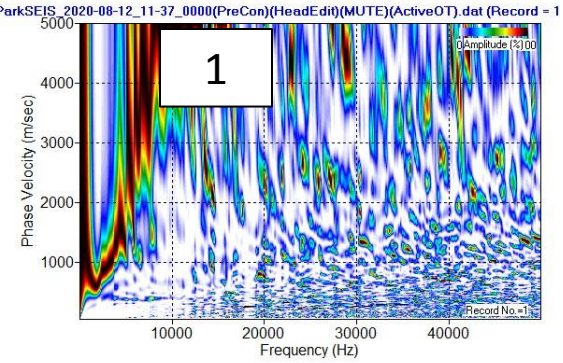




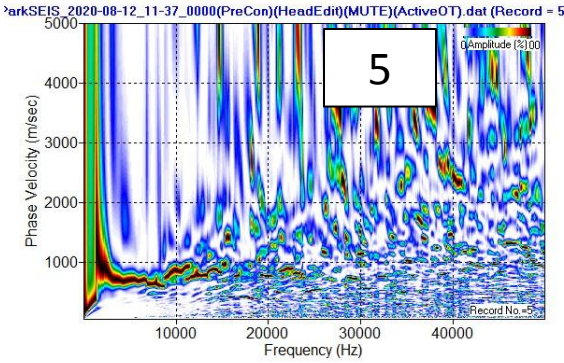
⇦ *: artifact created from improper muting window*

