Statics and directional stacking of P-S data from N.E. Colombia

Saul E. Guevara, Ecopetrol-ICP (Colombia) - Peter W. Cary, Sensor Geophysical Ltd.

CSEG Geophysics 2002

Abstract

Processing steps for converted-wave data from an on-shore survey carried out in Northeast Colombia are presented. A data-driven method was applied to the critical steps of velocity analysis and statics correction in an iterative way. Common receiver stacks were used to correct receiver statics. One of the lines corresponds to the strike of the geologic formations and other one to the dip. A reasonably good image of the strike line was obtained, but the dip line results were less satisfactory. This difference appears to be related to the geological complexity of the area.

Introduction

It is well known that converted waves contribute information to hydrocarbon exploration. Also, the processing of converted-wave data can be difficult, especially for on-shore data. Two critical steps for this processing are statics correction and velocity analysis (Anno, 1986). Closely related to them is converted wave binning, which is affected by the asymmetry of the wave-path, which in turn depends on the velocity model. These difficulties are apparent in the case of land data in complex geological settings, as is somehow the case presented in this work.

These data correspond to a multicomponent seismic survey acquired in northeast Colombia, aimed at fracture detection. Three seismic lines of 7 km length were acquired. From previous conventional data and modeling, it was known that the geological target is at approximately 1500 ms for P-waves and at 2400 ms for converted waves. Figure 1 is a map of the line location.

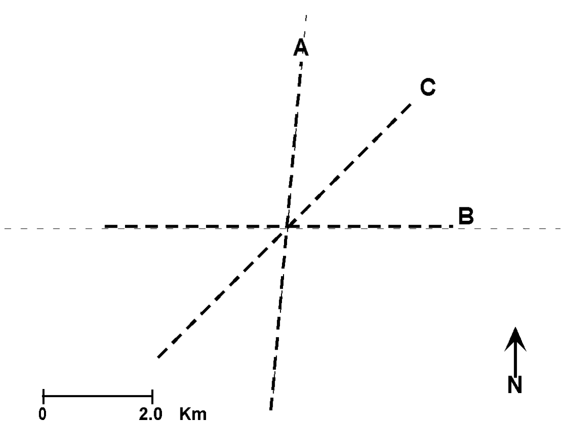

Figure 1: Map of the three multicomponent seismic lines. The strike line A is almost N-S and the dip line B is almost E-W.

The raw recorded data reveal some of the difficulties to overcome in processing. Figure 2(a) is a raw shot gather of the radial component. Notice the size of the noise cone, and the swinging character of the reflectors. It suggests receiver statics effects, coherent noise interference and dificulties to apply S-wave refraction statics. For comparison, Figure 2(b) shows a vertical component shot. Notice the much more continuous and regular reflections, the smaller noise cone and the clear first arrivals.

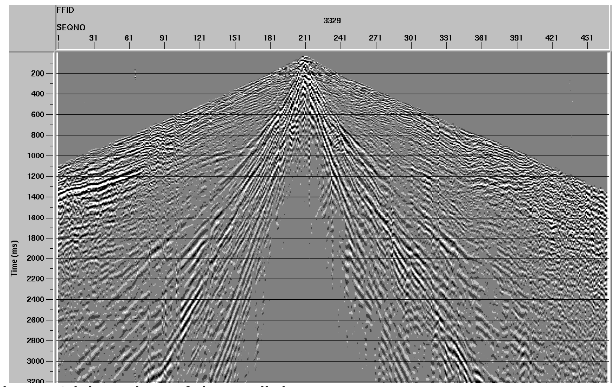

Figure 2(a) A shot of the radial component.

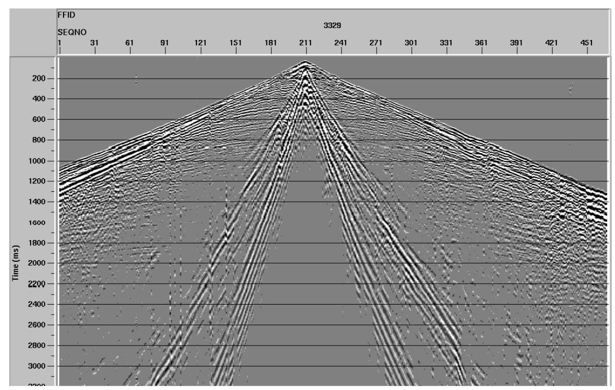

Figure 2(b), A shot of the vertical component.

Methodology

The first problem to overcome is in determining receiver statics for P-S wave. This statics are much larger and more variable than for P-wave and to solve it, the precise methods developed in conventional seismic appear useless.

