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Land 3C-2D Seismic Data Processing – Analysis of Crucial Issues

G. Zabik, M. W. Podolak*

Geofizyka Torun Sp. z o.o.

E-mail : Michal.Podolak@GTservices.pl

Summary

Review of seismic data processing issues specific to land C-wave 2D surveys provides practical hints and solutions to questions still faced by processors and interpreters dealing with the subject. Stress is on real data examples illustrating particular problems and their solutions. Samples of real 2D 3C datasets are used.

Introduction

The present state of 3-C-2D seismic data processing is outlined through the focus on essential and still controversial issues of that new technology. The review is limited to onshore applications, which, after successful implementation of marine version, recently undergone fast development. Converted wave seismic surveys offer economic link between elastic properties of reservoir and its seismic image. Assets and weaknesses are collated and analysed with illustrations from practical applications.

Review and analysis of the crucial elements of technology

From the very beginning of the seismic converted-wave technology, new elements are coming across. Special focus of this presentation is on land implementation.

Several years of experiments were limited to academic research because of relatively weak energy of shear waves coming through strongly attenuating LVL. Development of digital accelerometer made the turning point. The digital, multicomponent receiver is implying new standards from in-field QC, through processing to interpretation. Decisive points from recording seismic quality data have been moved far into processing domain. Sophisticated software tools enable getting useful information from data which were traditionally discarded in the field. Digitaly captured signal reveals features superior to features of the signal recorded with analog geophones. What is the most essential to processing domain: converted wavefield forces use of dedicated processing software.

Step-by-step analysis of the converted wave processing flowchart explains an impact of solutions adopted at particular processing stages, specific to C-wave seismic data, on final image.Generalized processing flowchart can be seen in Fig.1. Crucial issues are examined below

Surface wave noise attenuation

Intrinsic feature of digital accelerometer is to capture raw surface noise. Fig.2.

The amount of noise seen in Fig.2 can be mistaken for a weakness, but actually it can be reduced effectively with multicomponent adaptive filter working in time domain (Fig.3).

The adaptive filter we used, is a two-component implementation. One component, typically radial, provides a model of noise and is involved in adaptive process of subtracting from vertical component. During our own research work, it was discovered that combining two-pass application of that filter, with use of all the three components, gives the best result. The idea of such cascade filtering is skhetched in Fig.4.

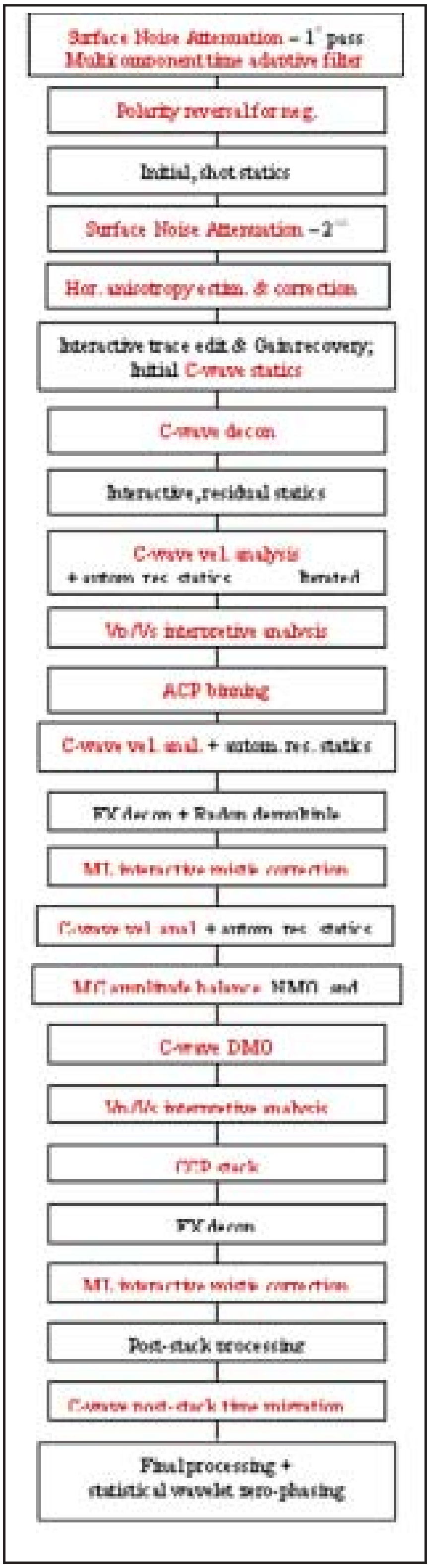
New axiom of seismic data analysis has become evident: with digital geophone, instead of in-field direct evaluation of recorded data, it must be done after at least preliminary processing with multicomponent adaptive filter. That software conserves signal: no multi-station operation bringing a smearing as with traditional, multitrace processes.

