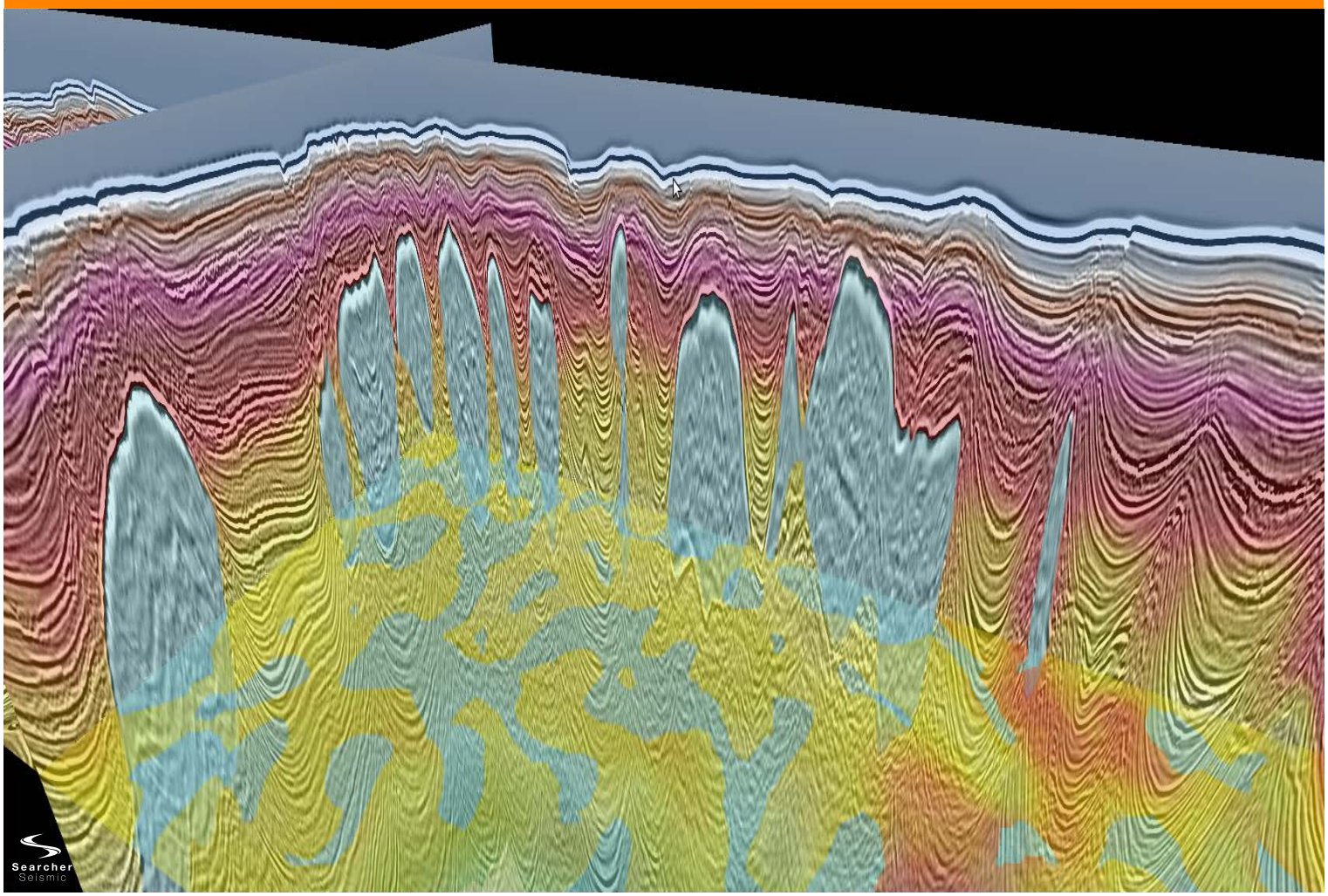
DEPTH IMAGING



dug
DownUnderGeoSolutions

DUG HAS EXTENSIVE EXPERIENCE WITH COMPLEX DEPTH IMAGING PROJECTS FROM ALL MAJOR OIL AND GAS PRECINCTS

This combined experience, along with our advanced toolkit, means that we are ready and able to tackle any project, large or small.