To obtain converted–wave statics corrections, Cary and Eaton (1993) proposed a method based on the surface-consistency equation. A procedure based on a similar equation was applied in this case. The traveltime τ_{ij} corresponding to a trace with source i, receiver j and reflection point k is composed of four terms:

$$\tau_{ij} = S_i + R_j + G_k + M_k \, , \quad (1)$$

where S_i corresponds to source statics, R_j to receiver statics, G_k to geological structure and M_k to NMO correction. The source statics can be taken from the vertical component (or conventional) processing, and likewise from this processing it is possible to obtain initial guesses for the G_k and M_k terms, then R_j becomes the only unknown factor. Thus, from the application of this equation, it is possible to get a solution for R_j from common receiver stacks. After that, an improved velocity field can be estimated, which means a better M_k term. In this way, after a number of iterations it would be possible to get optimal receiver statics correction and velocity field.

Asymptotic binning with a constant Vp/Vs ratio, which assume a simple converted wave propagation model, was used in this statics stage. After obtaining the final receiver statics and velocity field solutions, new binning was defined using common conversion points and taking into account the effective V_P/V_S ratio (γ_{eff}) (Thomsen, 1999). Then CCP (Common Conversion Point) stack was applied.

Results

The results of this processing scheme are quite different for each one of the lines. The statics correction procedure is illustrated in Figures 3(a) and 3(b), corresponding to two iterations of common receiver stacks on the strike line (line A). A relatively strong energy reflector (arriving close to 1 s for zero offset) was used as a horizon guide for receiver statics. A first guess of the velocity field was based on a simplified version of the final velocity field of the vertical component processing, assuming a V_P/V_S ratio of 1.9. Picking a reflector from the P-wave section (Figure 4 (b)) allowed the calculation of the structural component. To diminish the ground-roll effect an f-k filter was applied. After a number of iterations a solution of statics was considered satisfactory.

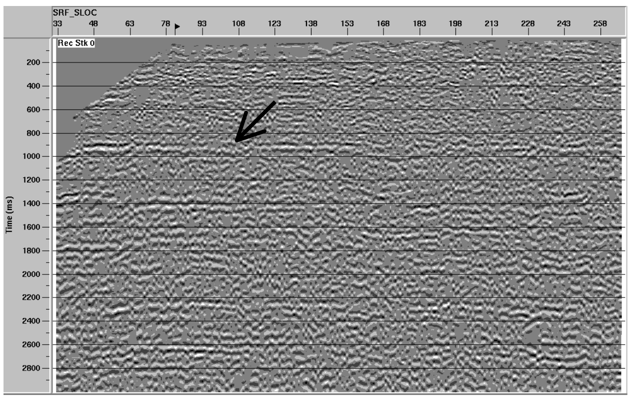

Figure 3(a)Common receiver stack before the first iteration. The arrow indicates the reflector (close to 1 s) used as a reference..

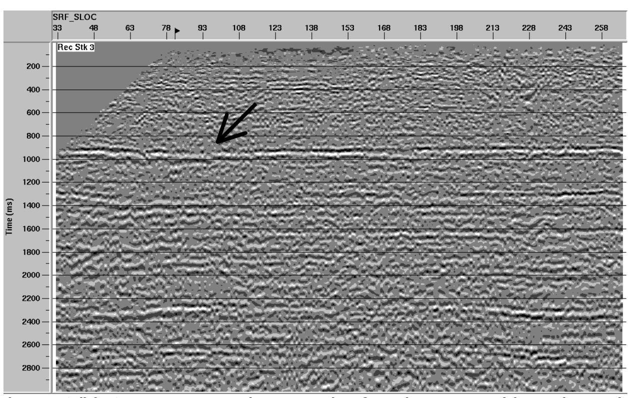

Figure 3(b) Common receiver stack after the second iteration. The arrow indicates the reflector used as a reference.

The resulting stack section is illustrated in Figure 4(a). This is a CCP stack after a γ_{eff} analysis. The P-wave stack (Figure 4(b)) supports the geological reliability of this result, since corresponding events can be identified in both.

On the other hand, application of this strategy to the other two lines produced different results. Figure 5 illustrates the final stack of line C after statics and filtering. Comparing with line A, the reflectors appear attenuated, revealing probably better stack in line A. Line B stack is even less clear. Velocities and stacking seems to depend on the sign of the offset, which Audebert et al (1999) analyze as an effect of the error in γ_{eff}. Both lines, especially line B, are more affected by dip, so equation (1) could be considered more adequate to plane layers.

