Introduction

In petroleum exploration and field development, the value of information is a key aspect. The seismic industry trend is to increase the amount of acquired data with higher fold, wider azimuth and broader sweep improving data signal to noise ratio (S/N) and resolution. The question is how the acquisition design impacts structural, AVO and AVAz seismic reservoir characterizations? This paper illustrates the comparison of 4 seismic surveys over the same area, the Jebel Grouz South Tunisian field, based on reservoir characterization objectives.

Datasets design and specification

Four acquisitions acquired in 2014 by CGG, are compared. The conventional (CONV) acquisition involves four vibrators per source location, 12 geophones per receiver location with a sweep length of 36s over [3-72] Hz bandwidth, see *Figure 1a*. This heavy field layout is compared to lighter field layouts: a Cross Spread survey (V1-XS), a NoDal survey (V1-ND) and a Carpet shooting survey (V1-CP), see *Figure 1 (b)*, *(c)* and *(d)*. These 3 latest acquisitions involve only a single vibrator per source location, 6 geophones per receiver location with a sweep length of 20s over the [2-100Hz] bandwidth. The Source/Receiver Line Intervals (SLI/RLI) as well as the Source/Receiver Increment along those lines (SI/RI) are described in *Figure 1*.

The important point to highlight here is the trace density (TD): V1-XS, V1-ND and V1-CP acquisition trace density are 10, 10 and 50 times higher when compared with the CONV acquisition. Also note that although the V1-XS and the V1-ND designs have the same trace density, the proportion of sources and receivers is completely different.

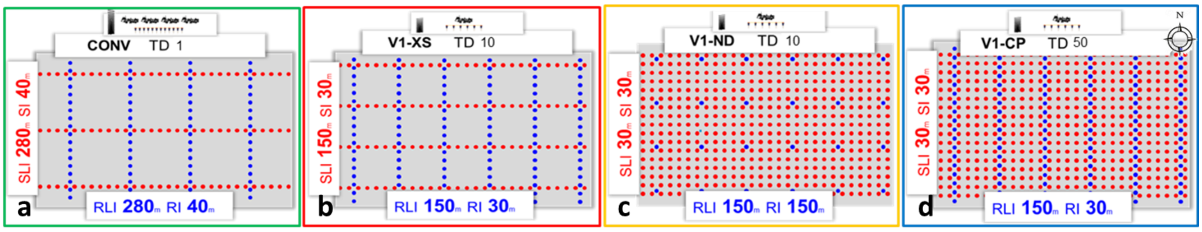

Figure 1 *Acquisition geometries: conventional (a), cross-spread (b), nodal (c) and carpet shooting (d). Source/Receiver Line Intervals (SLI/RLI) and Source/Receiver Increment (SI/RI).*

Equivalent processing sequences were applied on each seismic. Pradalié et al. (2016) demonstrated on the 4 same datasets that seismic acquisition value is primary driven by the recorded trace density and not the source strength. They proved that the higher the trace density (TD), the higher the signal to noise ratio.

Methodology

In the continuation of Pradalié et al. (2016) study, a qualitative and semi-quantitative interpretation analysis was carried out to assess the seismic data quality regarding the structure, the lithology/fluid classification prediction, and the azimuthal anisotropy. Several seismic reservoir attributes and QC were computed to compare the 4 acquisitions in their capacity to characterise reservoir properties. It is worth noticing that these attributes, computed first on full stack, then partial angle stacks and finally azimuthal partial angle stacks, have an increasing sensitivity to residual 'noise' content in the data set, as the less data stacked, the lower the signal to noise ratio. Hence, they can be used as a gradual measure of the acquisition's ability to assess seismic reservoir characterization quality. Besides, as there is no log data available the analysis only relies on seismic data, the comparison is relative between acquisitions. The denser acquisition, V1-CP, which by assumption gives the more reliable results, is used as the reference.

Structural seismic reservoir characterization comparison

The structural seismic reservoir characterization comparison is conducted on full stacks. *Figure 2* shows a full stack section per acquisition geometry. To the naked eyes, the CONV full stack (a) appears clearly noisier: the seismic events are less continuous than the ones measured from the 3 single vibrator acquisitions. However, the added value of V1-CP (d) trace density with respect to V1-XS (b) and V1-ND (c) acquisitions is not evident on these sections. To quantify the data spectral analysis differences, maps of energy and dominant frequency were computed on a 300 ms window around target level. Their correlations is about 90 % between V1-XS, V1-ND and V1-CP acquisitions and about 10 % lower between CONV and V1-CP acquisitions.