DUG OFFERS THE FOLLOWING MIGRATION ALGORITHMS:

- Kirchhoff time migration (KTM)
- Kirchhoff depth migration (KDM)
- Reverse time migration (RTM)
- Least-squares reverse time migration (LS-RTM)

The supported capabilities and anisotropic symmetries for our migration algorithms are summarised in the table below, where
VTI: vertical transverse isotropy,
HTI: horizontal transverse isotropy,
Ort: orthorhombic (HTI + VTI),
TTI: tilted transverse isotropy, and
TOrt: tilted orthorhombic,
Q: compensates for viscoelastic effects,
Topo: migration from topography.
DUG MigQ and DUG TomoQ can be used for both model-building and final migrations to compensate for variable Q.

DUG'S MODEL BUILDING WORKFLOW INCORPORATES BOTH FULL WAVEFORM INVERSION AND HIGH RESOLUTION REFLECTION TOMOGRAPHY. FEATURES OF DUG HRTomo INCLUDE:

- Multi-azimuth
- Anisotropic updates
- Horizon- and grid-consistent
- Structure and fault aware regularisation to prevent excessive smoothing across interfaces (including those with dip). Promotes structural continuity in the absence of other information while permitting abrupt changes when required
- Complete control over which part of the velocity model is updated, independent of input pick distribution
- RMO picks are weighted (which can be laterally- and/or depth-varying) and have a confidence value
- Reweighting of RMO picks during optimisation in order to minimise the influence of outliers
- Clusterised, allowing an unlimited model size (largest model to date is 22,000 sqkm)
- Picks can be volume-based, horizon-based, or a combination of both
- Picks can be parabolic or non-parabolic (any shape)

The entire workflow, including all interactive parts, is performed in DUG Insight, our 2D/3D/pre-stack interpretation system — allowing the geophysicist to immerse themselves in the data. This includes all RMO picking, velocity model manipulation, and various QC options such as unique vector moveout overlays.

MIGRATION ALGORITHM	POST-STACK	PRE-STACK	ISOTROPIC	ANISOTROPIC				Q	Topo
				VTI	TTI	HTI/Ort	TOrt		
KTM	✓	✓	✓	✓		✓			✓
KDM	✓	✓	✓	✓	✓	✓	✓	✓	✓
RTM		✓	✓	✓	✓			✓	✓
LS-RTM		✓	✓	✓	✓			✓	✓

