Using modeling for non-Oil and Gas seismic processing ratings

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Summary

Raytracing, and especially, finite-difference (full-wave) numerical modeling allow accurately simulate all seismic wave effects of the seismic wave-field propagation in geologically realistic multiparameter numerical models. Accuracy of modeling is limited only by approximation complexity of wave equation and technical perfection of employed calculation schemes used.

Full-wave seismic modeling may be applied in one or another way for various seismic methods used for mining industries, especially at proof of concept for following development stages. It may be helpful at testing of seismic data processing technologies and their comparative analysis, logistic and details of the implementation, areas of special interest, like geohazard, risk mitigations etc.

Workflow

To put it simply, evaluation of seismic processing technologies may be split in the stages:

1. Selection for investigated conditions of typical geological scenario and creation of 2D/3D numerical models.
2. Selection of:
    a. type wave equation, necessary by its complexity,
    b. survey geometry,
    c. some other numerical modeling conditions like surface and source properties.
3. Generation of synthetic seismic data.
4. Application of relevant seismic data processing procedures like: PSTM, PSDM, WEM (Wave Equation Migration), some other advanced proprietary procedures.
5. Comparison of different seismic processing results.

At initial stage, the easiest way is creating of 2D numerical models and 2D synthetic datasets. Then after comparisons of 2D variants of seismic data processing results, depending on the project, may be done more complex and time-consuming 3D modeling and comparisons of the 3D processing results can be conducted.

Case 1: Processing variants for complexly built medium model “MARMOUSI”

In this case study is used the Marmousi model (1990 EAEG) for testing practical aspects of seismic data inversion (*Figure 1a*).

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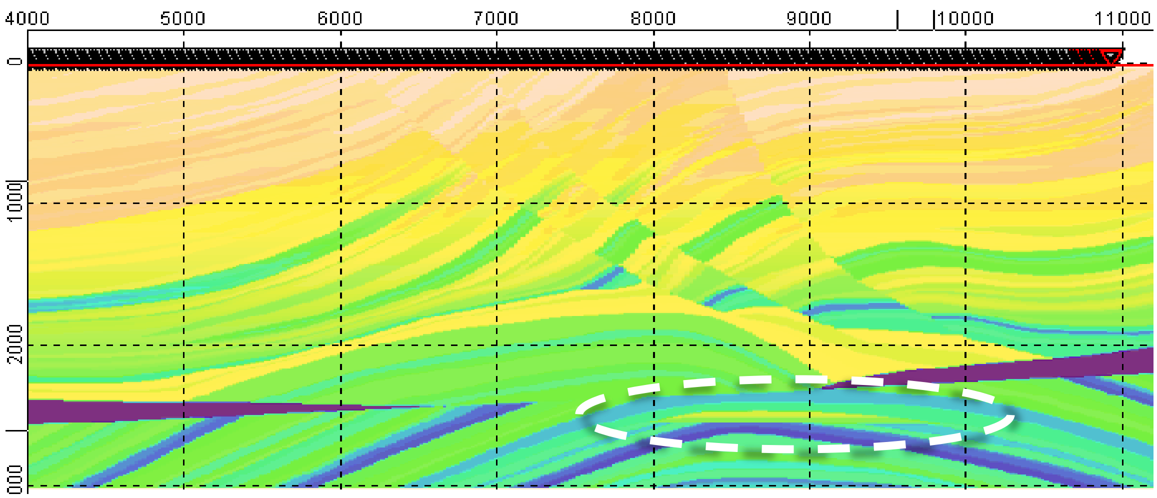

Figure 1a *The “Marmousi” model (1990 EAEG). With ellipse is shown target “gas deposit” representing low velocity anomaly, contrast with surrounding rocks.*

The “Marmousi” model allows to test and compare results of processing in conditions of abrupt lateral changes of migration velocities. Elastic synthetic seismograms were computed by solving the vector wave equation by finite-difference method. At stage of seismic data processing, it was assumed that we know exactly the velocity distribution.

