Timing issues on the Hussar low-frequency experiment

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ABSTRACT

Nanometrics Trillium compact seismometers were deployed at a nominal 200 meter station spacing from flag 564 (southwest end of line) to flag 264 at the Hussar low-frequency experiment. Three component data was acquired continuously on Nanometrics Taurus recorders at a two millisecond sample rate for the duration of the survey. The Taurus recorders were synchronized to GPS time. Two INOVA (ARAM) Aries recorders and an INOVA Scorpion recorder logged dates and times for each shot in their respective observer's logs. However, the time of shot does not match between these recorders for a given shot, and is not consistent between recorders for the time difference between subsequent shots. We speculate that the Aries time of shot is a file creation time. It is shown that the times derived from the Scorpion shot identification number (UNIX time stamp) are the best choice for extracting shot gathers from the seismometer continuous data, by visual inspection of observer's log times (converted to Coordinated Universal Time) plotted over the vertical component of seismometer data recorded at flag 524 for all sources at flag 524.

INTRODUCTION

Nanometrics Trillium Compact seismometers were deployed at a nominal 200 meter station spacing from station 564 (southwest end of line) to station 264 for the Hussar low-frequency experiment. The beginning of line (BOL) was at station 117. This gave us a total of fifteen seismometer stations for the experiment. An approximately one meter deep hole was augured at each flag. A metal cradle with long spikes on the underside was planted in the bottom of the hole, and the flat-bottomed seismometer (no leveling feet) was placed on top of the cradle. The plastic shipping case for the seismometer was then placed upside down over top of the seismometer and the hole was back-filled with clay and dirt. In order to protect the Taurus recorders (one per station) from the weather, the recorder and a 12 Volt car battery were stored inside a plastic food cooler Figure 2) on the surface. A GPS antenna was attached to the top of the cooler lid and used for timing.

FIG. 1. Nanometrics Taurus recorder and Trillium compact seismometer (Nanometrics, 2011).

Unfortunately the data from two of the seismometer stations was corrupted when copied from the Taurus recorders, so we have a total of thirteen stations, or 39 channels (vertical, east and north), to analyze for each shot. The seismometers were recorded continuously at a 2 ms sample rate, giving 165 Mb of data (at 4 bytes per sample, uncompressed) per channel per day. While the Taurus recorders where synchronized with GPS time, as independent recorders they have no way to record time zero for each seismic shot.

FIG. 2. Car battery and Taurus recorder inside a food cooler (left), and on the ground near VectorSeis and Aries equipment, during an INOVA 364 low-frequency vibe sweep (right).

TIMING

Observer's logs

Three seismic recorders were on-site for this experiment. CREWES ran an Aries SPML273 (our recorder) and a rental SPML29. Geokinetics ran a Scorpion recorder. The Aries recorders wrote time of shot into the observers logs based on the system time of the Microsoft Windows operating system. At the time of writing, we do not know what operating system the Scorpion was running. We do know that the Aries system clocks were not synchronized at the start of production, but were synchronized to cell-phone time before the second source line was acquired. Both Aries recorders were in Mountain Daylight Time, or Coordinated Universal Time (UTC) minus six hours. The Scorpion recorder was in East Greenland Time (also known as Azores Time, which sounds better somehow) or UTC minus one hour.

There were two sweeps per vibe point, and each of these was time-stamped in the SPML273 and 295 observer's logs with the exception of the first day of the survey. The 273 was slow to save uncorrelated data to disk, so this feature was turned off. A software patch, installed before production began on day two, solved the problem, but as a result, the 295 logs are more complete for this experiment. The Aries recorders also vertically stacked and correlated in the field, and the time stamp given for this data file is the same as for the first uncorrelated data file. The Scorpion saved the vertically stacked uncorrelated shot gathers (one uncorrelated data file per vibe point rather than two) as well as vertically stacked and correlated shot gathers. The Scorpion logs give a single shot identification number (UNIX timestamp) and date/time for each source point. When the shot identification number is converted to a time, it is the same or earlier than the date/time field, and appears to be the start time for the first of two sweeps (see next section).

