Tactics for Explosive Deployment Deep Basin Seismic Exploration

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Summary

This presentation examines main aspects of explosives in seismic acquisition. In a world that demands industry improve cohabitation with the ecosystems they occupy, what tools does the modern geophysicist have to meet these demands. And how can they advance much needed subsurface resolution for today's unconventional reservoirs. The possibility of exploiting sub-kg explosives in shallow shot holes may represent an effective tool for eco-friendly seismic exploration. Coupled with advancements in recording technology, these concepts were applied to deep basin reservoirs through field trials in Alberta, Canada.

Introduction

The seismic exploration industry, like most industries, is under a tremendous amount of pressure to reduce its footprint on the environment. For seismic operations, the primary focus is centered around seismic line construction within forested environments. This type of disturbance results in long-term carbon footprint. Seismic lines are further scrutinized for their impact on wildlife, predator verse prey relationships, and human interactions with the ecosystem. Historically, 5m wide seismic lines were constructed with bulldozers called "cat-cut". Due to the nature of this style of line clearing, regrowth is a very slow process, and in many cases, doesn't occur without reclamation. With this knowledge, industry made tremendous strides to reduce their impact. Utilizing mulchers instead of dozers and reducing the overall line widths. Today, seismic lines are commonly 2.75m wide for source and 1.75m for receiver. This was made possible largely with advancements in mulching and Low impact seismic drills (LIS). The receiver widths are due to safety restrictions and based on best practices, meaning 1.75m allowed for a speedy and safe extraction of injury workers.

Today, seismic vendors are poised to take another step to significantly reduce their footprint. Advancements in recording technology (aka, all-in-one nodes) and sophisticated planning to meet safety regulations, acquisition companies now have much needed versatility for recording equipment and their crews. These are some of the factors that permit sensor deployment, in some forest types, to operate without cutting. Similar attempts are being made with the seismic source. The primary focus is once again on versatility. Working with traditional and new explosive technology, companies like TGS aim to improve seismic resolution while advancing our environmental initiatives.

When acquiring new seismic programs, the acquisition strategy should incorporate measures to safely operate in an ever more eco-friendly manner. That is the big picture! For now, we dive deep into the world of explosive shot holes with a comprehensive dataset acquired by TGS in 2019. This study has demonstrated some interesting results, leading to the potential for source widths 1.75m, a 36% reduction per linear kilometer. To accommodate the narrowing of source lines, there are presently sub-kilogram explosive charges available, and 1.75m wide drilling equipment on the market. The question regarding the smaller drill becomes, what is the effective drill depths? And how to handle changing drilling conditions like, soft ground or hard/gravely rock. The consideration of charge size is also crucial. What is the best weight for a given depth or target? While there never seems to be a “one size fits all” solution, ascertaining the capabilities of shallow depth, sub-kilogram charges seemed to be the logical first step.

Theory and Methodology

TGS Initially began experimenting with source configurations near Fox Creek, Alberta, in 2014. This trial laid the groundwork for more elaborate studies. In the 2014 study, TGS wanted to emulate shockwave theory (from: W.E. Peet 1960) and the scaling of amplitudes as a function of frequency. The theory alluded to frequency being inversely proportional to the mass of the charge size. Meaning larger charges would yield lower frequencies, lower center frequency and ultimately, higher amplitudes across the full bandwidth. To measure this trend, TGS analyzed the first-break energy (Figure 1) of different charge sizes and found there to be reasonable correlation. In conjunction with these findings, we had been surprised with the sub-kilogram charges. The recording showed sensible clarity for refraction picking, and reflecting energy returning from deep subsurface events, illuminating far offsets. Intrigued by these finding, which seemed to solicit more questions associated to edge frequencies and repeatability, TGS undertook a comprehensive field trial, acquired near Edson, Alberta, in 2019.