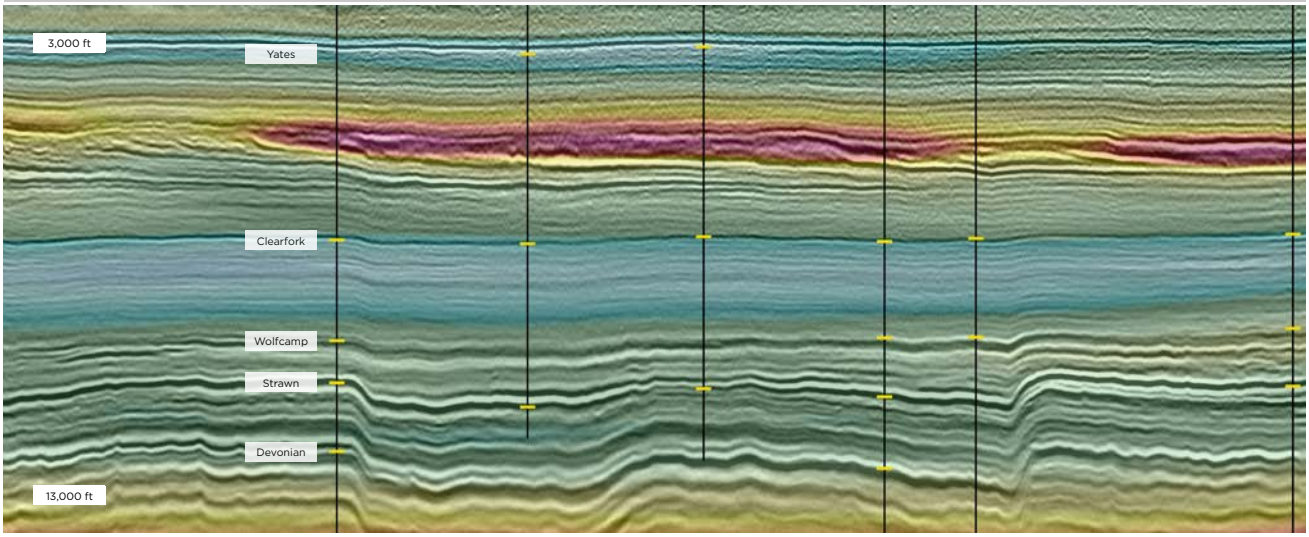
KIRCHHOFF MIGRATION

Kirchhoff migration uses the integral form of the wave equation (Kirchhoff integral) to back-propagate the seismic wavefield.

DUG's Kirchhoff migration algorithms are true relative amplitude implementations. The Green's functions are determined by dynamic ray tracing. The rays are traced through a gridded velocity model with maximum energy rays chosen.

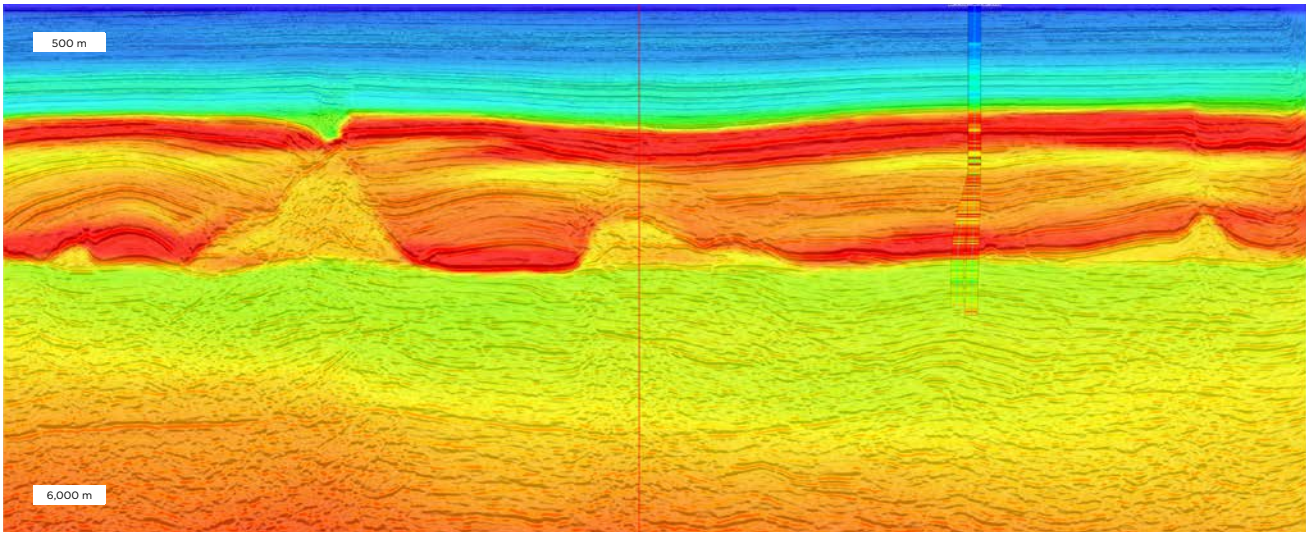
Note that, DUG MigQ and DUG TomoQ can be used for both model building and final migration to compensate for variable Q. Common-offset-vector (COV) binning and 5D regularisation can take place prior to migration for multi/wide azimuth data.