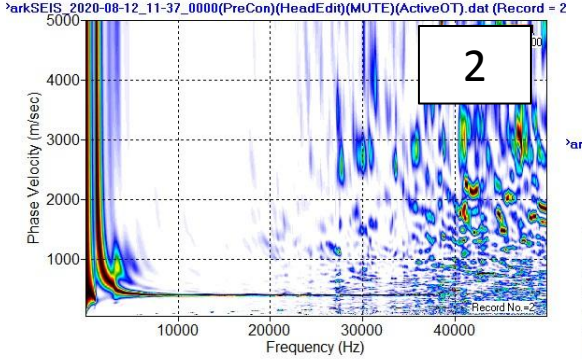


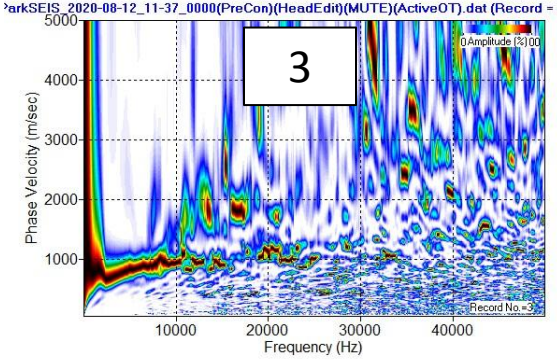


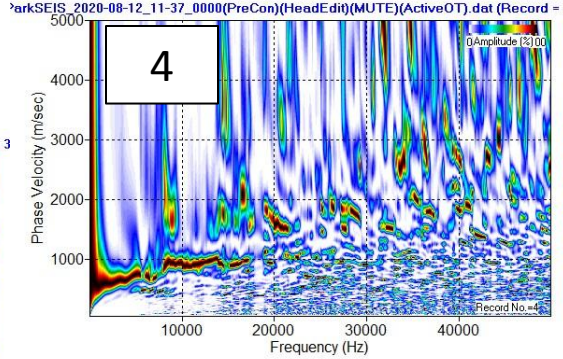


Air-Wave MANUALLY Muted Field Records

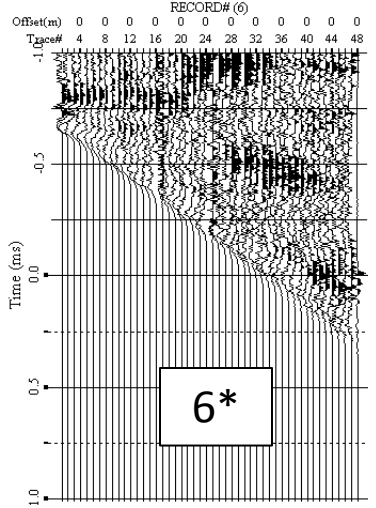


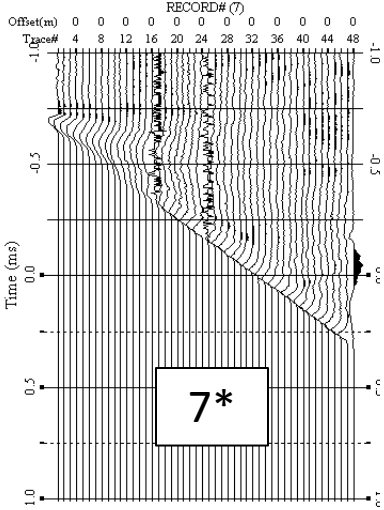


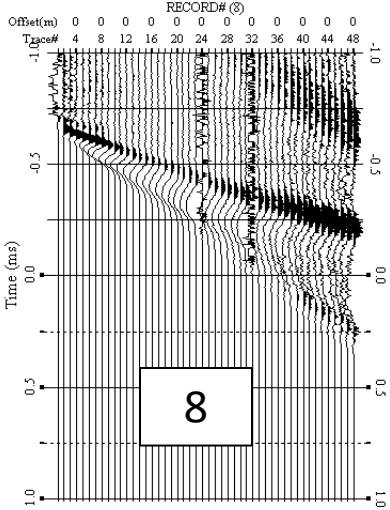


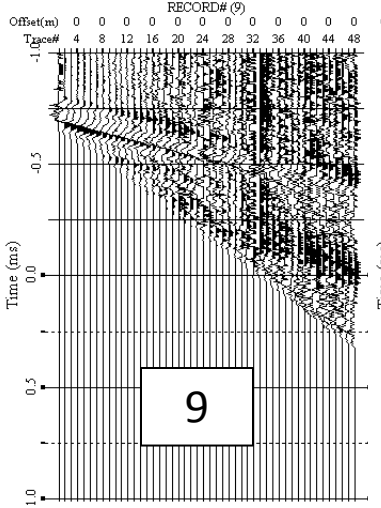


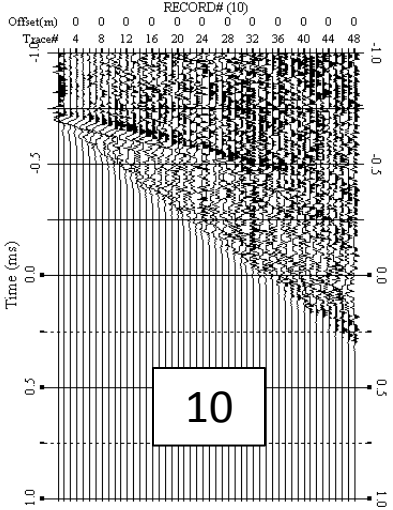
*Reverse shot

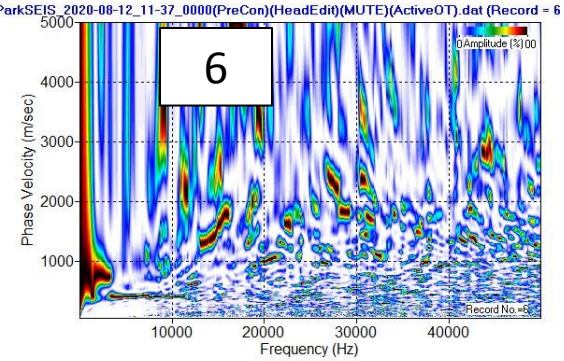




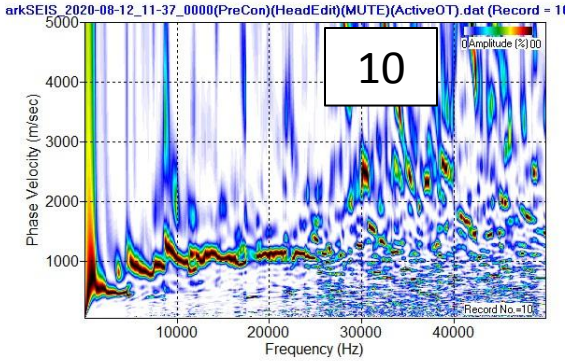


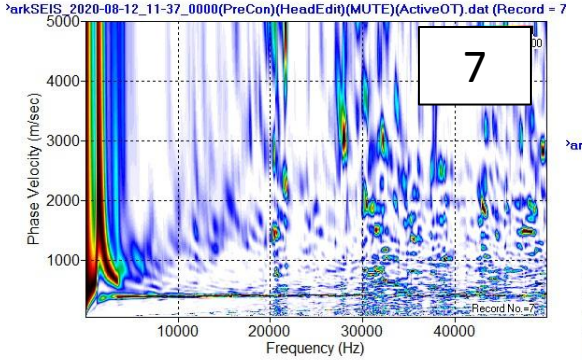


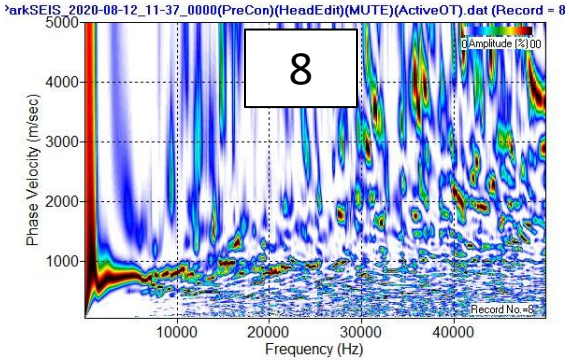


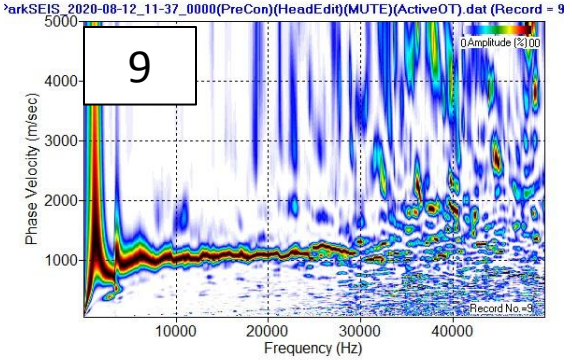


Air-Wave MANUALLY Muted Field Records

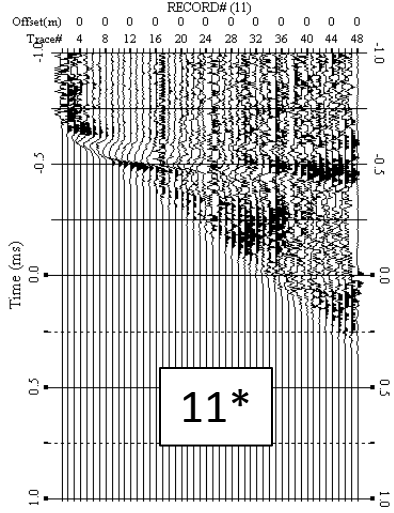


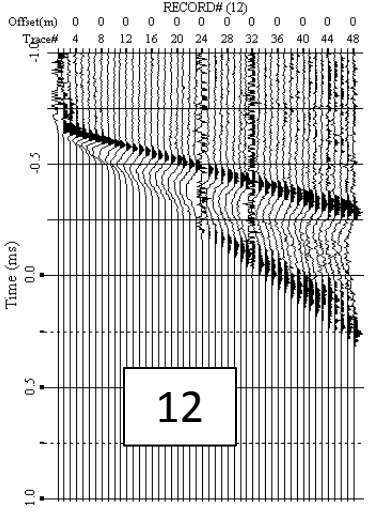


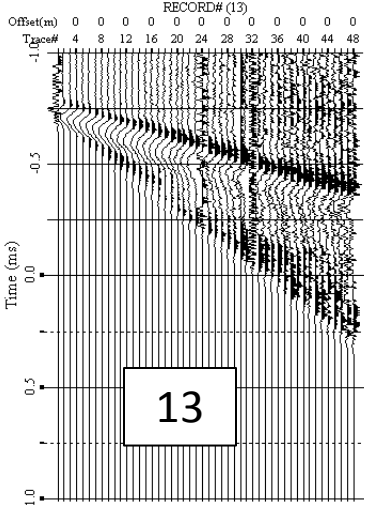


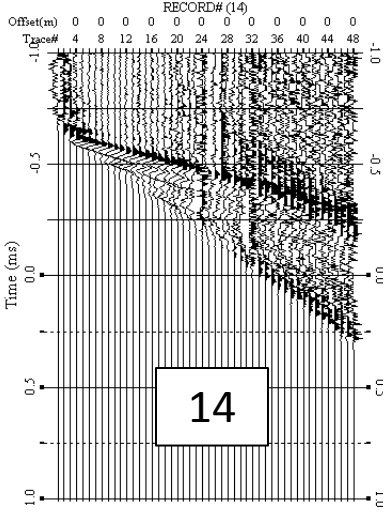


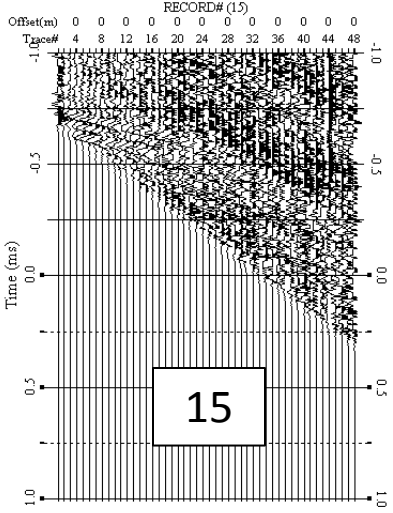
*Reverse shot

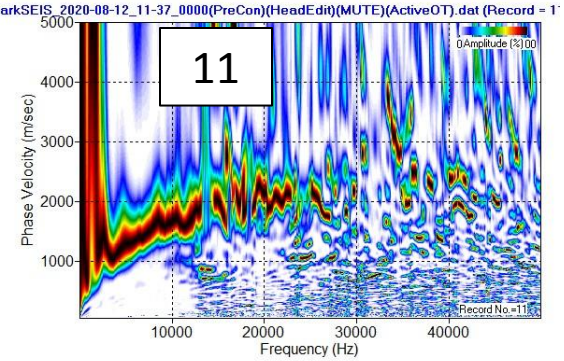




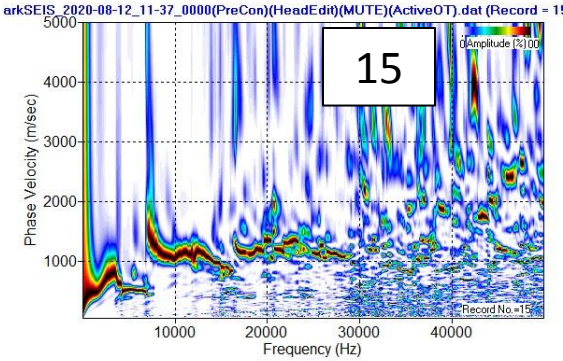


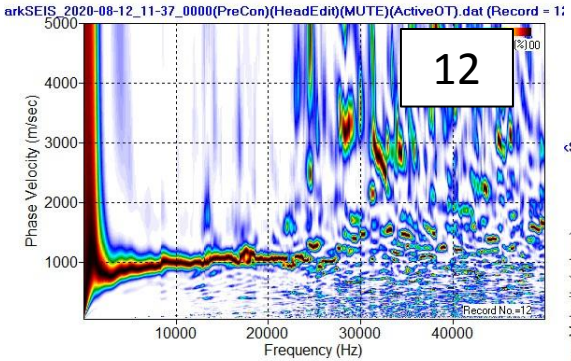


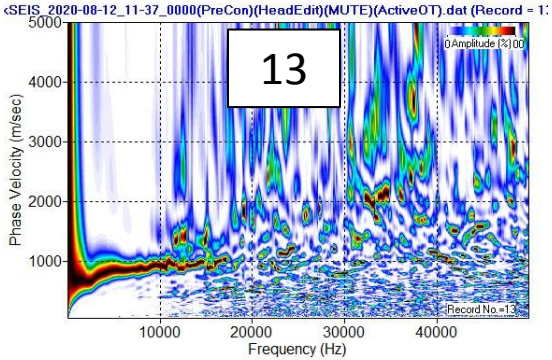


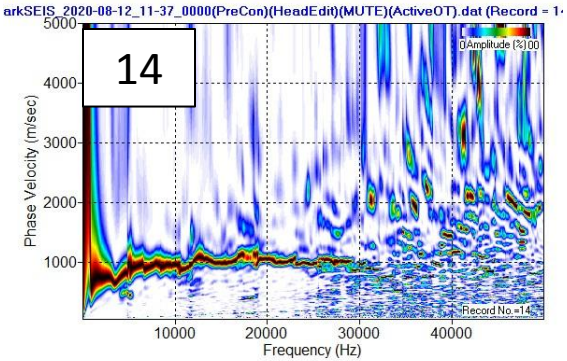


Air-Wave MANUALLY Muted Field Records









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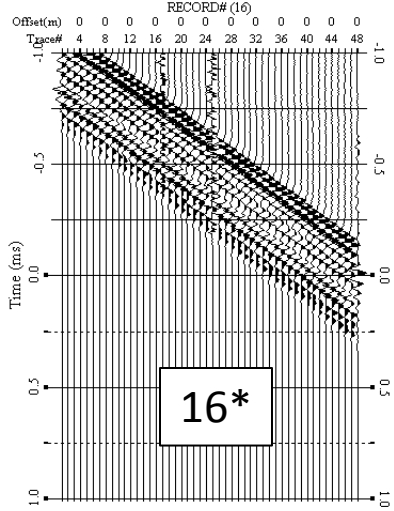
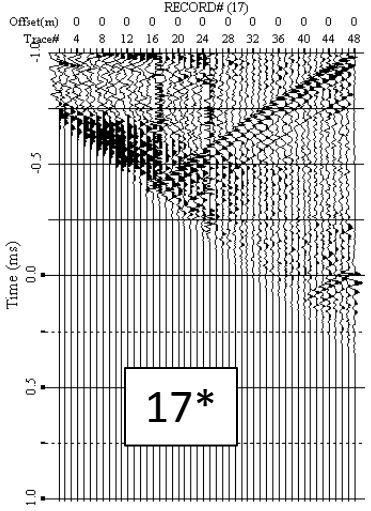
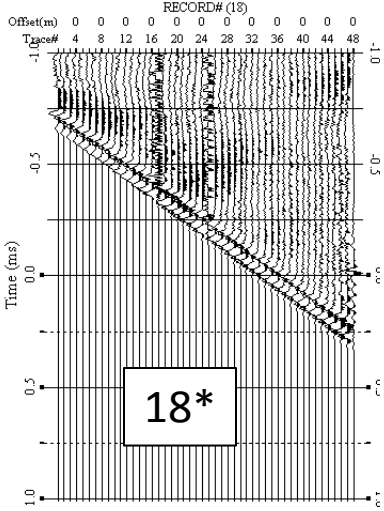
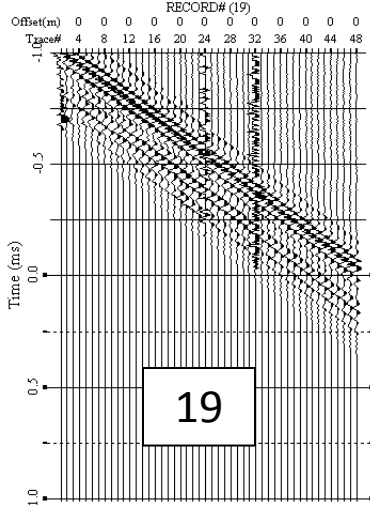
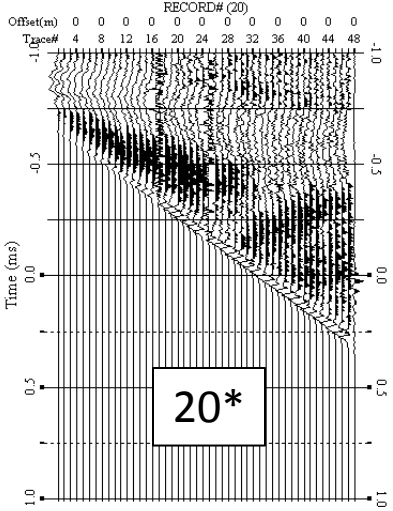
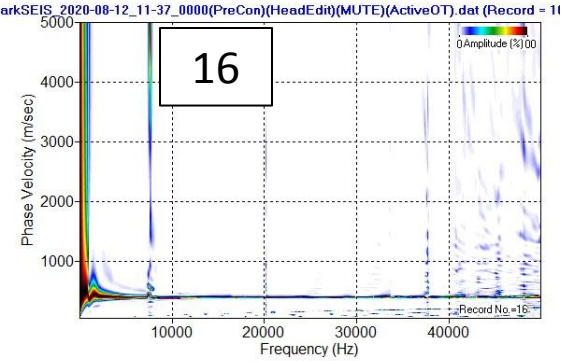




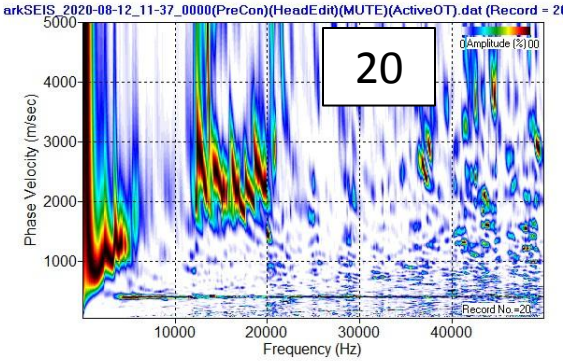


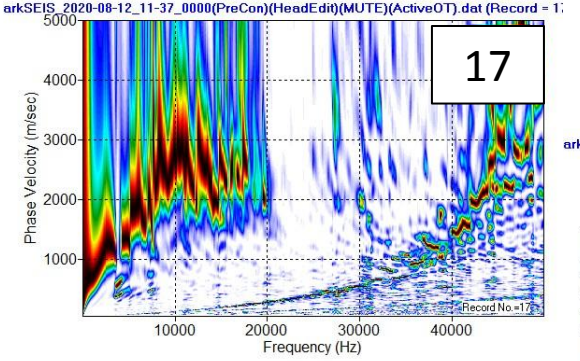


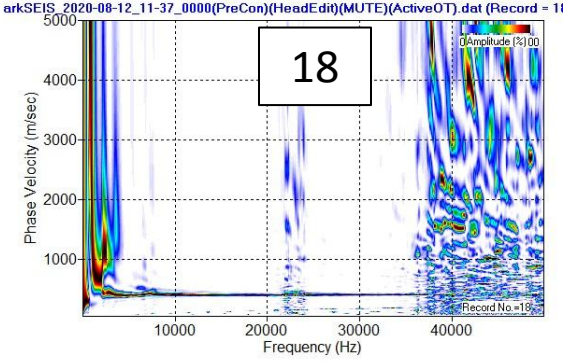


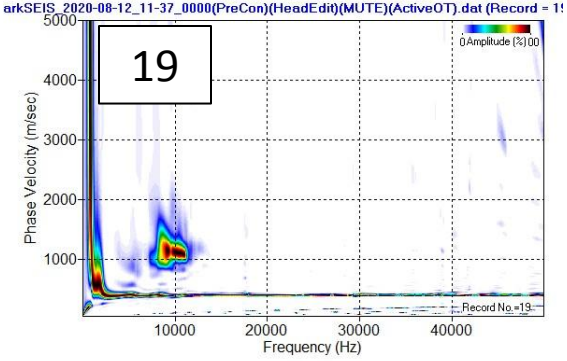


Air-Wave MANUALLY Muted Field Records

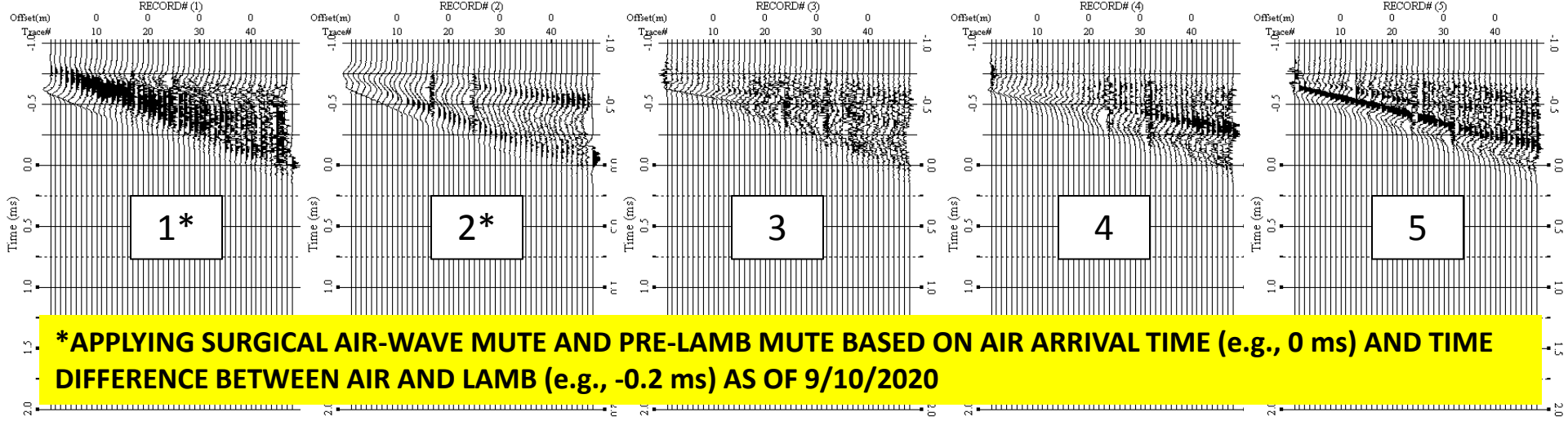




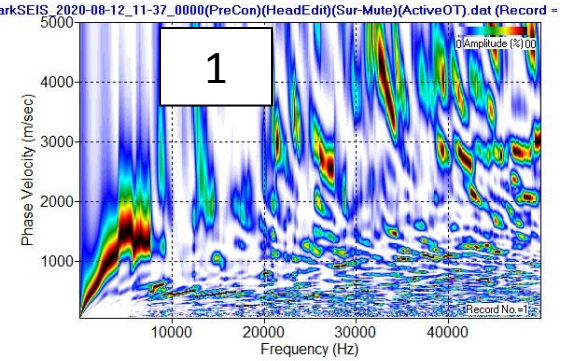




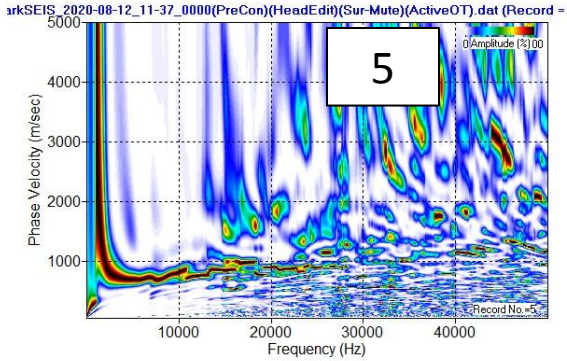
*Reverse shot

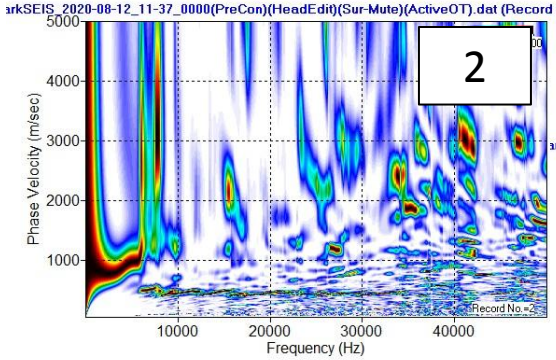


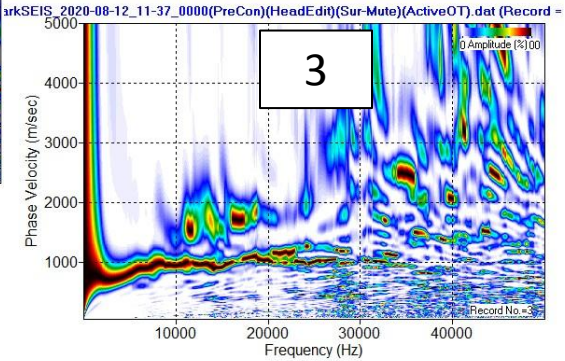
***APPLYING SURGICAL AIR-WAVE MUTE AND PRE-LAMB MUTE BASED ON AIR ARRIVAL TIME (e.g., 0 ms) AND TIME DIFFERENCE BETWEEN AIR AND LAMB (e.g., -0.2 ms) AS OF 9/10/2020**

