3D-VSP from interpreter's perspective

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Abstract

The point of view of interpreters working with 3D-VSPs interpretation is seldom explored. We report here their experience during the interpretation of a marine and two land 3D-VSP projects.

Introduction

3D-VSP has clearly become a borehole seismic technique with important contributions to reservoir characterization activities. Much attention has been given to operational aspects, new equipments and processing techniques, but the opinion of their interpreters is usually only superficially explored. We discuss here the interprets point of view, covering their experience in the use of three different 3D-VSPs surveys, one in marine and two others on land areas. Basic aspects of survey planning, acquisition and processing are revisited, with focus on interpretation by the perspective of lessons learned, highlighting benefits and obstacles in the use of those 3Ds, with suggestion of alternatives to improve future 3D-VSP acquisitions.

Land surveys:

1-Canto do Amaro (October, 2004)

Acquisition & processing: This 3D-VSP used three simultaneous wells, each one with eight 3-C geophones, set in the range between 550-665 m (15 meters interval). Dynamite was the source used in 1852 shot points, spreading over an elliptical grid with 60 (lines) x 60 m (shot interval) in 6.5 Km2, as shown on figure 1. The illumination obtained at target level reached 1.5 km².

Processing took advantage of existing 3D surface seismic for preliminary statics and velocity model. The workflow included horizontal and vertical plane rotations, 3D statics and median filters for wavefield separation. The final velocity model was updated using a tomography approach and VTI anisotropy, and migrated using kirchoff algorithm. VSP presented frequency content much higher than observed on surface seismic (figure 1).

Interpreter's perspective:

- Although the area presents many challenges, given its structural complexity and poor response at target levels, one can say that the 3D-VSP, was not such an important tool for solving problems and help in the interpretation, despite obtained data showed higher frequency content and better definition of high angle faults (figure 2);

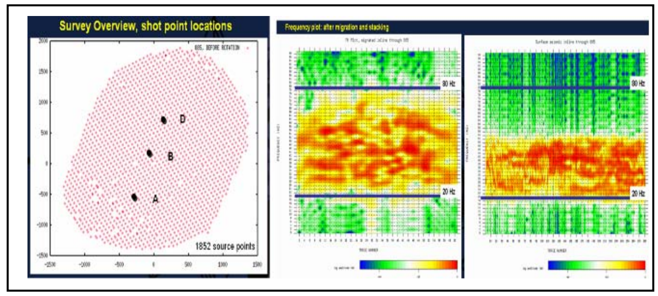


Figure 1. Three simultaneous receiver wells used an elliptical shooting grid (left). The frequencies recovered by 3D-VSP (middle) were much higher than those observed on surface seismic (right).

- The field is extremely complex and many questions still remain unanswered, especially with respect to the basement, which shows a more complex behaviour than other interfaces, even in 3D-VSP;

- The area illuminated by the 3D-VSP has slightly exceeded 500m radius, what didn't contribute to improve the regional understanding of the area;

- Additionally, seismic surface suggested the presence of reflectors inside the basement, which was confirmed by 3D-VSP. These events complicate further the mapping of the basement interval;

- 3D-VSP, in conjunction with seismic surface, provided subsidies for two new wells in the area and advised against a third one, but only the first was successful. The second did not reach the basement and produced a drilling error of 80 m beyond the target.

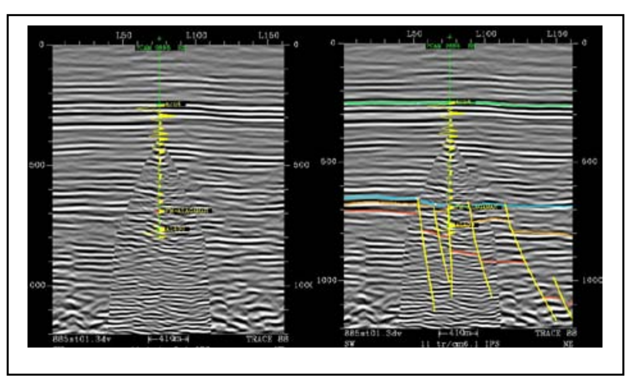
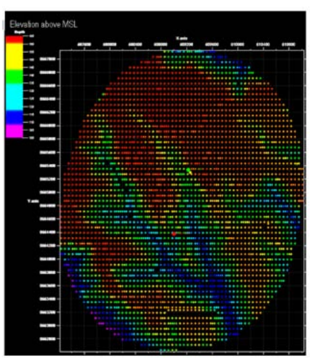


Figure 2 - The 3D-VSP superimposed over surface seismic shows high angle faults, but like surface seismic had difficult to individualize basement reflection

2-Riacho da Barra (December, 2006)

Acquisition & processing: This second acquisition used two receiver wells, instrumented with ten 3-C geophones on each, in 800-935 m interval (15 meters of geophone spacing). Dynamite was again the source used for 2881 shot points, in an elliptical grid with 60 (lines) x 80 m (shot interval) and 13.0 Km2, as shown on figure 3. The subsurface imaged area was close to 5.0 km² at deepest target level. Processing used all the information from surface seismic and a conventional workflow, through polarization, wavefield separation, statics application, tomography to surface velocity refinement and kirchoff migration. the results showed again, frequency content much higher than observed on surface seismic, and an impressive higher signal to noise ratio, making it possible to individualize reflections on intervals where surface seismic was quite “blind” (figure 4).



