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Improving Alaskan Seismic Acquisition

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Introduction

On several seismic acquisition programs on the North Slope of Alaska in 2014, recently developed acquisition methods were applied to improve imaging and operations. These included the improving station positioning for imaging, high productivity acquisition techniques, stake-less surveying, and the pursuit of lower frequencies. To no small extent these methods are intertwined and require extensive understanding and application of each to achieve the desired result. Testing of these theories and methods have led to distinct improvements in production parameters and program layout in comparison with conventional methods.

Station Positioning for Improved Trace Density and Distribution

The pursuit of increased trace density and improved offset and azimuth distributions has also been in the forefront of Alaskan operations. Restrictions to seismic operations impede the ability to locate stations in their theoretical positions. Steep slopes, waterways, thin ice, snow drifts, and extensive areas of willow trees are common restrictions in Alaska that can result in significant restrictions to seismic operation. A conventional approach to mitigate their effect on imaging is to use a series of station positioning guidelines which may include offset ellipses, or crossline-inline thresholds. There are also components to these guidelines in which the stations are relocated more than one to two receiver or source line intervals from their theoretical location. Where restrictions are significantly large or complex related to these guidelines, stations may be excluded from the program. Effort can be placed on mitigating the impact of these restrictions both in the planning and operation stage of the program (Millis 2014). A methodology can be employed whereby all of the stations that would be repositioned significantly far from their theoretical location, or would be otherwise excluded, could instead relocated to a central area within the program – the full imaging extent.

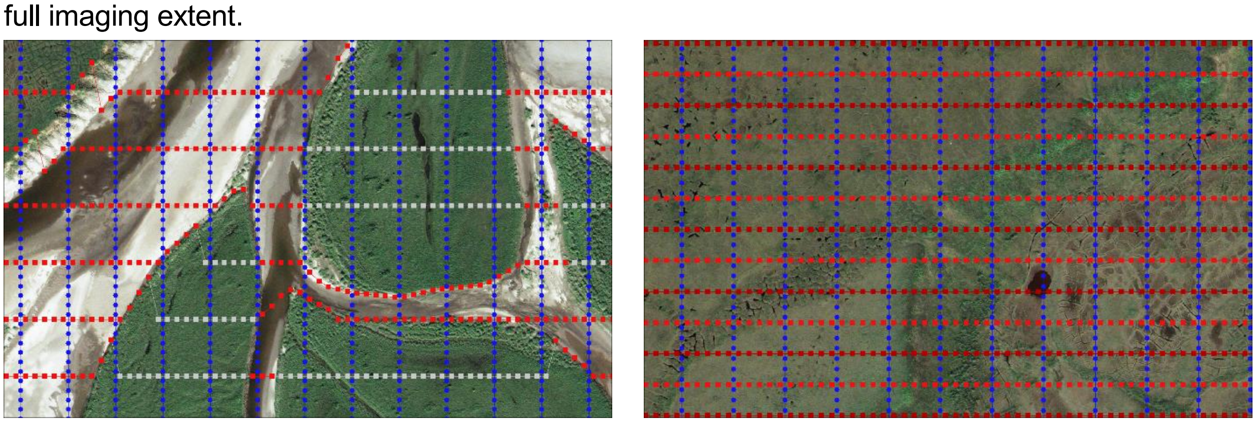

Figure 1: (Left) Sources, coloured gray, are inside willow restrictions, cannot be repositioned according to station positioning guidelines, and are removed from this area of the program. (Right) Sources have been repositioned within an area of interest within the program.

The full imaging extent would typically be delineated according to the area of interest, and areas where imaging may be compromised by a significant amount of restrictions are expected to impede the distribution of stations. Relocation of stations to this central area would significantly increased the trace density, offset and azimuthal distribution where it was required most, with the caveat that one would forgo any additional near-offset contributions in the original area. As near-offsets are difficult to acquire when faced with complex restrictions, by selectively positioning stations to target missing near-offsets any of the remaining stations can be relocated. Ideally, they could be positioned according to the migration and fold aprons of the program, but this is not necessarily so. Ensuring an increased complement of all available offsets and azimuths at the horizons and area of interest would be a driving focus. This technique uses the dynamic nature of a vibroseis operation, and having an array of personnel adequately equipped for this scenario.

Slip-Sweep

By capitalizing on the availability of vibrators and crews familiar with their operation, planning on several 3D programs have included the expected benefits from slip sweep operations. In the design stage, slip-sweep operations allows for a higher source effort throughout a program. This is of particular benefit on the North Slope of Alaska due to the imaging challenges related to permafrost conditions. Slip times tested in the programs range from 6 to 12 seconds depending on sweep length, with a typical slip time of 6s being used in production. One such slip-sweep record is shown in Figure 2 below.