Table 1 and Figure 3 show differences in the time of shot between the three recorders for the same shot after correcting for time zone. Note that while the mean and median differences between timestamps are less than one minute for source lines 4, 6 and 8, the maxima can be over twelve minutes. Given that we are searching for 34 seconds of data (uncorrelated vibe sweeps) or 10 seconds of data (dynamite), this is not good news.

Figure 4 shows the time between subsequent shots for each recorder type. We would expect these plots to directly overlay each other, but they do not. Based on Figure 4, we speculate that the times in the observers logs represent a file creation time rather than the time of shot. The file creation time would be expected to vary between systems due to differing computer hardware, differing numbers of channels attached to each system, and hence different amounts of time required to download data from each receiver line, and differing loads on the recording computers depending on (varying) concurrent tasks.

Table 1. Statistics are cruel.

	Source line	Max	Min	Mean	Median	Stdev	Nsamp
SPML 273 vs 295	2: 364 vibe, low-dwell	05:04	02:38	03:12	03:11	00:07	1586
	4: 364 vibe, linear	02:18	00:00	00:02	00:01	00:07	1586
	6: Failing vibe, low-dwell	09:09	00:00	00:04	00:01	00:33	1586
	8: Dynamite	02:00	00:00	00:02	00:01	00:08	1586
SPML 273 vs Scorpion	2: 364 vibe, low-dwell	07:52	00:16	01:48	01:54	00:36	1043
	4: 364 vibe, linear	06:18	00:13	00:39	00:22	00:50	1043
	6: Failing vibe, low-dwell	12:45	00:10	00:38	00:20	01:22	1043
	8: Dynamite	11:47	00:07	00:16	00:10	00:45	1043
SPML 295 vs Scorpion	2: 364 vibe, low-dwell	11:01	01:03	01:37	01:18	01:03	1043
	4: 364 vibe, linear	07:33	00:09	00:40	00:22	00:52	1043
	6: Failing vibe, low-dwell	12:53	00:10	00:43	00:21	01:30	1043
	8: Dynamite	11:46	00:07	00:16	00:11	00:45	1043

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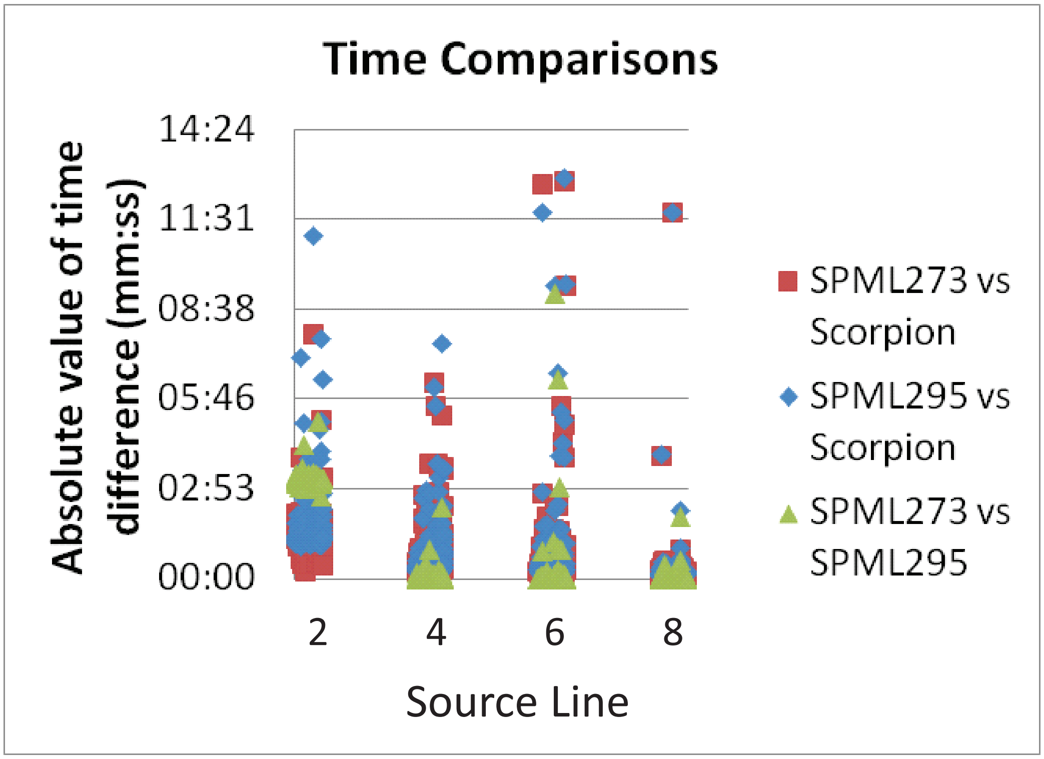

