P-wave seismic source comparison on a Kansas River point bar simulating Sable Island, Canada

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Summary

Among the many choices made in designing a seismic survey, the type of source selected for that particular environment is one of the most important. This paper provides preliminary comparisons of the overall effectiveness of several sources on a point bar. This particular environment was selected to simulate Sable Island, located off the east coast of Canada, as closely as possible. The near-surface can be geologically characterized as unconsolidated sand with a water table approximately 2 feet below the surface. Data were collected on a 1 km by 120 m point bar along the Kansas River, several miles downstream of Wamego, Kansas. Reflection events can be observed as shallow as 100 ms and as deep as 650 ms. The specific geologic units responsible for these events are unknown and not important for this study.

Introduction

Though the objectives of this source comparison test are similar to a series of previous shallow source experiments (Miller et al., 1986, 1992, 1994; Doll et al., 1998), this study is not intended to be directly compared to these earlier tests. The greatest difference between this and past experiments is the unique location of the survey. Located approximately 2.5 miles east of Wamego, Kansas, this survey was shot on a extremely active point bar in direct contact with the Kansas River (Figure 1).

Upon first arriving at the test site, a test hole was drilled to define the shallow unconsolidated geology beneath the point bar. This boring was drilled just south of the first station on line B. The data retrieved from the boring showed bedrock to be 35' beneath the surface. Sand dominated the lithology between the surface and bedrock with the lone exception being a <6" clay layer about 10' beneath the surface. The water table was measured to be 2' down.

Data were acquired over a 9-day period during late February and early March of 1999. ExxonMobil researchers originally selected this location as a testing bed for preliminary parameter designs for a future survey on Sable Island, which is approximately 200 miles off the eastern coast of mainland Nova Scotia, Canada. The researchers hoped to use this survey to optimize the seismic source for exploration beneath this sand island. All acquisition parameters and geometry tested were consistent with theories and estimations predicted or calculated for a future 3-D survey at Sable.

A unique testing location such as this presents a series of unique problems. In fact, the entire structure of this survey was altered shortly after the initial data acquisition of the first source. The Minivib II was the first source set up to acquire data along line A. However, the Minivib II sank 2 feet into the sand after only the fifth shot at the first station. Alterations to the test procedures were developed and recordable stations reassigned. Likewise, the survey was not originally designed for shooting all 12 shots at one end of each line, however deterioration and erosion of the point bar prevented any shots from occurring at the north end. Stations and recording geometries were placed to allow the test objectives to be met without jeopardizing equipment or personnel (Figure 2).

These environmental problems are not restricted to the data acquisition. The unique geologic structure of the test site provided for interesting hurdles during processing. Caused by fluvial processes, interbedded silts, sands, and clays

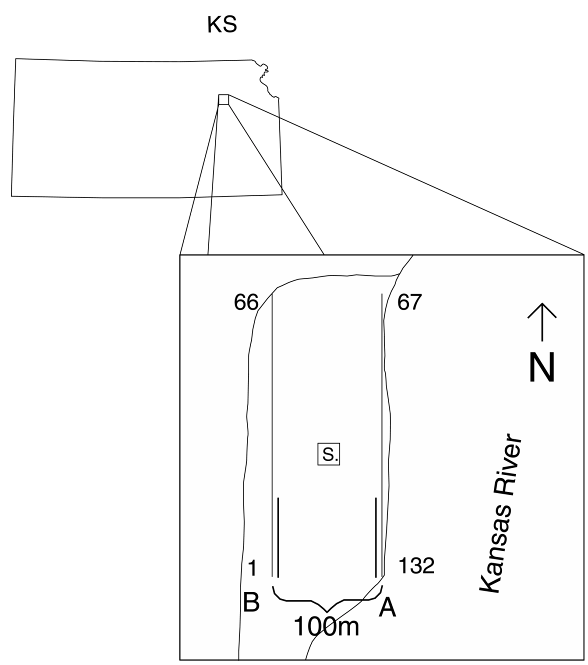

Figure 1. Location map showing relative locations of the two 1 km long seismic lines (A and B) with respect to the Kansas River. The darker inner lines represent the relative locations of the shot points. The beginning and ending stations for each seismic line are numbered.

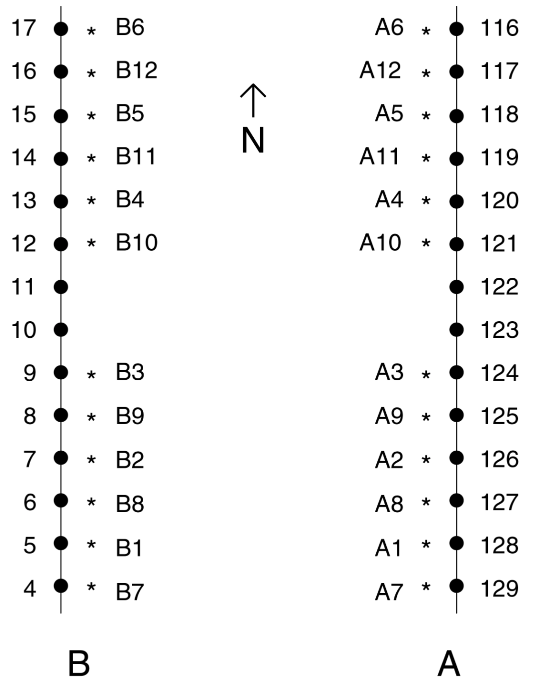

Figure 2. Close-up view at the south end of the seismic lines, showing the relative locations of the shot points in relation to the lines A and B, respectively. Station numbers are located on the outside of each line with the shot points numbered on the inside.

