



THE PICTURES THEY DON'T WANT YOU TO SEE!

WORLD FIRST EXCLUSIVE



WARNING: THE FUTURE OF SEISMIC IMAGING REVEALED

DUG MULTI-PARAMETER FWI IMAGING HAS CHANGED THE GAME

The traditional seismic processing and imaging workflow has been around for decades.

It involves the testing and application of dozens of processing steps such as deghosting, designature, demultiple and regularisation, which are all designed to overcome the restrictions of conventional imaging algorithms. These workflows can be complex, subjective, and very time-consuming due to their serial nature and they often rely on many assumptions and simplifications which require further steps to resolve. All of these issues can impact the output data quality. The resulting, primary-only data then undergoes a similarly complex model-building workflow to derive an estimate of the subsurface velocity. This treatment of seismic data means that projects can take many months or even years to complete.

DUG Multi-parameter FWI Imaging is a new and unique approach to seismic processing and imaging which turns this traditional paradigm on its head. Our innovative implementation of full waveform inversion (FWI) achieves simultaneous model-building and full-wavefield least-squares depth imaging directly from field data, without the need for the traditional processing workflow and its various assumptions.

It is now possible to determine a wide range of Earth parameters including attenuation, anisotropic velocity and true-amplitude three-component reflectivity using multi-parameter FWI. The more complete physics of DUG MP-FWI Imaging naturally allows parts of the data traditionally considered as noise, and therefore attenuated during pre-processing, to be retained and treated as valuable signal. Using primary reflections, as well as all forms of multiples and ghosts, guarantees significantly better subsurface sampling, which in turn provides much-improved illumination and resolution over conventional, primary-only imaging.

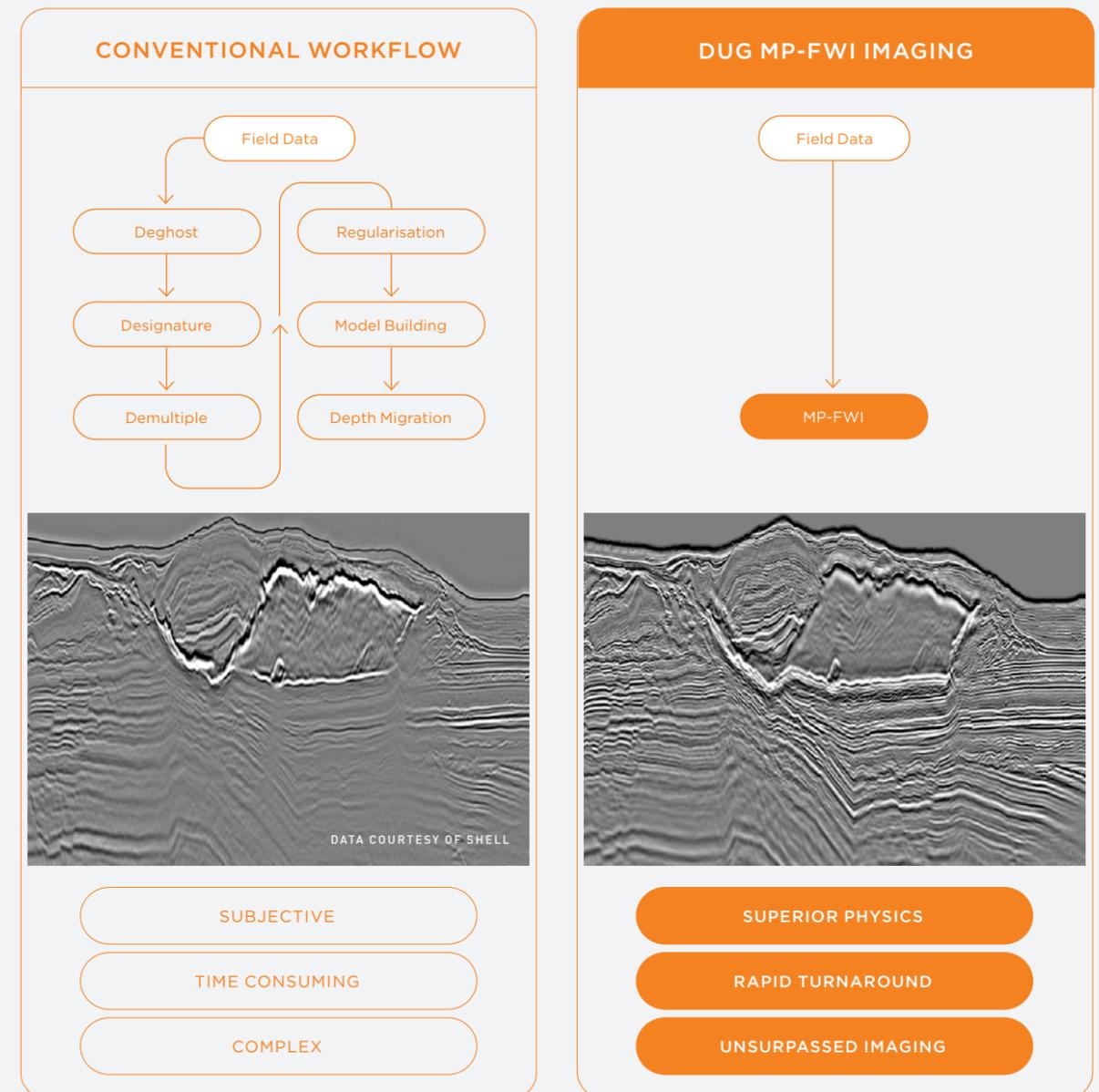
Our approach provides reflectivity images that can be used for both structural and quantitative interpretation including pre-stack outputs for AVA and elastic rock property analysis. **When using the full wavefield for simultaneous velocity model building and true-amplitude imaging a multi-parameter inversion is a necessity. A single-parameter FWI cannot separate velocity and reflectivity with validity.**

