Tu_P01_01

Innovative Inversion Schemes for Model Building and Reflectivity Estimation: A Deep Water West African Case Study

T. Martin[1]*, M. Barbaray[1], G. Venfield[1], V. Chavda[1]

[1] PGS

Summary

Late Cretaceous channel systems create structural uncertainty and impact amplitude fidelity of both Late and Early Cretaceous plays in deep water Côte d'Ivoire seismic data. We present a case study using a combination of Full Waveform Inversion (FWI) and image domain Least-squares migration (LSM) to resolve the impact of complex Late Cretaceous channel systems on deeper targets. A full wavefield FWI approach using a velocity kernel that eliminates the reflectivity imprint, created an accurate velocity model. This removed the structural uncertainty when used in the imaging step. A reflectivity estimate was then determined using LSM. The final dataset had improved amplitude fidelity by compensating for the loss of bandwidth and illumination associated with the Late Cretaceous channels.

Introduction

Late Cretaceous channel and canyon systems of Maastrichtian and Cenomanian age contaminate the reflectivity of Early Cretaceous fan systems in deep water Côte d'Ivoire seismic data. Intra-channel heterogeneity causes structural uncertainty and impacts the amplitude fidelity of the fan systems they overlay. Sediment provenance for the Late Cretaceous channels and canyons is based on regional scale basin modeling and suggests no single lithological origin. No wells exist in the area. Figure 1 illustrates the implications on prospectivity analysis caused by the Early Cretaceous channels.

The lack of reflectivity below the Late Cretaceous channels could be caused by an inaccurate velocity model, absorption or scattering. Full Waveform Inversion (FWI) was used to build a regional scale model. Modeling studies show that for this dataset, where the water bottom was between 3000 m and 3500 m, no transmission energy was recorded up to 8000 m offset. FWI relied on a reflection driven solution where the velocity kernel used to drive the update was based on the removal of the migration isochron (Ramos-Martinez et al., 2016).

Following this an image domain Least-squares migration (LSM) solution was applied to the data following Valenciano et al. (2006). Using a model, migrate and multi-dimensional deconvolution approach, the implementation compensates for limitations in the illumination and bandwidth associated with the interaction of the acquisition geometry and the complexity of the channel and canyon sequences.