FIG. 3. Difference in time of shot between different recording systems for the same shot.

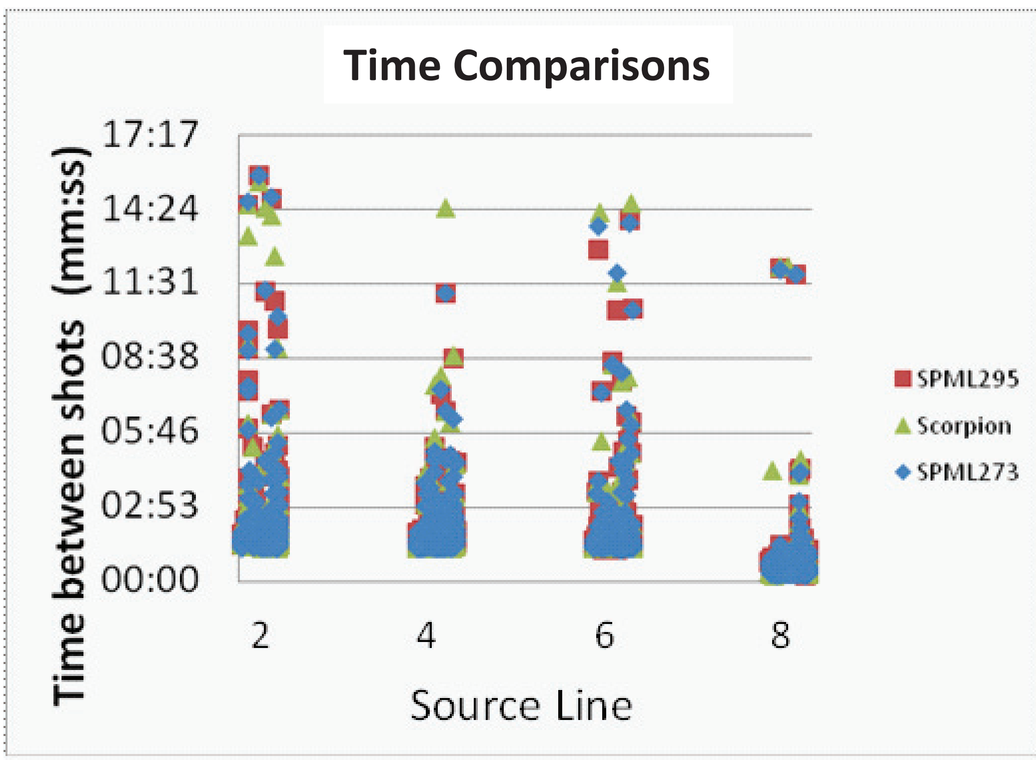

FIG. 4. Difference in time of shot between subsequent shots for each individual recorder.