DUG MP-FWI Imaging uses superior physics to get the most out of the recorded data, delivering unsurpassed imaging with rapid turnaround. It is a complete replacement for the traditional processing and imaging workflow. **On the following pages, you will see a selection of the great results that we have delivered to our clients, from every corner of the globe. We believe this is the new standard for seismic processing and imaging, and we are very excited about the future.**

Tom Rayment | DUG'S CHIEF GEOPHYSICIST



WORK SMARTER, NOT HARDER



“With this state-of-the-art imaging we have taken a huge step forward”

Interview with Tor Åkermoen | CEO - Europe - Geox MCG



DUG: Tell us a little bit about your seismic data?

Tor: Well, Geox MCG, along with our partners, recently acquired two multi-client 3D surveys in the Norwegian North Sea. The 2020 survey was the world's first true hybrid 3D acquisition, with OBN (ocean bottom nodes) and high-density streamer data acquired simultaneously. Given the success of the first survey the 2022 survey was acquired in a similar fashion, but with upgraded parameters to give a higher trace-density and fold.

DUG: Why did you choose DUG's MP-FWI Imaging technology?

Tor: A few reasons. We thought the dense, hybrid acquisition would be an ideal dataset to test the efficacy of DUG MP-FWI Imaging. We also knew that we needed state-of-the-art processing if we were to unravel the geological complexity of this area.

DUG: What are some of the geophysical challenges in this area?

Tor: The survey is located in the Måløy Slope in the northern North Sea. While there are some well-understood

Jurassic, as well as Cretaceous discoveries in this area, near-field exploration has had varying degrees of success. Sand distribution and reservoir quality are not fully understood due to their geological variability. So while the area is highly prospective, unravelling exactly which reservoir intervals are present and prospective requires innovative thinking. Our hope was that the combination of the new hybrid acquisition and DUG's novel FWI-based imaging would help shed new light on these challenges.

DUG: So, what did you think of the DUG MP-FWI Imaging results?

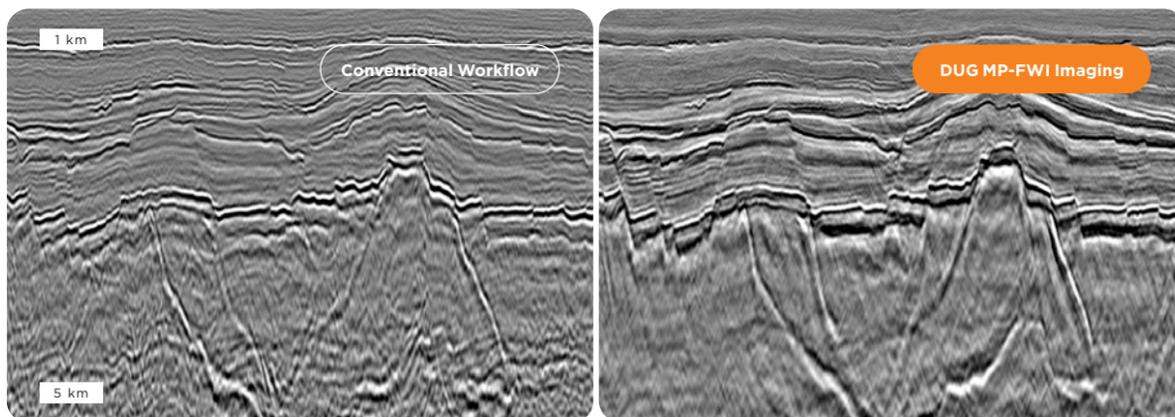
Tor: The data has indeed delivered some exceptional results! The resolution and continuity of the reflectors are significantly better and the overall imaging is excellent. The MP-FWI image has solved both multiple and noise issues which has in turn simplified the interpretation. There is some amazing shallow detail at the seafloor, some Lower Cretaceous reservoir amplitudes, some spectacular Upper Jurassic unconformities and specific reservoir sand units that are now clearly resolved.

DUG: Do you have any amplitude-driven prospects in the area?

Tor: We certainly do. The MP-FWI imaging also provided valuable angle-dependent information, for quantitative interpretation of AVA-driven prospects. I am confident we now have a better understanding of the Jurassic and Cretaceous reservoir locations in this region.

DUG: Will you use this imaging technology in the future?

