B002

Operational Implementation of Full Azimuth, High Density land Acquisition – 3D Irharen (Algeria)

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SUMMARY

Using a square spread of dense receiver stations (25 m), a full azimuth dense 3D survey (730 km² full fold 225) was recorded in 2005-06 over the Irharen gas discovery in Algeria. This land acquisition is representative of the coming trends aimed at improving reservoir illumination and anisotropy detection. If the basic square spread (7,200 channels) was defined from geophysical considerations, its practical implementation (a super-spread of 11,880 channels) resulted from a compromise between the daily source production and the receiver stations available.

A range of VibroSeis methodologies was implemented to increase productivity: three sets of 3 vibrators were used in flip-flop mode to keep the recording as continuous a possible; they were functioning in source driven mode; on the recorder side, the super-spread avoided delays for line forming and prevented vibrators from changing of shot line too often.

The huge quantity of data and quality controls produced every day by the crew led client representatives to use a Geographical Information System (GIS) to compile and analyze all of them. This approach enabled all kinds of immediate control over the different steps of the survey. It also helped to highlight geographic and temporal trends.

Introduction

For long time 3D land acquisition has been limited by the number of channels a recording system was able to manage simultaneously. As a consequence, dense spatial sampling and wide azimuthal acquisition were not available as an option to improve seismic imaging and reservoir characterization. With the latest telemetry systems, transmission rates have been increased up to the point that a spread may encompass several tens of lines as well as several thousands of channels, and a central unit is now able to record in real time a dense square grid of active stations.

The 913 km² single fold survey over the Irharen gas field, in the Timimoun basin, Algeria, perfectly illustrates the operational implementation of such ideal 3D geometry. The acquisition was performed by ENAGEO on behalf of Total E&P Algeria and partners Sonatrach and Cepsa. The contractor faced many challenges to keep high source productivity and to record in real time a large amount of stations.

This 3D seismic was aimed at describing porosity variations, within the lower Devonian clastic reservoir (3,000 m maximum depth), and at allowing the characterization of fractures, using anisotropy versus azimuth. This explains the requirement of full azimuth sampling. The processing started, early 2006, over a priority zone of 400 km² that already represents the enormous amount of 600 million traces. Pre-stack time migration was completed before starting the new appraisal well, late 2006.

Survey design: a wide azimuth geometry with a dense and symmetric sampling

A correct analysis of azimuthal anisotropy requires a square 3D acquisition geometry presenting an isotropic distribution of offsets versus azimuth (Yuh et al. 2005). Definition of three main parameters allowed the optimization of the final spread template, taking into account technical limitations and economical considerations:

1. 3000 m far offset, to provide full information at target depth for each azimuth;
2. 200 m x 200 m nominal box size. This box is the area limited by two adjacent receiver lines and two adjacent shot lines. It was chosen as the best geometry to deal with near offset requirements (picking for refraction static modeling & calculation, and shallow layer imaging). Points 1 & 2 resulted in a square spread made of 30 active receiver lines (Figure 1);
3. 25 m trace and shot intervals. This rather dense spatial sampling was selected after a decimation test performed on a 2D line during the feasibility study. This test showed that a 50 m sampling was enough to get an acceptable structural image of this gently dipping area. However, 25 m spacing would provide a cleaner impedance section and higher confidence in seismic attribute interpretation. The resulting bin size was 12.5 m x 12.5 m, corresponding to a trace density of 1,440,000 traces /km², equivalent to the highest density used in some Middle East 3D surveys.

Practical implementation: the super-spread

The basic spread of 6 km x 6 km = 36 km², as defined previously, must be shifted both in the inline & crossline directions to cover the whole survey area (913 km²). Each shift requires laying new stations and defining a new spread that slow productivity. To avoid such repeated line forming, a new capability of Sercel 408UL recording system, called “super-spread”, was used. A super-spread encompasses several successive elementary spreads. All channels of a super-spread transit to the central unit. Sorting is done before recording on tape to keep only the traces of the basic spread, as defined by the SPS files.

For the Irharen survey, the super-spread was designed as to make vibrating possible during daylight without having to layout new stations. If we consider the basic spread of 7,200 channels, one source (a set of three vibrators) is able to perform only 8 shots crossline, before

new receivers must be activated. Since 14,000 stations were required by contract, three more lines were laid out and activated in advance. This permitted the source to shoot 32 vibrating points in a raw (a salvo). The additional stations available were used to extend the length of the receiver lines. Each time 8 additional channels (i.e. 200 m per line) were added to all receiver lines, this made it possible for the source to move on to the next shot line to perform another salvo and so on. In its final configuration, the super-spread was made of 33 lines of 360 receivers (11,880 channels) resulting in the possibility to shoot 1,440 VPs during daylight (10-11 h) without shifting the spread.
On a daily basis, the super-spread itself was translated in the shot line direction to generate a corridor of acquisition (zipper) which length is of one dimension of the survey (Figure 1). Then, three zippers were juxtaposed up to cover the whole survey area. To keep the full fold inline, the successive zippers were superimposed on a width corresponding to half the line length (3,000 m). This can be done either by repeating shots (15 lines) in an area outside the active spread or by replanting receivers (120 stations) outside the grid of shot lines. The first solution was selected, corresponding to a duplication of 32% of the vibrating points.