Were applied following seismic data processing techniques (Figures 1b, c, d) to check different processing sequence scenarios.

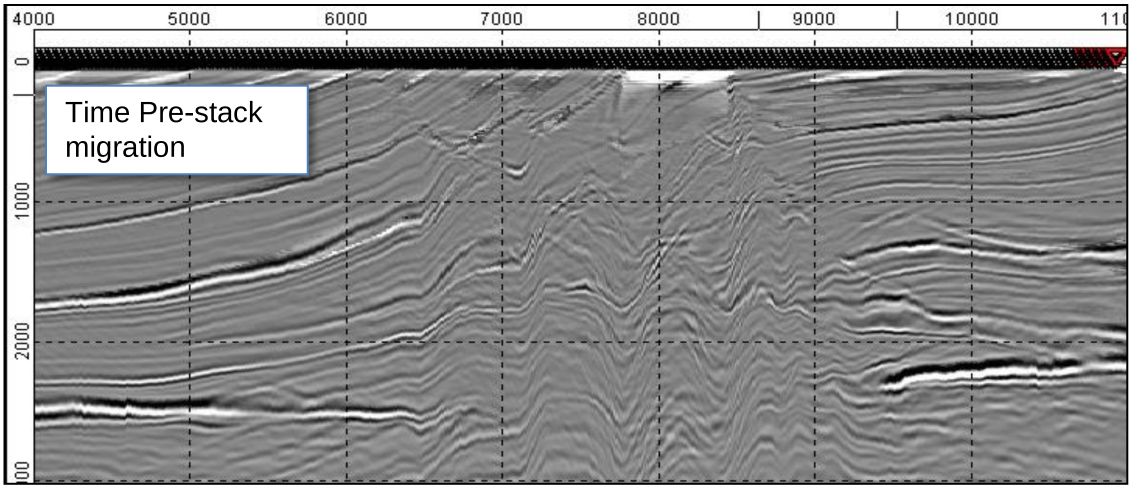

Figure 1b *Pre-stack time migration. The image obtained is substantially distorted against the model, especially in the central part with the contrast lateral velocity changes.*

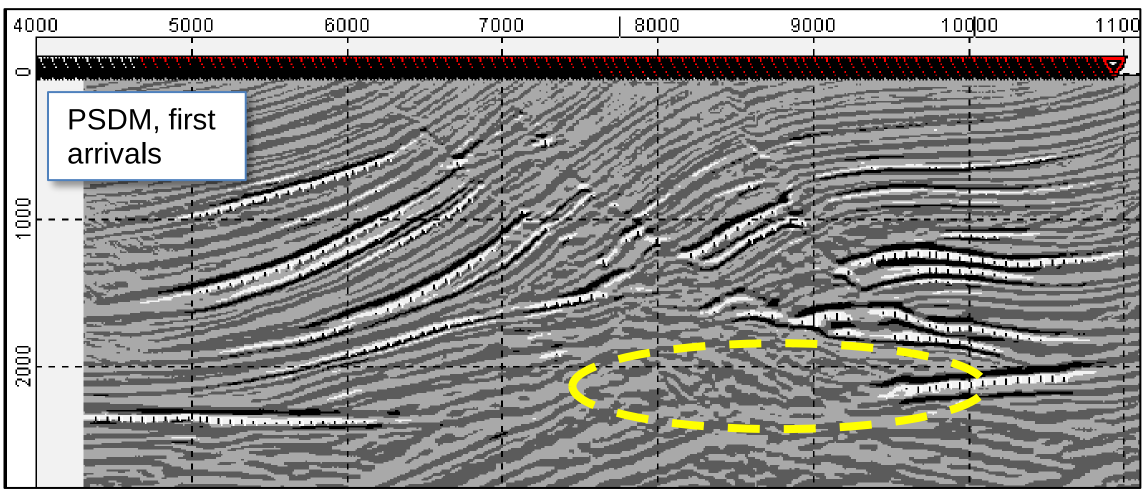

Figure 1c *Pre-stack depth migration with Eikonal (First Arrivals) operator. Sub-horizontal layering and thrusts (by miscorrelation between layers) can be clearly identified. The image obtained in the target "gas deposit" is distorted against the model and the target cannot be identified.*

First two PSTM and PSDM techniques (Figures 1b and c) are conventional types of processing procedures and they provide quite expected results.

