Reducing Exploration Risk Using the Latest Land Seismic Systems

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Summary

The land seismic crew count has been on an almost uninterrupted decline for more than 15 years (figure 1). Until recently it was claimed that a high oil price would see an international revival in land exploration. However, during this time there has been no correlation between oil price and land seismic activity, and despite $60/bbl oil and increasing world demand, the majority of oil companies still do not plan an expansion in their land exploration (figure 2). Their view may be summed up by saying that the oil exploration industry awaits a system which can provide “value for money land exploration”.

This paper briefly looks at the latest land technologies available and, combined with the results of an internationally conducted survey, summarises which technologies should be best in mitigating exploration risk and in offering such value for money.

Introduction

A recent survey amongst leading oil companies, contractors, manufacturers and independent geophysicists investigated issues in regard to views and first-hand knowledge of various new land exploration technologies. The results of the survey were recently published in SEG’s Leading Edge magazine. Questions were also asked about which technology would encourage an increase in land seismic activity. The results indicate strong feelings about how some new technologies can be helpful to increase land seismic activity and those which may not.

The invitation to this 2006 SPG Convention asks us to “share the benefits from technical experiences” and this paper is able to answer that invitation by sharing the experiences of many industry professionals around the world through referring to the survey’s results.

Using this feedback, for the first time in many years, we are able to analyze what hardware could most probably improve the lot of land seismic exploration. Since the turn of the century, a number of new techniques and technologies have been tried in the field. Some have proved surprisingly successful, while others have not lived up to expectations. With the experience now gained from the various systems, it seems possible to make statements about which technologies will be able to offer “value for money” exploration.

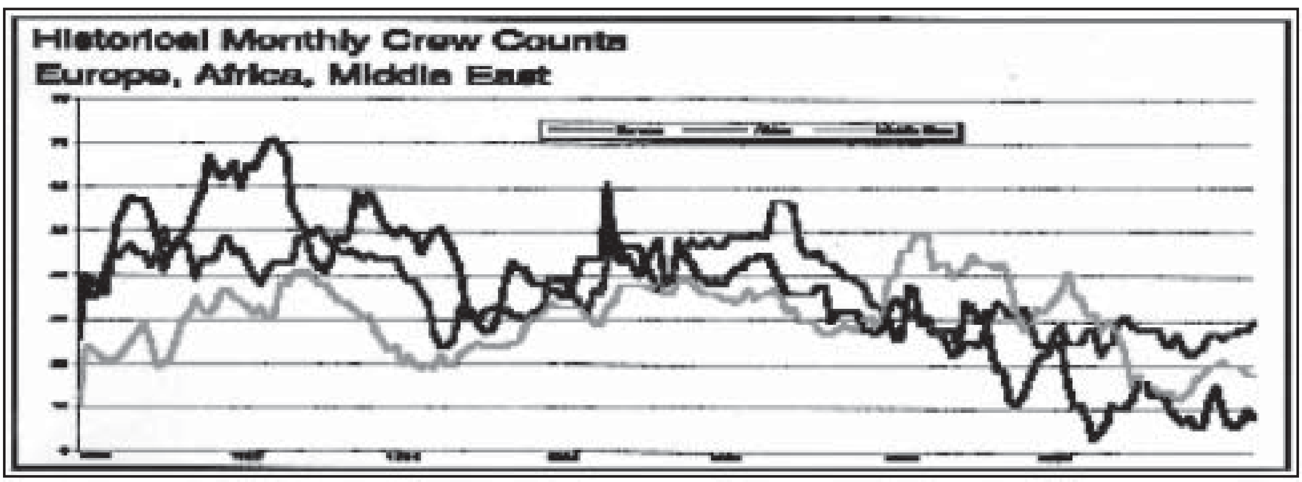

Fig 1 : Land crew activity for last 15 years. Information courtesy World Geophysical News copyright IHS Energy. A virtual uninterrupted decline with no widely used technology apparentlyable to improve matters.