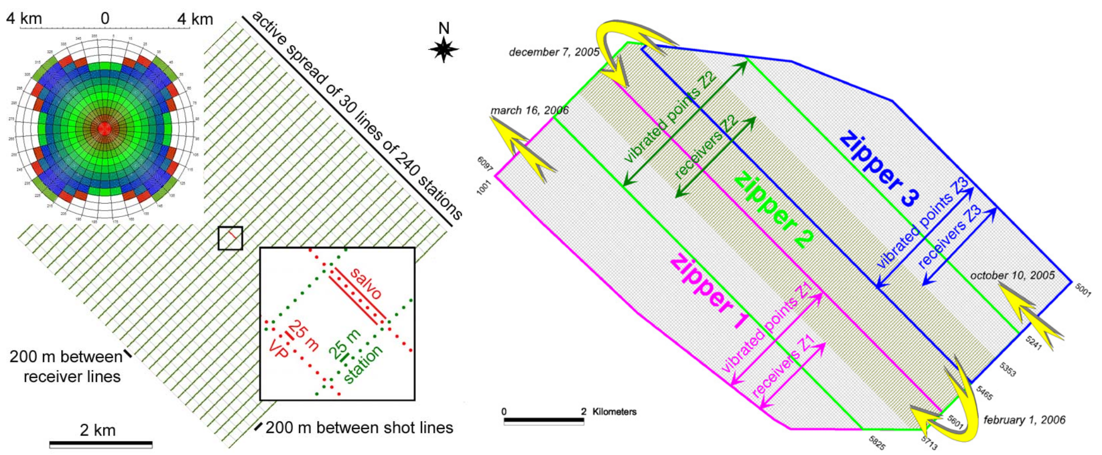

Figure 1: To the left, the basic 7,200 channel spread together with a rose diagram of the corresponding ray paths. To the right, the three zippers used to cover the 913 km² full survey area.

Productivity of the source: flip-flop shooting

Turnaround time is a crucial parameter for both client and contractor. To get it reduced, more and more seismic crews work 24h a day when HSE conditions allow. In Algeria, acquisition was only authorized during daylight, and the survey was to be performed during the winter seasons. To be able to complete this acquisition in five months (152 production days), advanced VibroSeis methodologies were implemented.
For this survey, three sets of 3 vibrators managed in flip-flop mode were necessary to keep continuous recording: when sweep and listening of one set of vibrator was completed, another set had already moved up and it was ready to vibrate. During the acquisition, the cycle time between two successive sweeps improved continuously. From 18 s at the start, it soon became 13 s by fine tuning different parameters (increase of the super-spread, repetition of time break (T0) emission, using two VHF frequencies to minimize interferences…). Taking into account sweep time (8 s) and listening time (4 s), the dead time with respect to a continuous recording was reduced down to 1 s. Overlapping slip-sweeps were tested at the end of the survey, but they did not improve significantly source productivity.

The three sets of vibrators were moving in parallel, each one on a shot line 200 m apart. At the end of a salvo, the vibrators had to turn towards a new shot line that was 600 m apart. Since this 600 m move-up may take few minutes, this reinforced the interest of having long salvos, thanks to the super-spread and the three groups of vibrators.
The total of 268,479 VP's shot during the 152 days of effective production corresponds to an impressive average production of 1,766 VP's a day, with a peak at 2,400 VP's. That sets a new record for the average hourly production (176 VP/h) in flip-flop mode.