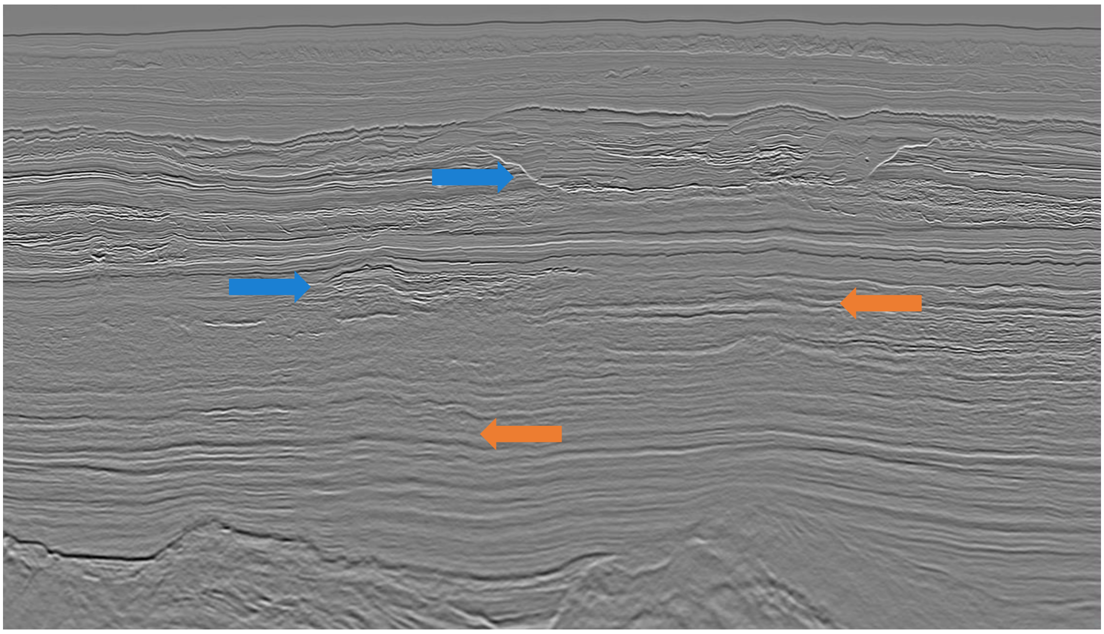

***Figure 1**. A vertical section through the data showing the Maastrichtian and Cenomanian channel systems (blue arrows) and their effect on Early Cretaceous reflectivity (orange arrows).*

Method

Due to the interaction of the water depth, sub-surface geology and acquisition parameters no diving wave energy on the recorded data; for FWI a method was used that relied on only reflection energy. First introduced by Ramos-Martinez et al. (2016), the method determines a gradient such that the high wavenumber reflectivity isochrones are removed, preserving low wavenumber back-scatter energy from the two-way wavefield extrapolation imaging condition. This is achieved using impedance-velocity parameterization to apply the inverse of the dynamic weights defined by Whitmore and Crawley (2012). The migration isochrones that dominate the gradient in heterogeneous media are eliminated, and the result produces a long wavelength velocity update at the depths required to solve the challenges of the channels.

An image domain LSM was then run to compensate for any illumination and bandwidth limitations associated with the imaging, geology and acquisition challenges. The method used follows Valenciano et al. (2006) and Klochikhina et al. (2016), and is outlined in Figure 2.

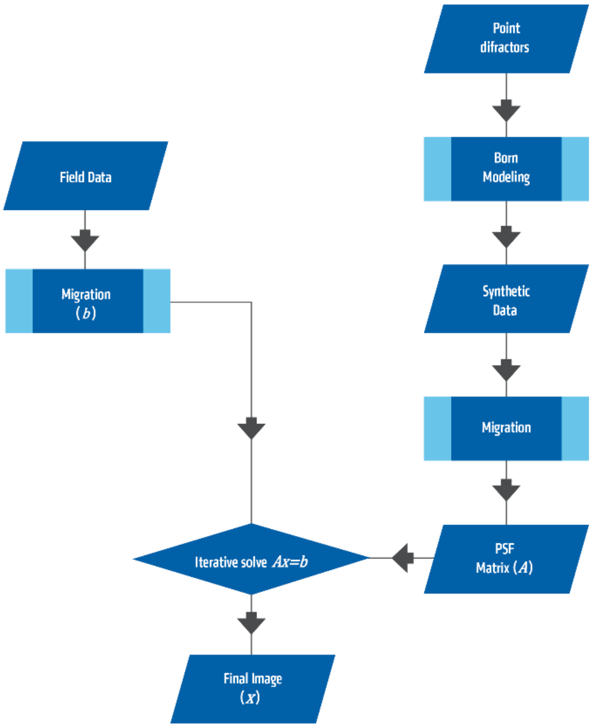

Figure 2. *Schematic flow showing the image domain LSM used to solve illumination and bandwidth limitations for the Côte d'Ivoire.*

Firstly, a migration (b) was generated from the recorded seismic data using a wavefield extrapolation migration. Secondly, Born modeling phase was run to create synthetic data from a sequence of point diffractors. This was followed by a migration of the data using the same algorithm used to obtain the migration result (b), which resulted in a finely sampled grid of point spread functions (PSF: A). PSFs describe the response of an imaging system to a point source or object. Our explicit calculation of the PSFs enables an iterative multi-dimensional deconvolution ($Ax=b$) from the effects of the response from the earth and acquisition geometry on the recorded data; restoring the illumination and wavenumber content of the seismic data (x).

