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Noise Examples from Two Microseismic Datasets

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The recording of microseismic surveys can be used to monitor hydraulic fracture stimulation of reservoirs. In these surveys, the continuous recording of three component geophones are used to detect P wave and S wave energy induced by the fracturing process and related stress changes. This paper will present a number of noise examples recorded on two microseismic datasets from Canada. The noise can be high in amplitude, persistent in time, and may adversely affect the recording of P and S wave signal energy.

INTRODUCTION

Microseismic methods have emerged as an important tool for hydraulic fracture monitoring (HFM). The purpose of recording microseismic data is to locate individual fractures and fracture networks introduced into a reservoir. The microseismic data are recorded at high sampling rates over the duration of the fracture stimulation. Three component geophones are usually used to record the data. The geophones may be placed down an observation well and clamped to the side of the borehole casing. This may allow for recording significantly higher frequencies than can be recorded at the surface.

Along with the primary signals of interest (i.e. P- and S-waves produced by the microseismic events), various types of noise (random or coherent) may be recorded during a microseismic survey. Examples include waves that propagate within the borehole casing, or noise generated by pump equipment at the surface. In addition, tube waves can be generated in a borehole when a P wave compresses a fluid-filled fracture and injects a fluid pulse into the borehole (Huang and Hunter, 1981; White, 1983). Although this type of noise can obscure the main signals of interest, tube waves may also be useful for detecting and characterizing fractures (e.g. Li et al., 1994).

RANDOM NOISE

Figure 1 is a 0.4 second window from a northeast British Columbia microseismic survey performed in the fall of 2009. This noise appears to be uniform random noise

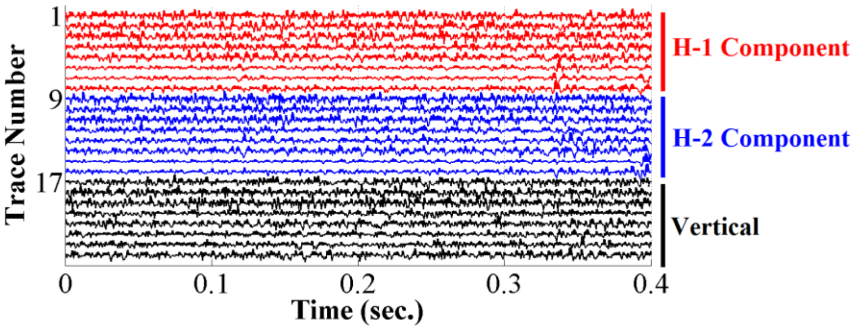

Fig. 1 - Random noise traces from 0.4 seconds of recording.

similar to surface seismic random noise. The broad spectrum of the noise ranges from D.C. to about 800 Hz., at which point it drops to the 1333 Hz. Nyquist frequency. It can be shown that most of these traces have a D.C. component. This component can hurt programs such as autopicking algorithms or deconvolution.

ALMOST "DEAD" TRACE

Figure 2 is another 1.5 second window from the Alberta dataset. There is a S wave arrival at about 0.15 seconds on most of the traces, except trace 9. This shallowest H-2 component geophone has recorded a noise spike. The cause for this recording is currently unknown and may warrant further investigation. This noise trace contains a D.C. component that would affect autopicking algorithms or velocity semblance routines.

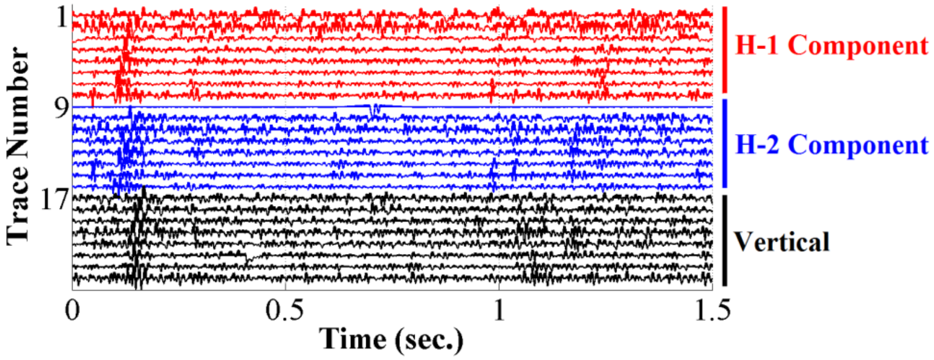

Fig. 2 - A 1.5 second record from a six hour recording of a HFM dataset recorded in March 2010. Note the onset of the P wave or S wave energy at just over 0.1 seconds (recorded on most channels). However, trace 9 has recorded no data except for a doublet peak at about 0.7 seconds.

HIGH FREQUENCY HARMONIC NOISE

figure 3 is a 0.2 sec. Window from the northeast British Columbia dataset. There is coherent noise occurring at 350 Hz., 700 Hz., 1050 Hz., and intervals in between.