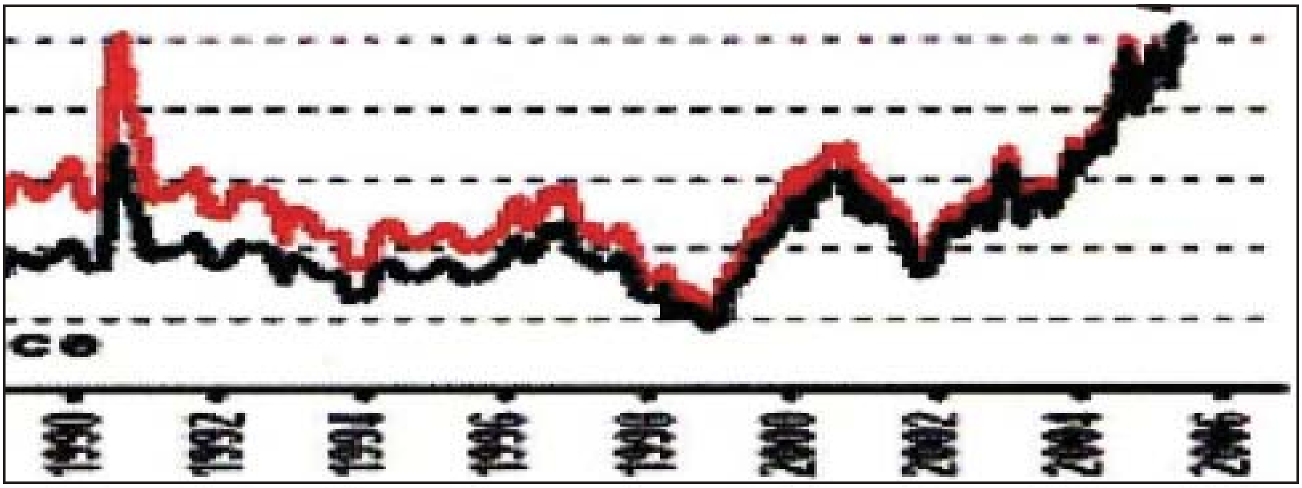

Fig. 2 : Oil price during last 15 years. No correlation with land crew activity.

Method

Over the last 6 months, this company has been involved in making an almost complete sweep in revisiting industry publications, questioned a large number of exploration experts in oil companies, manufacturers, seismic contractor and independent experts to investigate feedback and experience of new land technologies, how well new seismic systems have met initial claims, and met requirements for "value for money" land exploration. Questioning was informal and, to get a representative and reliable sample, participants were encouraged to talk freely about their personal views as well as those of the company which they worked for. Subsequently, not all participants wanted to be named.

Additionally, many of the world's professional geophysical associations, including the SEG and EAGE, hold regular workshops covering land exploration topics. Coupled with papers given at the annual, well-attended international conventions, and the articles (mentioned above) published in the professional magazines each year, there is significant information now available about many systems and hardware types.

All these are valuable and, used objectively, important suppliers of information. Combining all sources it was possible to see definite trends.

Examples

The main technologies discussed in the survey were those of MEMS both 3C and 1C, the very latest conventional digital cable telemetry systems with fixed cable take-out interval, systems able economically to increase in spatial sampling and those able to offer variable density spatial sampling.

First of all, we should remind ourselves how systems currently used fall short of what basic physics indicates is necessary, because this tells us what new problems all these technologies have to solve.

When we sample reflected seismic energy, we must take into account two types of sampling. The first is in the frequency domain, and this has been well taken care of by seismic instruments for decades. As long as we sample energy according to Nyquist criteria - at least two samples per maximum frequency of interest, and those samples are made with high dynamic range, low distortion and low inherent noise, then we can ask no more of field hardware.

The other domain is the spatial domain, and this requires us to have a spatial sample, or seismic trace, twice every maximum frequency of interest. In contrast to the frequency domain, it has been very difficult for seismic systems to meet this criteria, especially cable-based systems, as we would need traces perhaps every few meters in some cases, compared to trace intervals which are currently common in some parts of the world, of 50m. Cable systems tend not only to be too expensive to buy and to operate to meet this demand, but also it is likely that they would not be able to handle easily the real time data transmission bandwidth.

Let us remind ourselves of how much frequency-dependent attenuation takes place when we do not do the spatial job properly. According to this graph (figure 3) with average crews operating with trace intervals of 30-50m, we can see attenuations of high frequencies of the order of 20 dB. This is significantly in excess of the improvement which 24 bit systems normally give in performance compared to IFP systems, and probably almost completely explains why we see no data quality differences between IFP and 24-bit systems with similar trace intervals.

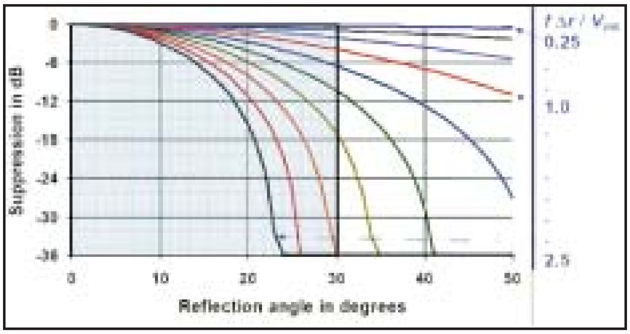

Fig 3 : From G. Vermeer - Effect of linear array on signal in 2D as function of reflection angle, frequency, array length and interval velocity. Many cable based systems force large spatial sample intervals causing high degrees of data suppression.