Real-time quality control: a visual combination of GIS and seismic attributes

The huge quantity of data and quality controls produced every day by the crew led client representatives to use a Geographical Information System (GIS) to compile and analyze all of them. This approach enabled all kinds of immediate control over the different steps of the survey. It also helped to highlight geographic and temporal trends. Positioning data, vibrators performance and seismic attributes were continuously added to the GIS project.
Diverse positioning files were generated at the successive stages of the survey: Real Time Kinematics stakes set by the surveyors, compensation schemes for detour, real-time vibrator coordinates by differential GPS and final shot coordinates after control. These files, which were processed and gathered every day in the GIS project, not only allowed a rapid control of the distances between the real vibrators positions and the planned ones, but also a fine analysis of the accuracy of the vibrators real-time positioning.
After each sweep and for each vibrator, the conformity of the emitted signal with respect to the pilot (phase, peak force & distortion) was sent via radio to the recorder for identification of anomalous trends that might be related to the ground characteristics and/or to mechanical problems requiring preventive maintenance. These status files were also gathered to monitor long-term evolutions of each vibrator performance. Either individual sweeps attributes were mapped, or the average of the different vibrators' attributes for the shot point. The first way made easy to pinpoint anomalies from one of the vibrators. The second enlightened variations that might relate to changes in terrain type and ultimately could help in the correction of near surface effects.
The survey area is made of a rocky plateau to the NW and of a depression to the SE, covered by fine sand and gypsum. In between, there is a continuous cliff which elevation in-creased northward (up to 25 m; Figure 2). Two of the most interesting attributes, directly related to the mechanical characteristics of the ground (Ground stiffness Gs & Ground viscosity Gv), are automatically defined by the vibrator electronics to compensate from the ground effect on the force. The ratio Gs/Gv had already been used as a continuous dataset to extrapolate the near surface velocities as defined by the up-holes (Al-Ali et al. 2003). Beyond the obvious relationship of Gs & Gv with the topography and with the near surface heterogeneities (Figure 2), it was proposed, for processing this survey, to use this ratio to drive surface consistent amplitude corrections (vibrator energy is strongly attenuated at the locations where gypsum outcrops). In practice, this deterministic approach did not provide as good result as a statistical one, probably due to the limited representativeness of the average of Gs & Gv values.
Shot points were not only displayed for visual control in the recording truck. Using Sercel SQCPro module, seismic attributes were computed in real time. After F/K filtering, RMS values provide an estimate of ambient noise, organized noise and signal, for every record. As for the vibrator parameters, a mapping of these attributes was performed on the GIS database. Another interesting approach was the combined use of the GIS database and of a SEGY viewer to display the most representative shot points just by clicking on a map. This provided a direct visual analysis of the relationship between terrain type, seismic data and any given attribute. It also avoided the usual print of each shot point that would have required a huge amount of paper.

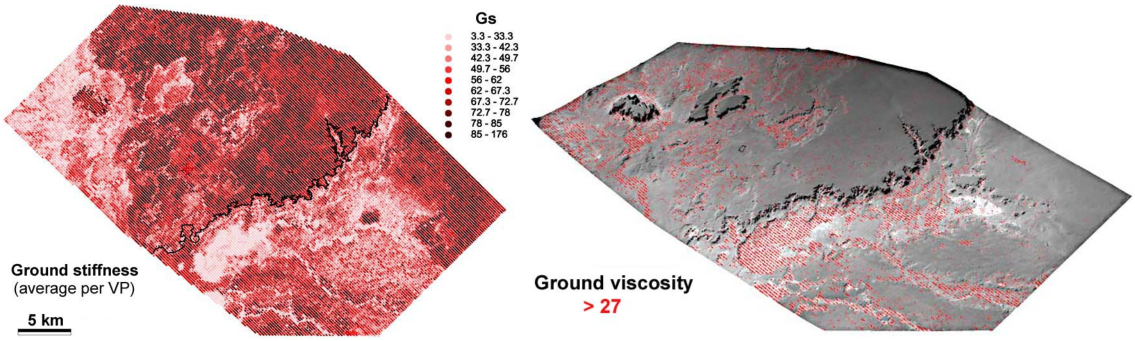

Figure 2: To the left, the map of the stiffness Gs is clearly correlated with the topography. To the right, a 3D view of the elevation (from SPS) is combined with a satellite photo and the distribution of the viscosity values (Gv > 27) to highlight near surface heterogeneities.

Conclusion

Such a seismic project shows that acquiring a large full azimuth high density 3D is possible using the latest recording systems, like the Sercel 408UL, with a productivity and a quality that met all survey requirements. The remarkable production (1,766 Vibrating Points /day) maintained by ENAGEO over 152 days resulted from a fine tuning of the crew performed by experienced people, both on the contractor and on the operator side. Among other parameters, it was the result of an appropriate equilibrium between the source and the receiver effort. This survey made clear that when both spatial sampling are equivalent, any increase on the source side (use of 3 vibrators sets in flip-flop mode) must be compensated by a significant increase on the receivers side (+65% more stations in the super-spread). The management of this kind of survey with high productivity and large data volume, demonstrates the interest of setting-up a suite of automated daily quality controls. The efficiency of this suite has been greatly optimized through a GIS database organization of all positioning, seismic and attributes files, generated by the land crew.

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