thread the shallow subsurface of the point bar. Thus, extreme lateral variation in the geology across the point bar exists. Another interesting problem presented by this environment is the static variability that arises from shooting over such unconsolidated sands.

Data Acquisition

Four cables were used to produce the fixed 2-line survey, with a 100 m gap between lines A and B. Each cable had 33 active channels with a receiver interval of 15 m. Channels 1-66 ran south-to-north along line B while channels 67-132 ran north-to-south along line A. The receivers were 5 L28A 30 Hz geophones on 0.09 m spikes. Line A was located on the eastern side of the survey, closer to the river.

Three sources were shot into previously undisturbed ground. Using a 1 ms sample interval, A total of 12288 samples were recorded for the uncorrelated Vibroseis records and 2048 for the explosives and land airgun. In chronological order of testing, the sources used here were:

(1) IVI Minivib II,
(2) LSS6 Land Airgun, and
(3) 1 kg of Pentalite (explosives).

The first shot on each line began near stations 4 and 129 on lines B and A, respectively. Twelve shotpoints were used per line in this data set, with a 45 m gap between each set of 6 shotpoints and 15 m spacing within the two sets. Originally, the two sets of shots were to be shot on opposite ends of the line. However, rapid erosion of the point bar prevented the execution of shots on the north end of the line. This unstable environment also prevented each shot from being executed at the exact same location. In some cases, there were variations in the inline and offline location at shotpoints.

The Minivib II recorded the data in linear upsweeps from 8 to 80 Hz. The 12 sec record consisted of an 8 sec sweep followed by a 4 sec listening period. Channel #1 recorded the pilot trace from the vibrator, which was cross-correlated with the remaining traces to produce 1024 ms data files. The initial record length of both the land airgun and the pentalite data sets were 2048 ms, which was cut down to 1024 ms. Using a 60 cu. in. chamber, the airgun was fired with 1500 psi gun pressure onto the surface. A geophone time break was set up 1.0 m from the source. The explosive source consisted of 1 kg of pentalite submersed in 4 m deep holes. Unlike the other 2 sources, the pentalite was always shot 2 m offline and a single shot was recorded at each shot point. In contrast, there were an average of 30 shots recorded from the airgun and 20 sweep recorded from the Minivib II, respectively, at each station.

Results

Preliminary finds on the point bar source comparison include variable area plots of each of the sources plotted with a 500 ms AGC applied (Figures 3,4, and 5). Complete stacked sections, frequency and power spectra analyses, as well as plots of the frequency and energy variations with offset provide unique understanding of the problems associated with this near-surface.

Reflections are clearly interpretable on shot gathers. The most distinct events across all three sources occur at approximately 250 and 600 ms, respectively. The reflection with an origin time of 250 ms was determined to be from a depth of about 265 m using a calculated NMO velocity of 2120 m/sec. The reflection with an origin time of 600 ms was determined to be from a depth of about 855 m using a calculated NMO velocity of 2850 m/sec. The field files displayed here are representative examples from the data set.

Discussion

The intent of this study was to provide guidelines for source selection in areas with a shallow water table and varying geology from very loose, unconsolidated sands (line A) to more compact sands and clays (line B). Initial investigations have provided some interesting insights regarding the differences between data recorded on each line as well as data shot with different sources. Over all three sources, it appears that data recorded along line A possess better shallow reflections (less than 250 ms), while data shot along line B produces clearer events deeper in the section (greater than 600 ms). This could be due to the type of geology located directly beneath each line. It was well-documented that the sands at the surface along line A were much looser than that found along line B. Another interesting observation from these records comes in the difference in clarity between shallow and deep events with each source. Both the land airgun and Minivib II appeared to produce better reflections deeper in the section, while the explosive source appeared to perform better up shallow. It seems that the ground roll noise produced from the explosion thoroughly dominates the reflections, masking them from view. It is also interesting to note that the Minivib II appears to have produced more distinct deeper reflections on line A while the land airgun produced clearer deep reflections on line B. Further processing on the data should provide a clearly evidence for or against either of these observations.