Data

The vertical channel for seismometer station 524 was converted from MiniSeed format (provided by Nanometrics) to Matlab (Matlab File Exchange, 2011). Four days of data were plotted with the observer's logs times for source point 524 overlain (Figure 5). At this scale, the seven sources (six vibe sweeps, one dynamite shot) at flag 524 are clearly visible. Figures 6-9 show ten minutes of data for each source type, centered on the Scorpion shot identification time. The Scorpion Unix timestamp (zero time is January 1, 1970 AD) and Aries times (Microsoft Excel zero time is January 1, 1900 AD), were converted to Matlab times (zero time is January 1, 0000 AD) for these displays (Matlab, 2011).

We can see all of the vibe sweeps that occurred during this ten minute period (Figures 5-7), however, we can only see half of the dynamite shots at this scale. There were two shooters on the line, half a spread apart. Zooming in on this plot reveals shots taken by the more distant shooting crew (not shown).

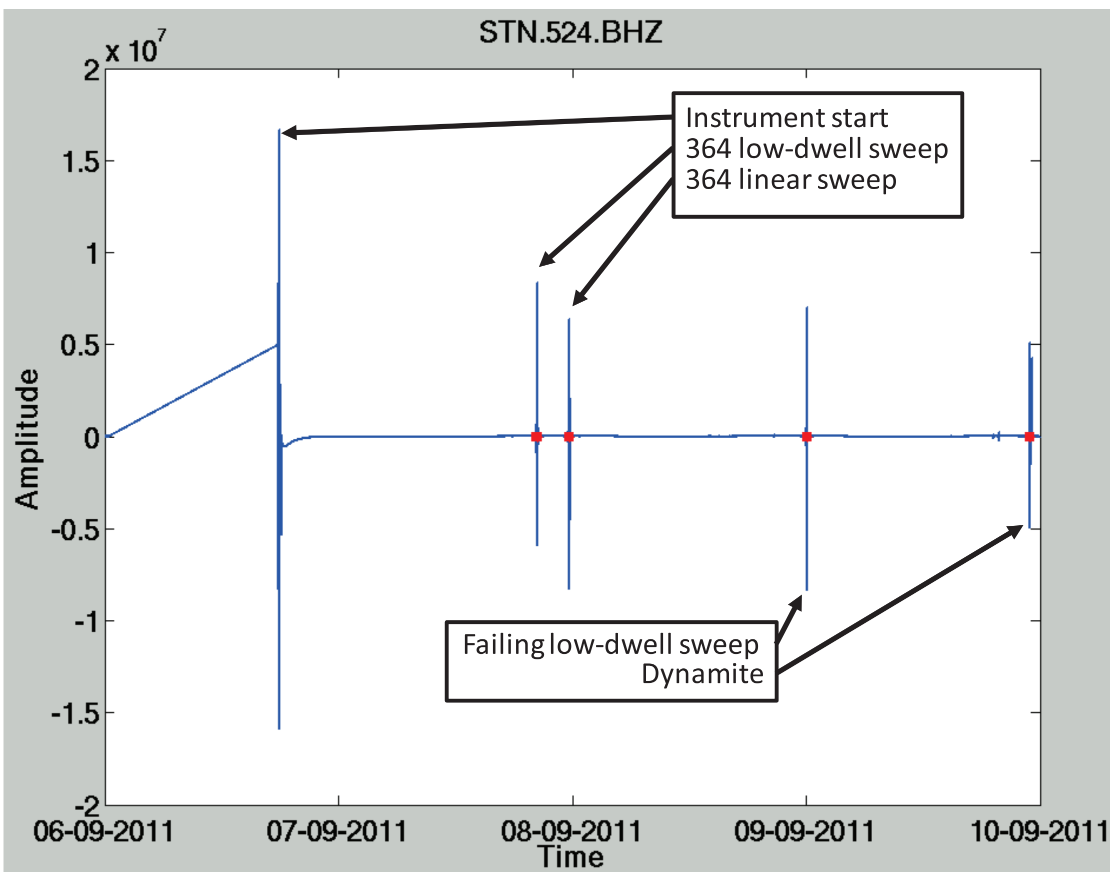

FIG. 5. All data for the vertical component of seismometer station 524 with no filtering and no scaling. Observer's notes times are plotted in red after being converted to UTC.