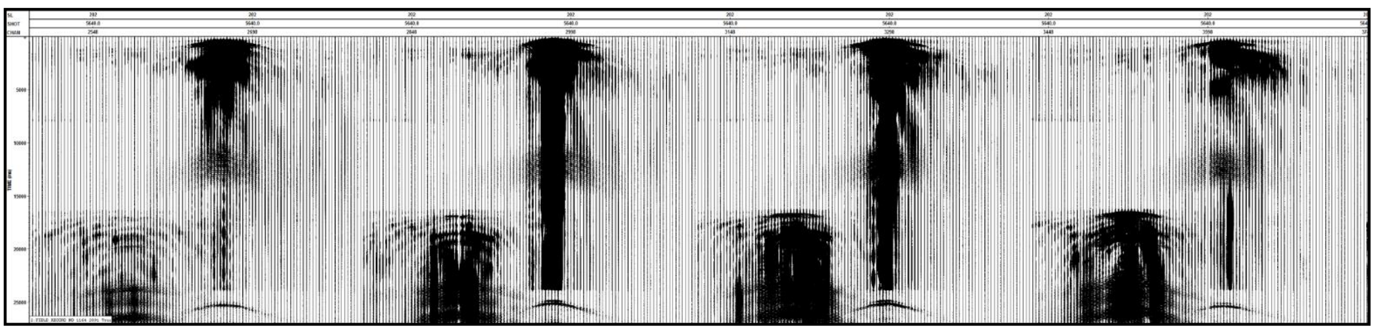

Figure 2: Slip-sweep record showing minimal overlap from two separate sources.

Stake-less Survey

Stake-less surveying describes a method in seismic acquisition wherein station locations are not predetermined by survey, but obtain survey coordinates during acquisition. Potential issues with conventional surveying include missing or damaged flags that may not be located by the acquisition crew station offsets applied some distance from the flagged station location, and changing conditions may necessitate relocation of stations. This may result in the potential for sources or receivers being mis-positioned, or omitted.

Another distinct advantage to using a high productivity acquisition techniques such as slip-sweep and stake-less surveying during operations is the ability to incorporate increased station sampling to image the weathering layer. Weathering reflection data can be acquired and used to build and put constraints on the near-surface model. To do so requires regular and dense sampling of the weathering layer, with the resulting data used as an input to the primary static first break inversion solution (Youssef 2011). In order to mitigate the effects above, allow for dynamic response to design and imaging criteria, and accommodate the other improvements discussed, stake-less surveying has become a component of Alaskan operations, and incorporated into the design and planning of programs.

Low Frequency Pursuit

Due to the importance of low frequencies for inversion and structutral analysis, the pursuit and importance of acquiring low frequencies continues to increase. As low frequency sweeps are limited mechanically by pump flow and reaction mass, the sweeps must be adjusted and tested to determine which sweep is ideal for a given area. Specific consideration was given to the sweep tapers, rate, and length. By recognizing and utilizing advantages in different equipment, including vibrators and geophones, and operating them according to their specifications, distinct improvements in the acquired data can be made. To determine expectations of a given set of equipment, tests have been developed to identify sweeps and geophones that showed benefit in recording low frequency data. This test used a series of 15 sweeps to push the capabilities of the vibrator at these low frequencies with two sets of twenty-five geophones from different manufacturers that were co-located along a receiver line. Results of this test are shown in figure 3, which confirm that acquisition of lower frequencies is achievable, can be improved upon with the proper selection of equipment, and that the pursuit of, and testing for lower frequencies is an important component of Alaskan operations.

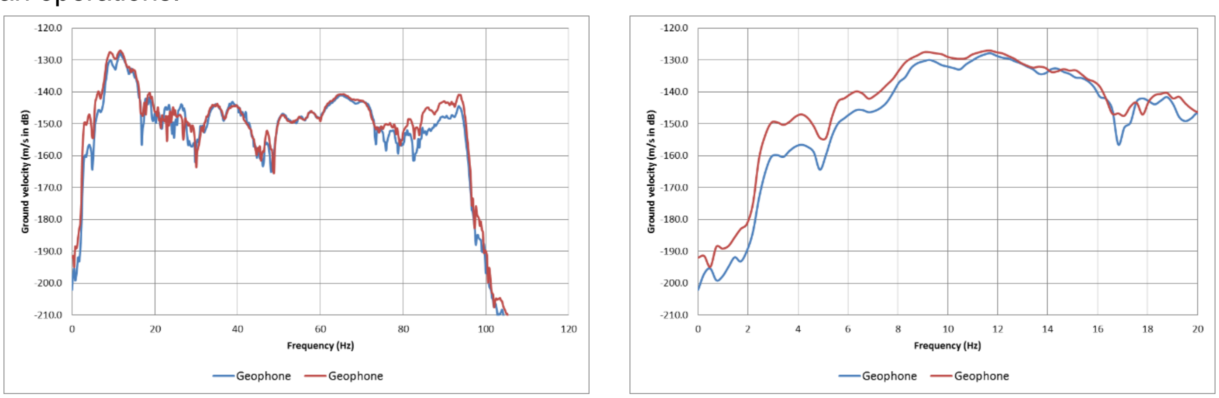

Figure 3:Ground velocity vs. frequency for two separate lines of geophones. (Left) Complete response. (Right) Zoomed in to 0-20Hz.

Conclusions

Many recent acquisition techniques have been used in Alaskan production. By continuing to utilize these techniques, and ensuring they are understood at many levels of the operation, the ability to image targets of interest and to operate land seismic acquisition programs efficiently and safely, has been improved.

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