Land 3D: groups or single sensors? cables or radio? geophysical and operational considerations

Malcolm Lansley, Sercel; Mike Laurin and Shuki Ronen, CGGVeritas*

Summary

Is the future of land acquisition systems in single sensors or groups? Cable, radio or no data telemetry (ie autonomous node) systems? Single or multi-component? Single sensors provide better signal than geophone groups; improved resolution and improved multi-component data. However, the increased noise with single sensors must be compensated with increased data density and more sophisticated data processing, and getting the value from shear waves seems more difficult than acquiring multi-component data. The potential operational advantage of systems without cables is in areas with limited access or if the receiver station interval is large. Cable based systems have operational advantages where cables can be deployed, receiver station intervals are small and the geophysical advantage of improved field QC.

Introduction

As hydrocarbons are becoming more difficult to find and to produce, operators who use relevant advanced technology have an advantage. But what advanced technology is relevant and for what? Multi-component (3C) recording has been conducted on land since the 1970s. For many years analogue (or moving coil) sensors were used, either in arrays or individually, together with conventional data recording systems. The weight of the 3C geophones, together with the operational difficulties of leveling and aligning them, (Lansley et al, 1998a and1998b) and channel capacity limitations of the old recording systems lead to a high cost of data acquisition and hence limited use of multi-component surveys. In recent times the introduction of 3C digital MEMS sensors and very high channel count recording systems has eliminated most of these problems, yet we still do not see widespread recording of 3C surveys. Why should this be? If asked, most geophysicists would answer this question with their two favorite subjects: data quality and cost. In this paper we consider a few relevant geophysical and operational factors.

Geophysical considerations (data quality)

Single sensors eliminate intra-array statics and MEMS have wider frequency band, do not have high frequency spurious noise, and therefore provide increased resolution, but they also provide more random and coherent noise. To deliver the same final data quality, surveys with single sensors must have smaller station intervals. We have found that single sensor intervals must be at most half of group intervals. Figures 1-3 show one example of 3D data from the USA in which single sensors at 110' interval provided similar final data quality to groups of 6 geophones at 220'.

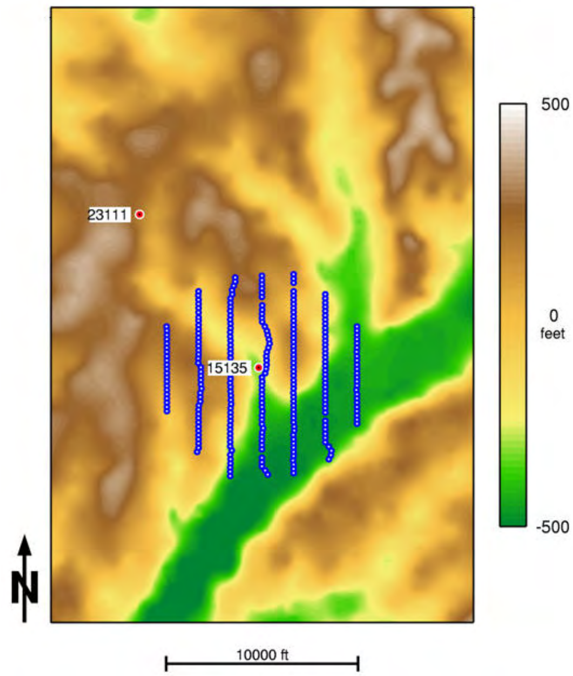

Fig 1: Location map of the receiver spread (in a circle) and two shots, one at the center of the spread and one outside.

A few years ago acquisition systems were limited by channel count and reducing the receiver interval and recording 3C was not practical. Fortunately, channel counts are no longer an issue with modern systems capable of 100,000 channels in real time with either cable or radio telemetry.

Reducing the receiver interval by a factor of 2-3 is an effective solution for random noise such as wind or culture induced. To attenuate coherent noise such as ground roll there are two solutions. One solution is to reduce the station interval to less than half a wavelength of the ground roll so that FK filters can be used. This is a very expensive solution. Ground roll wavelength can be less than 20 m and the implied 10m station interval may be prohibitively expensive. In 3D we have to provide sampling in the cross-line as well as in the inline direction. In 3D, ground roll can be sampled and attenuated by FKK filters only at great cost of increased receiver and source effort. The other solution is polarization filters (de Meersman and Kendall, 2005). Polarization filters use the data recorded on the horizontal components to attenuate ground roll on the vertical component and vice versa (Fig 4).