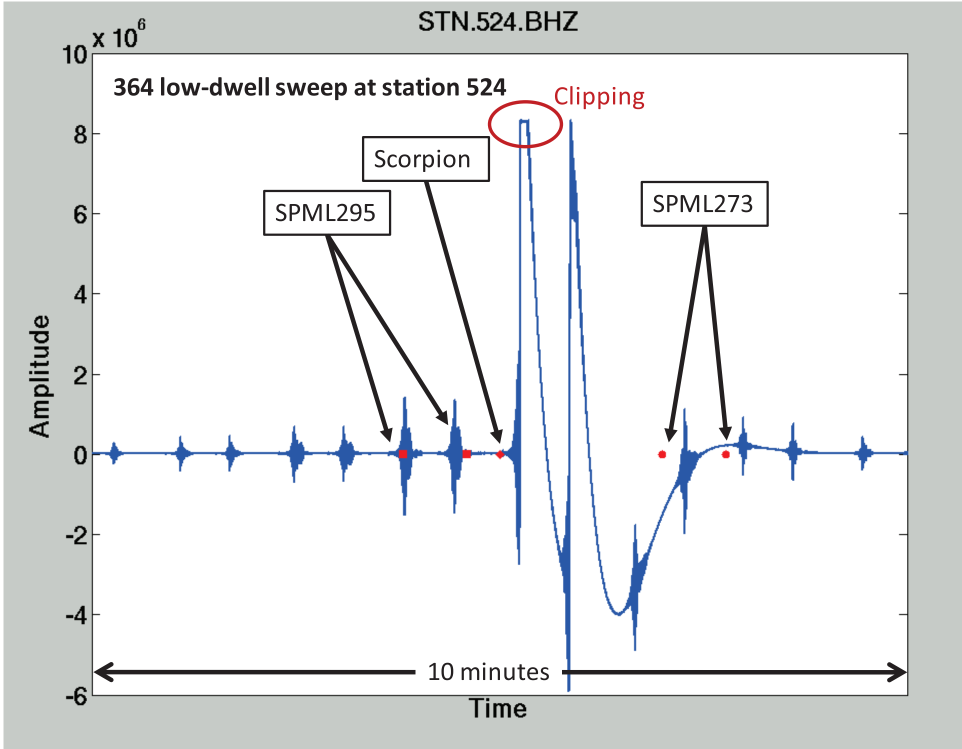

FIG. 6. INOVA 364 low-dwell sweep. SPML295 times are early and SPML273 times are late, but the Scorpion time appears to be correct. SPML times were not synchronized for this source line.