LAND IMAGING – ANISOTROPIC KIRCHHOFF PreSDM



01. Anisotropic (TTI) pre-stack Kirchhoff depth-migrated section from onshore Texas. Final velocity model and corresponding migrated stack after six iterations of anisotropic reflection tomography. Note the excellent match to the well markers over a range of depths. Multi-client data presented with permission from Geophysical Pursuit, Inc.

MARINE IMAGING – ANISOTROPIC KIRCHHOFF PreSDM



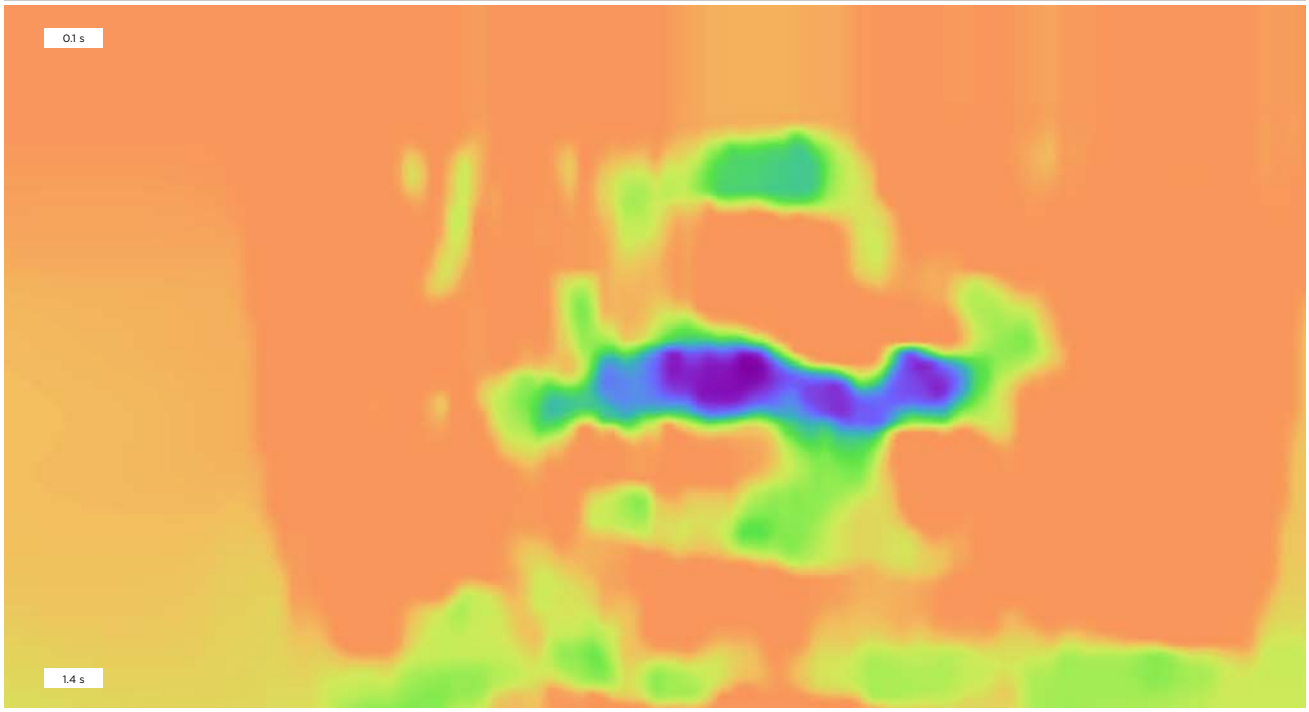
02. Anisotropic (TTI) pre-stack Kirchhoff depth-migrated section from offshore Gabon. The final stack and interval velocity model after five iterations of anisotropic reflection tomography are shown. Image is courtesy of Harvest Natural Resources Inc.

DUG MigQ AND TomoQ

Geological complexities in the overburden (for example structure, gas hydrates, shallow gas and carbonate reefs) result in spatially varying and frequency dependent attenuation of the recorded seismic wavefield.