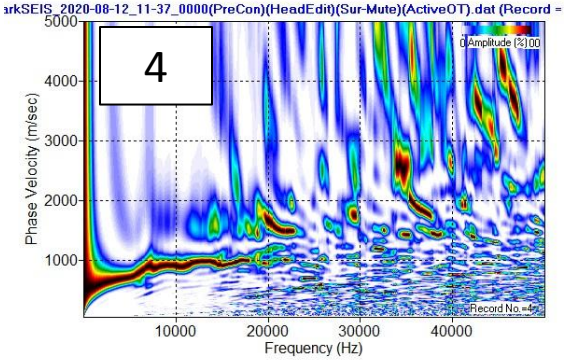


Air-Wave SURGICALLY* Muted Field Records

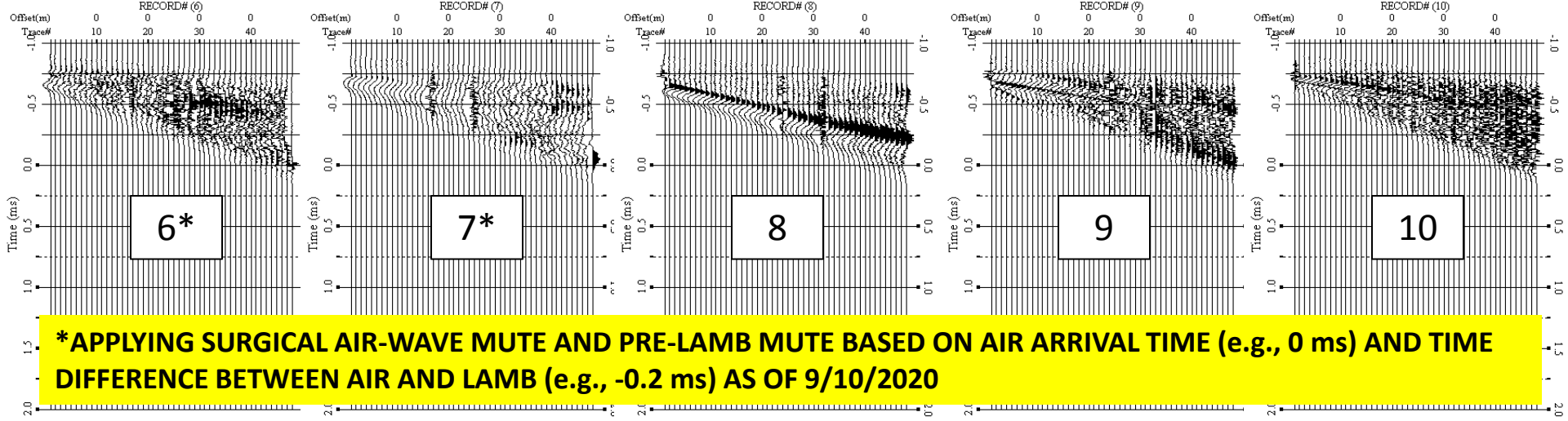






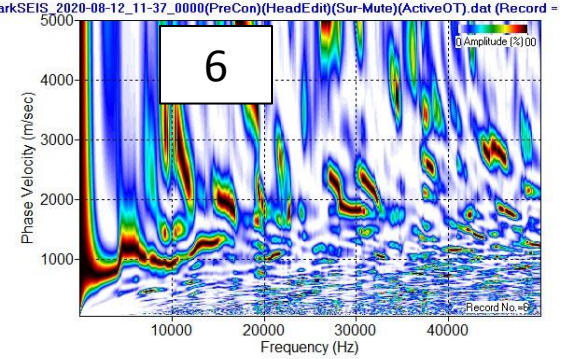


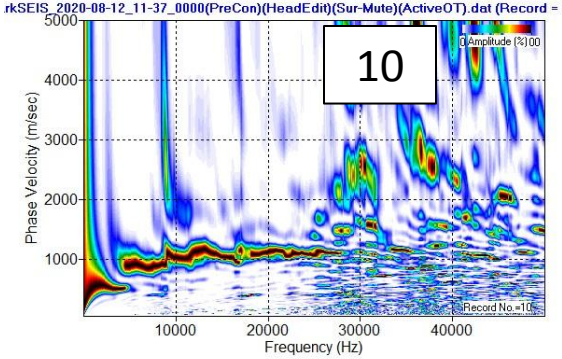
*Reverse shot

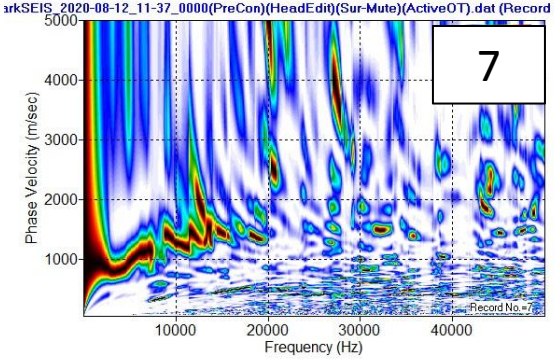


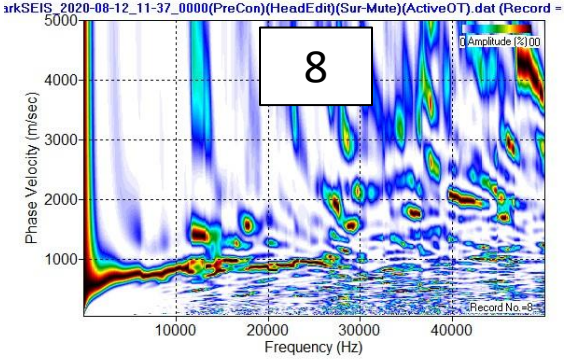
***APPLYING SURGICAL AIR-WAVE MUTE AND PRE-LAMB MUTE BASED ON AIR ARRIVAL TIME (e.g., 0 ms) AND TIME DIFFERENCE BETWEEN AIR AND LAMB (e.g., -0.2 ms) AS OF 9/10/2020**

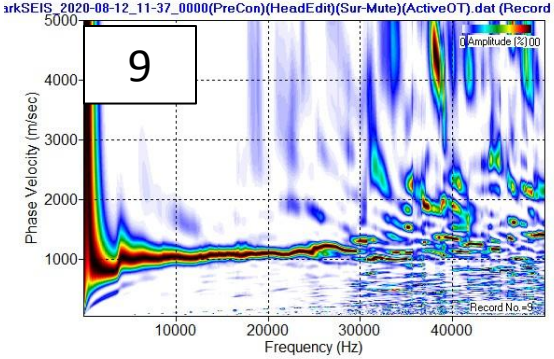
Air-Wave SURGICALLY* Muted Field Records



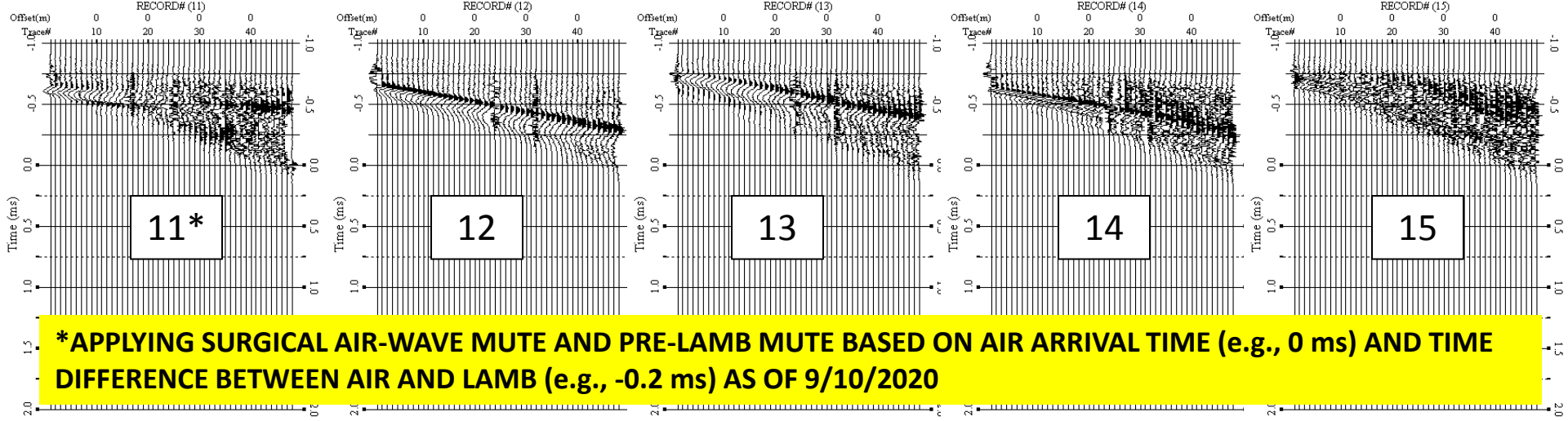






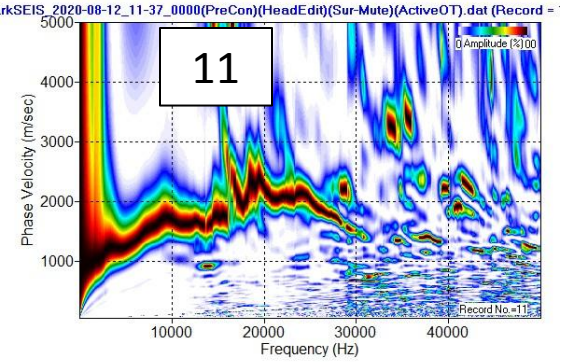


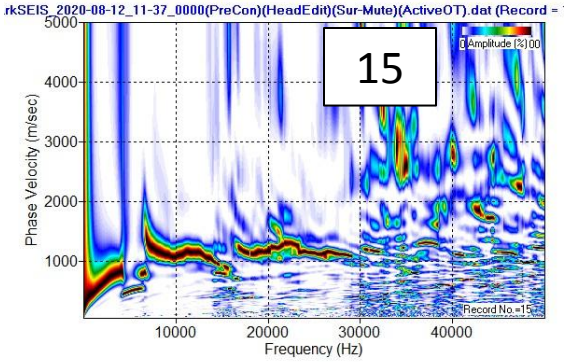
*Reverse shot

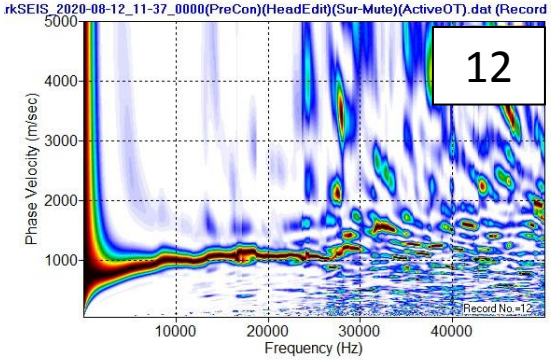


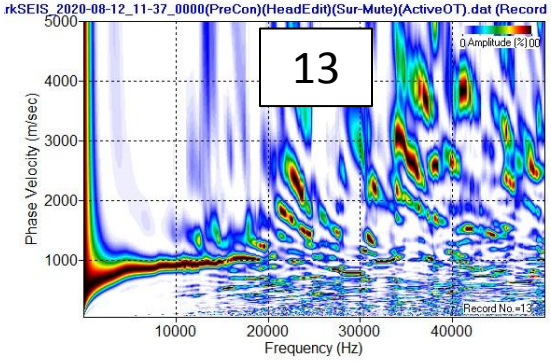
***APPLYING SURGICAL AIR-WAVE MUTE AND PRE-LAMB MUTE BASED ON AIR ARRIVAL TIME (e.g., 0 ms) AND TIME DIFFERENCE BETWEEN AIR AND LAMB (e.g., -0.2 ms) AS OF 9/10/2020**

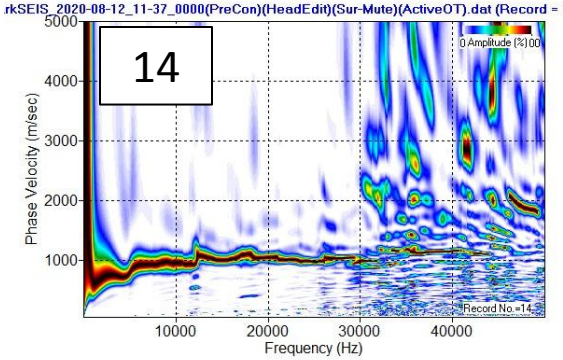
Air-Wave SURGICALLY* Muted Field Records