Groups or Single Sensors? Cables or Radio?

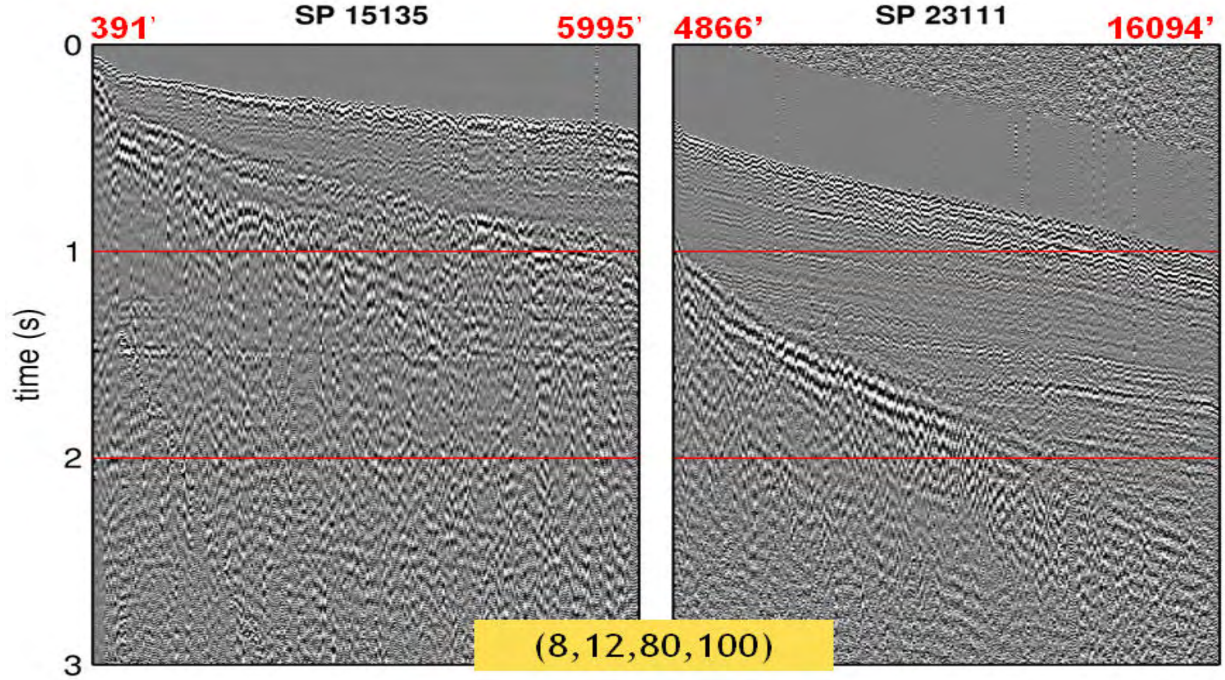

Figure 2a: Geophone groups data. Two shot profiles are shown with two different offset ranges. Bandpass filter and AGC.