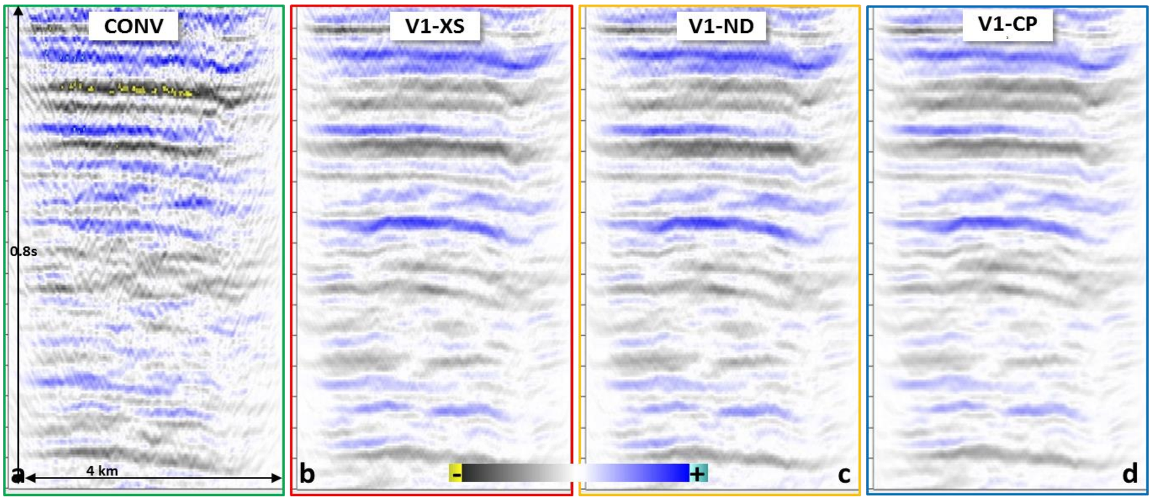

Figure 2 *Full stack section: conventional (a), cross-spread (b), nodal (c), carpet-shooting (d).*

To characterize and compare the data quality in terms of structure, let's look at acoustic inversion results and more specifically, at the layer's thickness. Four stratigraphic acoustic inversions were conducted (one per dataset) with the same initial model and the same inversion parameters as described by Coulon et al., 2006. Statistical wavelets were derived from each frequency spectrum for the inversion process. Both P impedance and TWT (directly linked to the layer's thickness) are inverted. Results reveal the higher the trace density the more the inversion output layer's thickness spatially organizes itself, see *Figure 3*. The output CONV layer's thickness (a) is disrupted; whereas the V1-XS (b) and V1-ND (c) layer's thickness seem organized. The V1-CP layer's thickness (d) appears even more coherent: some small features are only visible on this denser acquisition as illustrated with the black arrow in *Figure 3 (d)*. Therefore the "residual noise" left in the seismic data leads to a significant jittering on the stratigraphic output model, hence on the structure, which could bias the impedance and the porosity estimations.

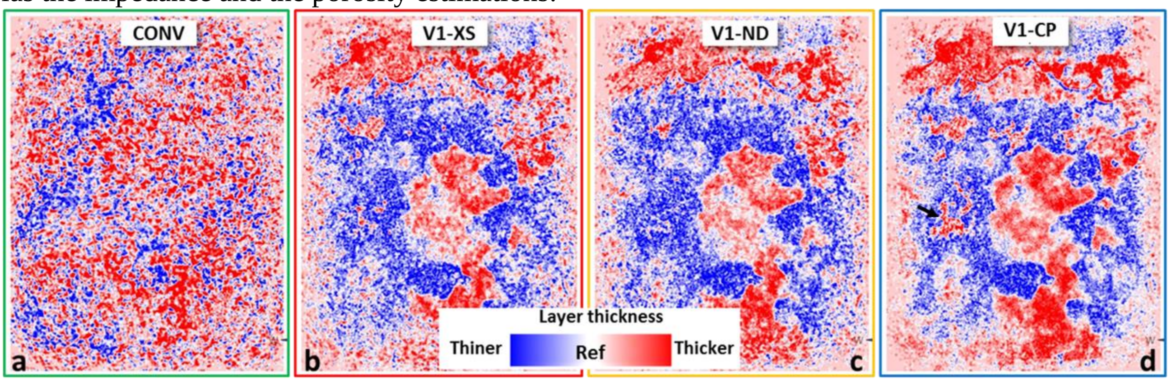

Figure 3 *Relative layer's thickness: respectively increase and decrease of layer's thickness compared to the initial model in red and blue. Layer located around 1500 ms. The higher trace density, the more the layer's thickness is spatially coherent.*