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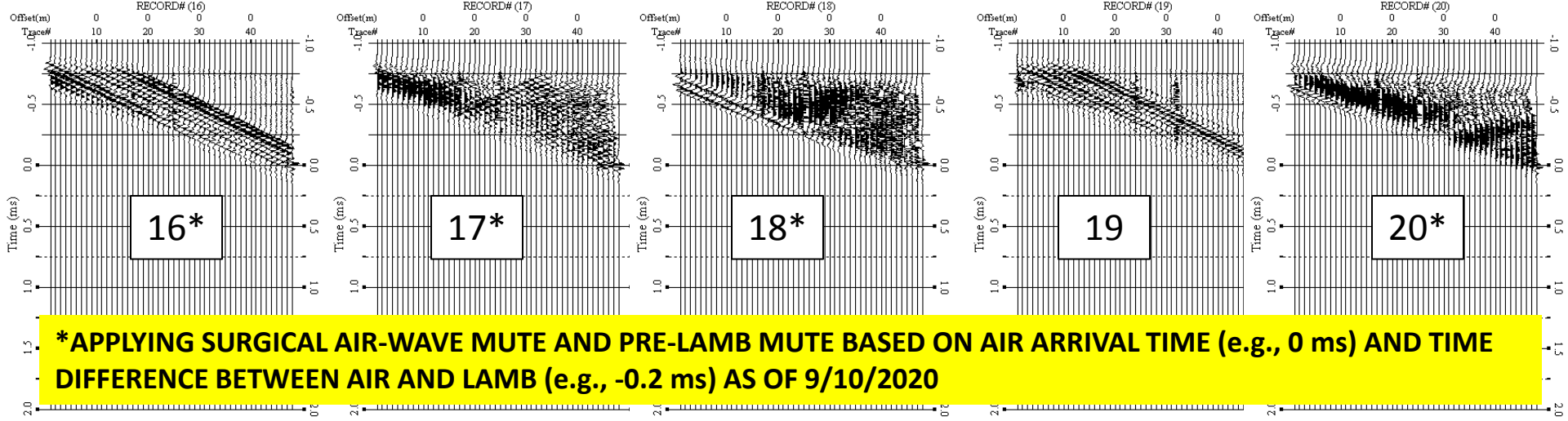
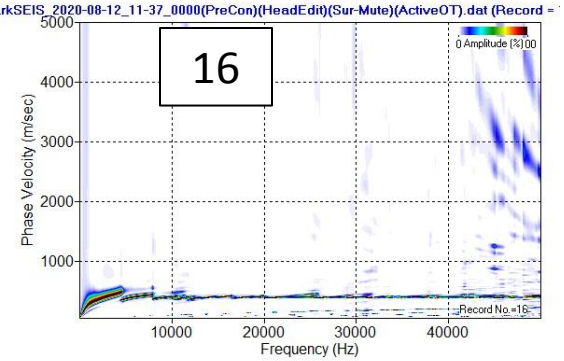
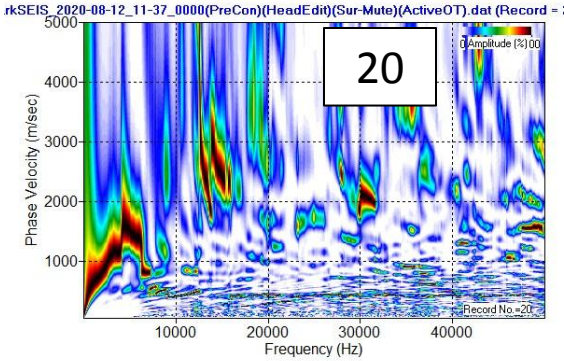
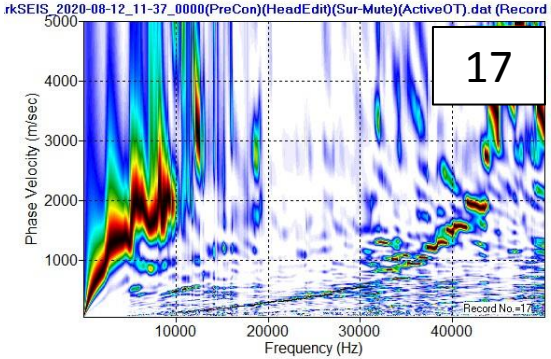


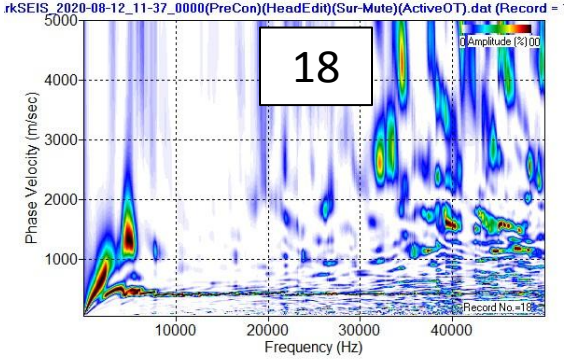
***APPLYING SURGICAL AIR-WAVE MUTE AND PRE-LAMB MUTE BASED ON AIR ARRIVAL TIME (e.g., 0 ms) AND TIME DIFFERENCE BETWEEN AIR AND LAMB (e.g., -0.2 ms) AS OF 9/10/2020**

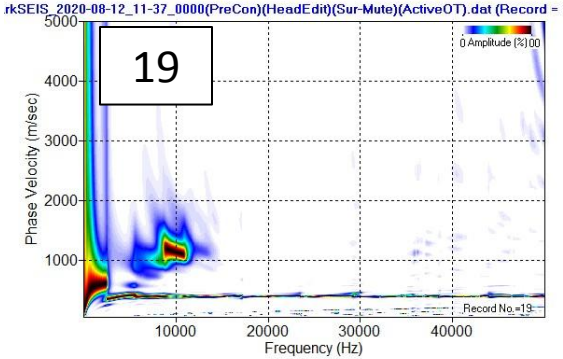
Air-Wave SURGICALLY* Muted Field Records



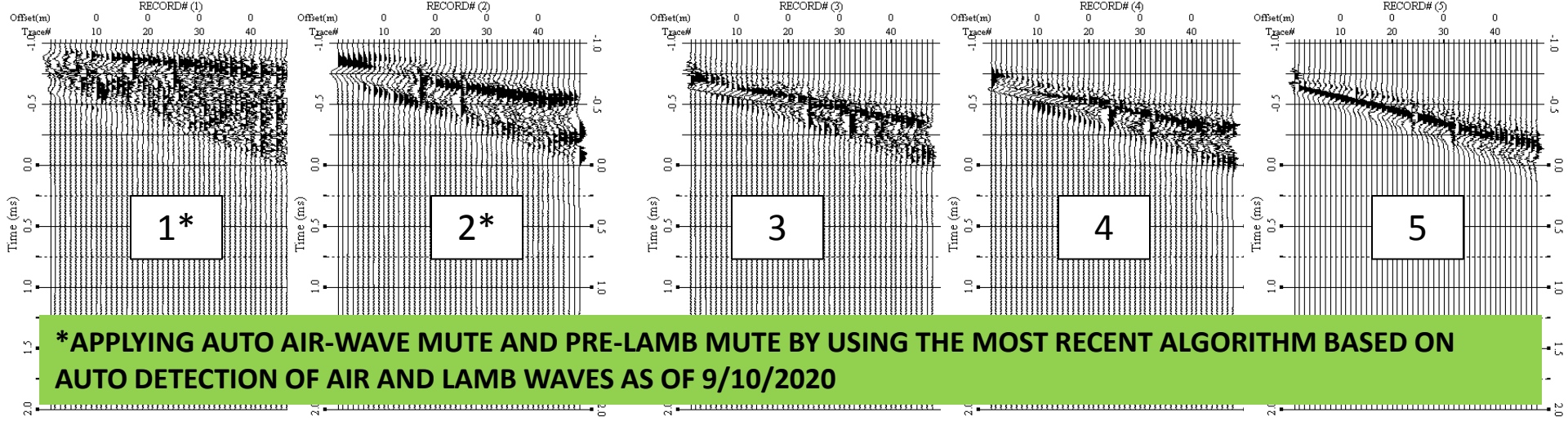






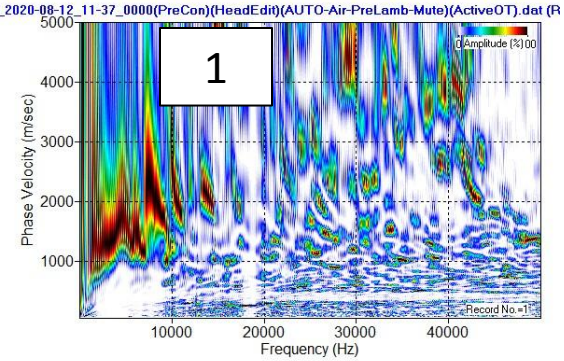


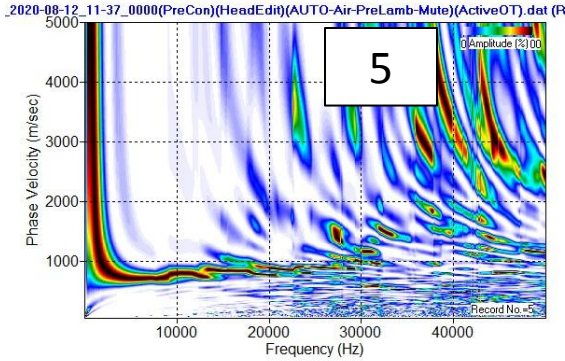
*Reverse shot

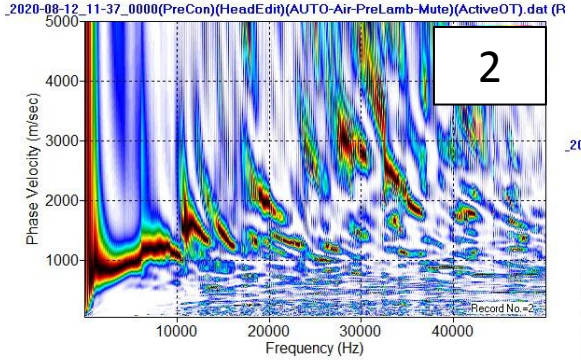


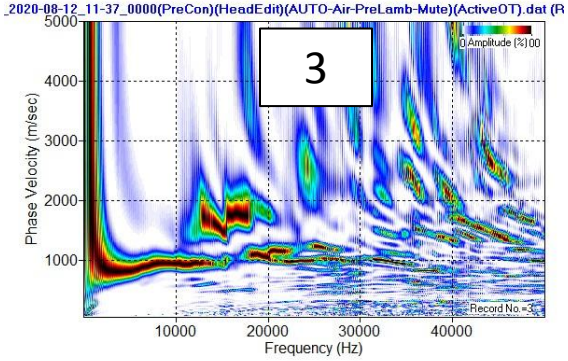
***APPLYING AUTO AIR-WAVE MUTE AND PRE-LAMB MUTE BY USING THE MOST RECENT ALGORITHM BASED ON AUTO DETECTION OF AIR AND LAMB WAVES AS OF 9/10/2020**

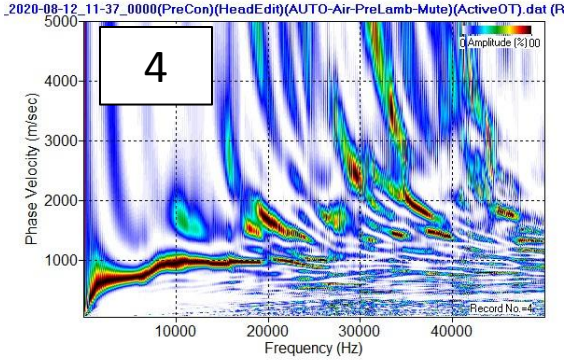
Air-Wave AUTOMATICALLY* Muted Field Records











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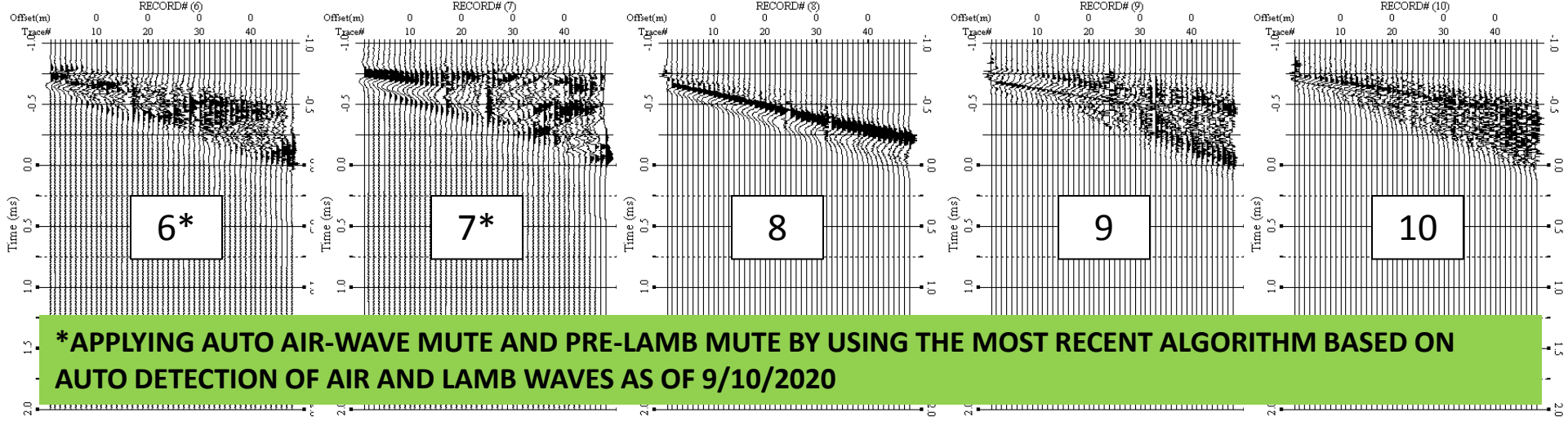
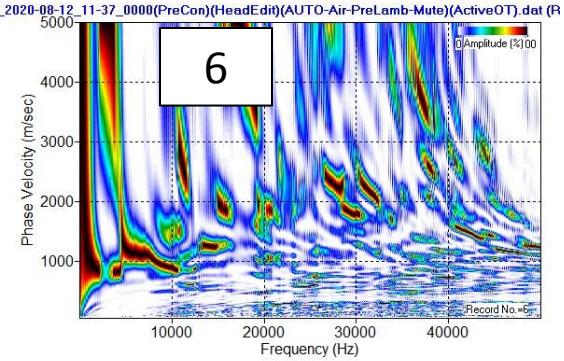
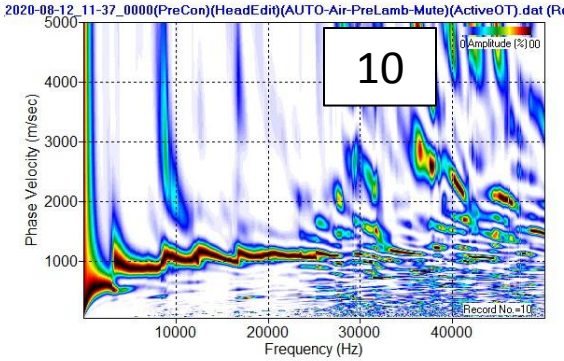
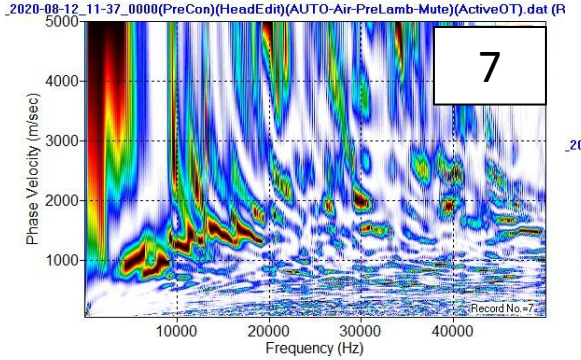