Tor: Yes! With this state-of-the-art imaging directly from field data, we have taken a huge step forward in our ability to interpret the geological complexity of this basin. And the hybrid 3D concept acquires a fuller wavefield than regular, conventional surveys. Time is money in this business. The importance of getting a superior image quickly can't be understated. This technology allows us to do exactly that.

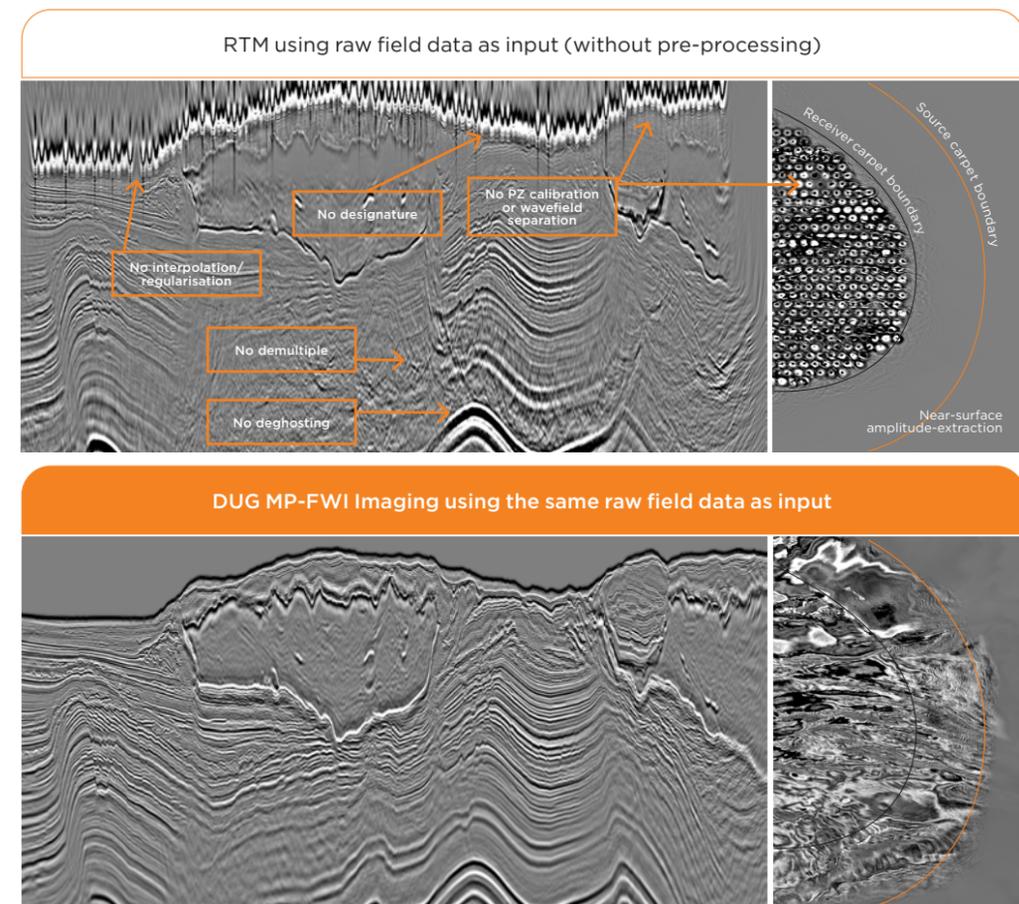


A comparison of results from a hybrid (towed-streamer and OBN) dataset from the Norwegian North Sea. Data courtesy of Seismic Partner and Geox MCG

SHOCK

COMPARISONS

HIGHLIGHT THE POWER OF LEAST-SQUARES IMAGING WITH THE FULL WAVEFIELD



DUG MP-FWI Imaging simultaneously solves the challenges of a complex pre-processing and imaging workflow, while removing assumptions. Least-squares imaging of the full wavefield delivers superior focussing, superior illumination, superior vertical and horizontal resolution and true amplitudes. Data courtesy of Shell