Examples

The data used for this case study was acquired in 2015 using dual-sensor acquisition with a geometry of 10 streamers each separated by 100 m. Prospectivity in Late Cretaceous fan systems were obscured by Early Cretaceous channel systems. FWI was used to determine an accurate, long wavelength velocity model that captured both the regional trend, and localized velocity variations. Used in conjunction with tomographic methods to update anisotropy, the model produced an improvement in gather flatness and focusing of events below the Early Cretaceous channel systems. Figure 3 illustrates the benefits of the FWI model over a legacy ray-based tomographic approach. The FWI model is more conformable to the expected velocity profile of the data. Lateral continuity aligns with reflectivity, whilst vertical resolution is better than the historical model. This is best observed at the base of the Maastrichtian canyon system where the anticipated fast channel base is isolated and contained at the expected location (blue arrow). The structure below the main channel system is simplified and the stack response is improved.

Despite the uplift achieved in the seismic response below the Late Cretaceous channel systems when imaging with the FWI model, there was still a residual impact on bandwidth and illumination on the deeper Early Cretaceous fan systems.

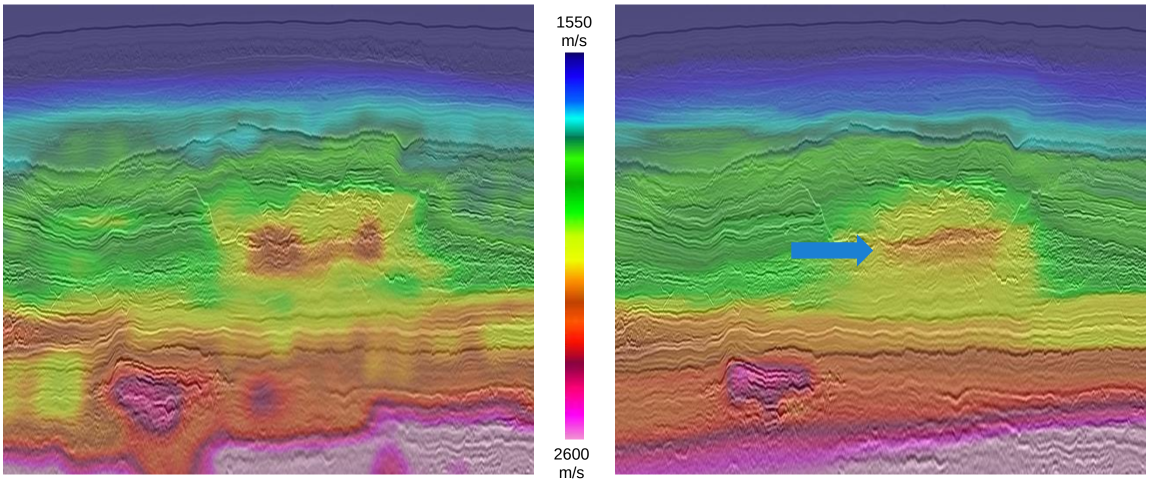

Figure 3*. Legacy velocity model (left) derived using ray-tracing tomography and the new reflection only FWI model (right). Note the improvement in stack response and simplification of the structure under the main channel feature.*

Figure 4b shows the results of the image domain LSM. When compared to the conventional image (Figure 4a) the least squares solution shows a marked improvement in resolution and amplitude fidelity through improved event continuity. This is achieved by compensating for insufficient acquisition sampling and the limitations in the imaging operator through explicit computation of the PSFs. An image point representation of the PSFs in the data domain are co-rendered on Figure 4b. The decay in PSF resolution with increasing depth is evident; this is compensated for through the inversion scheme. The wavenumber-frequency response inset in Figure 4d shows an improvement in the wavenumber content from the least squares result when compared to the conventional image response in Figure 4c.