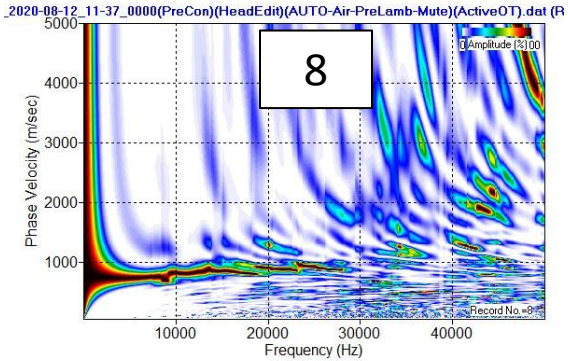
***APPLYING AUTO AIR-WAVE MUTE AND PRE-LAMB MUTE BY USING THE MOST RECENT ALGORITHM BASED ON AUTO DETECTION OF AIR AND LAMB WAVES AS OF 9/10/2020**

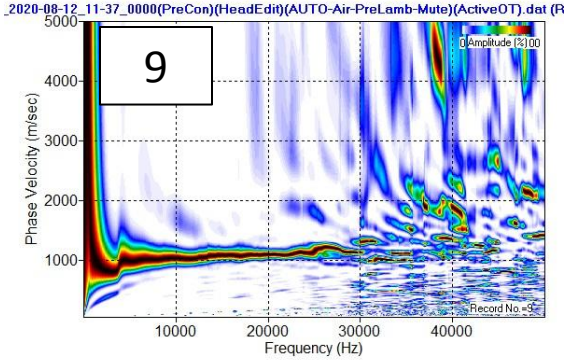


Air-Wave AUTOMATICALLY* Muted Field Records

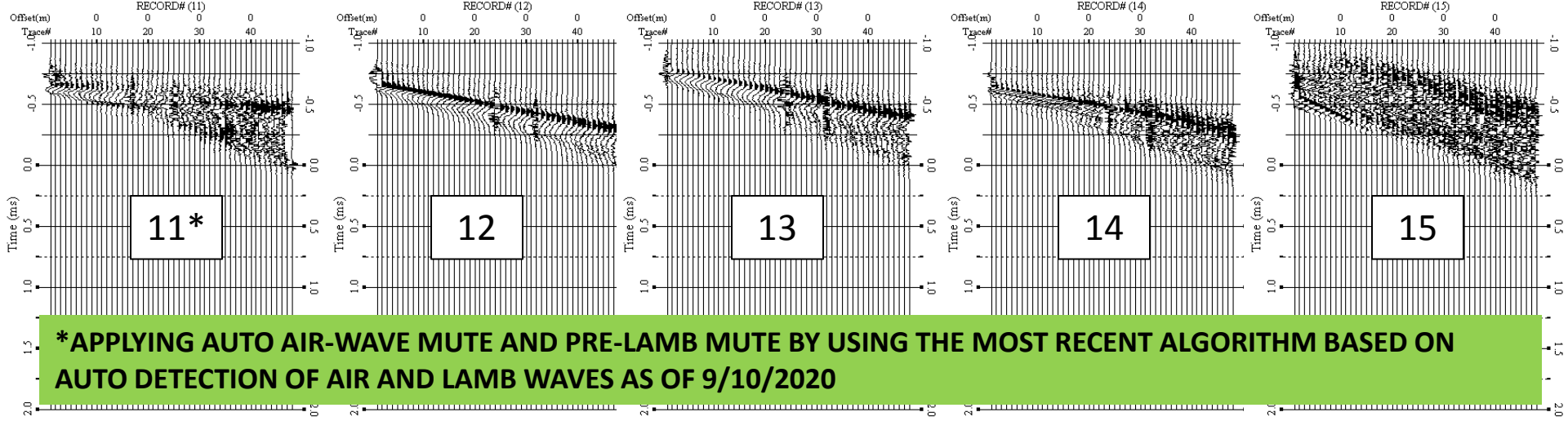






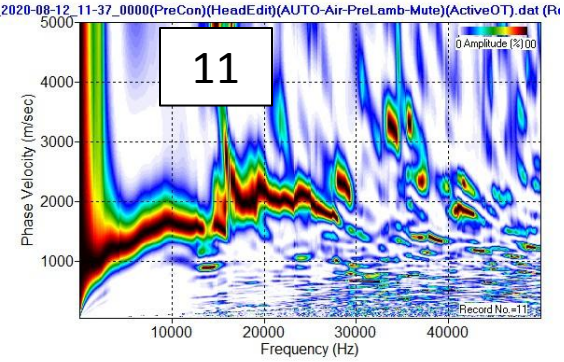


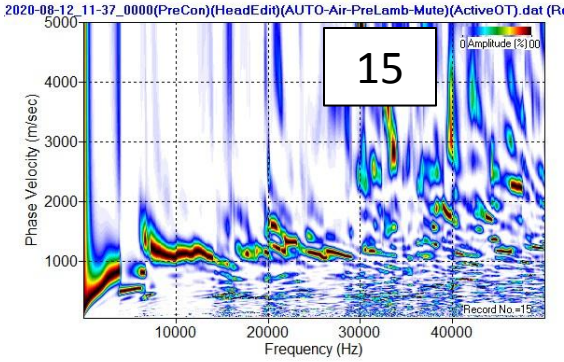
*Reverse shot

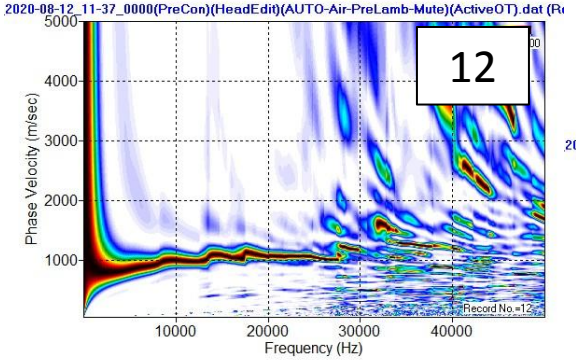


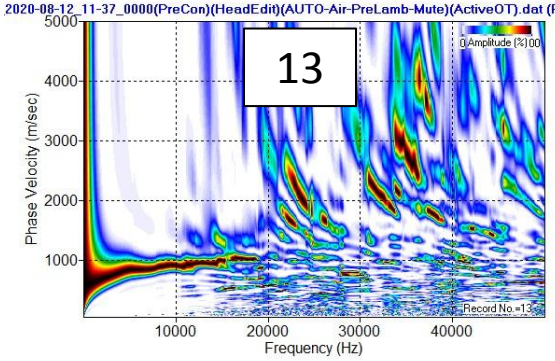
***APPLYING AUTO AIR-WAVE MUTE AND PRE-LAMB MUTE BY USING THE MOST RECENT ALGORITHM BASED ON AUTO DETECTION OF AIR AND LAMB WAVES AS OF 9/10/2020**

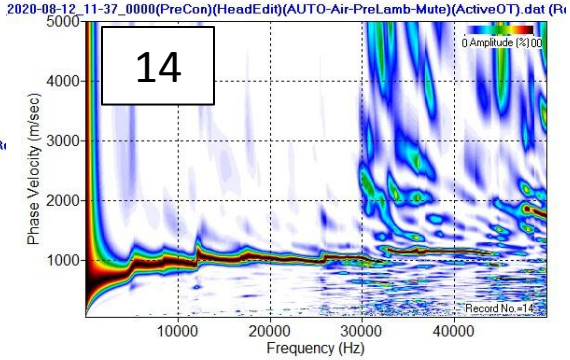
Air-Wave AUTOMATICALLY* Muted Field Records



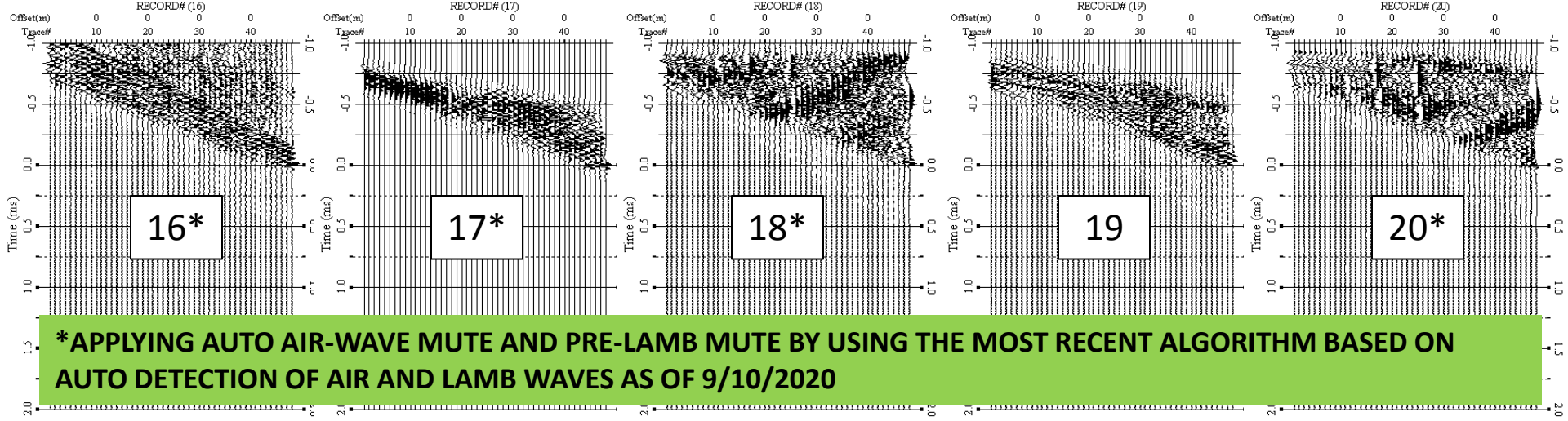




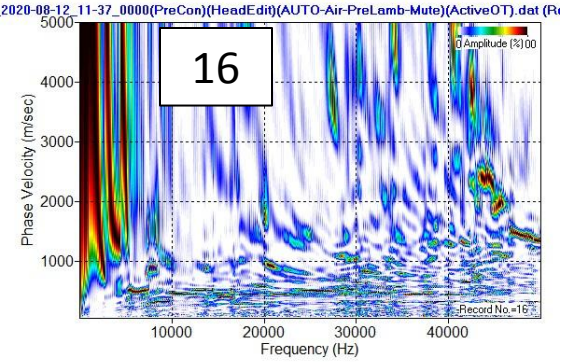




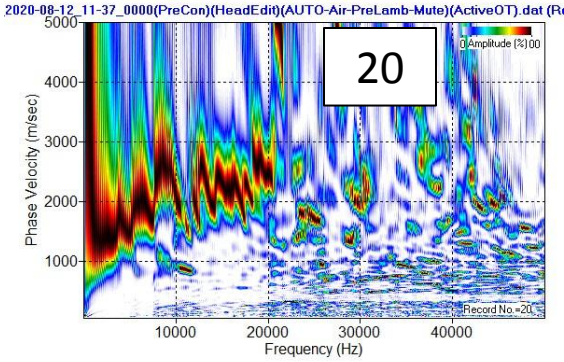
*Reverse shot

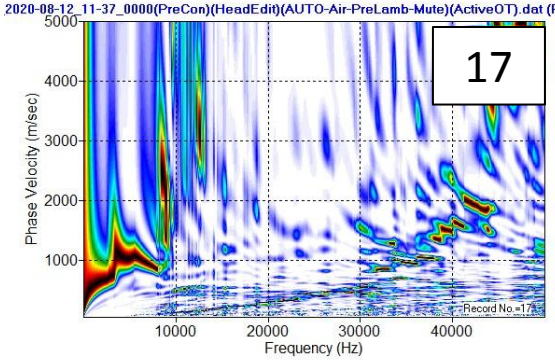


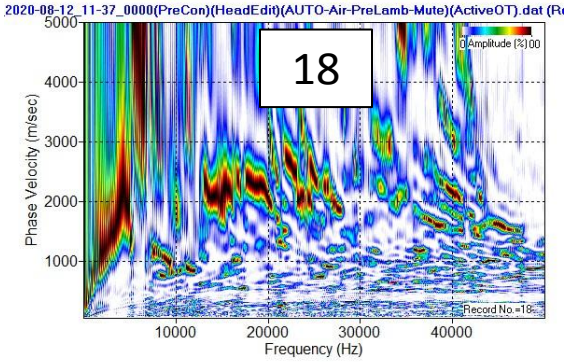
***APPLYING AUTO AIR-WAVE MUTE AND PRE-LAMB MUTE BY USING THE MOST RECENT ALGORITHM BASED ON AUTO DETECTION OF AIR AND LAMB WAVES AS OF 9/10/2020**