This results in phase distortion of the wavelet and a reduction in both amplitude and bandwidth that can mask deeper events of interest. In order to correctly image deeper targets (and preserve true relative amplitudes) these effects should be addressed as part of a migration workflow. DUG MigQ is a pre-stack depth migration-based workflow that compensates for laterally and vertically varying attenuation (or quality factor Q). It is is implemented for both Kirchhoff and RTM migrations. In order to compensate for attenuation a Q model must first be estimated. DUG TomoQ is a robust frequency-dependent Q tomography process. Both the geometry of the anomalous attenuation zones and the corresponding Q values are calculated. As well as qualitative improvements such as easier interpretation of deeper events there are significant quantitative improvements that result from accounting for attenuation as part of a 3D pre-stack depth migration workflow. Accounting for attenuation variations that can result from changes in incident angle (and thus raypath) allows more accurate AVA analysis and delineation of reservoir properties.

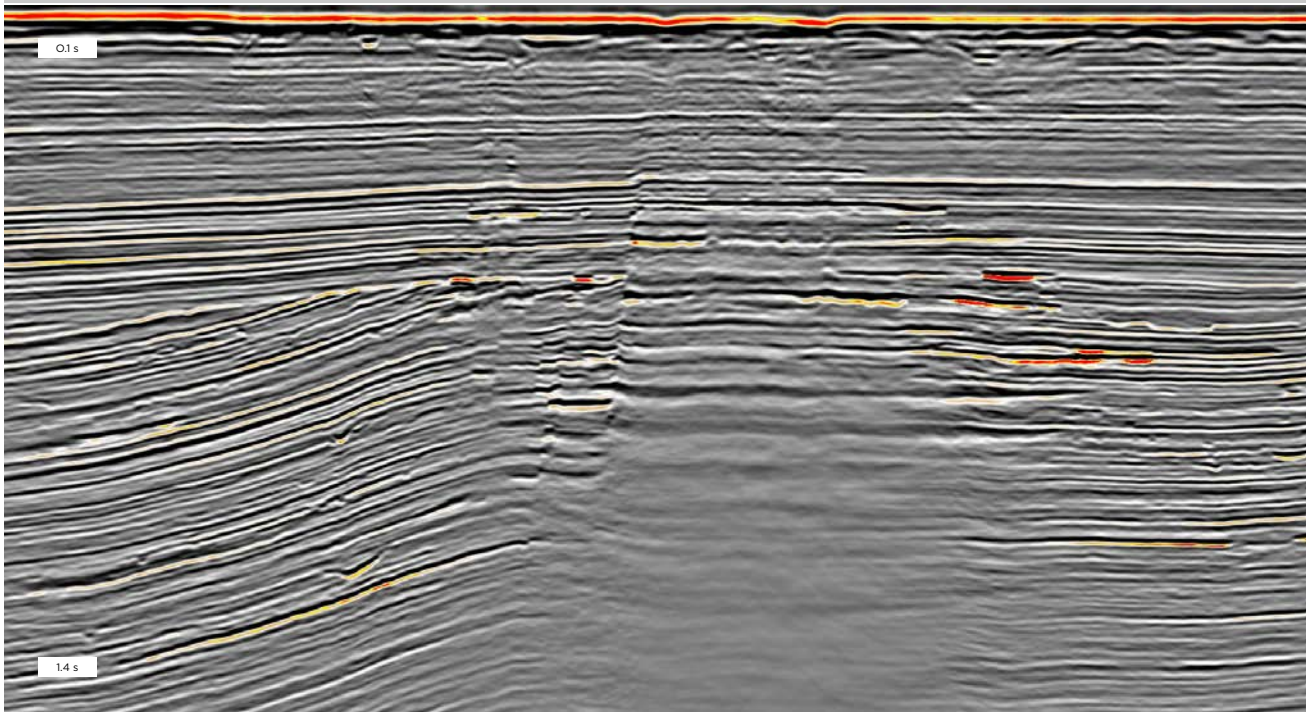
DUG TomoQ MODEL



03. Section showing a 1/Q model, derived using DUG TomoQ. The result shows high 1/Q layers (in blue/purple) corresponding to shallow gas, which are conformable to a four-way dip closure. This model was used to produce the DUG MigQ result shown in Figure 05.