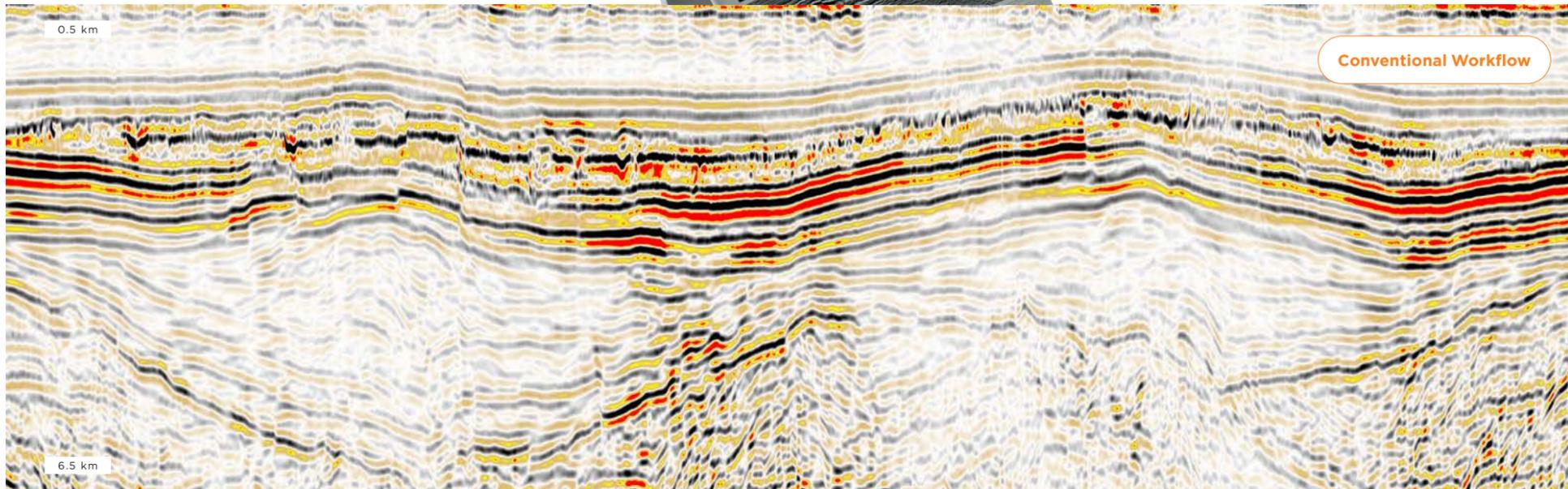
“DUG's MP-FWI technology has provided an improved subsalt image in our deepwater GOM project compared to conventional processing. We are impressed with the results thus far and are excited to push this technology into other complex areas.”

B. Tredrea, Murphy Oil Seismic SME

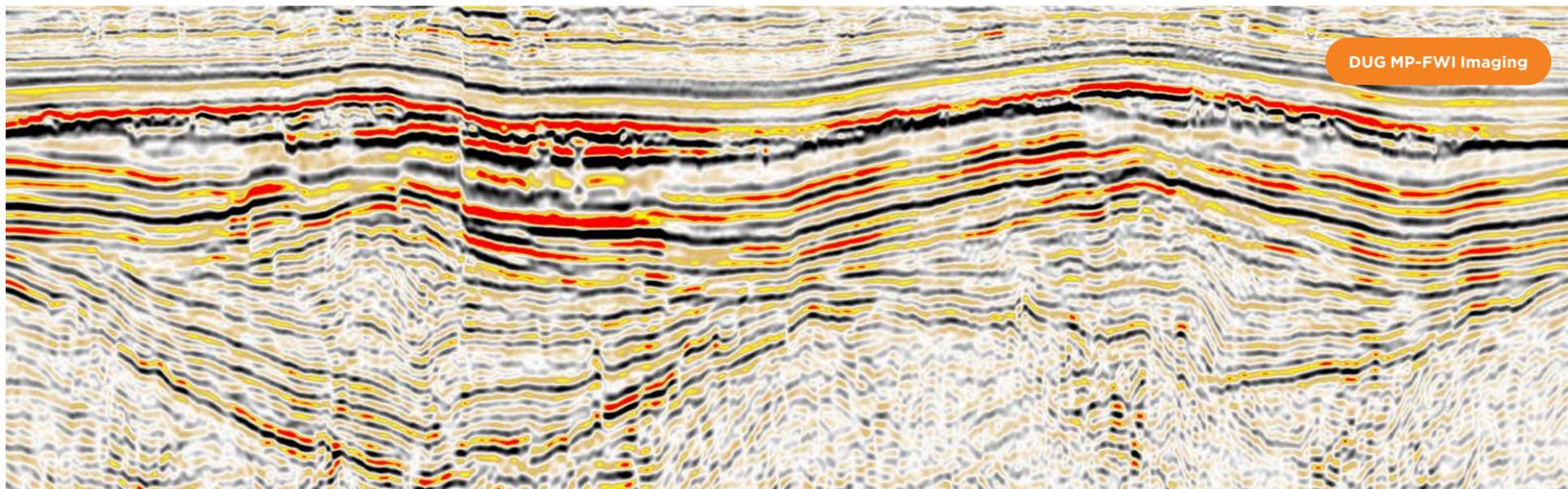
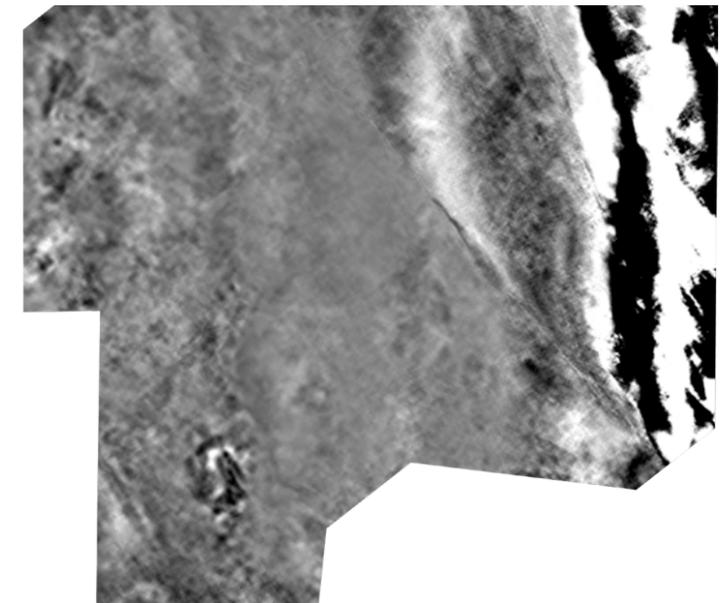
A LAND OF OPPORTUNITY!