Third technique (Figure 1d) is a proprietary procedure Vector Wave Equation Migration [2005].

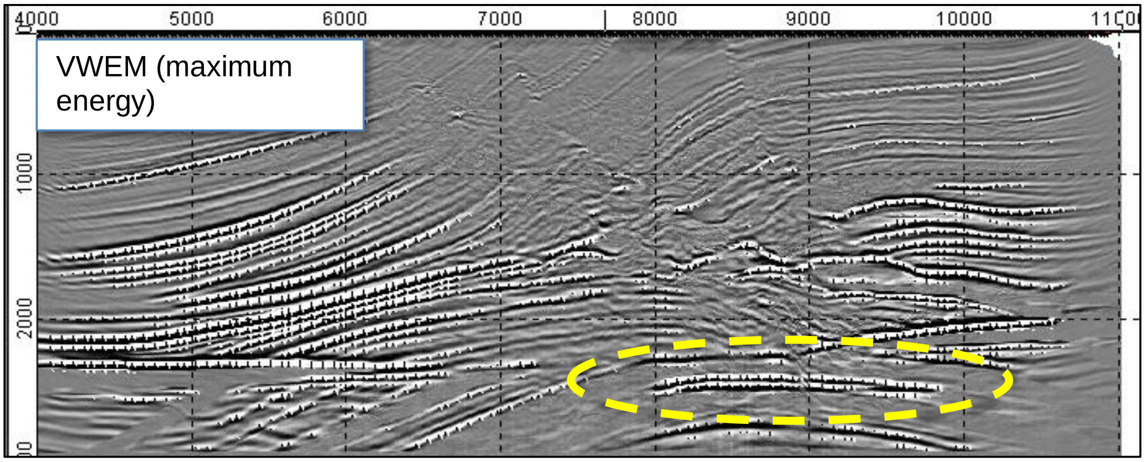

Figure 1d *Pre-stack depth migration with maximum-energy acoustic operator. This image virtually completely coincides with the model and the target "gas deposit" (low velocity anomaly) can be clearly identified. Upper part of cross-section has same resolution as in Figure1d – just other output enhancement.*

VWEM allows computing Maximum Energy Operators (MEO) for Kirchhoff PSDM employing the full vector wave equation for the evaluation of additional wave modes used in migration. This class of waves may be defined as not just P-waves but as waves excited and received as P-waves.

This study shows that in complex medium conditions imaging of target deposits require using at least of PSDM technique. Better results also may be expected from Wave Equation Migration approaches, like VWEM.

Case 2: Processing variants for hard-rock seismic conditions model "MntProF"

This (Figure 2a) numerical model example for hard-rock seismic conditions which are typical for geological conditions in mining industry.