The survey indicated that many companies believe that the largest cable-based crew which is practical and, in most cases able to offer "value for money" is one with no more 5000 live channels plus sufficient roll, so perhaps 7-10,000 channels in all. If we took the example of a cable system with a 10m trace interval and minimum 3km offset (figure 4), a live survey patch of only 6 km x 6 km, with 5,000 live channels at our disposal, this would allow us to conduct a survey with rather good in-line sampling, but cross-line sampling of around 800m, which would be effectively make the operation look like a series of parallel 2D surveys rather than provide a useful 3D volume.

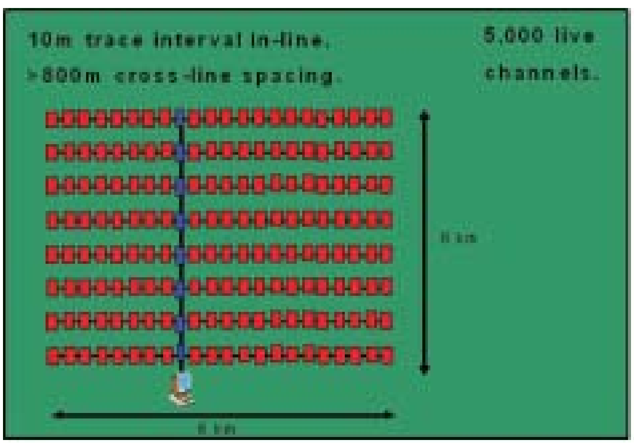

Fig 4 : The practical limit for cable-based telemetry systems? 5,000 live channels, 10m trace interval, >800m line spacing? The future for good data?

This rather graphically shows how the average cable-based system is unable to meet even minimal real spatial sampling requirements at an acceptable economic cost, and we believe this explains rather well why land seismic has not been on the increase. Digital cable technology has not kept up with the demands for improved data quality as reservoirs get harder to delineate. For these reasons, it seems that cable-based systems, especially those with some sort of built-in, hardwired and long take-out interval, will be part of almost no oil companies' geophysical future.

Next we looked at MEMS systems. It came as shock to us to find that few major oil companies now plan any major 3C acquisition. Vibtech started its life as a company involved in developing digital geophones, so to hear point-receiver 3C was no longer seen as a viable future has astounded us. Now that there is feedback about the use of such systems, we were particularly curious to compare original claims from various digital geophone manufacturers - which were sometimes contradictory - with how things have turned out. In many cases, original claims for MEMS seem over-optimistic, especially in terms of data quality, cost and operational efficiency.

There are of course success stories for 3C acquisition, but the feedback indicates that we have learned most from 3C acquisition in the last few years, is that things are even more complicated than we thought. But if the jury has been out for half a decade while 3C was given a chance, I think it has come back into the court room now and found against devoting much more effort into that type of acquisition except in certain niche applications. Other technologies have now also become available and some believe that it will be very difficult for 3C to compete for most applications, with the exception of surveys where surface energy is well behaved, very low levels of ambient and coherent noise, and near surface lithology relatively simple, where 3C may work as well as some of these new technologies.

As an example - a major Canadian oil company were vociferous proponents of 3C acquisition about five years ago and undertook a number of surveys. They have now reverted only to using crews using conventional geophones arrays. They give several reasons for this, including the high cost of acquiring either 3C or single sensor 1C data, saying that their experience is "it is expensive to acquire P-wave 3D data of equivalent or better quality than if conventional electro-dynamic geophones (in groups) were used."

They go on to say that, in collaboration with another very large oil company "we see no indications of improvement to conventional 3D data through the use of digital phones when programs have been re-shot using both sensor types – even when compared to strings of only 4 or 6 elements". They feel that the tests they conducted particularly re-enforce the importance of coupling and that, any transduction process is going to be improved by an increase in the number of properly coupled transducer points at each spatial sample, to enhance signal by summing outputs from several sensors.

One explanation of the lack of performance and take-up of digital phones is that we now think that some marketers of the products have tended to look at the wrong issues. Under some, but not all circumstances, they have good response compared to a single coil geophone, but the real comparisons should be against an array of coil geophones (figure 5) and it is surprising how little there is in the literature in reference to this.

