Recent advances in land seismic acquisition

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Summary

In recent years, there have been a number of technological advances in electronics and communications that have permitted significant changes in the way that seismic data can be collected on land. We have seen an exponential increase in the number of channels that can be recorded by modern seismic recording instruments, whether using cables for data transmission or not. This has led to an increased number of high trace density surveys being recorded in many parts of the world. New capabilities for the management of multiple fleets of vibrators, together with innovative vibrator usage methodologies, have permitted a similar increase in the source density, resulting in a corresponding increase in the trace density in some areas of the world, but not everywhere. Although the standard moving-coil geophone is still used in most surveys, we have begun to see an increased usage of MEMS-based 3C accelerometer sensors in a few areas. We have also seen the introduction of new surface source technology and safety improvements when using explosives. This paper will discuss these technological advances and some of the novel methods of using them to increase data quality and/or reduce cost.

Introduction

High trace density surveys have been being acquired in the Middle East for more than 10 years and in the USA for about the last eight years. In the old days there were many discussions about the merits of "wide azimuth" versus "narrow azimuth" geometries, but these were typically based on geometries that would provide similar trace densities. Today, with recording systems capable of acquiring up to 100,000 traces in real time, we no longer need to make the compromise of either poor offset distributions but with good azimuth sampling or vice-versa. With such systems it is now possible to obtain both good offset and azimuth sampling simultaneously. Lansley (2004) showed several data comparisons between high density and conventional surveys that demonstrate the superior data quality of the high density methods. Figures 1 and 2 show examples of some of these improvements. Surveys with active spreads of more than thirty to forty receiver lines and more than 30,000 channels are becoming routine and in the summer of 2009 a crew recording ~80,000 live channels will be recording in the USA.

Discussion

For an optimum operational balance of the recording crew and the best imaging results, it is preferable to have the source density similar to the receiver density. However, in many operations the required sweep time of the vibrator crews becomes a limiting factor in the data acquisition time and with conventional vibrator recording the speed of the crew is restricted. A number of interesting techniques have been developed to overcome this problem. The first of these was simultaneous sweeping (Silverman, 1979) in which multiple sets of vibrators would sweep with mutually orthogonal sweep sets at the same time into the same spread. The different data sets were then separated in the correlation process. Unfortunately, the number of sweeps required to get good signal separation usually meant that the sweep time may have to be increased and this method did not see a lot of usage.

The next method to gain acceptance in some parts of the world was slip-sweep (Rozemund, 1996.) In this technique, different sets of vibrators sweep at different locations with sweeps that are allowed to overlap the listen time of the other sets, and in many cases the sweeps may actually overlap. Slip sweep has been used in Oman for more than 10 years with more than 60 3D surveys recorded with productivity gains of up to 100% (Matheny, 2008.)

Because of the overlapping of the sweeps, harmonic noise from one set of sweeps may contaminate the signal from the other sets, and this has resulted in this method not seeing much use in some areas. A patented technique known as High Productivity Vibroseis Acquisition or HPVA (Meunier et al, 2002) was developed to attenuate this harmonic noise and has proven to be very effective.

High Fidelity Vibratory Seismic or HFVS (Allen et al, 1998) was introduced as a method to improve the fidelity of the vibrator signals by measuring and recording the baseplate and reaction mass signals and utilizing them in the processing of the data. It permits greatly improved simultaneous source separation and has been used in some cases to also provide improved productivity.

Additional high productivity methods have been developed, such as Independent Simultaneous Sweeping or ISS (Howe et al, 2008) and Distance Separated Simultaneous Sweeping or DSSS (Bouska, 2008) which have permitted production rates as high as 1000 VPs per hour and up to 12,000 VPs in a 24 hour recording period. These techniques rely upon the highly productive recording systems and newly developed vibrator control systems with TDMA radios to control the large number of vibrator fleets that are operating.

An interesting point to note is that many of these recent innovations have not seen significant usage inside the Americas, except for HFVS and some applications of slip-sweep. This is probably related to the fact that in the Americas the surface access is much more restricted and many of these high source density designs are based on having open access to allow the vibrators to move easily to the required source locations. Some of these surveys in areas with open access have also been able take advantage of some of the new larger vibrators with increased ground force output up to 90,000 peak force which have become available in recent years. Because of their increased size these are not road-legal in many areas and are only operationally viable in desert or Arctic environments. In these areas their increased power can be profitably utilized to improve data quality and/or crew productivity. With open access, source navigation systems can also be used which permit the vibrators to be directed to the next location by GPS units in the vibrator cab. This eliminates the need for survey stakes or flags for the source locations and also reduces the effort of clearing the lines after the acquisition is finished.

Weight drops as a seismic source were in use many years ago, but were typically thought to be a low frequency source. The idea of weight drops was revisited and the Accelerated Weight Drop (Monk et al, 2004) was the result. As this is an impulsive source, the time required per source location is reduced in comparison with vibrators and as long as the timing is carefully controlled, multiple units can be used together to increase the source energy. As a surface source, navigation systems can also be used.