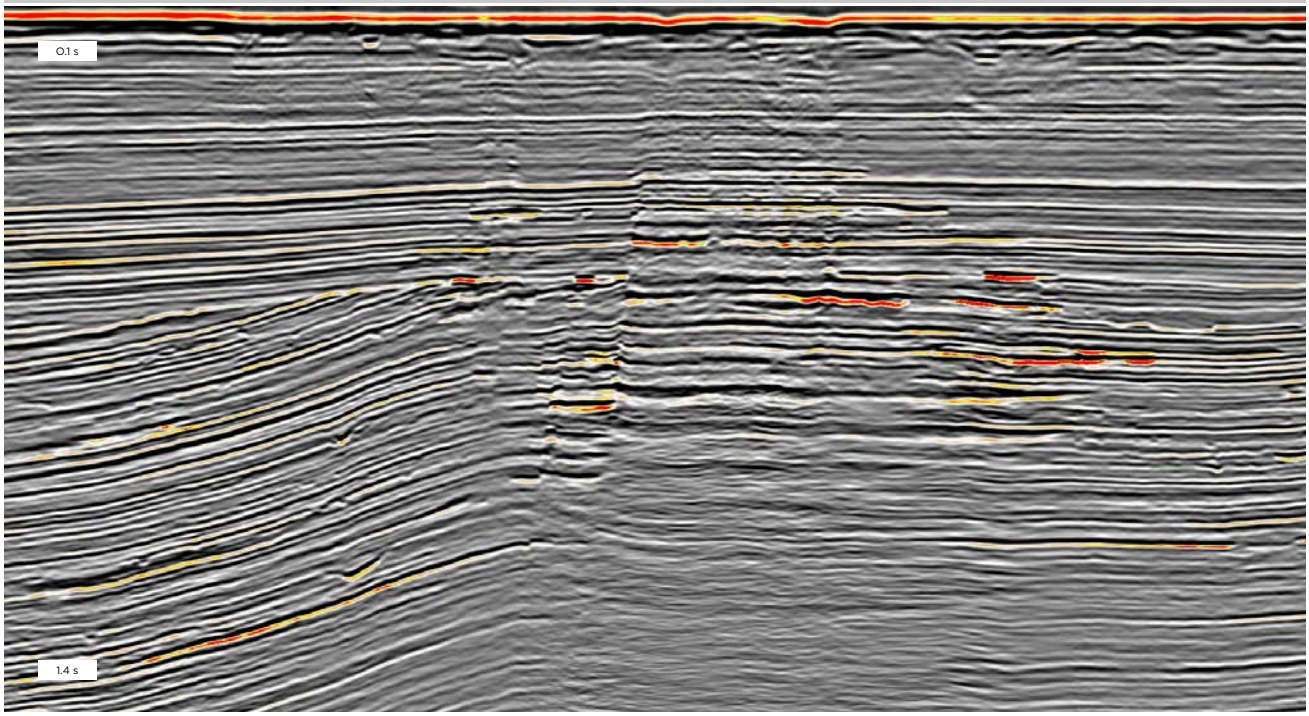
DUG MigQ AND TomoQ

WITHOUT DUG MigQ



04. Full stack section after Kirchhoff depth migration.

WITH DUG MigQ



05. Full stack section after DUG MigQ.

DUG RTM

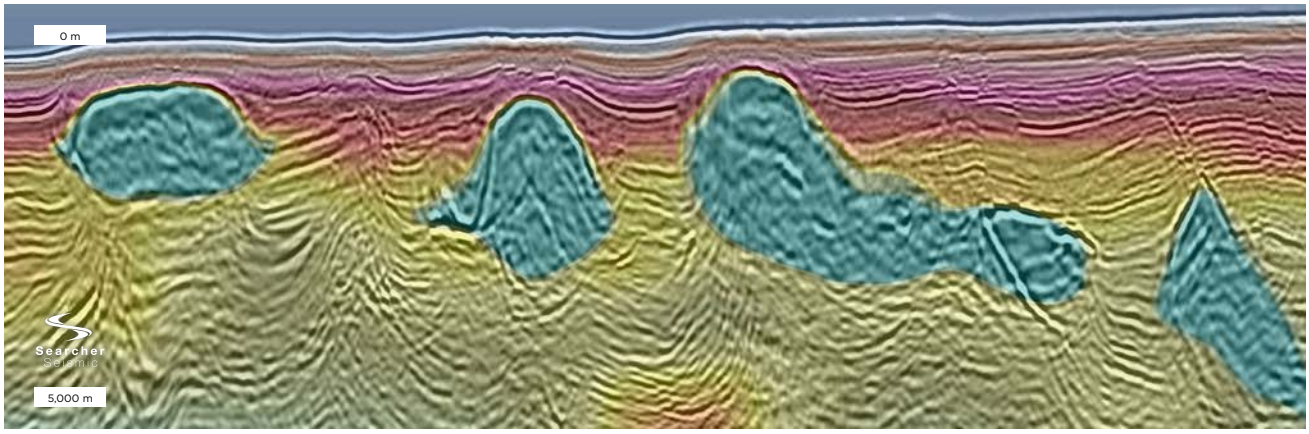
RTM is a two-way, wave equation migration that operates in the shot domain.

All forms of complex propagation pathways can be accurately accounted for including turning rays, caustics (multi-arrivals) and prismatic waves. DUG RTM is therefore capable of handling extremely complicated structure and abrupt lateral velocity changes. This results in superior imaging - both positioning and amplitudes - in geologically complex environments