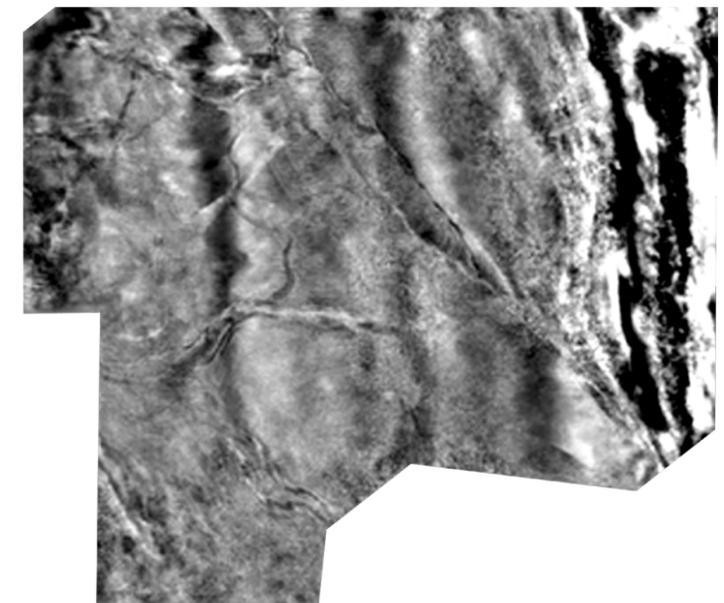
In these land dataset examples quite spectacular uplift was observed. DUG MP-FWI Imaging resolved subtle structural and stratigraphic features that were simply not imaged with a conventional processing and imaging workflow. Even with the additional complexity that comes with onshore data acquisition (such as topography and near-surface effects), DUG MP-FWI Imaging produced far superior results. Significantly better illumination and event continuity is obvious when comparing the sections below, thanks to least-squares imaging of the full wavefield—that includes interbedded multiples. Incredible near-surface detail has been resolved, as can be seen on the shallow depth-slices to the right. This example highlights why DUG MP-FWI Imaging is now the technology of choice, and a must-have for any seismic project, either land or marine. A land of opportunity awaits!



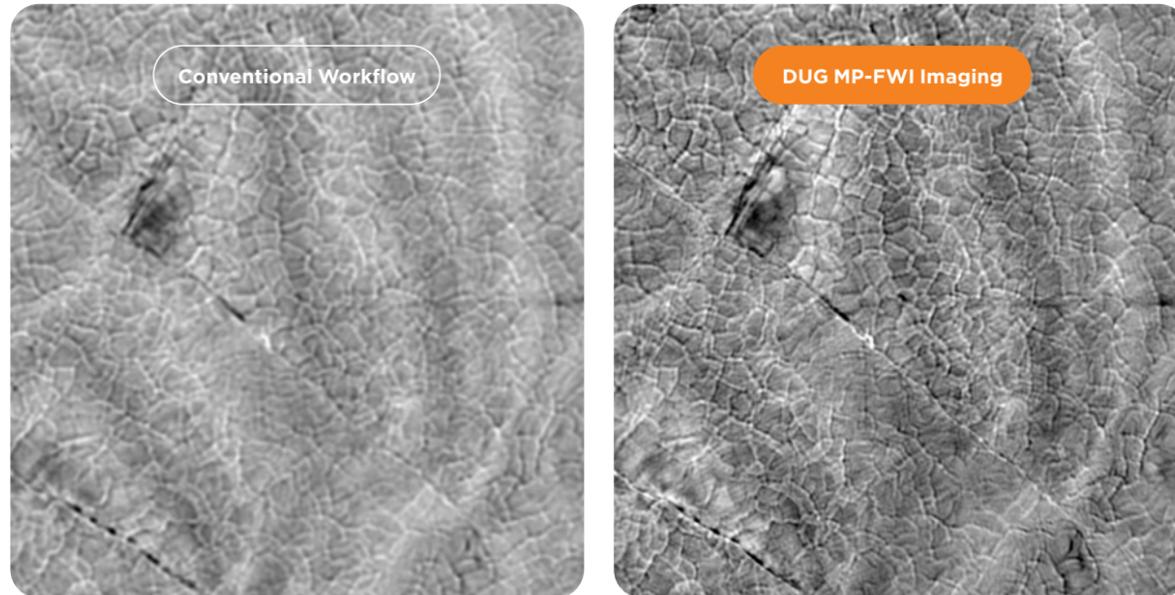
Conventional Workflow



DUG MP-FWI Imaging



Shallow-water environments are notoriously challenging for conventional processing workflows due to the presence of strong, short-period multiples that obscure primary signal.