AVO/AVA seismic reservoir characterization comparison

To go further in the survey design comparison, an amplitude versus angle (AVA) analysis was conducted. The same partial angle stacks were defined for all datasets to compute intercept and gradient volumes. To highlight the quality of the AVA analysis, let’s look at the ability for an automatic horizon picker to track an event from a single seed on the gradient volume, see *Figure 4*. The illustrated event is located just above the target, no AVO anomaly is expected. An improved propagation of the picking when trace density increases, is observed. This QC illustrates the gradient spatial coherency and stability: the more stable the gradient event, the more reliable the AVA characterization. Consequently, trace density allows for a better data-driven lithologies and potentially fluids interpretation with less need of subjective, i.e. user dependent input.

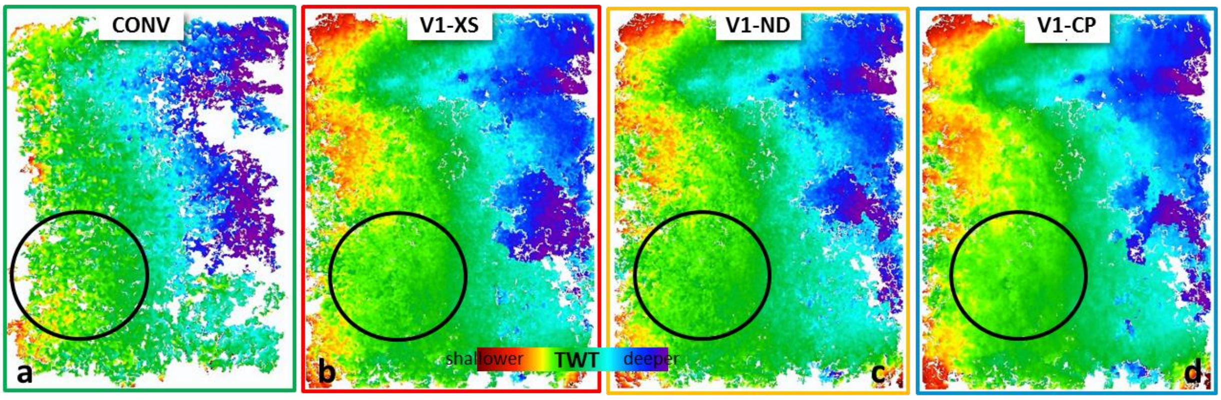

Figure 4 *Automatic event picked on the gradient volume per acquisition. The higher the trace density, the more stable the gradient.*

AVAz seismic reservoir characterization comparison

Let’s now consider a third way to quantify the geophysical value of an acquisition, the ability of seismic amplitudes to retrieve subsurface anisotropy. According to Ruger (2002) AVAz approximation, if an azimuthal anisotropy is caused by a set of fractures, the azimuthal near and far angle stack amplitude distributions are expected to be described by a constant and a sinusoid respectively. The ellipse fitting technique provides an indication of the dominant anisotropy orientation and its intensity.

A simple QC of this approach in order to assess the data quality for seismic anisotropy characterization consists in computing energy maps around a layer per azimuthal angle stack. On a small area, we compute the average of the azimuthal angle stack energy maps and materialized it as a dot in *Figure 5*. A distinct sinusoid joins V1-CP azimuthal far angle stack points, see *Figure 5 (a)*. The V1-XS and V1-ND acquisitions show poorer fit with the theoretical sinusoid response. The azimuthal variation from the CONV dataset is completely different than from the V1-CP used as the reference. Assuming that the denser acquisition leads the most reliable results, the seismic anisotropy characterization from the CONV acquisition would have been erroneous and would have been biased with the V1-XS and V1-ND acquisitions. The main anisotropy direction observed on the ellipse correlates with dip orientation pointed on the V1-CP horizon, see *Figure 5 (b)* and *(c)*.