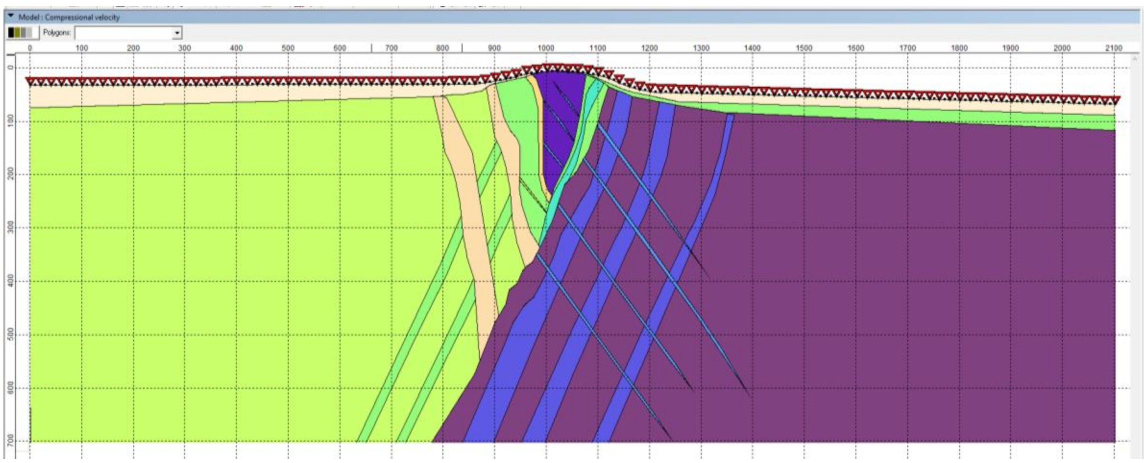

Figure 2a *Model "MntProfileF" 2100x700 m with steep (70-80 deg) seismic discontinuities for better PSDM and DSWM testing and comparison purposes.*

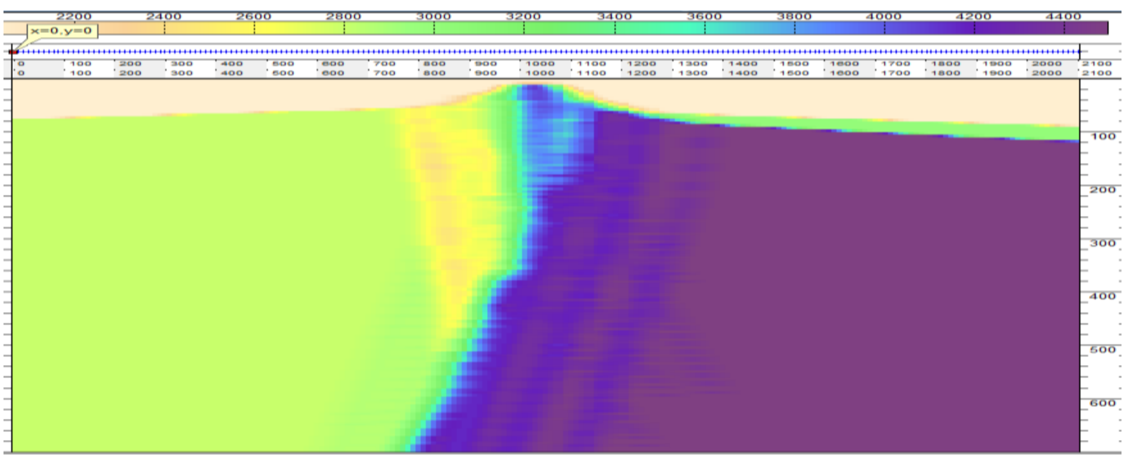

Figure 2b *Smoothed (from "MntProfileF") migration velocity model.*

The produced synthetic seismic data may be considered to be similar to the real field data, but with eliminated surface multiples and without conversions to shear waves ("well preprocessed"). It allows investigating "best possible case scenario" – with relatively clean seismic data. The interbed multiples though are not eliminated. Typically, modeling is done in Acoustic wave approximation with “Invisible surface” condition.

In this case study was done comparison of PSDM (conventional approach) and DSWM/DWM proprietary technique [2005, 2013].. Duplex Scattered Wave Migration (DSWM) and Duplex Wave Migration (DWM) allows directly image sub-vertical seismic discontinuities like faults (including zero-throw faults) and fracturing zones, which are a major cause of mining hazards. The denser survey brings a benefit of a better resolution for DSWM/DWM imaging and enables a more robust and accurate prediction.