In this shallow-water dataset from the Barents Sea, DUG MP-FWI Imaging generated a high-resolution image up to 110 Hz. Data courtesy of Aker BP

NAVIGATING SHALLOW WATERS

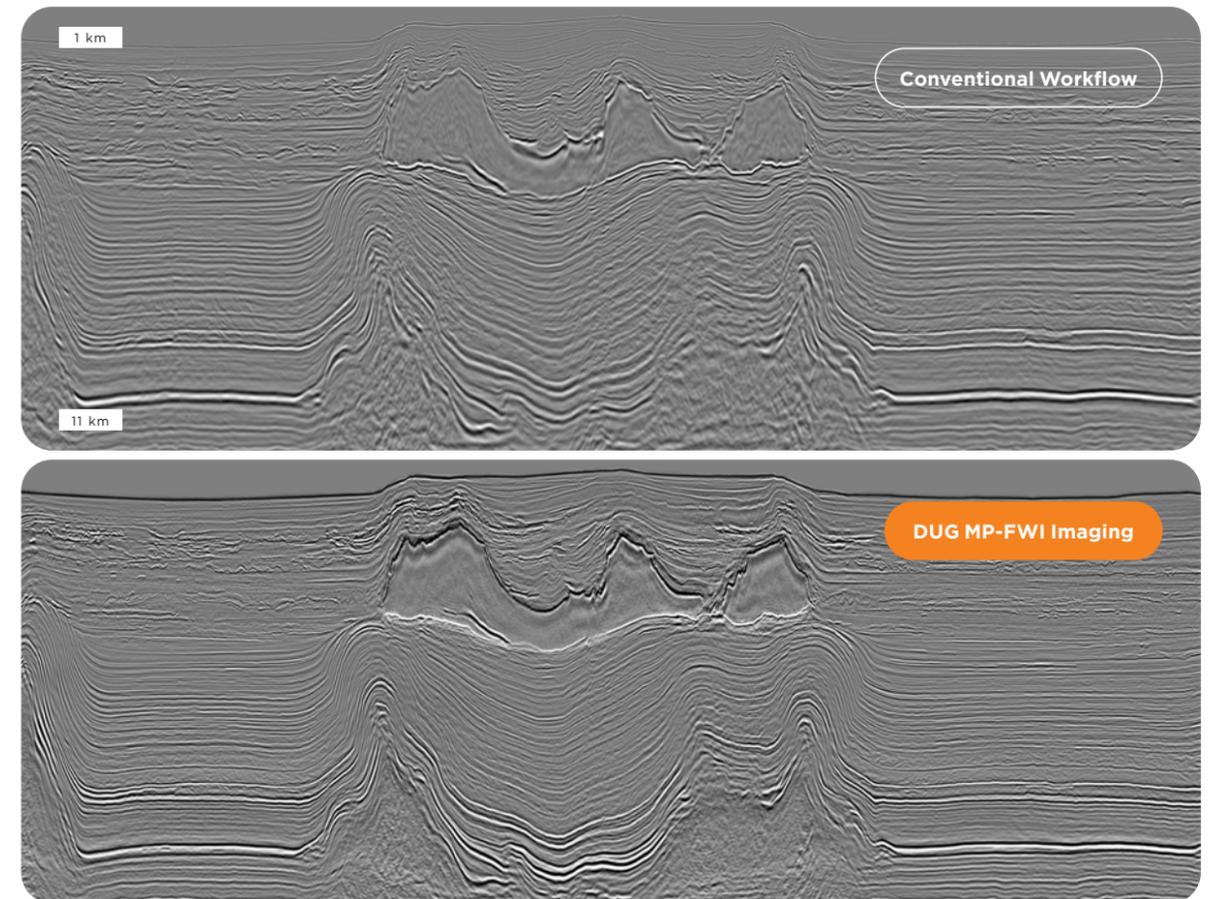
Limitations in common multiple-prediction schemes often result in derived models that require windowed adaptive-subtraction techniques to improve the match with the observed data. This has the potential to compromise the fidelity of primary amplitudes. This problem is compounded with towed-streamer type acquisitions due to the lack of recorded near offset reflections which are required for such schemes.

DUG MP-FWI Imaging, on the other hand, uses primaries, multiples, and ghosts as valuable signal! No complex, shallow-water demultiple workflows are required since the multiples are correctly mapped back to the reflectors that generated them, and are used to improve the image quality as a whole. **DUG MP-FWI Imaging** supersedes the traditional workflow in terms of quality of result and project turnaround-time.

“MP-FWI applied to vintage offshore seismic surveys has produced a level of imaging quality that may now allow for the revisiting of development opportunities and prospecting in previously untested stratigraphy beyond 10,000 ft.”

Happy Oil Co. Client

CHECK OUT THESE SALTY BODIES!