Horizontal anisotropy estimation and correction

2-D-C-wave surveys are not the best way to estimate horizontal anisotropy parameters. However, software based on Harrison [2] provides an approximate solution.

There are two parameters of horizontal anisotropy: orientation of the principal axis, and intensity, e.g. density

Fig.1: C-wave dedicated processing flowchart. Modules specific to C-wave processing are in red.



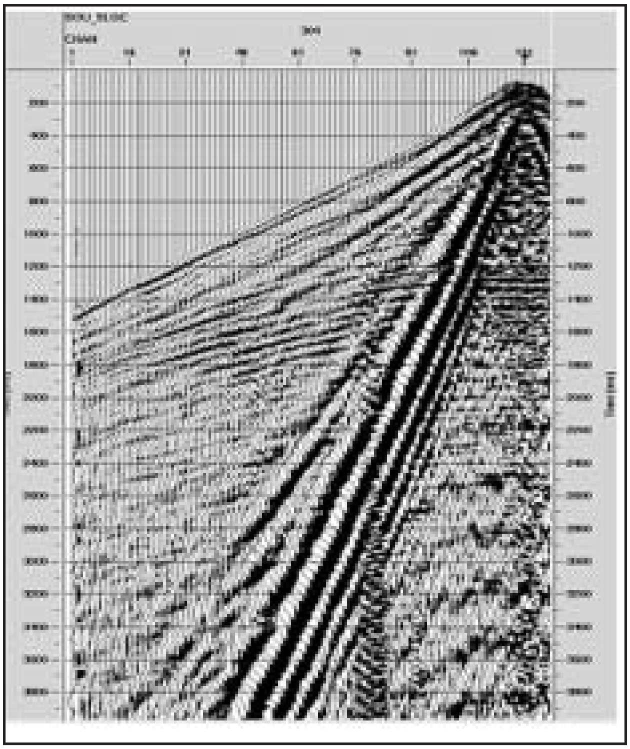


Fig.2: Raw shot gather recorded on vertical component with digital accelerometer.

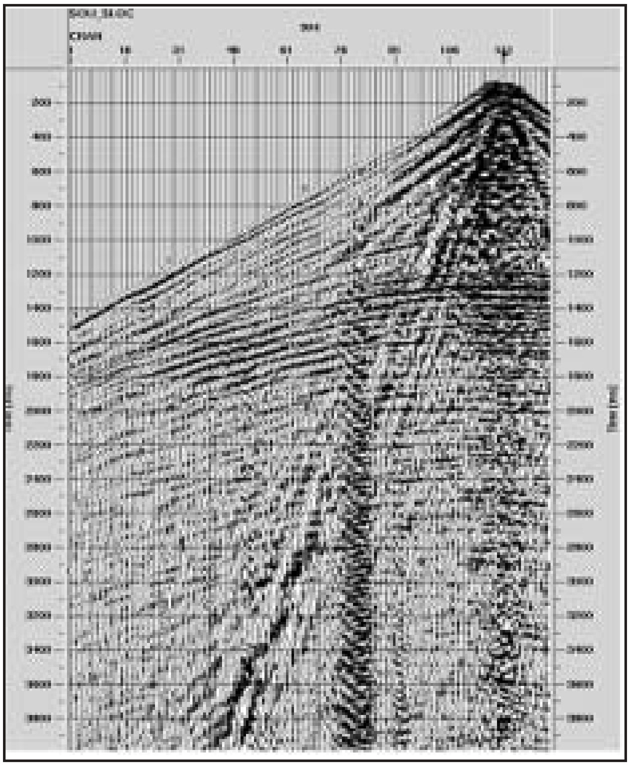


Fig.3: Shot gather from Fig.2 after being processed with multicomponent filter.