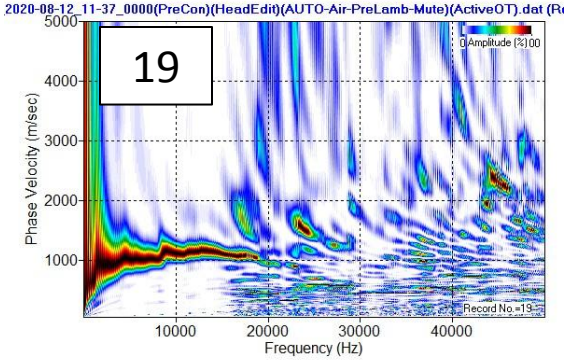


Air-Wave AUTOMATICALLY* Muted Field Records

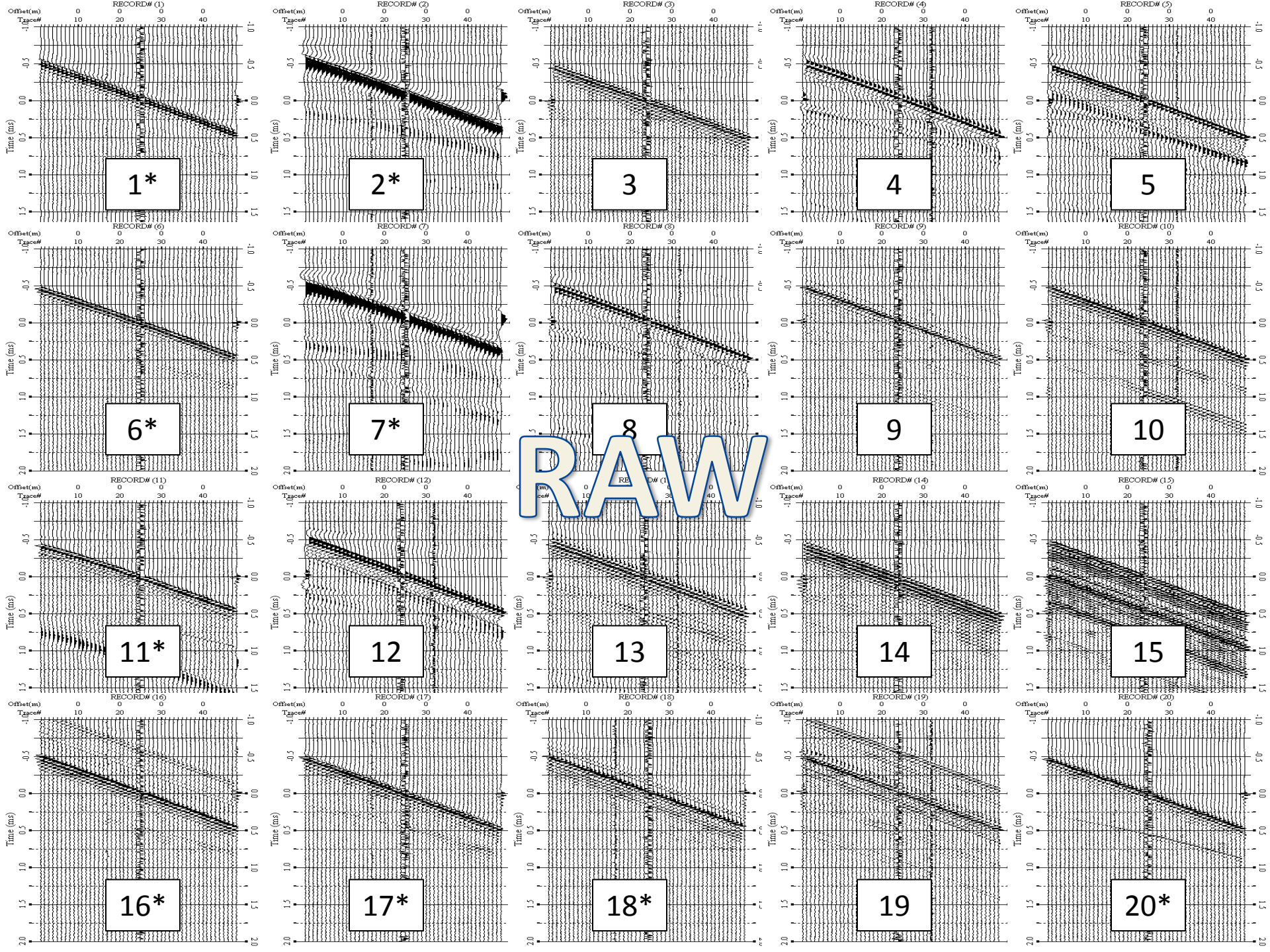








*Reverse shot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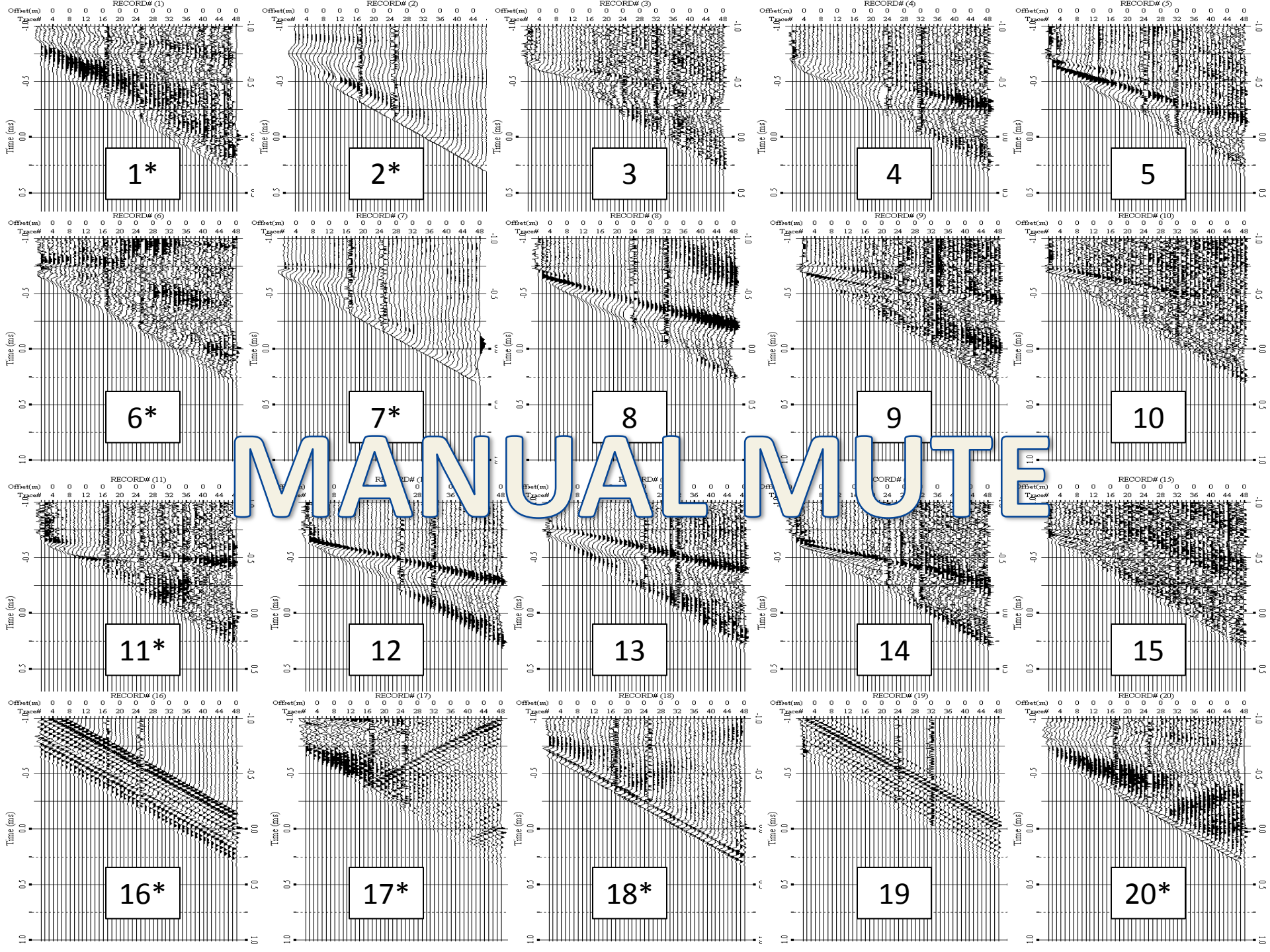
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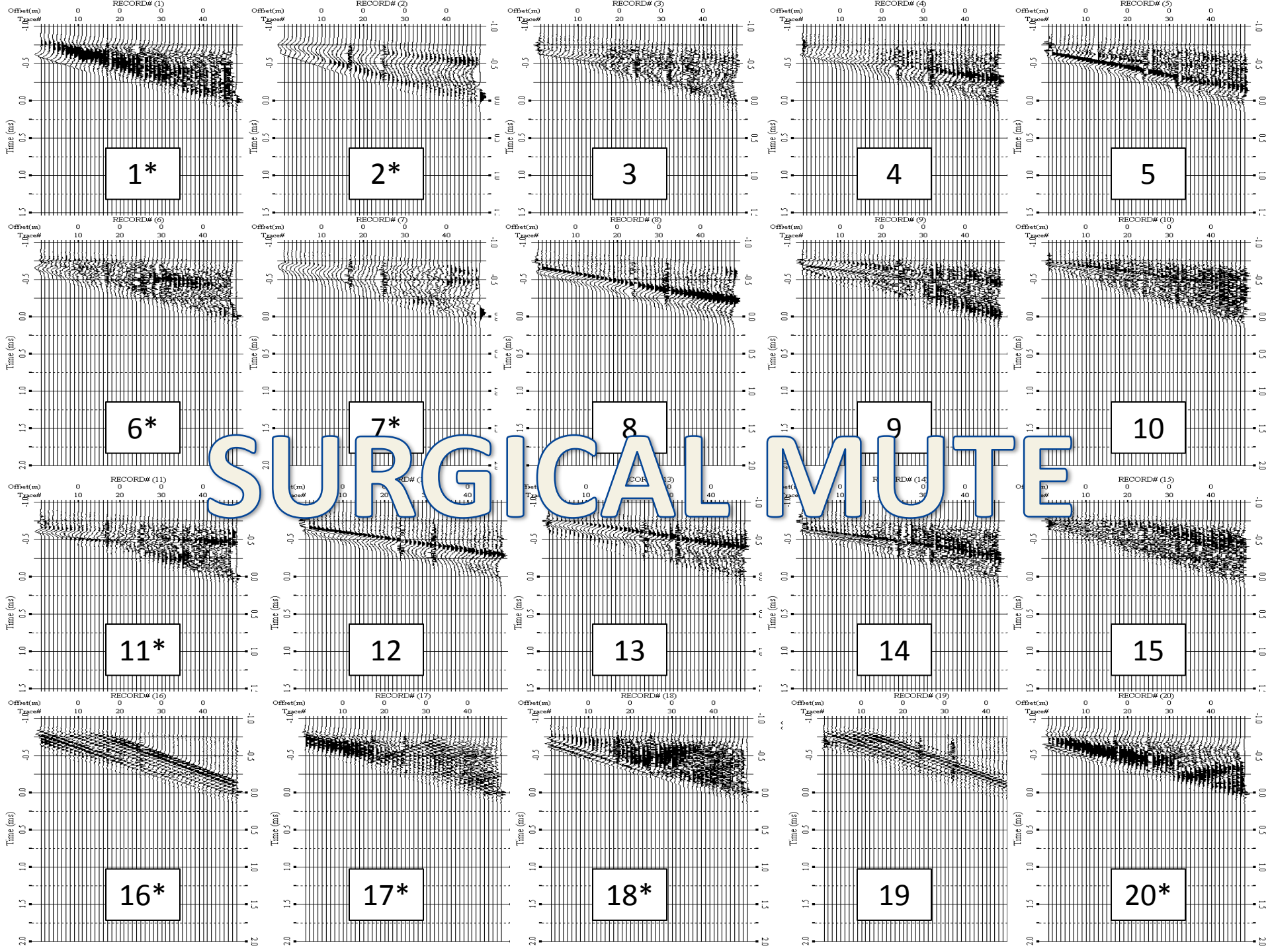
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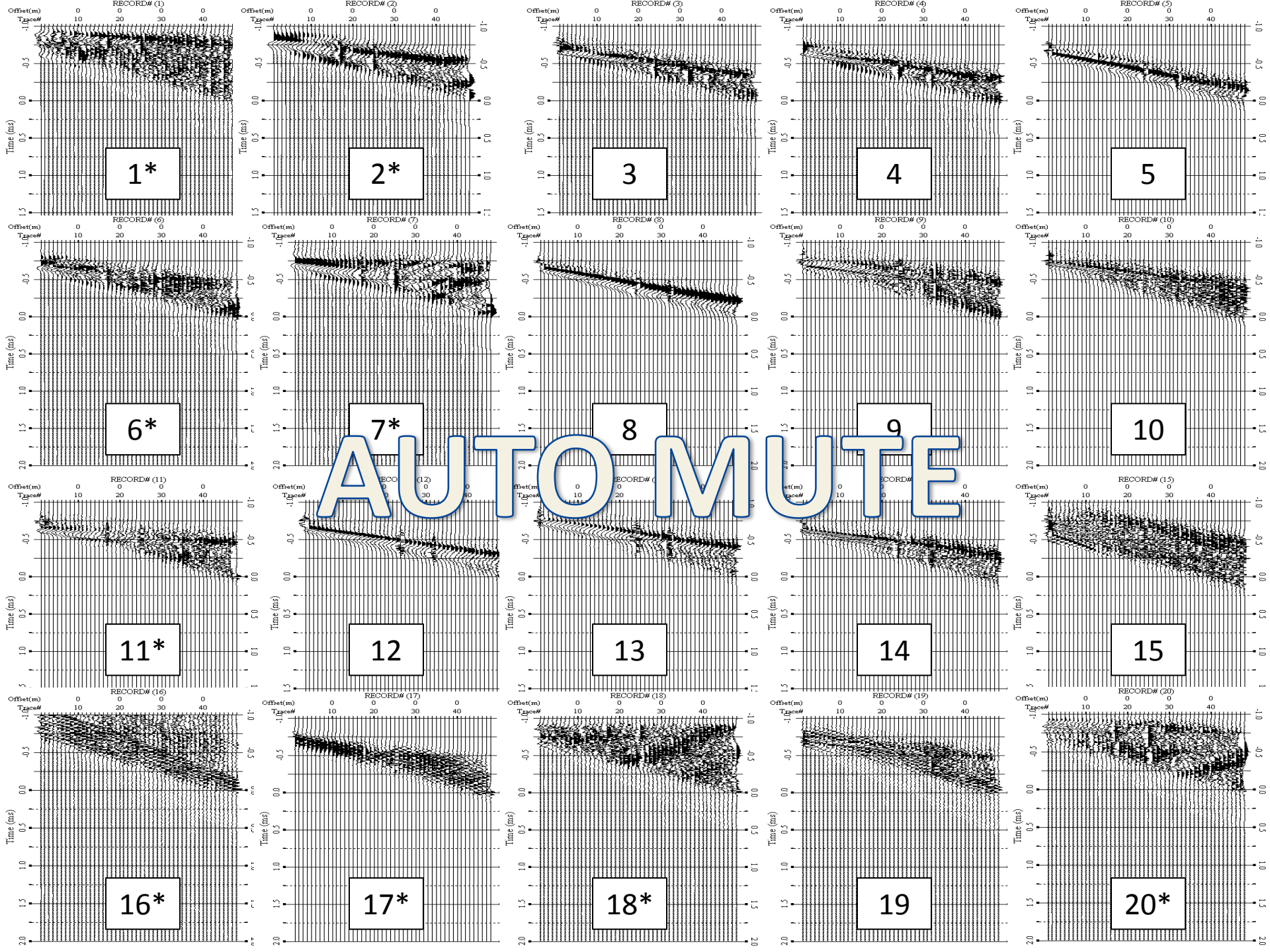
SURGICAL MUTE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RECORD# (20)
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AUTO MUTE

