Looking for SS waves in conventional 3C seismic data

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Summary

This is an experiment with real data intended to identify the presence of pure S wave reflections (SS-waves) generated by conventional explosive sources. This work has two parts: first the identification of feasible SS events, and second a test on source statics correction. The Hussard 2011 3C survey were used to this purpose. From the velocity information, it was found that the possible SS-wave arrival times concur with the highly energetic Ground Roll. Therefore noise attenuation for coherent surface waves and other events that preserves the expected SS-waves was required. After that, probable SS-events were identified, however relatively weak. As it is well known, statics of S-wave have proved challenging, hence critical to obtain a stacked seismic section. A source statics correction method is proposed and partially tested.

Introduction

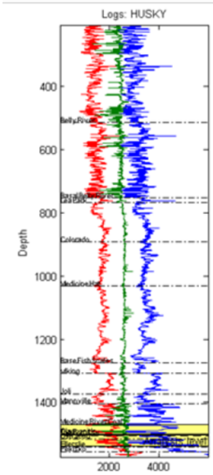
In conventional seismic surveys just PP and PS waves are usually expected. SS reflections have been hardly identified even though S-wave generation has been predicted theoretically. Mathematical models have been proposed for elastics waves generated at the free surface and for an explosive source inside boreholes (e.g. Lee and Balch, 1984). Experiments that confirm these models have been published (e.g. Hardage and Wagner, 2015, Lash, 1985, Guevara 2017). This is an experiment with real data intended to identify the presence of pure S wave reflections (SS-waves), using the horizontal components of the Hussard 2011 3C.

The first step is to identify the events corresponding to SS reflections. After that, the source statics should be different and probably much larger than the P-wave statics, and also different than the receiver statics of the PS-wave at the same location, since the source is not at the surface but about 10 or 15 m depth. Then a method is proposed to obtain this source statics. Finally a stack section is obtained.

Method and data

From the Sonic logs (shown in Figure 1a) there were estimated the zero-offset arrival times and RMS velocities for PP, PS and SS waves, shown in the Table 1b. The approximated expected arrival times of two highlighted events (yellow color in Table 1b) are illustrated by their arrival times in Figure 2.

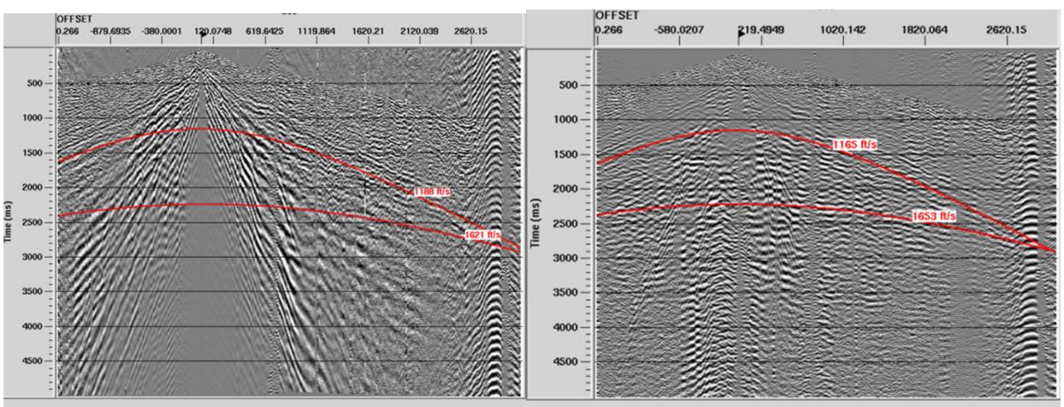
According to the velocity information, the SS-wave arrival times concur with the highly energetic Ground Roll (Figure 2a). Therefore it was required noise attenuation for surface waves and other events simultaneously preserving as much as possible the expected SS-waves. Surface wae noise attenuation, noise burst edition and a bandpass filter were applied to this purpose. An example of the resulting record is shown in Figure 2b for the transverse component. Notice that appears energy with the expected arrival time of SS-waves, even though mixed with some other events or artifacts (Fig. 2b). A similar result was obtained in the radial component, however not too strong and affected by PS-waves. These results were the input to the net step, the source statics correction.



Depth m	Vp m/s	Vs m/s	t_o SS s	V_{SS} RMS m/s
30	1500	200	0.300	200
400	2900	1500	0.907	1207
520	3400	1100	1.125	1168
750	3300	1500	1.416	1399
1270	3250	1500	2.013	1645
1450	3900	1900	2.217	1664
1550	4400	2200	2.310	1745

a **b**

Figure 1. Velocities and expected arrival times. (a) Sonic logs with V_P (blue) and V_S (red); (b) simplified velocity model derived from the sonic logs and the expected zero offset arrival time ($t_{o\ SS}$) and RMS velocity (V_{SS} RMS) for SS reflections. The highlighted horizons are analyzed below.



a **b**

Figure 2. Surface wave attenuation applied to a shot gather of the transverse component (a) before and (b) after. The red lines correspond to the expected NMO curve of the SS events highlighted in Table 1b. Notice the events that approximately follow these curves in Fig. 2b.

Source static corrections method

The S-wave source statics correction method is by cross-correlation of adjacent Common shot gathers (CSG), hence obtaining the differential delay between them. This method is based in the surface consistent equation, hence assumes normal incidence to the surface. After applying the receiver statics (obtained from PS data processing), the structural component is assumed negligible, and analogous traces of adjacent CSG are cross-correlated, to obtain the differential delay between them. Analogous traces mean that have the same (or very close) offset, therefore there is not delay from this origin. After that the cross-correlations of all traces between adjacent CSG are stacked to obtain the maximum value, which is assumed corresponding to the differential delay. Figure 3 shows two partial results of this method. Fig. 3a shows to the resulting stack of the cross-correlations for all the sources, and Fig. 3b shows the picking of the maximum of these values, after some editing, which corresponds to the differential statics between sources. After that the differential delays are added together to obtain the static corrections. This method follows the same approach than the PS-wave receiver proposed in Guevara et al., 2015.