Geophone Array	Single MEMS 3C – 1C
Ambient noise attenuation, proportional to sq.root of no of geophones	No inherent ambient noise attenuation
Statistical averaging of receiver coupling and geophone variance	Averaging must be done in computer centre
Suppression of high-k noise versus low-k signal (up to 24 dB)	No inherent suppression of high-k noise
Spatial anti-alias filter when laid out correctly.	No inherent filtering
Low power – easy battery management	Possible significant battery management problems
Improved useable dynamic range	Limited useful dynamic range
Available from many sources	Limited range of suppliers
No specialist handling	Requires specialist handling
"Arrays of geophones are here to stay"	Niche applications?

Fig. 5 : Comparison between geophone array and point receiver

Next the survey talked systems able economically to offer increased spatial sampling. There was no doubt that such systems would, once accepted, offer a new lease of life to land seismic. If we compare a MEMS 3C system with 3C stations laid down on X locations, against a system offering Vp-wave acquisition with traces put down on 3X locations - in other words systems using the same number of channels, then we saw almost no one wishing to use the 3C system assuming that such systems are the same cost to buy and operate. Ever-increasing use of our own system - the Infinite Telemetry System, shows that this requirement can be achieved on many crews.

On our own figures, the higher the channel density becomes, the cheaper it gets to work with, and in some surveys, we could show the use of ten times as many channels used for no additional operational cost. But where the survey did not show agreement was in the best way to use many more channels. Whether we consider crews able to offer 3X or 10X as many channels for the same operational cost, some want to use them for increased cross-line sampling, others for increased in-line, some want far larger live spreads to allow for full offset multi-azimuth surveys.

In summary for this section, I would simply like to quote a few companies - "I am not looking for a slightly cheaper 4,000 channel crew, am looking for a cost effective 14,000 channel crew". "Give me a value for money 20,000 channel operation, and we'll find lots of things to do with it".

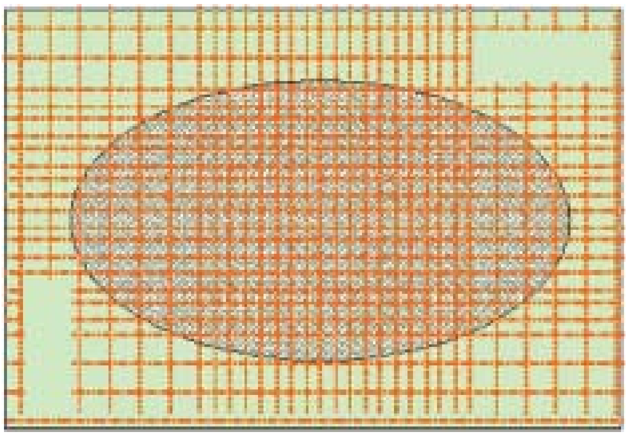

Fig 6 : Future systems must be able to offer increased spatial sampling, variable spatial sampling, so digital must be cable-free and still use geophone arrays.

We also identified the need, not just to have a digital cable-free ability to significantly increase spatial sampling at low cost, but also for the ultimate in crew flexibility - a system able to offer variable spatial sampling. In other words, one which could just as easily be used for 5 m sampling on part of the operation, 15 m on another, 25 m or more elsewhere. This would enable the same crew to do almost every type of survey with true minimal cost, it would also enable it to deal with obstacles and gradients in a way which cable systems just seem to find a bit difficult. Once again, our own system was one which could meet this requirement.

A final personal thought for this section - after 30 years of working with different land seismic systems, the results of the survey came as a surprise even to me. It has become apparent the seismic systems of the future, and some that exist already, do not fit into one or other of the traditional descriptions of RF or cable systems, and it is a mistake to continue to think in this way. In the case of our hybrid system, we can operate in both these areas and my advice is for users to stop thinking in these binary terms.

Conclusions

Finally, seeing the results of this survey and trying to understand it, should make us all think of our responsibilities to those who rely on us to find more oil safely, economically and with respect for the environment, so that we can all maintain and improve our standard of living, But the most interesting comment made during the survey was not geophysical - it was said to me that this biggest problem affecting the land seismic industry is not a technical one or an economic one, it is one of conservatism.

New technologies and techniques are already available which will offer better data quality at lower cost, but just like 25 years ago when we switched from analog cable transmission to digital telemetry, conservatism will ensure that only the brave adopt the new technologies quickly and they will be the first to benefit. Perhaps 25 years ago, this was not so much of a problem, but given the demands of the world, and in particular of India and China, to find and produce more oil very quickly, perhaps conservatism is a luxury we can no longer enjoy if we truly want to mitigate exploration risk.

Acknowledgments

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