We03

Seismic Processing - What is required?

T. Martin[1] *, Ø. Korsmo[2], N. Chemingui[3]

[1] PGS; [2] PGS; [3] PGS

Summary

In a turnaround and cost conscious environment, do we really need to apply all the algorithmic processes in a seismic processing sequence? Full wavefield migration may be one way to eliminate certain processes. If we treat the full wavefield migrated image as part of an inverse problem in a least-squares migration, we may exclude more steps. Least-squares full wavefield migration (Lu et al., 2018) uses the raw seismic data, and many processing steps in both the data and image domain can be excluded, potentially reducing turnaround whilst maintaining, or improving, image quality for the entire data record.

Introduction

In a turnaround and cost conscious environment, do we really need to apply all the algorithmic processes in a seismic processing sequence? Full wavefield migration may be one way to eliminate certain processes. If we treat the full wavefield migrated image as part of an inverse problem in a least-squares migration, we may exclude more steps. Least-squares full wavefield migration (Lu et al., 2018) uses the raw seismic data, and many processing steps in both the data and image domain can be excluded, potentially reducing turnaround whilst maintaining, or improving, image quality for the entire data record.

Method

Separated wavefield imaging uses free-surface energy to improve the illumination and angular diversity of data (Whitmore et al., 2010). This can be valuable in shallow water environments, where towed streamer and ocean-bottom acquisition geometries can cause sub-optimal imaging. Using multiple energy in imaging bypasses time-consuming multiple attenuation processes. Separated wavefield imaging uses a stabilized deconvolution imaging condition (Guitton et al., 2007). This produces a zero-phase reflectivity image, whilst minimizing challenges such as crosstalk (Poole et al., 2010, Lu et al., 2013). The imaging condition improves resolution, and together with enhanced illumination and angular diversity, separated wavefield imaging in shallow water environments produces data that are suitable for geohazard analysis (Martin et al., 2017). The imaging condition also enables us to exclude designature and deghosting processes. Finally, when using separated wavefield imaging, some types of noise do not adversely affect the migration (Lecerf et al., 2017), and this can reduce the effort and time in data domain noise attenuation.

Imaging with multiple energy using narrow azimuth towed streamer acquisition in shallow water environments can have limited benefit; at some depth primary-only imaging is equivalent or superior. Full wavefield migration uses both primary and multiple reflections, as they are complementary. The same stabilized deconvolution imaging condition enables the combined energy to augment the overall image, by producing a top to bottom seismic image benefitting from both free-surface reflections and primaries. Figure 1 shows a schematic of the evolution to full wavefield migration.

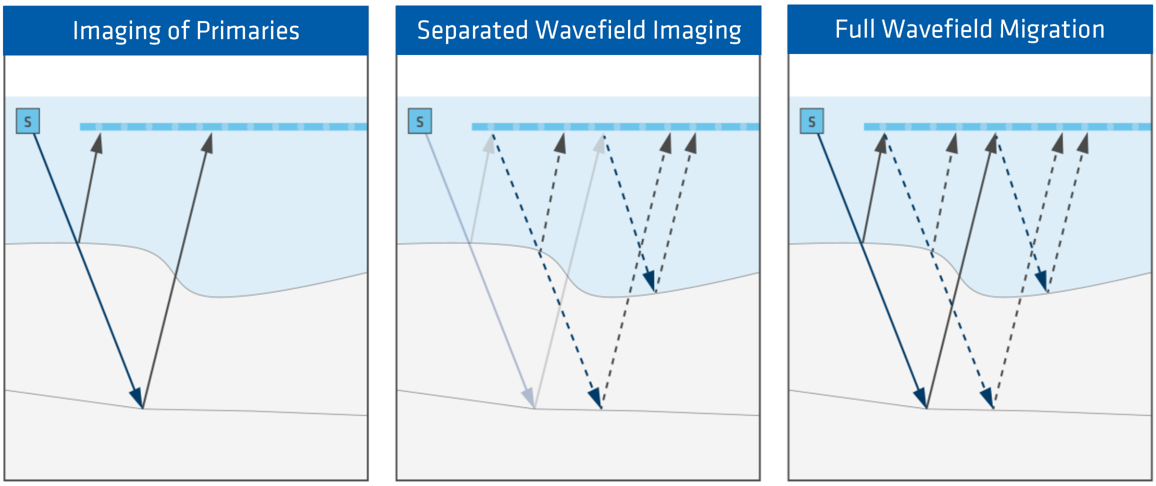

Figure 1. *Schematic demonstrating the evolution from primary only imaging to imaging with the full wavefield (primaries and multiples) to improve imaging illumination and angular diversity for the entire record.*

It can be difficult to balance the contribution from both primary and free-surface components, and additionally, the imaging process is a blending one, which can exacerbate crosstalk. If the imaging step is reformulated to be part of an inverse problem, we can solve this using Least-Squares Migration (Figure 2). To do this, we minimize the difference between modeled data and its recorded equivalent. Consequently, we automatically weight the contributions from primaries and free-surface energy, estimating the earth reflectivity, without matching crosstalk. This leads to an improvement in the image resolution and noise content. Therefore, we can avoid some of the time-consuming post-processing aesthetics.