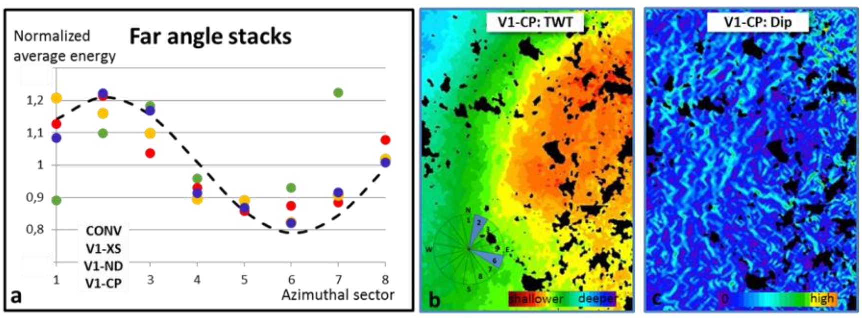

Figure 5 *Anisotropy comparison: (a) azimuthal far angle stack variations; (b) picked horizon on V1-CP acquisition and (c) V1-CP horizon dip. The main dip orientation correlates with the ellipse’s maximum.*

Figure 6 illustrates the results of the nonlinear Fourier Coefficient (FC) inversion on V1-XS and V1-CP datasets: in colour is the anisotropic gradient calculated from the magnitude of the 2nd and 4th FC and the small tiles indicate the main azimuthal anisotropic direction. The methodology used was described by B. Roure and J. Downton in 2012. All Mid (10-20°) and Far (20-30°) azimuthal angle stacks were used for the calculation. The main anisotropy direction is more consistent for theV1-CP acquisition than the V1-XS dataset.

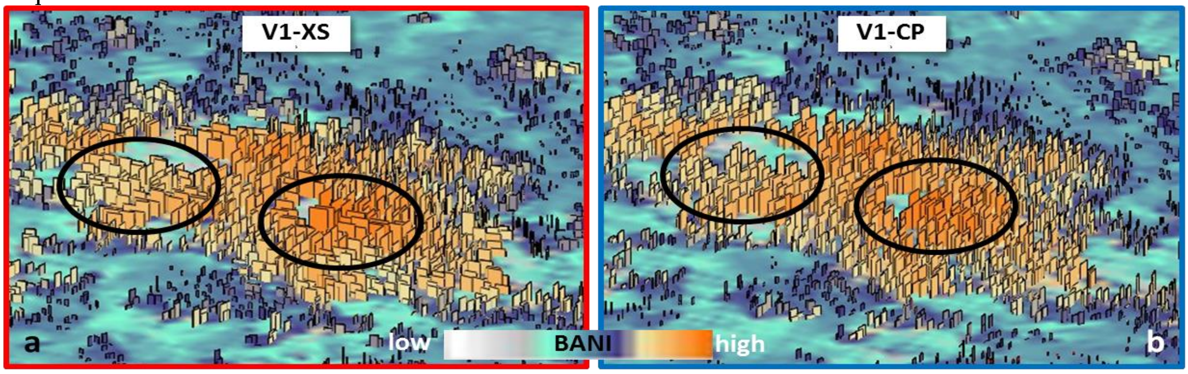

Figure 6 *A time slice showing Bani overlaid with anisotropy tiles (orientation and intensity) from the cross-spread (a) and carpet shooting (b) acquisitions. The denser acquisition shows more coherent anisotropic direction.*

Discussion and conclusions

In this fairly simple geological context, the CONV seismic is strongly impacted by the S/N ratio leading to a poorer interpretation with higher uncertainty. V1-XS and V1-ND acquisitions are giving good structural interpretation. AVO and conventional QI studies when compared to the V1-CP reference, V1-XS and V1-ND datasets are in appearance very close but more advance attributes show the uplift of carpet shooting acquisition.

Seismic survey design should be driven by the seismic reservoir characterization objectives. As illustrated by comparing 4 acquisition geometries over Jebel Grouz Tunisian field, a key parameter that drives the signal to noise ratio hence assess the data quality for seismic reservoir interpretation is the trace density and not the acquisition source strength. Besides V1-XS and V1-ND dataset comparison illustrates that source and receiver density individually are not the right metric to measure the acquisition value regarding seismic reservoir characterization objectives; it is the trace density.

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