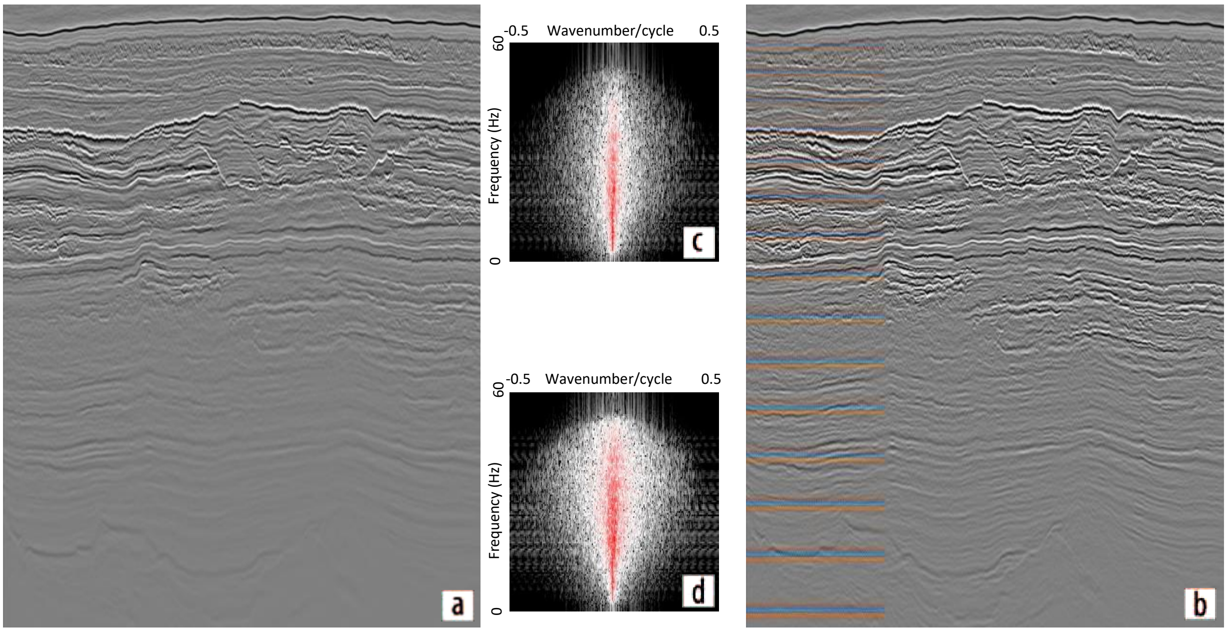

Figure 4. *4a) Conventional one-way migration; 4b) Image domain LSM, with co-rendered PSFs; 4c) The F-K spectrum for conventional imaging and 4d) F-K spectrum for image domain LSM.*

Conclusions

We have presented a case study where advanced inversion algorithms have been used to solve the seismic reflectivity challenges associated with the imprint of a complex set of deep water Maastrichtian and Cenomanian channel systems on deeper Turonian and Aptian fan systems in Côte d'Ivoire. Due to the environmental, acquisition geometry and geological setting, reflection only FWI determined a long wavelength velocity model, compensating for the challenges of the complex heterogeneous channel systems. To solve for illumination limitations and broadening wavenumber content in the data, an image domain least squares migration was applied to further enhance the imaging. The result is a seismic image where Early Cretaceous prospectivity is more readily defined, with less structural uncertainty and higher amplitude fidelity.

Acknowledgements

We thank PGS for permission to present this paper and to publish the results. We thank Stuart Fairhead, Alejandro Valenciano and Nizar Chemingui for helpful discussions.

References

Klochikhina, E., Lu., S., Valenciano, A. A. and Chemingui, N. [2016] Subsalt Imaging by Wave Equation Reflectivity Inversion, *78th, EAGE Conference & Exhibition, Extended Abstracts. Th SRS1 15.*

Ramos-Martinez, J., Crawley, S., Zou, K., Valenciano, A.A., Qiu, L. and Chemingui. N. [2016] A robust gradient for long wavelength FWI updates, *78th, EAGE Conference & Exhibition, Extended Abstracts, Th SRS2 03.*

Valenciano, A.A., Biondi, B. and Guitton, A. [2006] Target-oriented wave-equation inversion. *Geophysics*, **71**(4), A35-A38.

Whitmore, N.D. and Crawley, S. [2012] Applications of RTM inverse scattering imaging conditions. *82nd SEG Technical Program, Expanded Abstracts, 1-6.*