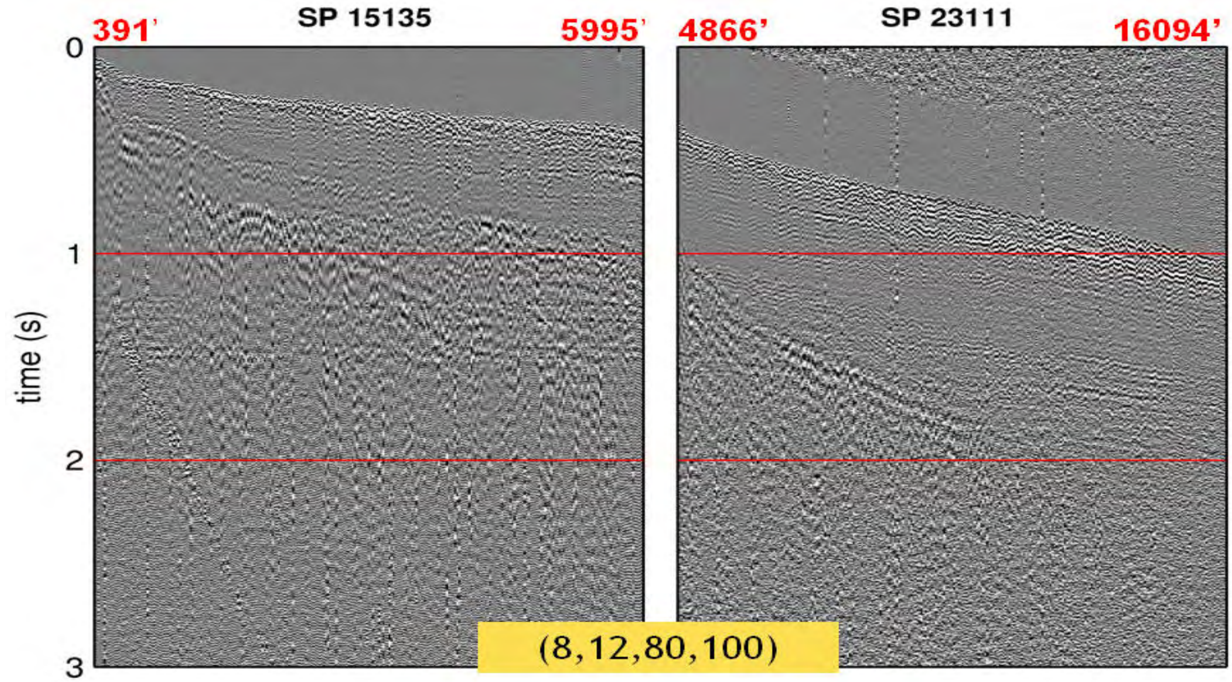

Figure 2b: Single sensor MEMS data. Two shot profiles are shown with two different offset ranges. Bandpass filter and AGC.

Groups or Single Sensors? Cables or Radio?