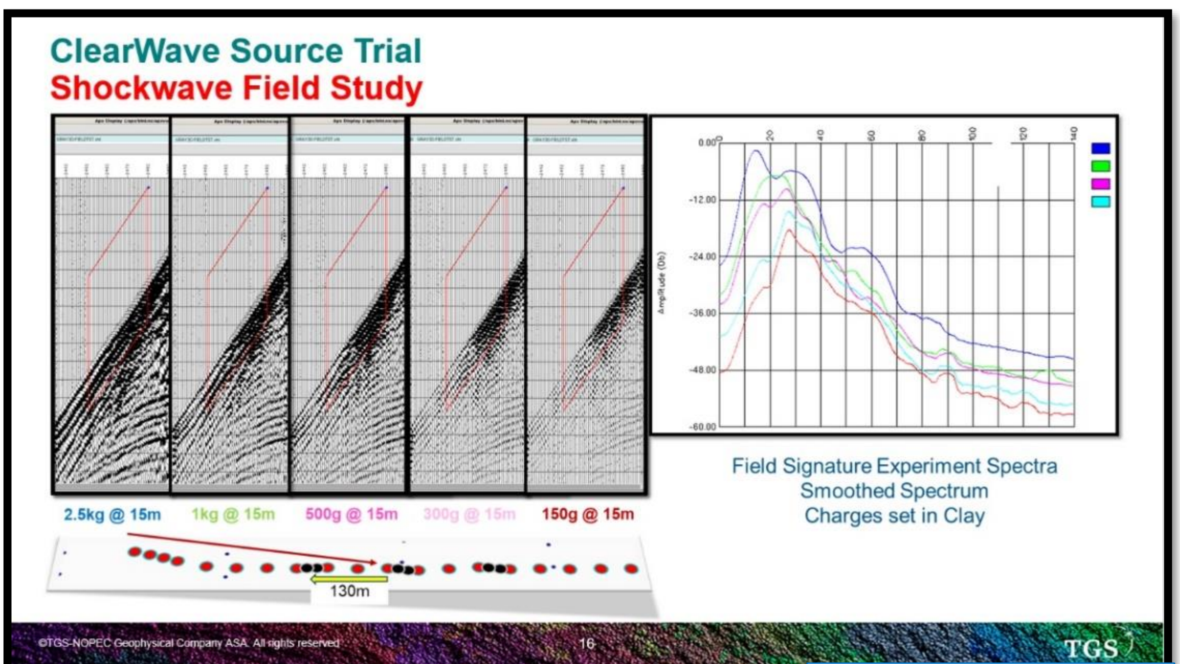

Figure 1: 2014 Field Results

Shockwave theory is only part of the equation. Blasting conducted in mining operations bestows substantial scientific background related to explosives. Setting explosives into a bored hole and detonating entails the explosive charge would interact with the surrounding rock. The intense pressure, thermal dynamics and chemical reactions are confined by the rock. These factors influence the bored hole, causing distortion and fracturing that consumes some of the explosive energy. This implies coupling plays an important role in seismic data quality.

The Edson experiment (Figure 2) positioned the standard 3D explosive source, single shot 2kg at 12m, as the baseline for comparison. Along the 3D source line, sub-kilogram explosive was deployed at depths ranging from the benchmark 12m to 1m deep. The depths within the range included 3m, 6m and 9m shot holes. Observing seismic data quality with different charge mass and depths was intended to provide insight to both shockwave theory and knowledge gained from mining studies. Could we realize broad, reliable bandwidth with smaller charges. And would the quality be consistent with changing near surface conditions.