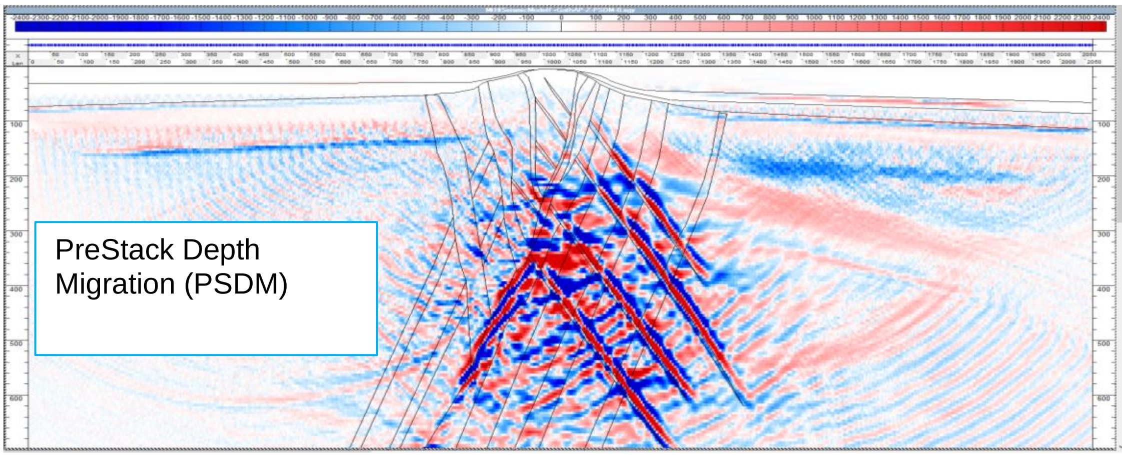

Figure 2c *Results of Pre-stack depth migration (source model contours shown on background)*

Comparison of lineaments that can be recognized in PSDM and DSWM images (Figures 2c, d, e) show that in similar conditions of steeply dipping (60-80 degrees) boundaries DSWM allows to see almost all steeply dipping contacts. PSDM images only some (from 200m depth) of such steeply dipping boundaries

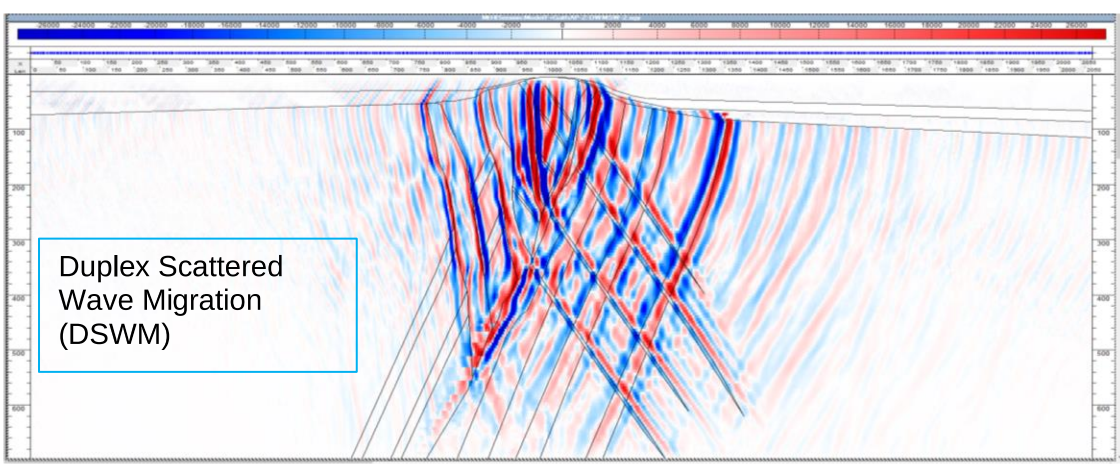

Figure 2d *Results of Duplex Scattered Wave migration (source model contours shown on background)*