Finally, Figure 4 shows the stack section of the radial component, using the RMS SS velocity of Table 1b and the statics correction obtained with the method proposed here, after applying the receiver statics obtained from PS data processing. Notice that it is possible to follow events which have the expected arrival times for SS waves in the Table.

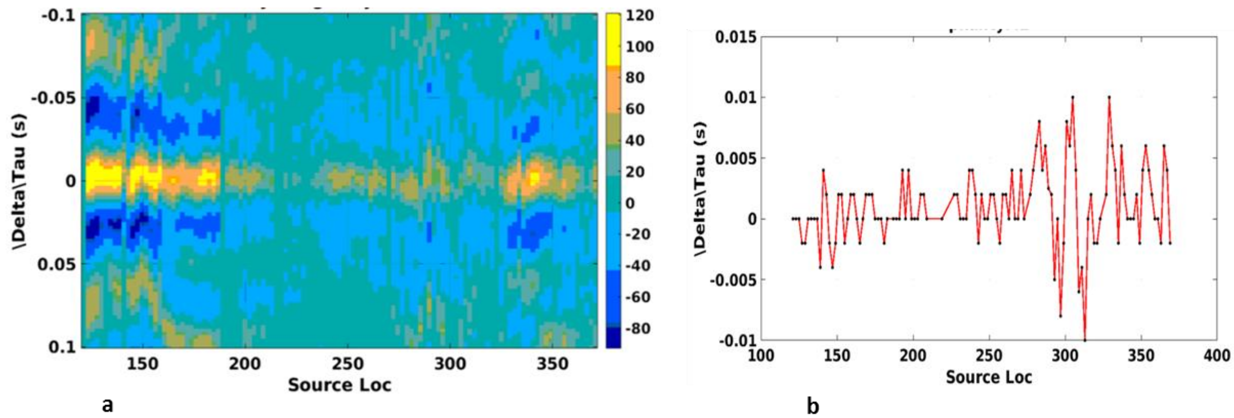


Figure 3. Two steps of the source static corrections method proposed. (a) Cross-correlation between sources, (b) picking of the maximum cross-correlation, corresponding to the differential statics.

Conclusions

- The shots gathers after noise attenuation show events whose energy agree with the expected arrival time of SS waves. They appear easier to identify in the transversal component than in the radial.
- The cross-correlations of the statics correction method proposed show energy that appears corresponding to the expected for the differential statics.
- The source S-wave statics correction method proposed appears promising; however it requires more extended analysis and testing.
- The possibility to obtain a third seismic section, corresponding to SS reflections, can increase the feasible information that can be obtained from the elastic wave field, therefore can provide a new tool for better reliability of geophysical exploration.

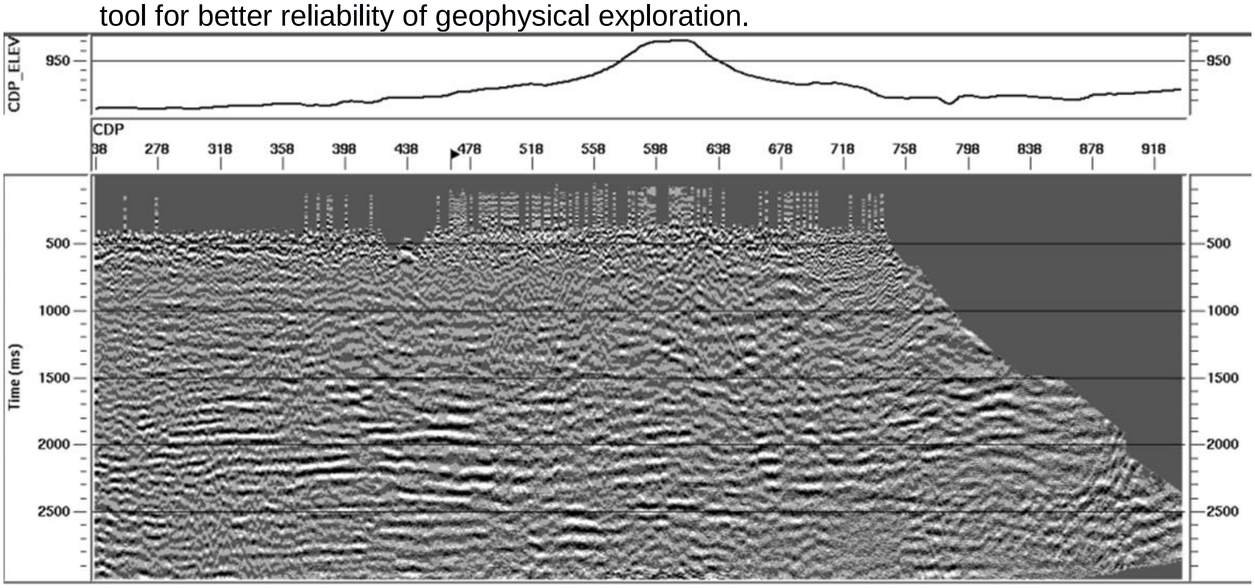


Figure 4. Hussard's SS seismic section of the radial component. Stacking was obtained with the RMS SS velocity of Table 1b and with the S-wave source statics from the method proposed. Even though not perfect Notice that here are events at the expected arrival times for SS reflections.

Acknowledgements

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