Although many surveys are acquired with surface sources, explosives are still in use in a number of areas. Although not a benefit to productivity or a cost reduction, a major HSE improvement has been achieved by the use of coded caps for detonation of the explosives. These cannot be detonated by a simple connection to a battery and require a coded digital signal to be generated and sent to the detonator in order to fire the charge.

We have seen the introduction of several cable-less systems in the last two or three years and many claims have been made about the potential advantages of weight and flexibility of such systems. However, Lansley et al (2007) showed that in most cases when using smaller group intervals, the weight advantage is, in fact, in favor of the cabled systems. In addition, the number of batteries for cable-less systems is much greater than for a cabled system and the battery management and charging becomes a greater operational burden for the crew. Finally, the data recovery process can be a headache for the recording crew when using very large channel counts. The advantage of cable-less recording equipment is mainly observed when recording with large receiver intervals, in urban areas and possibly in areas of environmental sensitivity. In many cases it may be advantageous to have both capabilities on the crew and to use cables in open areas and no cables when in an urban environment. Data harvesting can also be significantly enhanced by the opportunistic or mobile harvesting technique (patent applied for.) This technique uses data harvesting units installed on any line vehicles, boats and helicopters that will be traveling within or over the recording spread (see Figure #4.) Quality control information and even full data recovery has been successfully achieved with this technology.

Conclusions

There have been a number of advances in recording and source technology which have provided a major increase in the number of recording channels that can be recorded in real time. These have given the industry the capability to acquire surveys with much higher trace density with greatly improved offset and azimuth sampling and correspondingly improved data quality. This has been achieved at only a marginal cost increase, or in some cases even a cost decrease, when compared with surveys acquired just a few years ago.

Acknowledgements

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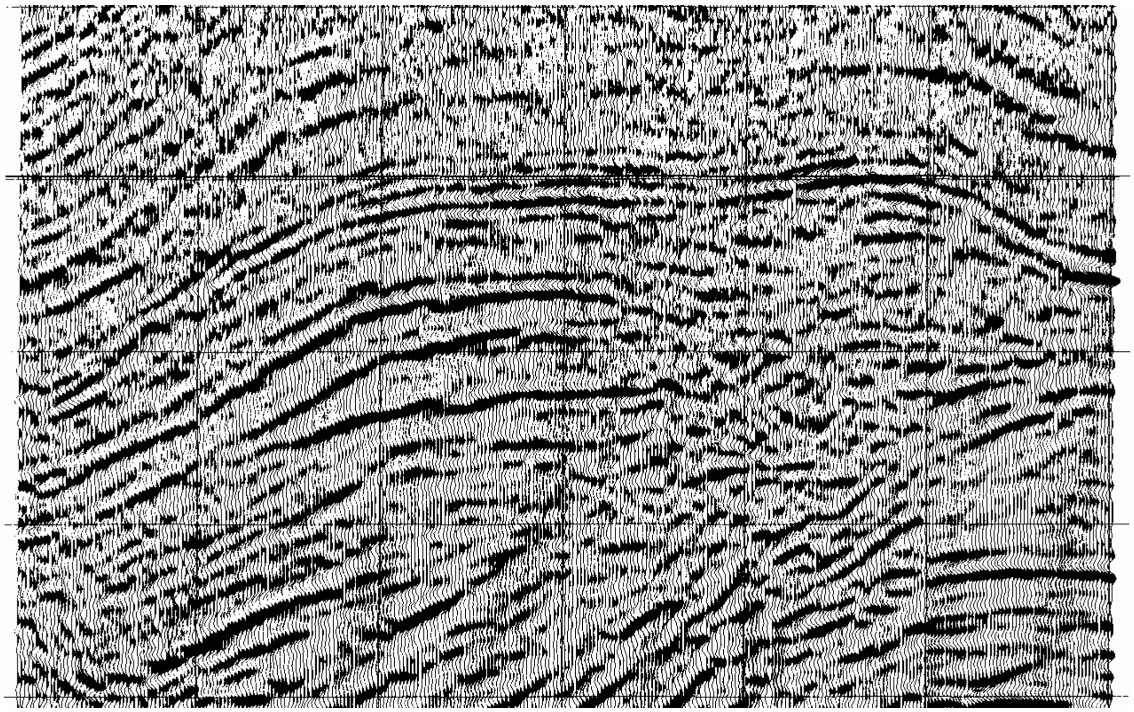

*Figure 1a   High Density 3D data, trace density = 884,736 traces per square mile
Bin size 55 x 55 ft.*