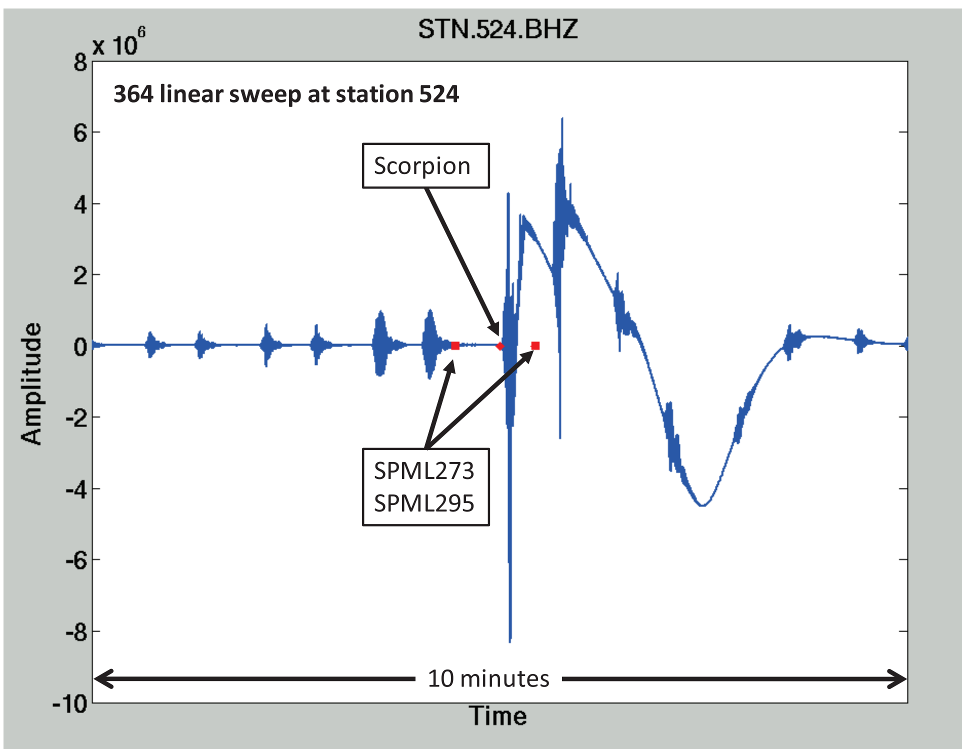

FIG. 7. INOVA 364 linear sweep. SPML times are early, but do occur before each of the two sweeps. Scorpion time appears to be correct. SPML times were synchronized to cell phone time.

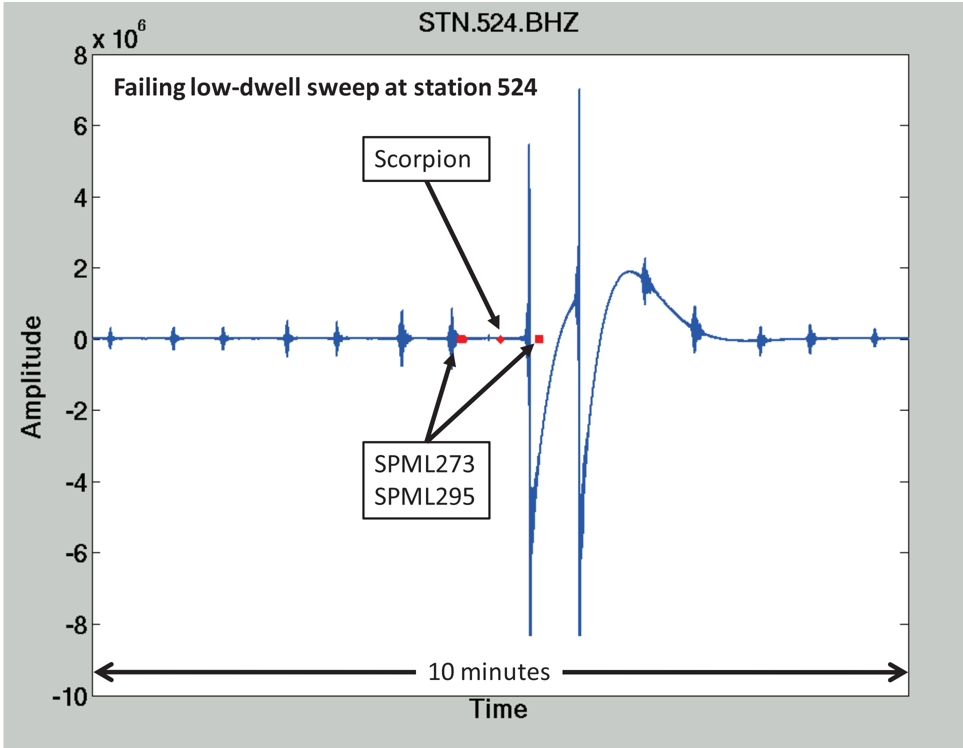

FIG. 8. Failing low-dwell sweep. All times are early, but Scorpion time appears to be closest to being the correct time. SPML times synced to cell phone time.