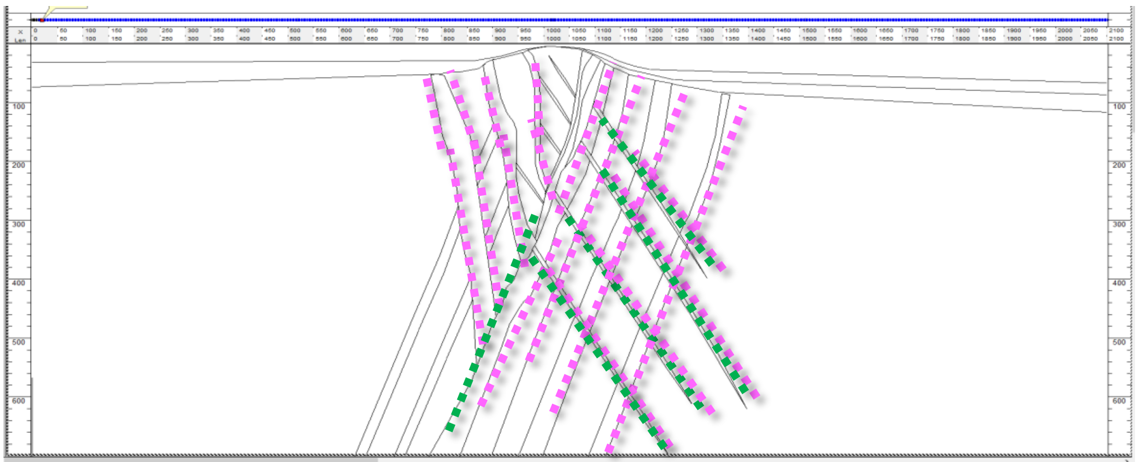

Figure 2e *Legend: Dashed lines show elements of imaging coinciding with the initial model Green lines – PSDM; Magenta lines – DSWM.*

Provided comparisons show that DSWM (experimental technique for hard-rock seismic) provide complementary to PSDM (conventional for hard-rock seismic) results, especially in cases of steeply dipping (45-90 deg) seismic discontinuities.

It can be concluded that DSWM in conditions of steeply dipping boundaries may produce much better results than PSDM.

The DSWM processing with much smoother than shown in the *Figure 2b* migration velocity model was also performed. Based on the results it may be concluded that in similar conditions the much courser (rougher) velocity model may be used without considerable loss of DSWM images quality. As velocity model-building is a process that is prone to uncertainties and fully accurate velocity model is not always easy to achieve, this conclusion is vital and is an added “bonus” to the already achieved results.

This feasibility study shows that this type of modeling can be successfully used for better determining capabilities of hard rock seismic in conditions of complex non-stratigraphic bedrock geology.

Conclusions

Presented approach and case studies show that this type of modeling can be successfully used for better determining capabilities of hard rock seismic in conditions of complex non-stratigraphic bedrock geology.

Creating complexly built 2D and 3D medium models and producing high quality synthetic seismic data for development and testing of seismic processing algorithms, analysis of seismic records for typical in the region of interest geological conditions, etc.

Further analysis on other models of complex non-stratigraphic geology with targeted applications for mining industry may be certainly beneficial for identification of optimized approaches and effective seismic imaging techniques for successful implementation of the technology for mining in hard-rock non-stratigraphic environment. Such approach may be used for purposes of testing and tuning of existing seismic processing procedures, as well as, for R&D of specialized seismic surveys and processing technologies by:

- allowing to better understand the strengths and weaknesses of the new technologies so that the adoption cycle time may be greatly reduced.
- enabling (by presentation, report, training course) a clear understanding of the complexities of seismic signal mode conversion, multiples, the creation of surface related noise, etc.

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