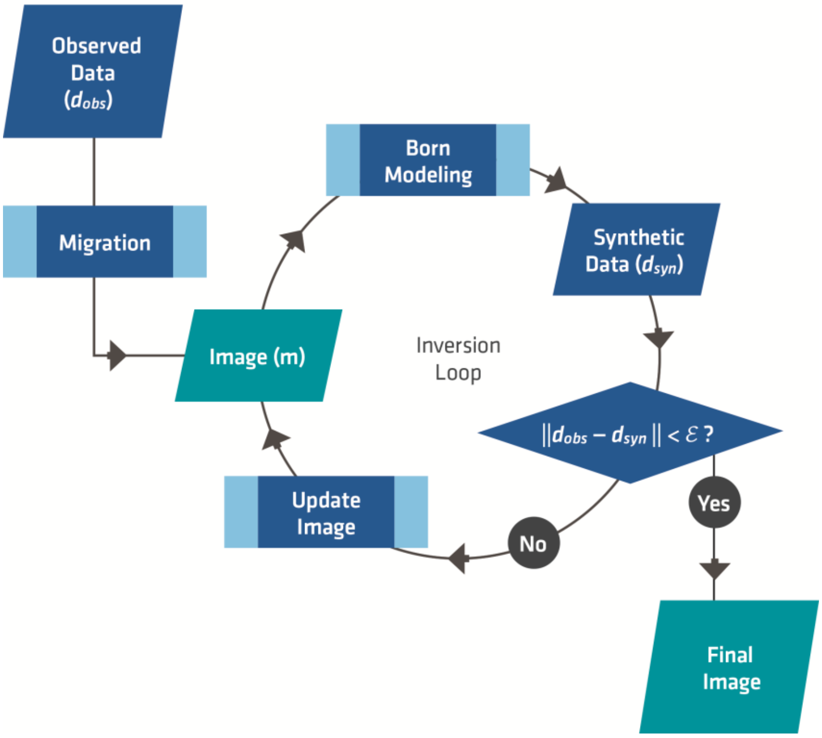

Figure 2. *Schematic demonstrating iterative least-squares migration.*

By using a least-squares full wavefield migration we benefit from improved illumination and angular diversity for the full record, and produce an image where resolution is enhanced and crosstalk attenuated.

Example

Figure 3 shows an example depth slice at 1200 m from the PGS Crystal survey in the Gulf of Mexico. Figures 3B and 3C compare the data from a conventional wavefield extrapolation shot-profile migration (Figure 3B) with a least-squares full wavefield migration (Figure 3C). Despite not undertaking much of the data and image domain processing used in the conventional migration, the least-squares full wavefield migration produces an image with higher spatial resolution, in significantly less time.

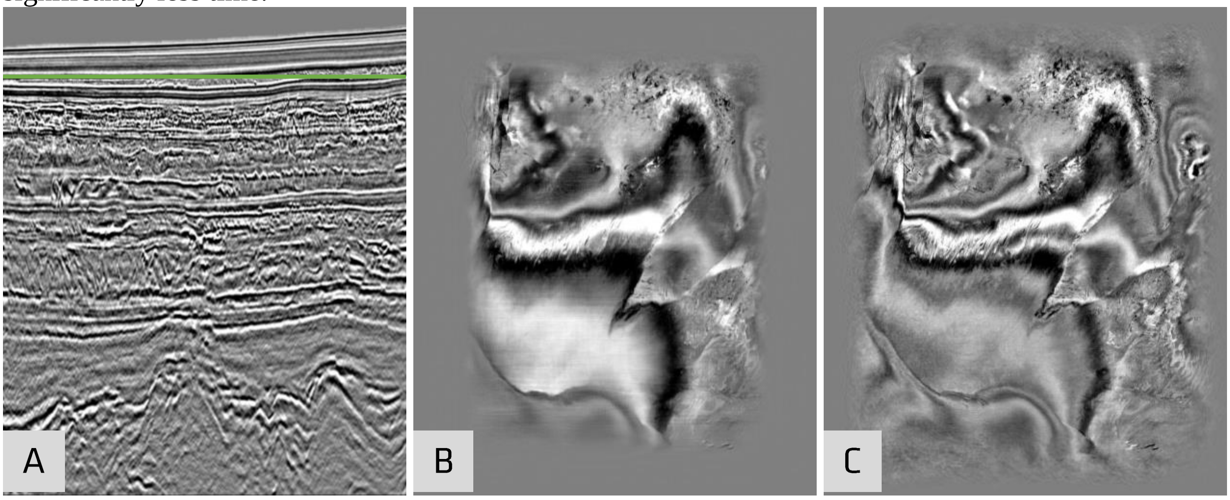

Figure 3. *A – Vertical section with 1200 m marked (green); B – Conventional primary only shot-profile migration; C – Least-squares full wavefield migration. Note the improvement in spatial resolution in C compared to B.*