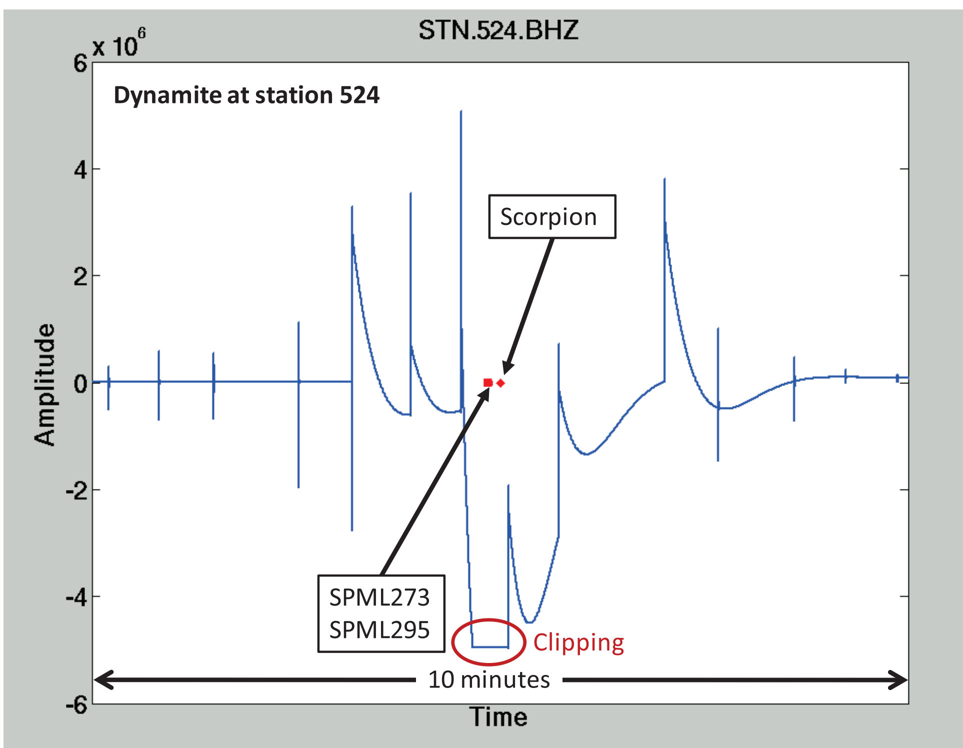

FIG. 9. Dynamite. Scorpion time appears to be correct, but previous nearby shots have pushed the seismometer off scale. SPML times synced to cell phone time.

SUMMARY AND FUTURE WORK

Based on these results, Aries times were discarded, and Scorpion times were used to extract shot gathers from the seismometer data assuming the second of two sweeps per vibe point started 34 seconds (24 second sweep plus 10 second listen time) after the first sweep. All extracted seismometer shots gathers have been correlated with synthetic sweeps for the three sweep types, and appear in other CREWES research reports from this year.

It is clear that CREWES needs to pay more attention to the time of shot in the recorders that we operate during future work, where instrumentation that is synchronized with GPS time is also used as part of an experiment.

No quality control work has been done at the time of writing, so future work will include scanning the shot gathers to ensure that we have extracted data that includes the entire uncorrelated sweep and listen time for each vibe source type, fine-tuning the extracted shot gathers to find which sample corresponds to zero-time for each shot by cross-correlating with data from other receivers that were at the same receiver station.

This would be a suitable dataset for testing event detection algorithms. Some work has been started on this, but so far, the Earthquake that was recorded on the last day is detected better than the seismic sources. At any rate, time of event will not be the same as time of shot. It could be corrected using first-break pick times from the other datasets.

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