such as salt, very steep dips and complex rugose overburden. DUG RTM can output gathers for model updates, and can be used on 2D or 3D data, both marine and land.

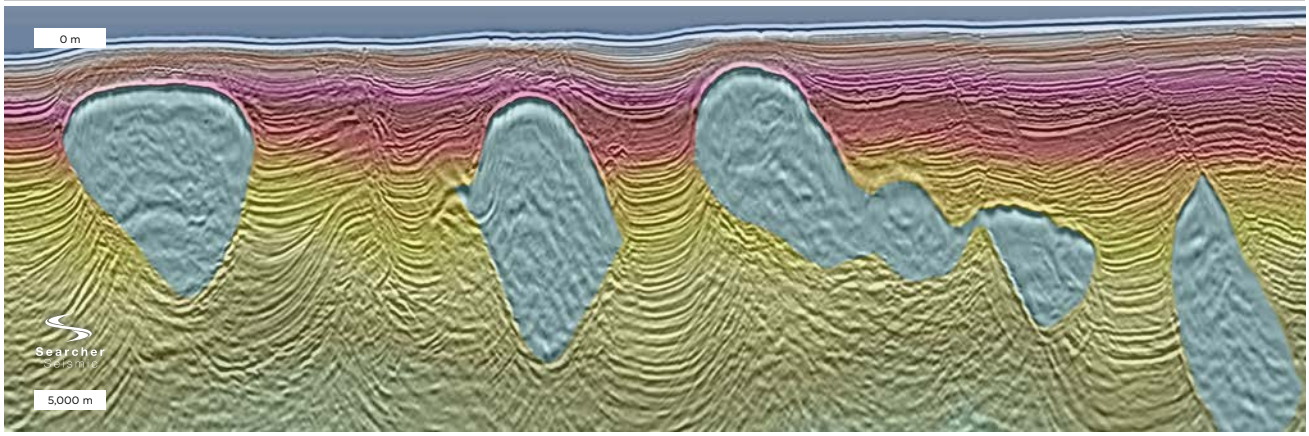
FEATURES OF DUG RTM INCLUDE:

- Output sparse or dense angle gathers or surface offset gathers (SOG)
- State of the art post-processing toolkit and interpretation products
- Isotropic and anisotropic (VTI, TTI)
- Vector offset output (VOO) for high SNR images to aid interpretation
- DUG sRTM for rapid scenario testing
- DUG Q-RTM to compensate for laterally and vertically varying Q
- DUG LS-RTM for better illumination, improved resolution and amplitude fidelity