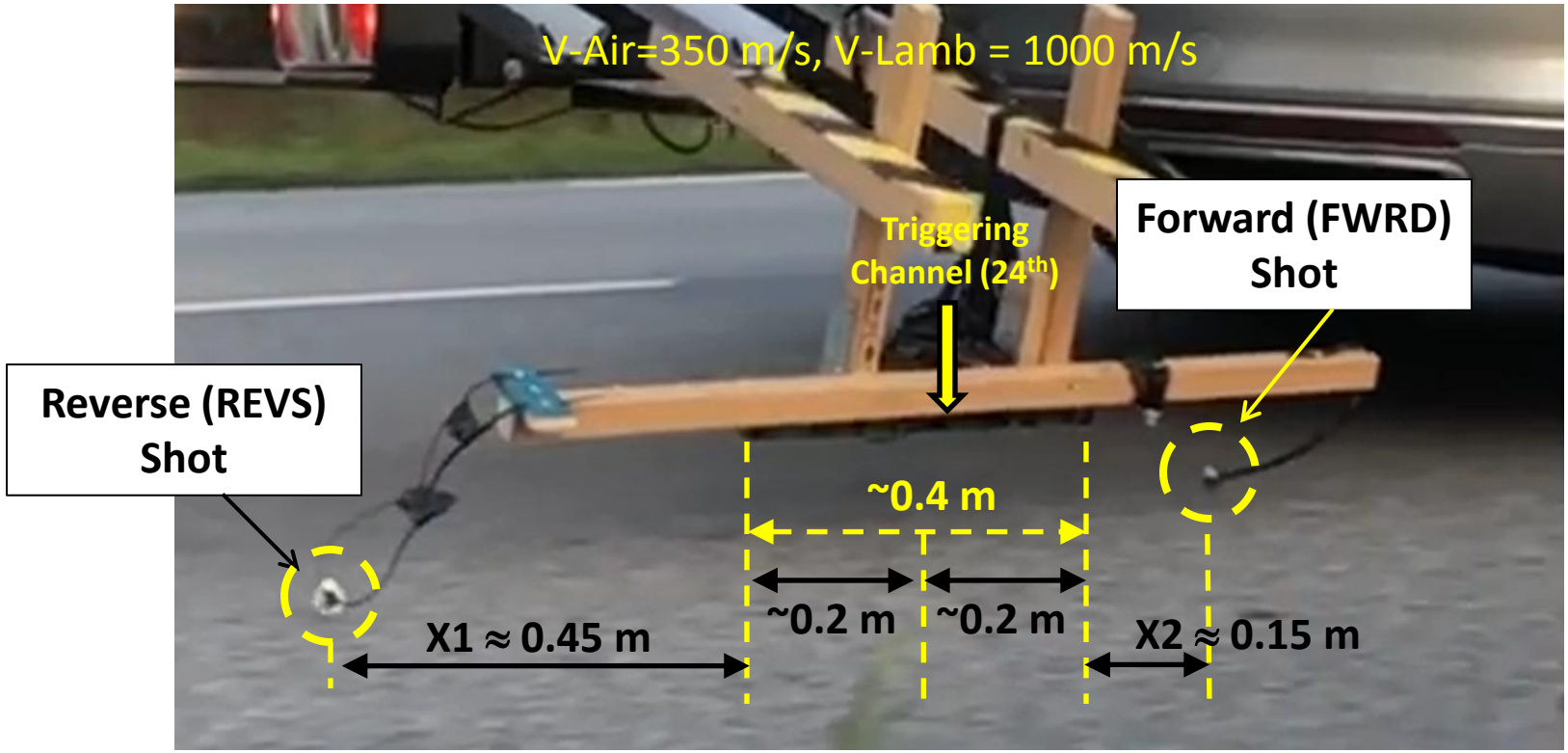
Forward (FWRD) vs. Reverse (REVS) Shots

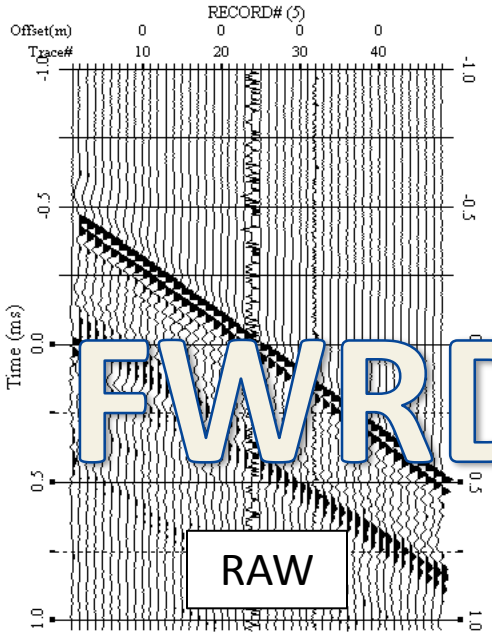
Forward (FWRD) Shot:

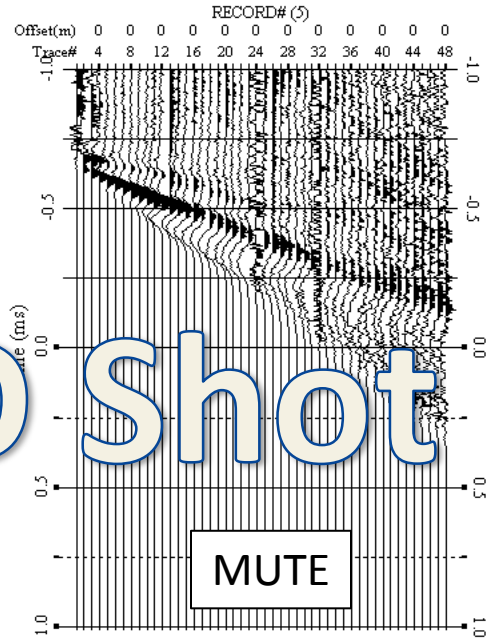
- T0-Air = (X2+0.2)/V-Air = 1.0 ms, T0-Lamb = (X2+0.2)/V-Lamb = 0.35 ms,
  - ***T0-Air – T0-Lamb ≈0.65 ms***

Reverse (REVS) Shot:

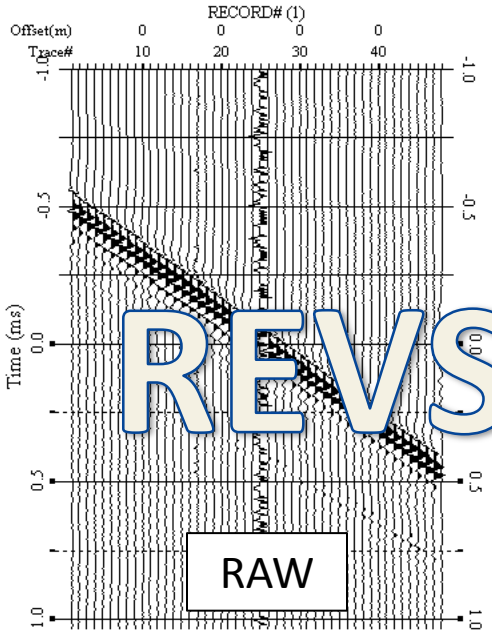
- T0-Air = (X1+0.2)/V-Air ≈ 1.86 ms, T0-Lamb = (X1+0.2)/V-Lamb = 0.65 ms,
  - ***T0-Air – T0-Lamb ≈1.21 ms***