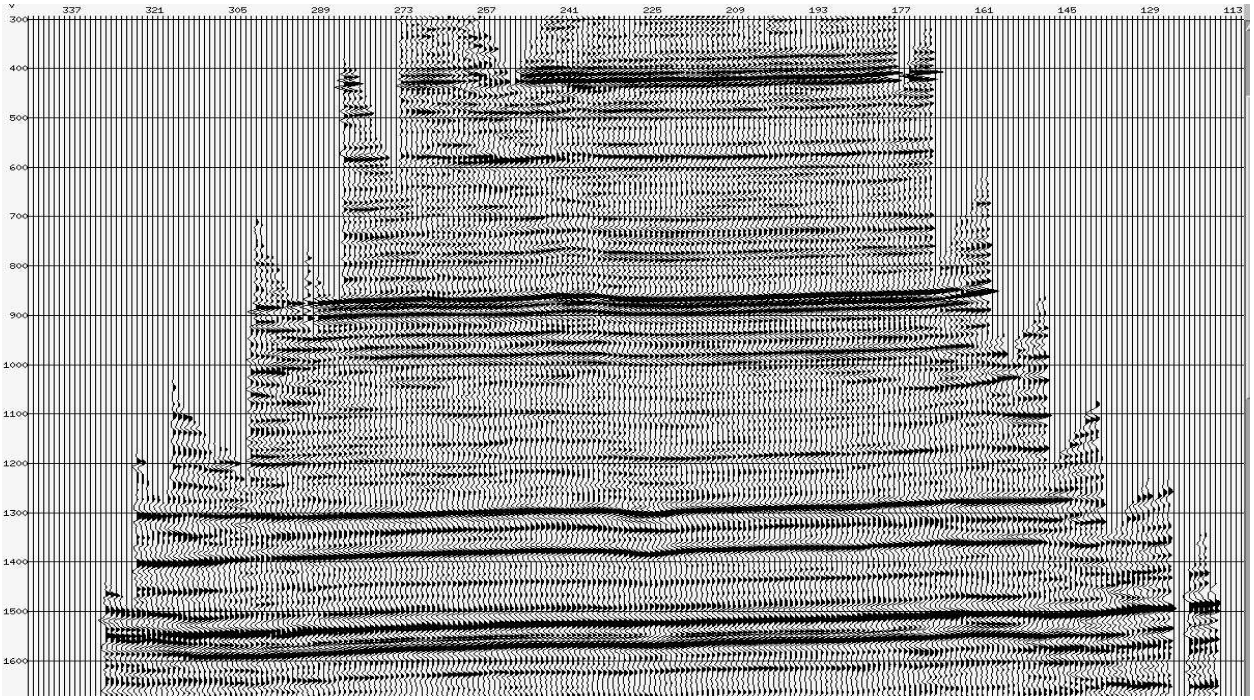

Figure 3a: Cross section from the conventional geophone groups data after migration.

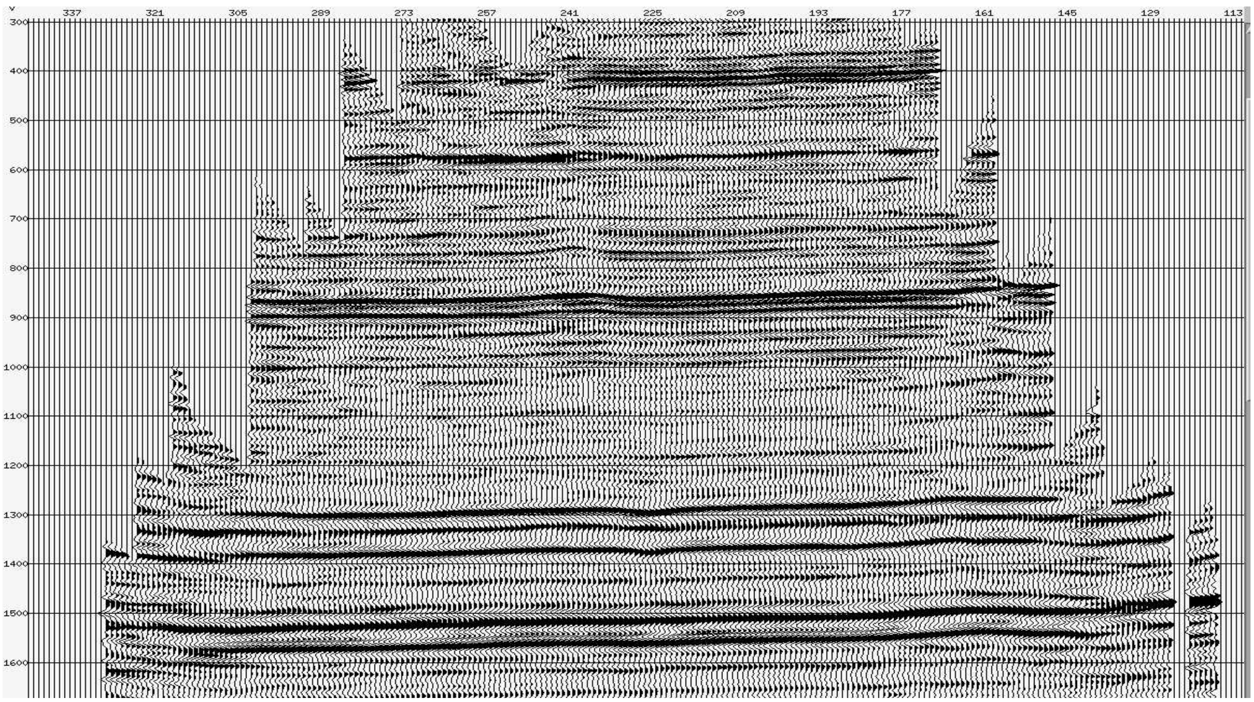

Figure 3b: Cross section from the vertical component of the MEMS single sensor data after migration.

Groups or Single Sensors? Cables or Radio?