SALT IMAGING WITH DUG RTM - LEGACY MODEL



SALT IMAGING WITH DUG RTM - FINAL MODEL



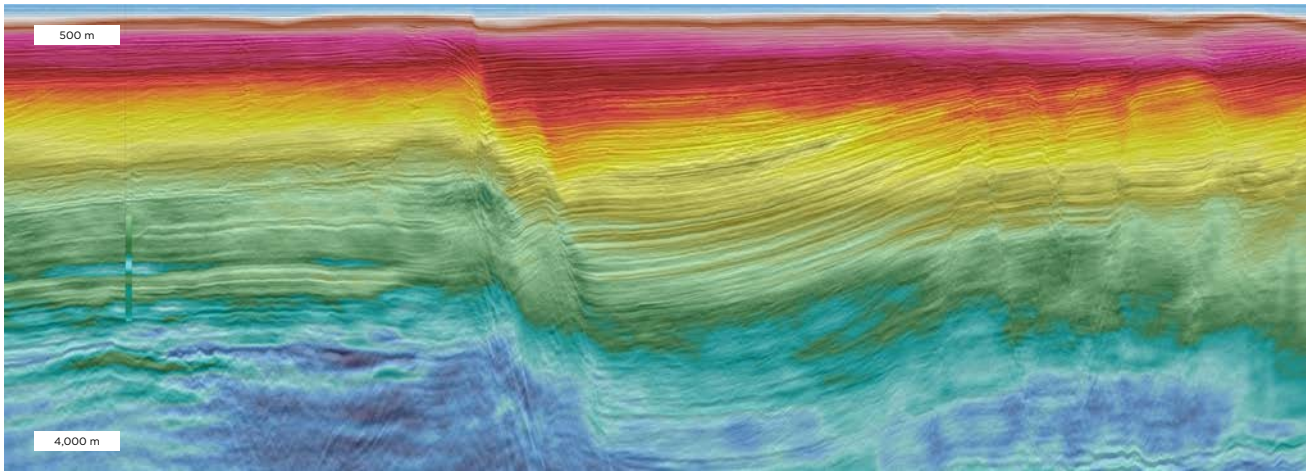
06. Top: 20 Hz RTM with legacy interval velocity model overlay. Bottom: Final anisotropic (TTI) 30 Hz RTM, overlain with the final interval velocity model. A comprehensive salt model building workflow was an integral part of this project (South Campeche 3D Ultracube).

FULL WAVEFORM INVERSION (FWI)

FWI utilises the entire wavefield to generate refined, high-resolution velocity models for imaging and characterisation.

FWI iteratively updates an initial model by forward modelling synthetics and comparing them to field data. In order to generate synthetics, we have to reproduce the seismic experiment that we carried out in the field. This requires knowledge of the source wavelet, the acquisition geometry, and the physics of 3D wave propagation. Just as the physics of wave propagation is non-linear, FWI is a highly non-linear parameter estimation problem. As part of our DUG Wave software infrastructure the FWI implementation can incorporate isotropy, VTI, TTI and Q.

AFTER FWI



07. FWI model, co-rendered with the seismic data. Note the stratigraphic and structural details in the FWI model. Data courtesy of Shell NZ.

WE'VE GOT THE POWER

DUG utilises its own proprietary depth imaging toolkit that has been developed to meet the requirements of the most demanding regions on earth.

State of the art, highly parallel codes take full advantage of our high-tech supercomputing facilities and co-processor technology. DUG boasts some of the largest privately owned supercomputers in the world with high-tech data centres in Perth, Houston, London and Kuala Lumpur. We have developed (Patent Publication WA 2017/091862A1) our own dielectric fluid-cooling solution which has greatly reduced our energy usage and costs, increased the life and efficiency of our hardware, and given us some of the greenest compute centres on the planet. Our supercomputing technology allows us to turnaround large projects much faster for our clients. In an industry where time is both critical and valuable, our innovative solutions have given us a significant competitive advantage.

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