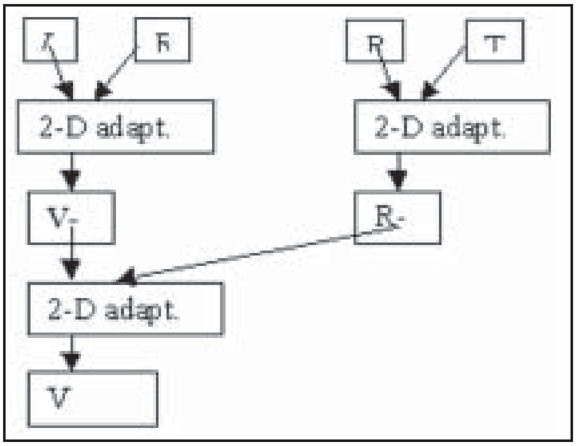


Fig.4: Idea of multicomponent application of the two-component adaptive filter.

of fracturing. They can be estimated from two recorded components regarded as components of a vector. True amplitude data on input render information in form displayed in Fig.5.

Experiments proved that in case of orientation angle less than 15°, possible rotation of components does not significantly changes images, at least in 2D case.

In the case of survey from south of Poland, estimated horizontal anisotropy gave consistent image, shown in Fig.6.

Shear-wave static corrections for receivers

There are two steps in C-wave statics: just a copy of P-wave statics for shot point and challenging estimation for receivers. Usually that estimation takes several iterations, and that is troublesome. Fortunately, the procedure is convergent, and QC tests, same as for P-waves, confirm the results are correct.

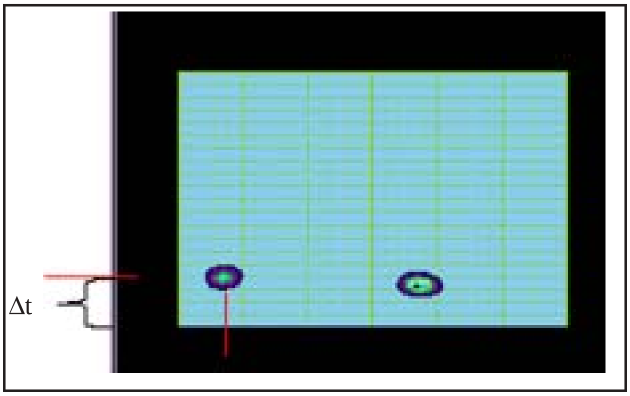


Fig.5: Sample of interactive analysis of the horizontal anisotropy.

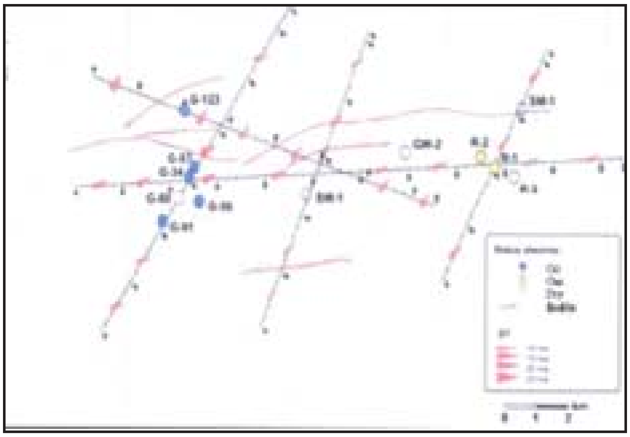


Fig.6: Orientation of the Sv axis (along red triangles) and density of cracks (base trianles) found from 2D-3C seismic survey. Note consistency of triangles' orientation with orientation of major faults in the area.

Typical C-wave statics estimation procedure is:

- copy of P-wave statics for SPs,
- estimate ã scaling factor for receivers,
- interactive correction of gross errors,
- automatic residual correction,
- iterations with upgrade of PS velocities.

Statics are surface-consistent, so operation is commutative with ACP binning.

Converted-wave deconvolution

That element of C-wave processing, similarily to statics, is split into two steps: for source and for receiver. Different shapes of P-wave and S-wave signals must be accounted for.

The involved steps are:

- computing of single-trace decon operator for P-wave shot gathers,
- averaging of operators within shots over receiver spread,
- application of estimated operators to C-wavefield,
- computing of single-trace decon operator for C-wave receiver gathers,
- averaging of operators within particular receiver gathers over traces from different shots,
- application of estimated operators to C-wavefield.

Usually decon parameters estimated from C-wave data are different from those from P-wave data. Both types of operators are applied to the C-wave data and tests decide about values of decon parameters.

CDP, ACP, and CCP binning

Three types of collecting C-wave traces into gathers, but no doubt CCP binng is the only best choice. Figures 7 to 9 illustrate considered binning types. Fig.10 shows Vp/Vs model used for CCP binning.