Discussion

A least-squares full wavefield migration enables some, but not all, processing steps to be eliminated. Raw seismic data produces the image, therefore, for the imaging step we need an accurate earth model early in the project. This is also important for least-squares migration, a process whose concept is to understand if the migration and demigration of a data set describes the raw acquired data, and if it does not, update the image accordingly. Any difference is assumed unrelated to model inaccuracies. In virgin seismic territory, generating an accurate model for imaging may be time-consuming, especially if traditional methods are used. Whilst there are some attempts at automation in model building (Martin and Bell, 2019), more effort is needed for unexplored regions.

Least-squares migration also needs some data conditioning. Noise contaminating the residual will adversely influence the inverted result, however much of this work can happen in parallel to the image creation (‘m’ in Figure 2).

Finally, as full wavefield migration is a wavefield extrapolation shot-profile migration, incorporating an extended imaging condition is essential for prestack image domain data. This is challenging, especially for imaging involving primary and multiple energy. This is the focus of on-going work (Duan et al., 2020). Figure 4 demonstrates the data quality benefits of prestack least-squares full wavefield migration, compared to a conventional primary-only imaged data set; improved resolution, angular diversity and illumination without some time-consuming data and image domain processing.

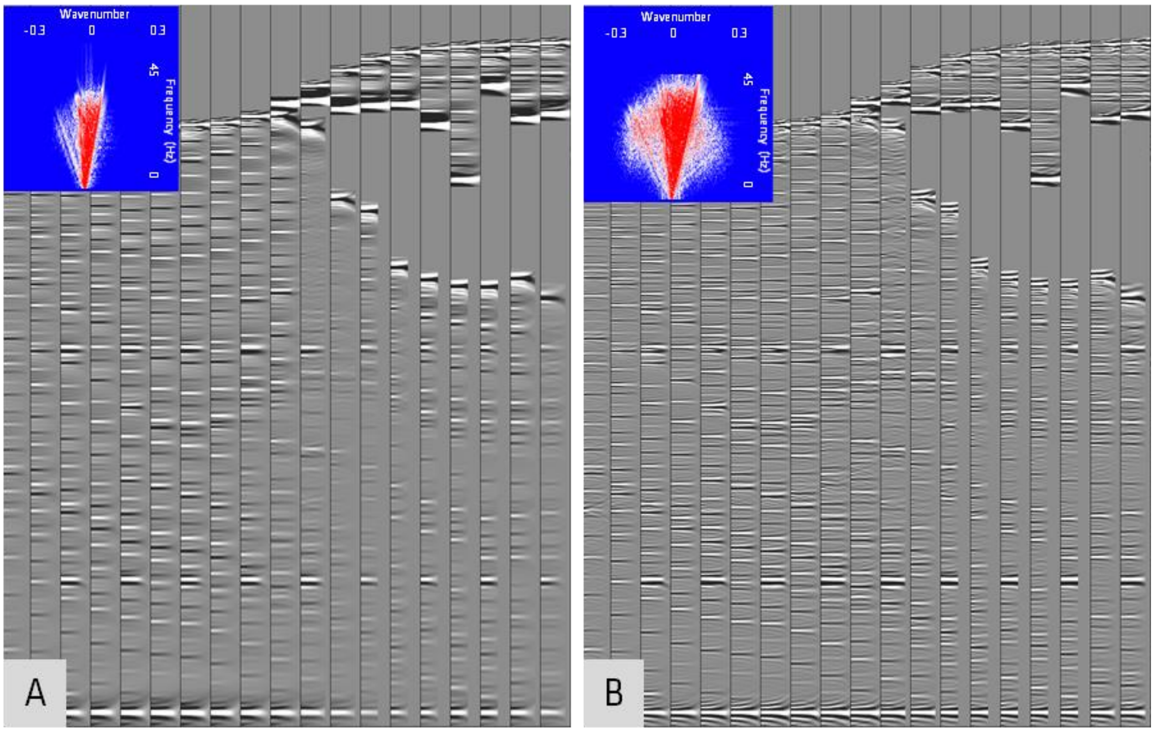

Figure 4. *Sigsbee2b synthetic data. A – Conventional primary only angle domain common image gathers; B – Least-squares full wavefield migration angle domain common image gathers. Note the improvement in resolution, illumination and angular diversity in B compared to A.*

Conclusions

Least-squares full wavefield migration may be a way to reduce turnaround in seismic processing, enabling an acceleration in the delivery of data for interpreters. It can achieve this by bypassing key steps necessary in conventional imaging. Additionally, the method improves illumination and angular diversity for the full record, recovers higher wavenumbers and minimizes the impact of algorithms and geometries that adversely affect conventional methods.

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