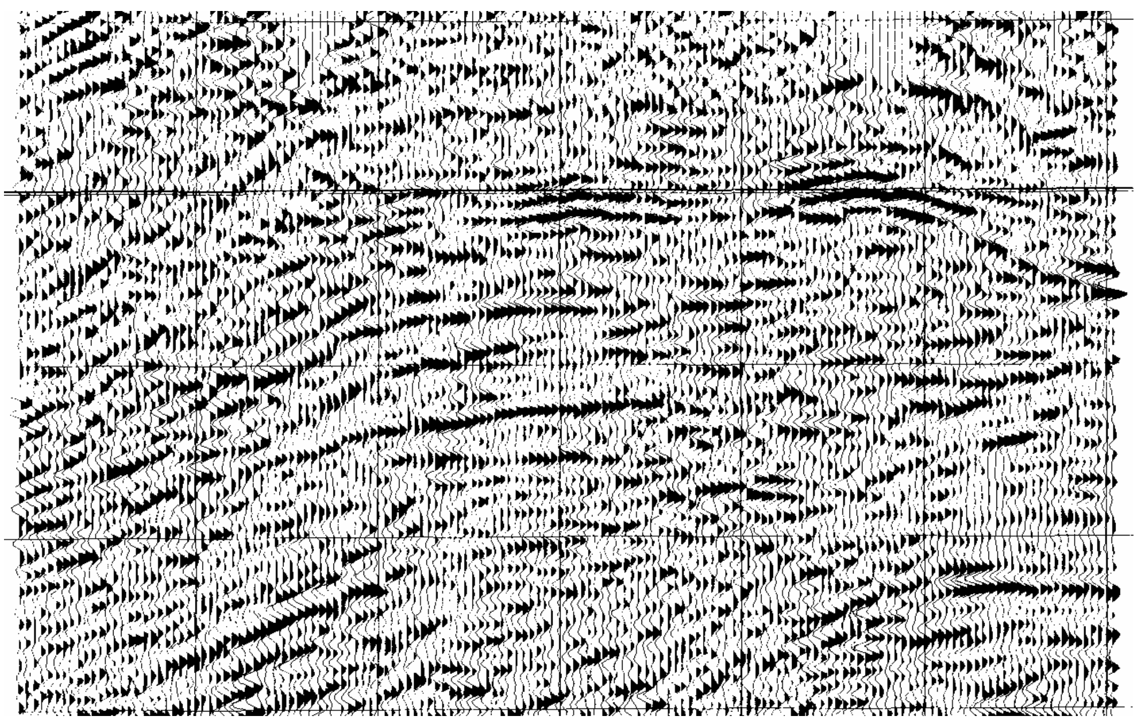

*Figure 1b   Simulated conventional 3D data, trace density = 55,296 traces per square mile
Bin size 110 x 110 ft.*

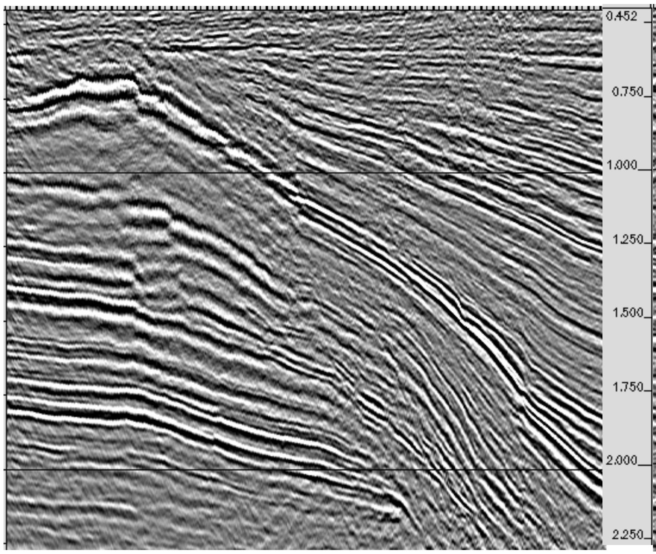

Figure 2a 2003 High density 3D vibroseis data
Trace density = 663,552 traces per square mile
Bin size 55 x 55 ft.

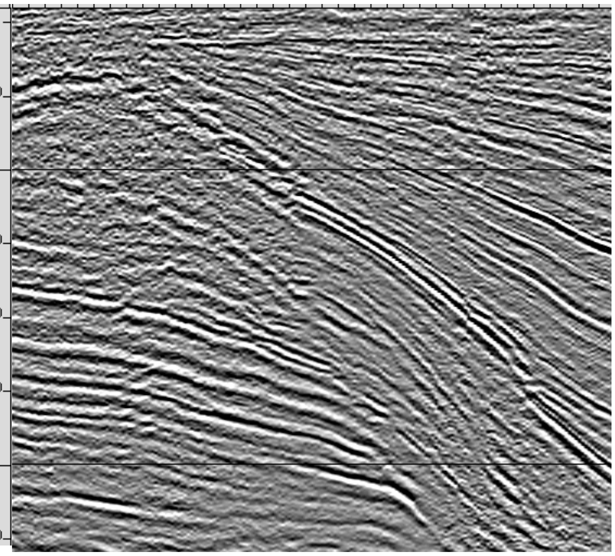

Figure 2b 1995 3D explosives data
Trace density = 36,864 traces per square mile
Bin size 165 x 110 ft.

Figure 3 Data harvesting unit mounted on front of helicopter