The trouble is that for CCP binning, a time and space variant Vp/Vs (called γ) model is necessary, and it is unknown before processing of C-wave data. As usually in seismic data processing, an iterative approach is employed: just at the beginning CDP stack is done, except for the situation when an estimation of γ value at the geologic target level is already known. In that case, one can start directly from ACP binning. After getting statics and stacking C-wave velocities, it's time to estimate ã distribution for CCP binning.

Two ways of estimating γ distribution have been tested:

- interactive picking from pre-stack data, similar to P-wave stacking velocity analysis, and
- post-stack estimation in dedicated interpretation software.

While the first choice seems to be more automatic, it is more sensitive to low S/N ratio and to static errors. Interpretive version proved to be more consistent and reliable, however slower at work.

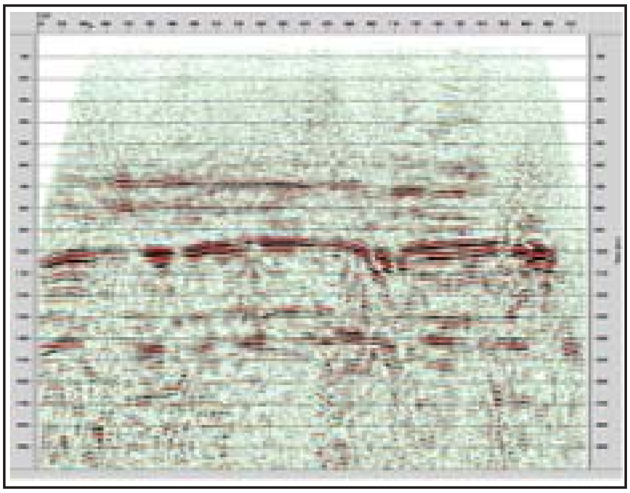


Fig.7. Stack of CDP-binned C-wave data.

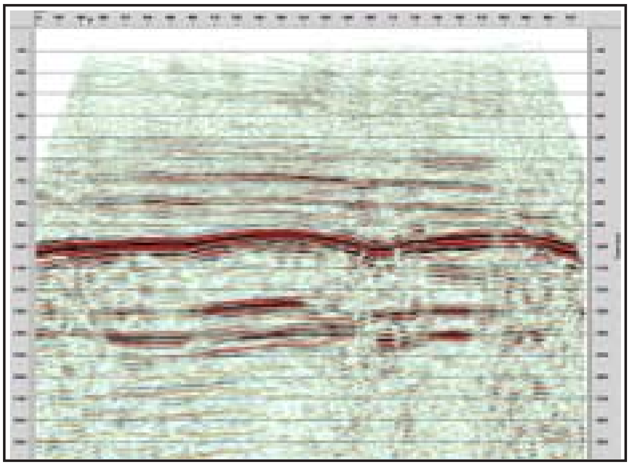


Fig.8. Stack of ACP-binned C-wave data.

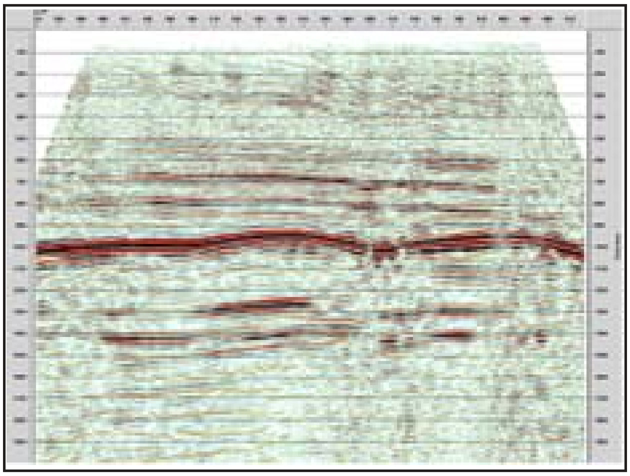


Fig.9. Stack of CCP-binned C-wave data.

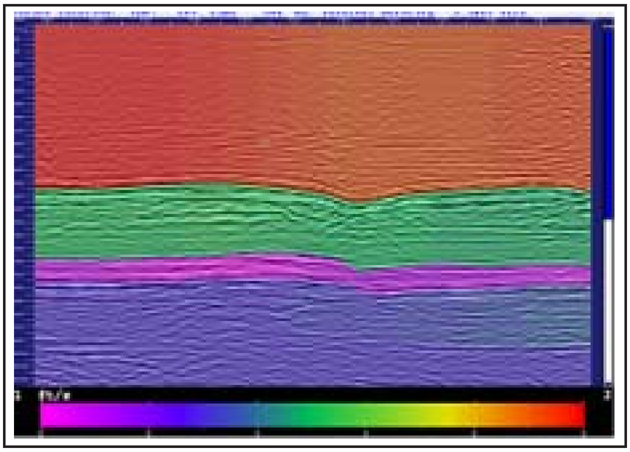


Fig.10. Vp/Vs model of C-wave data commented in Figures 7 to 9..