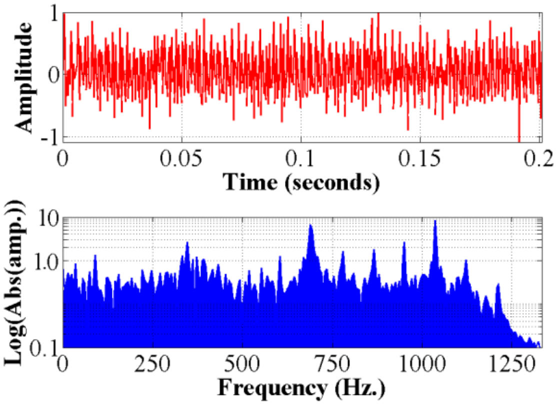

Fig. 3 – A 0.20 second example of the persistent low-amplitude harmonic noise that was observed on most traces in the northeast British Columbia dataset. The 350 Hz., 700 Hz., and 1050 Hz. peaks were observed on numerous files.

A possible source of this noise is the pumps used in the hydraulic fracture system. The noise does not appear to impede the data quality, but recognition and further noise analyses may be warranted on other datasets or future field work.

TUBE WAVE (STONELEY WAVE)

Figure 4 is one 1.5 second window from the Alberta dataset. There are two linear events that are high very amplitude and appear on all 24 channels. A straight line through the first arrivals of the energy gives an apparent velocity of 1460 m/sec. By analogy with other studies (eg. Le et al, 1994), this noise train is thought to be a tube wave propagating the borehole. This noise is similar to that predicted by Rama Rao and Vandiver (1999) as a "Mode 2" Stoneley wave propagating between the steel casing and the casing cement. The source of the tube wave is from the top of the geophone assembly – it may have been a P or an S that was converted to a Stoneley wave or it may have been induced at the surface. The tube wave is high in amplitude and affects all geophones. This wave may obscure the arrival of P wave or S wave signals.

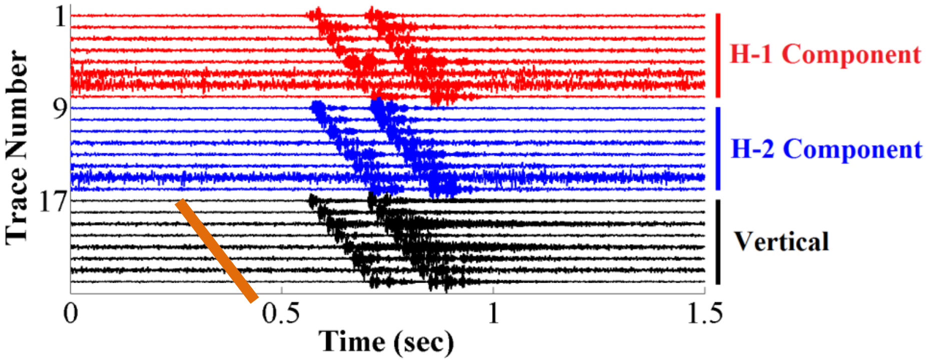

Fig. 4 - . A 1.5 sec. record showing the propagation of two tube waves in a wellbore.

P WAVE IN THE CASING CEMENT

Figure 5 shows two high amplitude linear events from the Alberta dataset. There are very high amplitude events on the vertical component, but only a few horizontal traces record any of this motion. A straight line through the first arrivals of the vertical component energy gives an apparent velocity of 4,200 m/sec travelling down the borehole. This velocity is approximately equal to the P wave velocity for in the casing cement (Tang and Chang, 2004). The later event on the vertical component also has an apparent velocity of about 4,200 m/sec, but travelling down the borehole. This down-going wave may be the result of a reflection of the upgoing wave from an impedance contrast. The P wave in the wellbore cement is high amplitude and affects all vertical geophones. This wave may obscure the arrival of P wave or S wave signals on the vertical geophones.

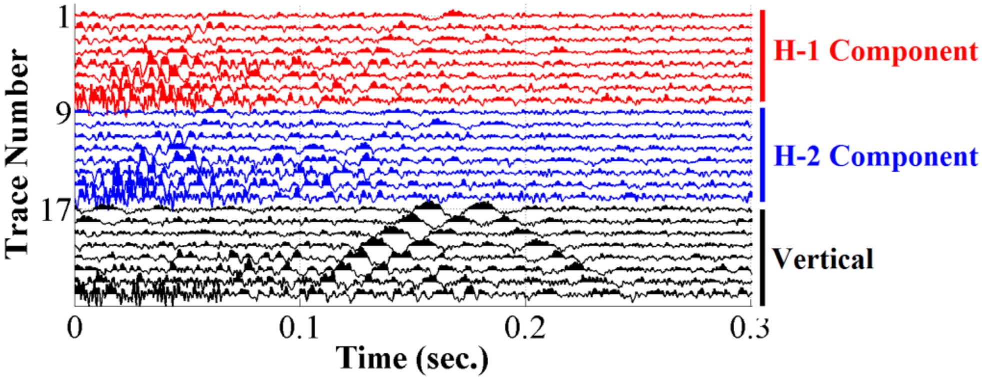

Fig. 5 - A 1.5 second record from a six hour recording of a HFM dataset recorded in March 2010. The onset of the P wave is followed by

CONCLUSIONS AND FUTURE WORK

A number of noise examples from the microseismic monitoring of two Canadian HFM surveys have been presented. The noise examples range from almost dead traces with no amplitude recorded to very high amplitude energy recorded on all traces. Characterizing sources of noise such as this is important for processing and interpreting microseismic data. Careful study of tube waves may even hold promise in the future for fracture characterization and analysis.

ACKNOWLEDGMENTS

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