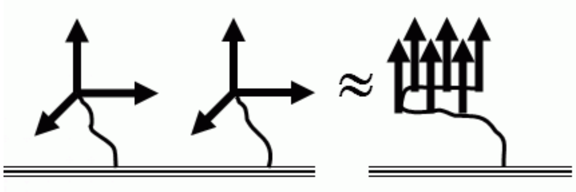

Fig 4: Can we use single 3C sensors instead of groups? This cartoon claims that the answer is yes, at half the station interval.

Signal/Noise ratio has both a numerator and a denominator. While matching the denominator of geophone groups comes at an effort, single sensors are way ahead of groups with the numerator. Single sensors provide better P-wave imaging (Ronen et al, 2005) better converted PS waves for lithology (Roche et al, 2006) and for fracture characterization (Mattocks et al, 2005) and better both P and PS waves for heavy oil (Gray et al, 2006).

The geophysical considerations relevant to comparing cable to cable-less systems are less obvious. The same receivers can be connected to either system. However, one big advantage of cable telemetry is improved field QC with better monitoring of noise levels and early detection of poor coupling.

Operational considerations (time and money)

The most important factors that govern the operational and recording efficiency are:

- Equipment weight
- Power consumption of the ground electronics
- Battery and power management
- Source/spread management

As discussed earlier, when using point receivers the trace density is typically doubled in order to provide a similar signal to random noise ratio as would be achieved when using arrays of 6 geophones. Therefore, when considering equipment weight this factor needs to be comprehended. Figure 5 shows the approximate weight relationship between three different recording scenarios: a cable system with arrays of 6 geophones, a cable system with 3C digital point receivers and a cable-less system also using 3C point receivers. As can be clearly seen, there is a significant weight advantage to using the digital 3C sensors, even when the recording group interval is halved as shown by the arrow on the graph. What is also apparent is that for large group intervals (coarse spatial sampling) there may be a slight weight advantage for the system without cables. However, as the industry moves to higher and higher trace densities and finer spatial sampling the weight advantage moves in favor of the cable system. In this comparison the crossover is at approximately 30m (or ~100 to 110 feet.)

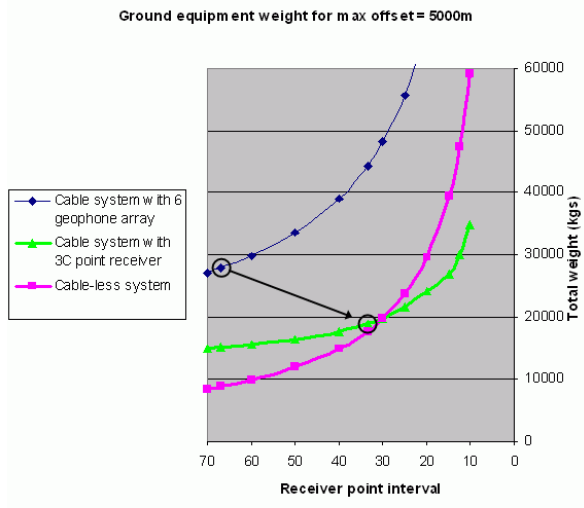

Fig 5: Equipment weight as a function of receiver interval.

Power consumption and battery management are obviously related and the lower the power consumption of the ground electronics the better. Although some battery types may have very good power to weight ratios, initial and replacement cost may be significantly higher. Low temperatures also affect battery life and some types (e.g. lithium-ion) may not be very well suited to low-temperature environments. When we consider the number of batteries that are deployed within an active recording spread, with the cable-less system we have as many batteries as receiver points, which today may range from 5,000 to 50,000. With a cable system that number is typically divided by 30 to 40 which is much more manageable. Although each individual battery may be heavier, the type can be selected to be appropriate for the operating environment and the management and recharging is much easier.

Modern high channel count recording systems incorporate very efficient source and receiver spread management tools that enable source-controlled shooting to be effectively used. These, together with the real-time verification of data quality, can ensure that these high density multi-component surveys meet the desired objectives. Actual recording production statistics averaged over a number of Canadian surveys show an average of 40% improvement when using multi-component point receivers versus 6-geophone arrays.

Conclusions

High quality, high density, multi-component 3D surveys are being acquired very cost-effectively using single sensors. As the spatial sampling becomes smaller and the trace density greater, significant operational and recording efficiency benefits are gained using cables.

EDITED REFERENCES

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