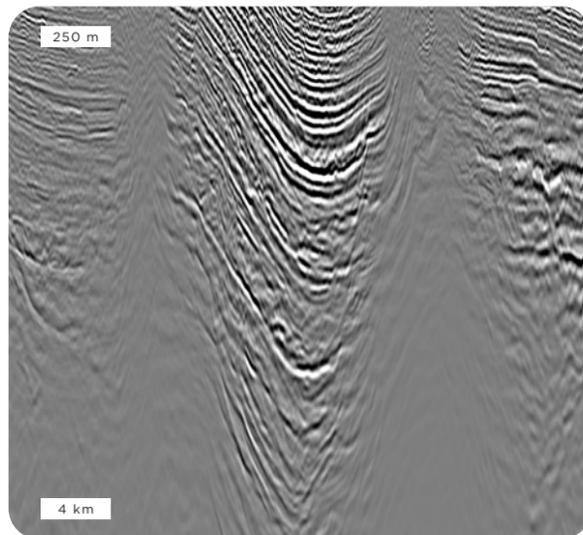


Resolving illumination issues caused by complex salt bodies has been a persistent geophysical challenge. **DUG MP-FWI Imaging** uses all parts of the scattered wavefield to reconstruct the reflectivity and kinematic Earth parameters. Naturally treating both up- and down-going wavefields, along with prismatic waves, multiples and ghosts as valuable information, guarantees significantly better subsurface sampling than primary-only imaging. This in turn delivers much-improved illumination, resolution and ultimately imaging of subsurface geology.

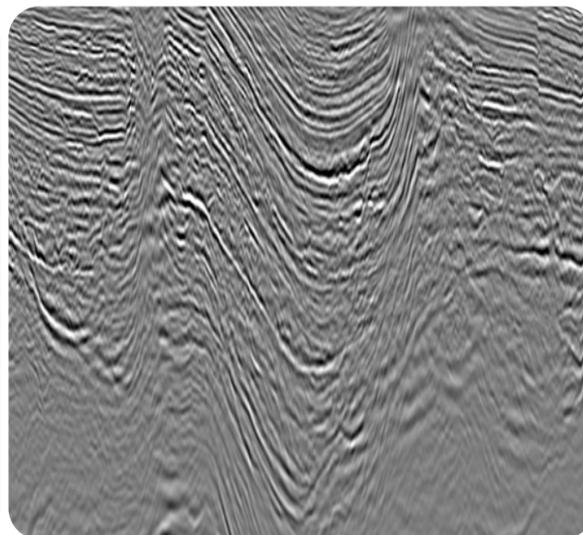
“MP-FWI has improved the deep imaging to a point where we are now able to generate a new structural and fault interpretation that is consistent with the regional tectonics, enhancing our understanding of the petroleum system and potentially leading to the identification of new exploration ideas.”

Another Happy Oil Co. Client

CONVENTIONAL WORKFLOW



DUG MP-FWI IMAGING

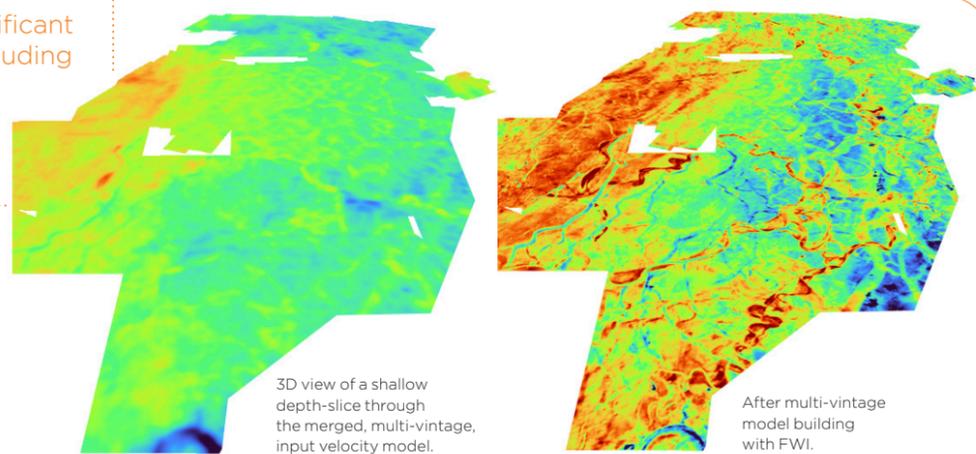


A comparison of results from a legacy shallow-water OBC dataset with only 4 km maximum offset.

NEW DISCOVERIES WITH OLD DATA

DUG MP-FWI Imaging is not just a solution for modern acquisition. It's not just for high-density, full-azimuth, long-offset data. While modern acquisition has many benefits, significant uplift can still be achieved by reprocessing legacy data with DUG MP-FWI Imaging. **Why?** Because more of the recorded wavefield, no matter when or how it was recorded, can be used to invert for the image. For example, consider the problem of limited near offsets, which complicate conventional multiple attenuation workflows. DUG MP-FWI Imaging uses multiples as signal! Those multiples provide extra sampling and contribute to a superior image.

The FWI velocity model resolved significant geological detail including channel complexes and low-velocity gas pockets.



3D view of a shallow depth-slice through the merged, multi-vintage, input velocity model.