Clearly, consistency of the CDP stack is inferior to ACP and CCP stacks. ACP and CCP stacks seem to be comparable, but when investigating details, it can be discovered, that positions of particulat events, like faults or reflections' edges (discontinuities) have not the same position. Comparison to P-wave stack decides: the CCP stack (with post-stack estimated γ distribution) features correctly positioned events.

This is important conclusion, and remembers that position of point of conversion is sensitive point of the C-wave data processing.

Another thing worth to be mentioned is that, as in Fig.10, most of C-wave parameters are expressed in the same time scale: P-wave time scale.

C-wave velocity analysis

To get optimum stack of radial or transverse components of the C-wave data, employing hyperbolic velocity analysis is quite robust routine.

However, values of C-wave velocities are specific. Rough approximation is the following formula:

$$Vc = (Vp * Vs)^{1/2}$$

Validity of the formula can be checked when an extra information on Vs (pure shear wave velocity) is available, e.g. from well measurements. Once identification of C-waves is confirmed with the formula, it can be used to get approximate values of Vs, because Vp and Vc are known from respective velocity analysis for P-waves, and next, for C-waves:

$$Vs = Vc^2 / Vp.$$

Figures 11 and 12 show samples of Vp and Vc velocity analyses of data at the same position.

Conclusions

Multicomponent seismic technology became feasible onshore with development of digital, multicomponent receiver and suitable software.

Wide range of profits to seismic applications is accessible through understanding specific features of new tools and new ideas. Interpreter creating maps of C-wave seismic attributes should be aware of unique features of these images. C-wave images are not stand-alone products, but complement P-wave images.

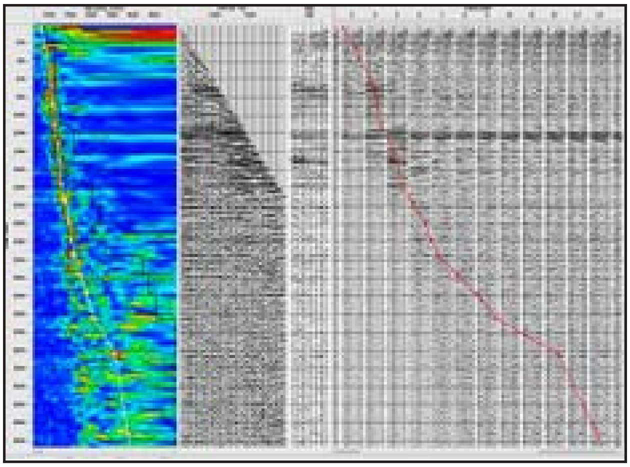


Fig.11. Sample of P-wave stacking velocity analysis

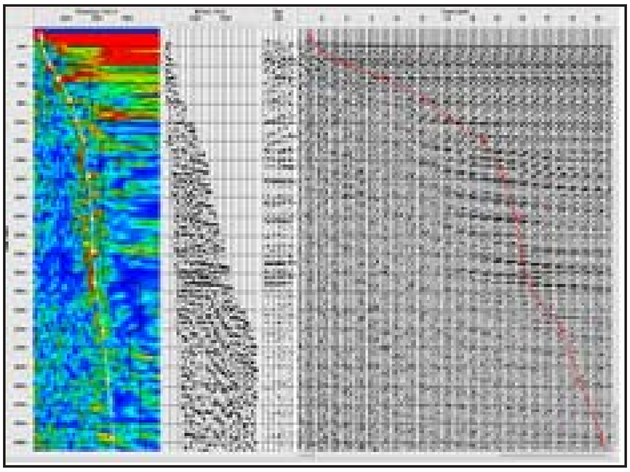


Fig.12: Sample of C-wave velocity analysis. The same location of data as in Fig.11.

Several years of experience from acquisition to interpretation show that 3C seismic surveys can be valuable complementation of classical P-wave imaging, and with commercialy available both processing as well as interpretation software packages, make land C-wave seismic imaging method ready to use where limitation to the P-waves seems to be insufficient.

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