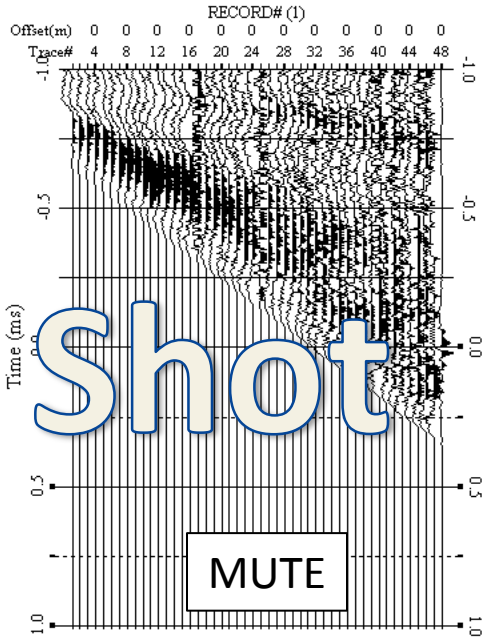




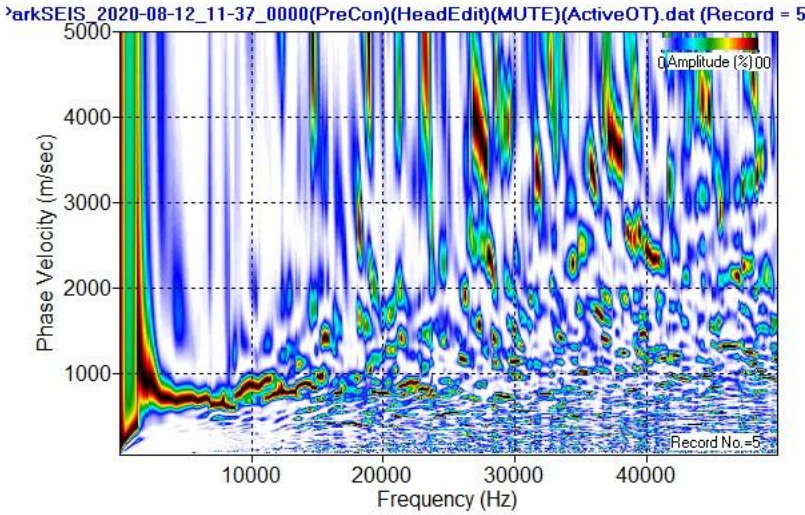


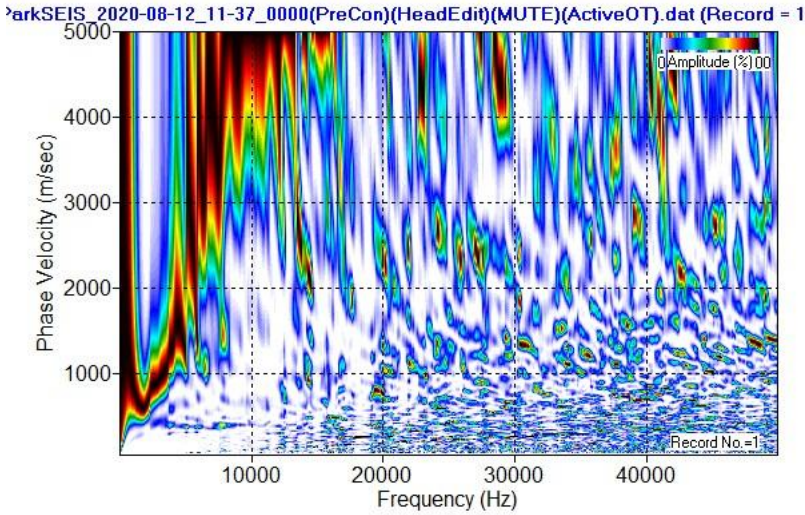
FWRD Shot





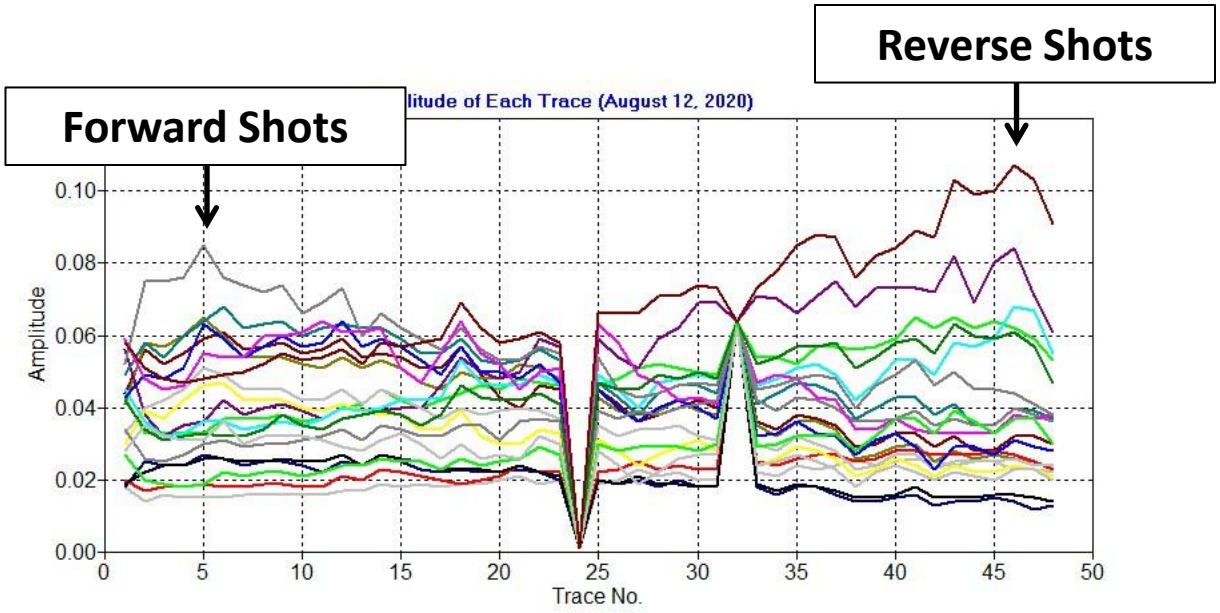
REVS Shot



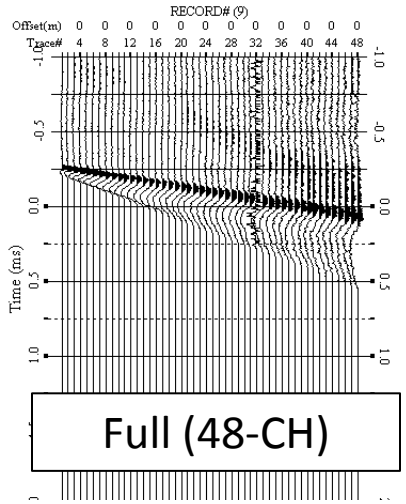


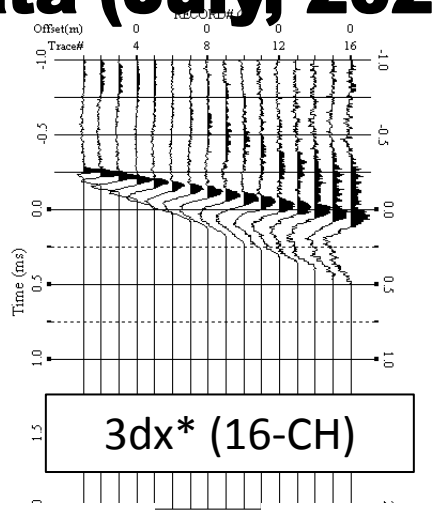
AMPLITUDE of Forward (FWRD) vs. Reverse (REVS) Shots

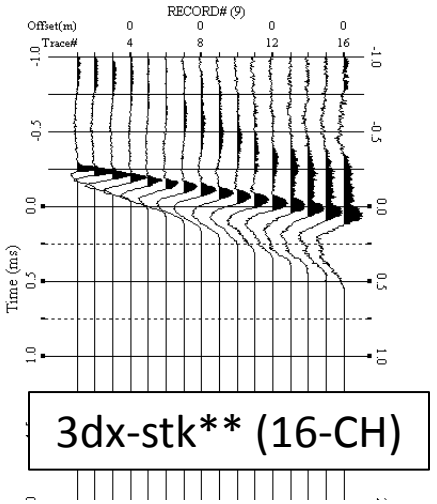
Forward Shots < Reverse Shots

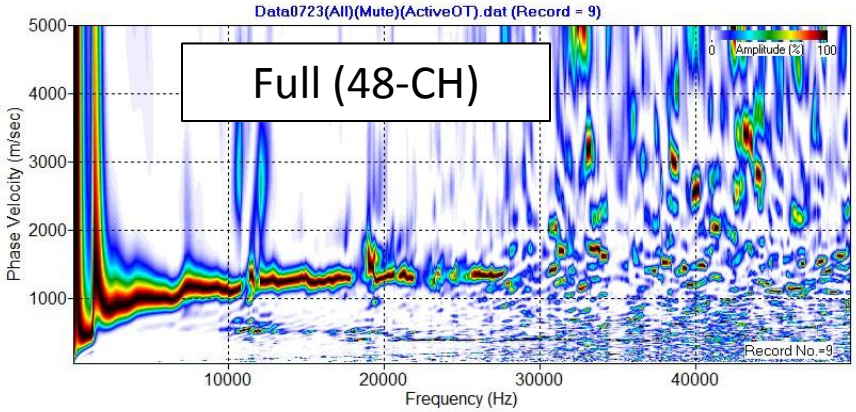


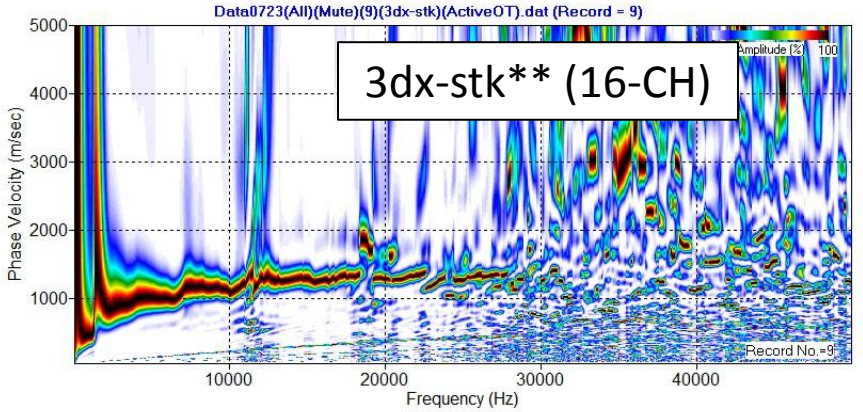
Data (July, 2020)

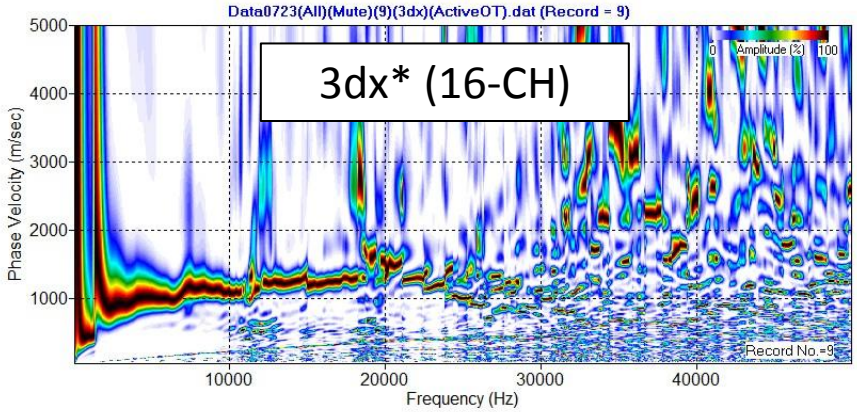








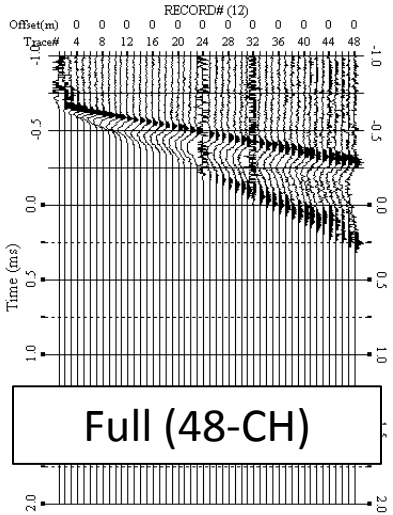




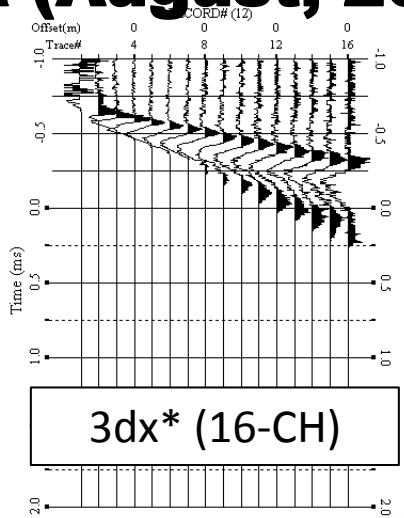
*simple resampling

**stack resampling

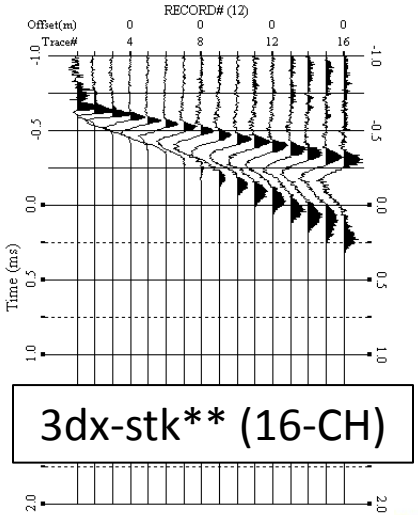
Data (August, 2020)



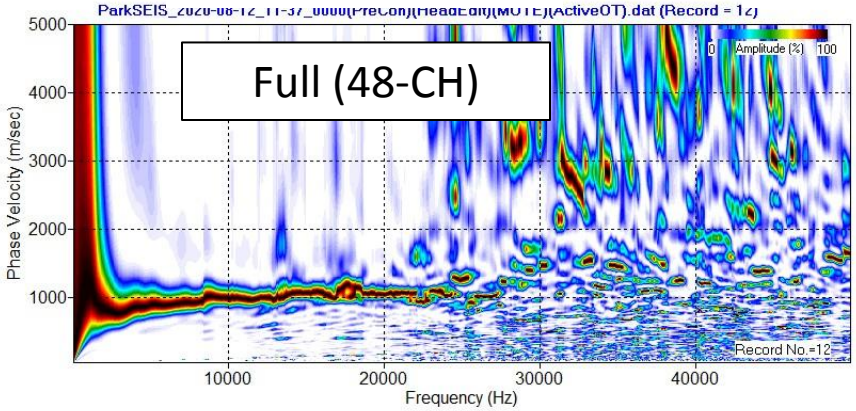
Full (48-CH)



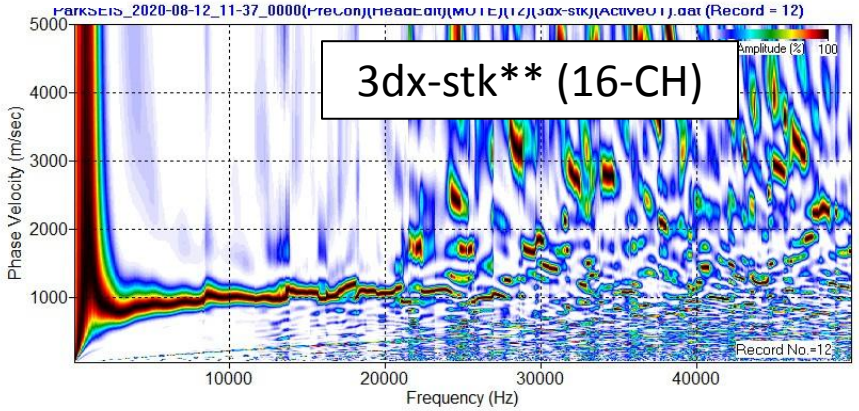
3dx* (16-CH)



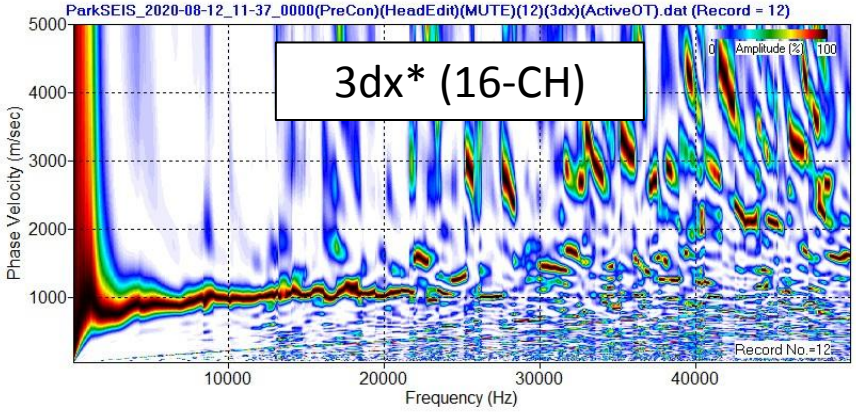
3dx-stk** (16-CH)



Full (48-CH)



3dx-stk** (16-CH)



3dx* (16-CH)

*simple resampling

**stack resampling