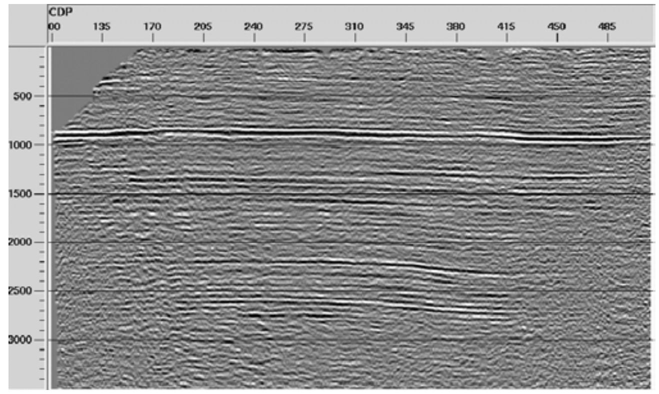

Figure 4(a): CCP stack section of the converted-wave (radial component) line A.

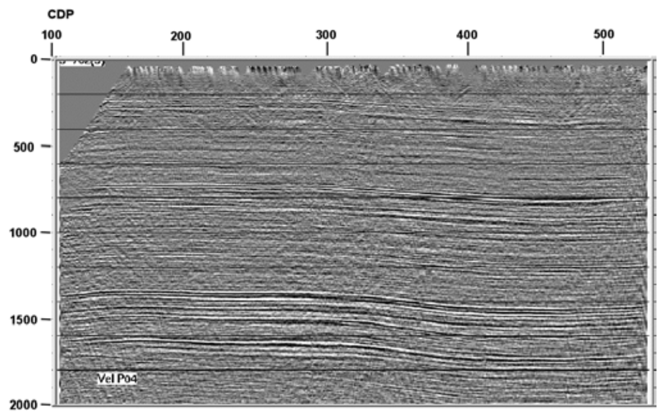

Figure 4(b): P-wave (Vertical component) stack of line A.

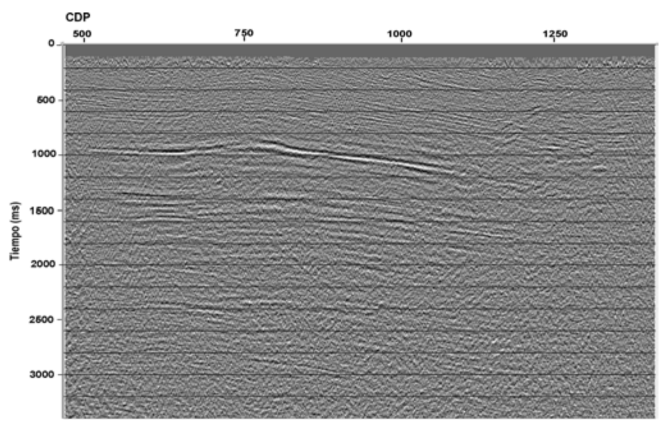

Figure 5: Stack of the diagonal line (line C). In this case the effect of dip is smaller than in line B.

Conclusions

Receiver statics correction is a critical problem in these data processing. Use of common receiver stacks is an effective approach to solve it in the case of the strike line (line A). However this solution is not as effective in the case of lines B and C, which are more affected by geological dip. On these dip lines, especially on line B, the velocity appears to depend on the sign of the offset. This statics solution depends on the velocity field and on binning, which apparently demand further analysis and supplementary methods in dip lines.

Acknowledgements

The authors thank Ecopetrol (Colombia) for authorizing the publication of this work. Suggestions by Robert Garotta, and the support of the geophysical processing lab at Ecopetrol-ICP contributed to the results.

References

Anno, P. D., 1986, Two critical aspects of shear-wave analysis: statics solutions and reflection correlations, *in* Shear-wave exploration, S.H. Danbom and S. N. Domenico eds., SEG Geophysical development series, Vol. 1.

Audebert, F. Granger, P. Y., Herrenschmidt, A, 1999, CCP-scan technique: true common conversion point sorting and converted wave velocity analysis solved by PP and PS pre-stack depth migration: Expanded Abstracts 69st SEG Ann. Mtg, 1186-1189.

Cary, P. W., and Eaton, D. W. S, 1993, A simple method for resolving large converted wave (P-SV) statics: Geophysics, **58**, 429-433.

Thomsen, L. , 1999, Converted-wave reflection seismology over inhomogeneous, anisotropic media: Geophysics, **64**, 678-690.