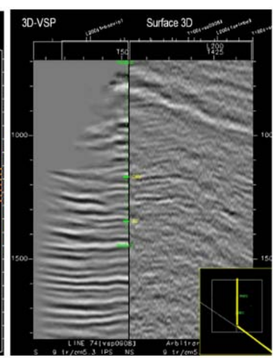


Figure 3. Shooting grid elevations.

Figure 4. 3D-VSP compared with surface seismic.

Interpreter's perspective:

- The 3D-VSP is much more rich in reflections on intervals where surface seismic has a very low signal/noise ratio. That may be related with an intensive absorption in overburden and surface intervals;

- The correlation between upper and deeper reservoirs shows very good match with structure maps based on wells, what made it easier to trust on 3D-VSP results;

- Amplitudes seemed over normalized, what made it difficult to differentiate seismic patterns or different targets based on just their amplitude response, probably due to side effects of filters used to wavefield separation;

- Near to external limits of 3D-VSP some dips behave different from what is observed on surface seismic, making it difficult to establish the limits of trustful area, outside the migration artifacts interval;

- Although the receivers string wasn't optimized for upper reservoir, the erosion controlling its truncation, was better revealed in 3D-VSP, but within a very limited area.

Marine survey: Marlim (May, 2005)

Acquisition & processing: This marine 3D-VSP was acquired to assist in the positioning of a new well with high geological risk, trying to verify the connectivity between the new area to be drilled and the main area of the field. Another objective was to assist in geological interpretation towards north area of the field for future drilling. Finally the 3D-VSP was complemented with some walkway lines using long offsets to obtain information for processing of streamer seismic being acquired, (anisotropy, Q factor, calibrate processes for multiple attenuation and calibration of amplitude and phase).This survey used, twelve 3-C receivers anchored between 1675 and 1810 m on a deviated well. A seismic shooter was used for 13271 shot points, spreading over a spiral pattern (figure 5)

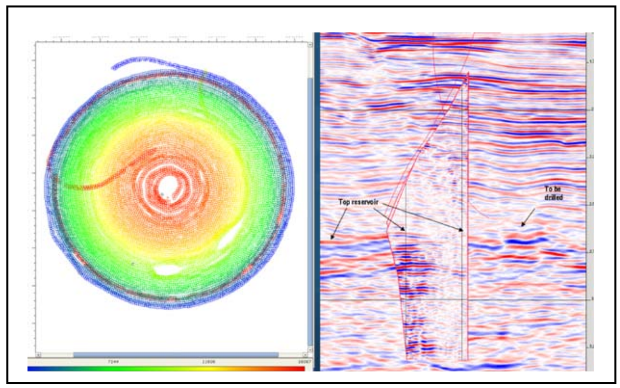


Figure 5. Shooting grid and zero offset VSP spliced on surface seismic

Interpreter's perspective: VSP-3D did not help in the placement of the new well for the following main reasons:

- As processing phase was longest than scheduled, the well drilling was concomitant with the arrival of processed data, without enough time to interpret an unconventional seismic;

-The new well proposed was drilled at the opposite direction of the cone data in relation to the receiver well position, and located at the edge of 3D-VSP data, what made it difficult the precision on steering well. That difficult was partially anticipated on survey modelling.

-Result from 3D-VSP didn't provide a trustful data to help on interpretation in the area of new well due to illumination difficulties.

-3D VSP helped to improve the geological interpretation in the area around the receiver well, collaborating in the drilling of another well nearby;

-Useful information was obtained that could assist with 3D surface data (anisotropy, Q factor, multiples attenuation, calibration of amplitude and phase);

-The converted P-S cube has not extended to the area of proposed well and wasn't used by interpreters;

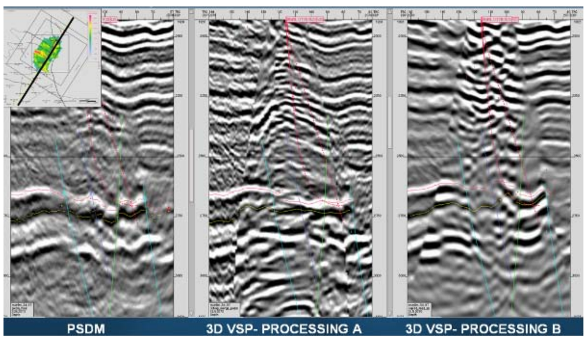


Figure 6. Notice the differences between 3D-VSP processing results obtained by two different companies

Conclusions

The following considerations may be addressed based on the point of view of interpreters of those three projects and our future strategy for next 3D-VSPs:

a) From the comparison of land and marine results, it is clear that the former produces better results when compared to surface seismic. One possible explanation is related with high absorptive near surface intervals, observed on land areas, which has stronger impact over seismic response compared with marine areas;

b) Processing workflows, different from surface seismic, can generate very different results (figure 6), what suggest the processing stage of 3D-VSP technique still in evolution;

c) The fact that 3D-VSPs are usually acquired on areas with previous surface seismic, makes it possible to conduct simultaneous processing to understand better the relations of both data, and reason for observed differences. That may help to improve the confidence on 3D-VSP results and calibrate surface seismic processing as well;

d) Although a small number of receivers are usually enough for imaging purposes, massive string of geophones may help to avoid the impact of some side effects related with wavefield separation and others processing phases. At the same time, a larger number of geophones may help to target on multiple objectives in a single acquisition;

e)The interpreter's expectation needs to be tuned with the possibilities of 3D-VSP technique. Participation on modelling phase may help us to anticipate the technique limitations before deciding for it;

f)The experience obtained on those projects will help to optimize our future 3D-VSP acquisition, especially on low seismic quality land fields, and marine sub-salt areas.

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