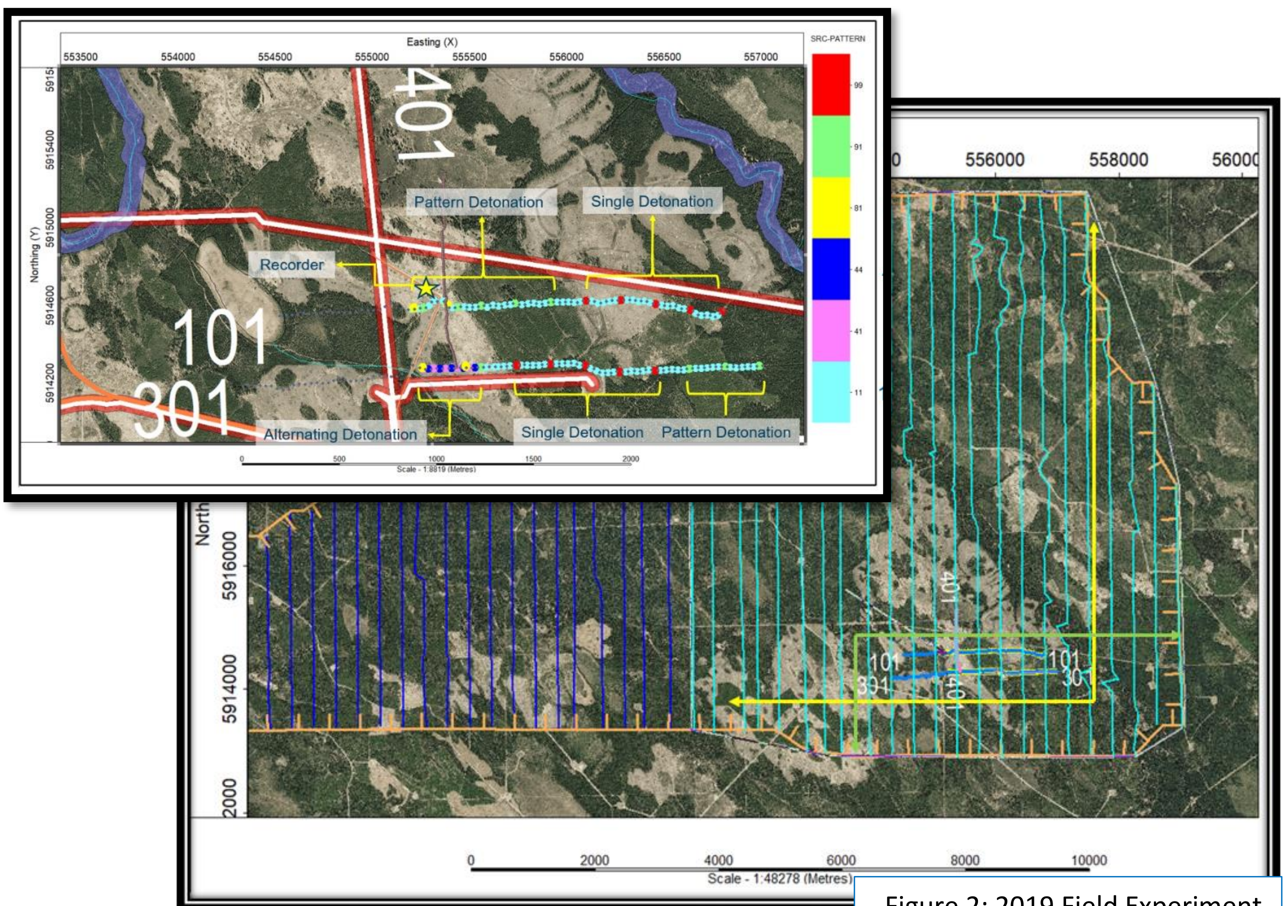

Figure 2: 2019 Field Experiment

In addition, a new technology that should peak your interests was implemented, OSXTM ClearWaveTM. This 58g explosive unit developed by Orica incorporates a wave shaper that is designed to direct the energy into the subsurface. In seismic imaging, this is an obvious aspiration. Given the experimental nature of the product at the time, limited access to the units and small mass of the charge, 34.5 times smaller than the benchmark 2kg, the concession was made to deploy the product in patterns. These patterns, 4 units for a combined weight of 232g and 9 units for a combined weight of 522g, were detonated at one time and individually for later vertical stacking experiments. The patterns were designed to limit the array effect, and to emulate 250g and 500g products.

It is noteworthy to mention peak particle velocity measurements had been recorded during the acquisition of this field trail. The ground vibrations had since been evaluated, and vector sums plotted with both standard and modern seismic sources. Finally, an ultra-high-density receiver line (5m spacing) was deployed to capture source generated noise. Along this line, two hundred 5Hz single component receivers covered 1km distance, and laid perpendicular to the source line. Although this data will not be featured in this CSEG presentation, the data will be leveraged for future endeavors.

Conclusions

Through these efforts, TGS will reveal the potential for sub-kilogram explosives, in shallow shot holes, to illuminate subsurface geology within deep basin exploration. This shift in charge and hole depth will ultimately employ smaller drilling equipment and thus, be an effective tool in eco-friendly operations. That is the big picture! Now let's conclude the deep dive into the world of seismic shot holes. Given the nature of the charge size and resulting energy produced, I was at first skeptical the reflecting signal, especially at the edge frequencies, would have enough energy to overcome the noise. I will show evidence (Figure 3) that charges as small as 58g can yield dominate signal band thru to far offsets and deep into the subsurface. In addition, the edge frequencies are not absent in smaller charges. This will give the exploration Geophysicist some confidence they can retain bandwidth comparable to historical seismic shot holes of 12m and 2kg.

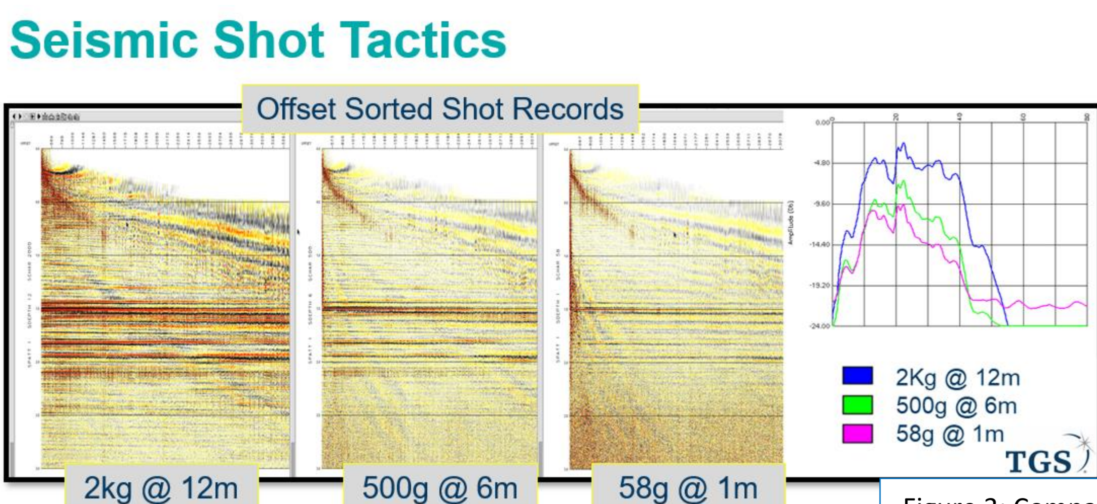

Figure 3: Comparison

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