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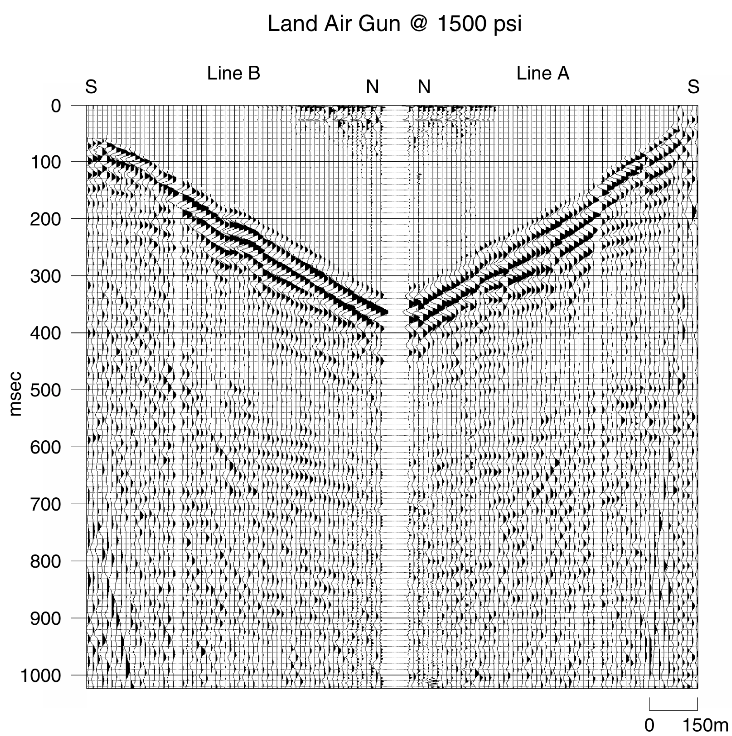

Figure 3. Recorded data from shot point A1 using LSS6 land airgun.

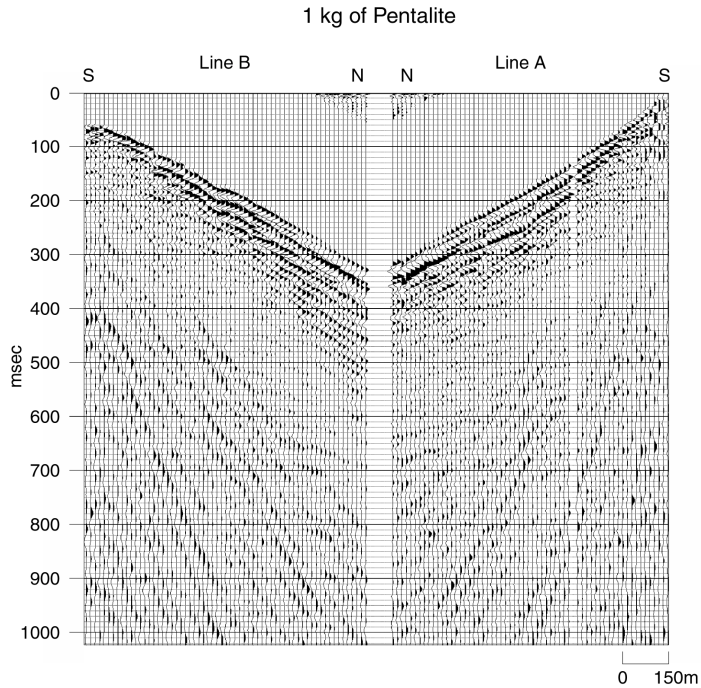

Figure 4. Recorded data from shotpoint A1 using 1 kg of pentalite.

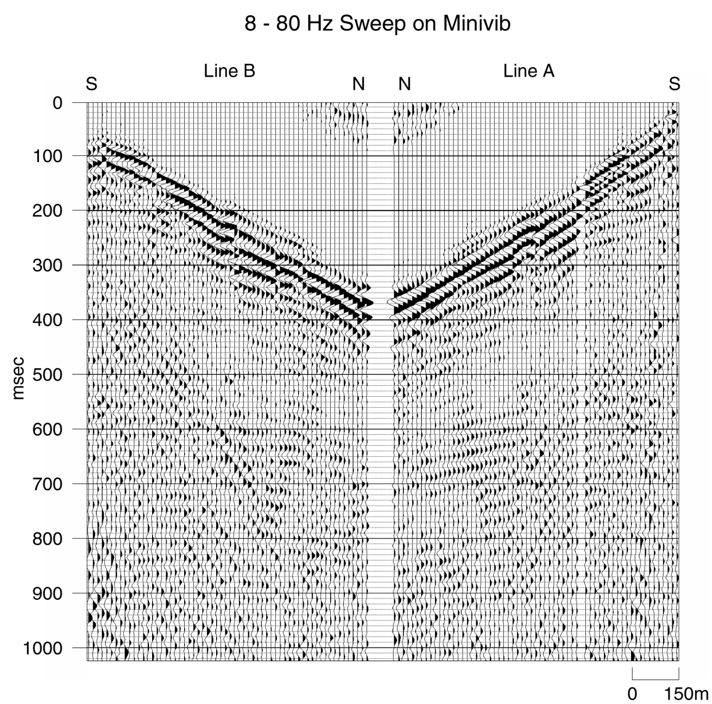

Figure 5. Recorded data from shotpoint A1 using IVI Minivib II.