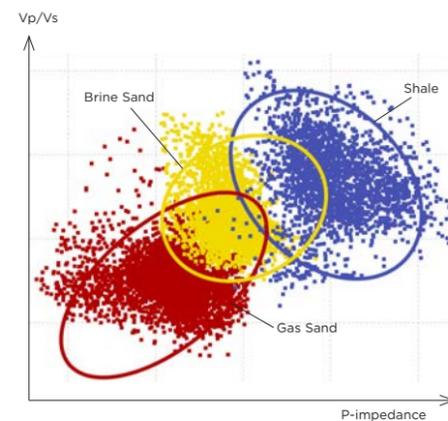
After multi-vintage model building with FWI.

A JV project between TGS and DUG, the "Peninsular Malaysia Mega Merge 3D" involved 39 different surveys (including 3 OBC surveys). With data vintages from 1989 to 2014 the combined area was over 17,000 square kilometres. The high-resolution velocity model was built up to a maximum frequency of 35 Hz.

FIELD DATA TO FLUID PREDICTION

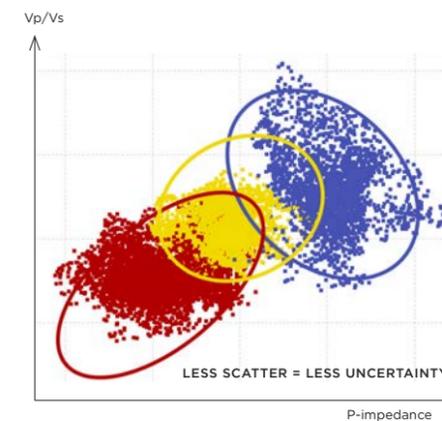
CONVENTIONAL WORKFLOW

(PRE-PROCESSING, VELOCITY-MODEL BUILDING AND KIRCHHOFF DEPTH MIGRATION)



DUG MP-FWI IMAGING

(USING FIELD-DATA INPUT)



BEX MC3D data courtesy of Multi-Client Resources

In the figures above, two equivalent crossplots of elastic rock properties (from simultaneous AVA inversion of pre-stack reflectivity) are shown. On the left, the inputs are from a conventional workflow. On the right, from DUG MP-FWI Imaging. The ellipses indicate the expected distribution of the labelled lithology and fluid combinations from well-log analysis. **Quantitative interpretation** requires true amplitudes and high signal-to-noise ratio. The MP-FWI results exhibit less scatter, which translates to less uncertainty.

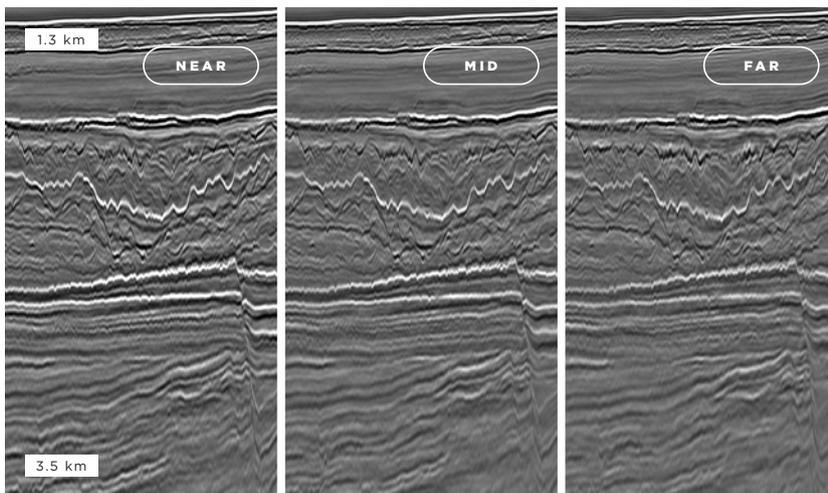
DUG MP-FWI Imaging delivers superior pre-stack reflectivity outputs for both AVA analysis, and, elastic rock property and fluid prediction—directly from field data. By eliminating the need for a conventional pre-processing workflow (and its assumptions/workarounds that ultimately affect the AVA compliance of the data) more certain predictions can be realised.

“Results from a shallow water environment indicate that MP-FWI from raw shots provides useful information for AVA analysis not readily available through conventional processing.”

Gunnar Aschjem, Exploration Geophysicist, & Christian Hidalgo, Processing Geophysicist, Aker BP

DUG MP-FWI Imaging is part of DUG Insight

A SUPERIOR IMAGE NEXT MONTH NOT NEXT YEAR



LEFT TO RIGHT: Pre-stack outputs from DUG MP-FWI Imaging, in this case near, mid and far angle stacks, allow for more advanced quantitative interpretation workflows. BEX MC3D data courtesy of Multi-Client Resources



Imagine producing a subsurface image, ready for interpretation, straight from field data. Imagine receiving better results in weeks, not months. Using superior physics, **DUG Multi-parameter FWI Imaging** completely replaces the traditional processing and imaging workflow, making all that possible now.

Don't wait another day to ask us how. Contact info@dug.com