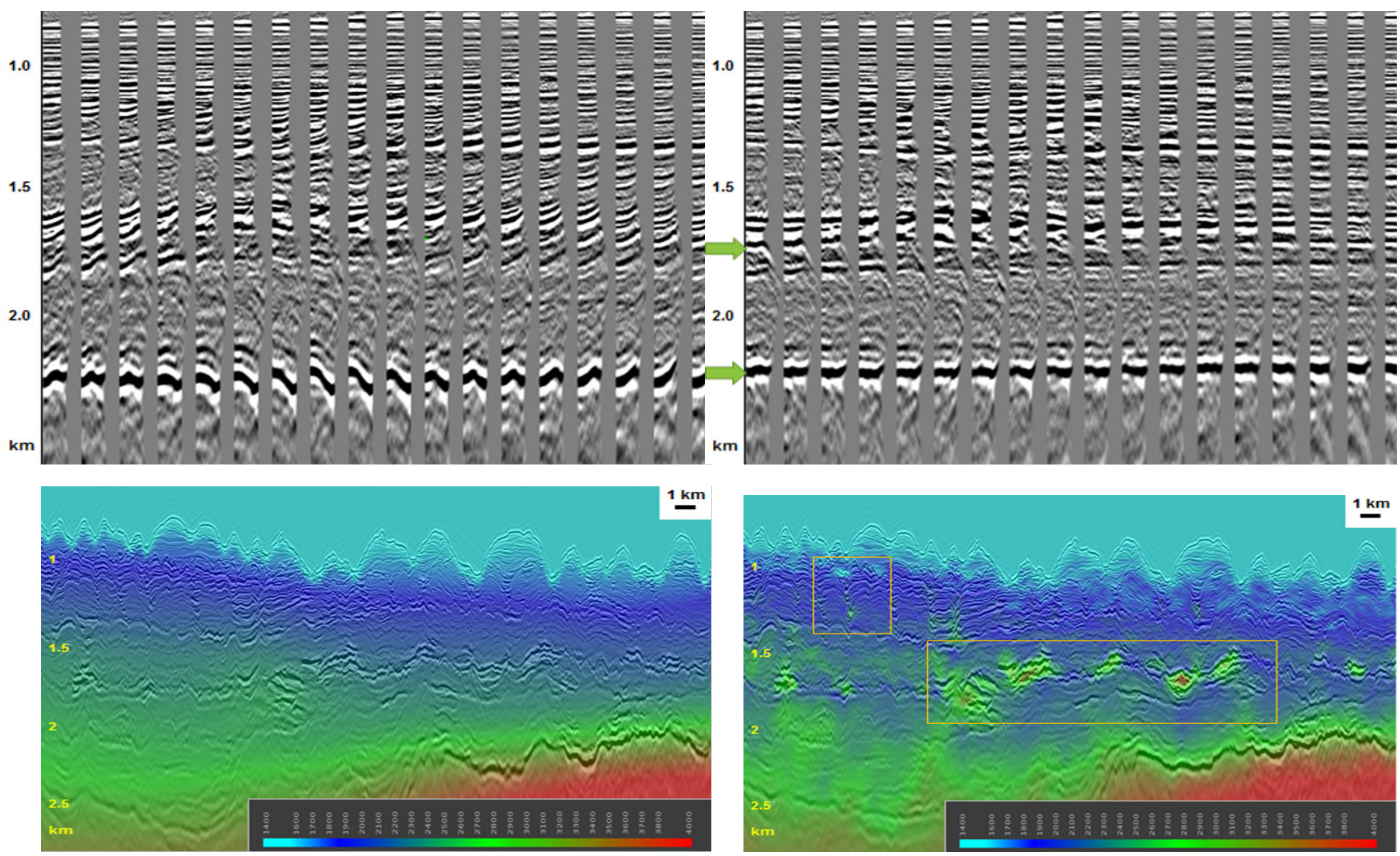
DATA SHEET

Tomography

Building and employing accurate velocity models as input to the pre-stack depth migration process is critical in generating accurate subsurface images. In geological environments where the sediments are not overly compacted, the iso-velocity contours tend to follow the seabed. In such cases, a purely gridded representation of the subsurface could be appropriate. For older, more compacted sediments, a purely layer based approach could work. However, for a model of general complexity, we often need to combine a gridded velocity distribution along with discreet layers (for example, the surface of a salt body in an otherwise simple gridded velocity field, or perhaps for a hard chalk layer, with subtle lateral and vertical variations within the chalk). We refer to a model which permits both layers and gridded parameter distribution within layers as a 'hybrid-gridded' model. With this flexibility in mind, ION has developed a hybrid-gridded TTI tomographic solution, using a 3D conjugate gradient technique, which can not only accelerate the velocity model building process, but also provide higher resolution velocity models. High density residual moveout picks on offset or angle gathers are generated automatically for a dense grid of depth migrated gathers and used as input to the tomography with an associated dip and coherency field. Tomography then adjusts the velocity model iteratively to minimize residual moveout in the depth gathers and subsequent depth migrations until the solution coverages. The conjugate gradient approach permits the building of coherent 3D models by the solution of very large tomographic systems.

The example below is from deep water offshore Sri Lanka, where the sea floor is incised with deep canyons, and the sedimentary sequence below these shows clear evidence of the presence of buried paleo-canyons with significant lateral velocity variation in comparison to the surrounding sediments. For the vast majority of



the study area, parametric picking and ray-based hybrid gridded tomographic inversion worked well. However, this conventional 2nd and 4th order residual moveout picking of CRP PreSDM gathers failed to capture the short wavelength velocity variation associated with the buried canyons, thus limiting the ability of subsequent ray-based tomographic inversion to resolve the required level of complexity. The top figures show the gathers after inversion with parametric (left) and non-parametric (GMO) picking (right). The GMO tomography results are clearly superior. The corresponding models and images are shown in the lower figure.

Key Features and Benefits

→ **Accuracy**
Tomography updates the velocity model along ray-paths, thereby taking into account the actual propagation in the media. It solves the entire medium simultaneously and there is no top-down accumulations of errors. This makes the velocity model accurate for any migration and greatly improves the imaging of the subsurface.

→ **Resolution**
A large number of automatically derived parametric or non-parametric input picks provide dense horizontal and vertical sampling of the velocity field. The resultant high signal-to-noise ratio yields a high resolution final velocity field. This makes the technique appropriate for obtaining more accurate velocity solutions in complex, rapidly varying velocity media.

→ **Non-parametric Autopicking**
For moderately complex media, it is practical to characterize the residual moveout behaviour by fitting a smooth 2nd or 4th order moveout trajectory to the reflection events in the migrated CRP gathers. However, for shorter wavelength velocity variation (on a scale length of a few hundred meters), non-parametric picking is preferred. Such generalized moveout (GMO) behavior permits us to better characterize residual moveout anomalies, thus permitting the back-propagation of residuals in the tomography to better localize the velocity anomalies that gave rise to these RMO features.

→ **Anisotropy**
Our TTI scheme has the option to invert for any combination of velocity, epsilon, and delta, depending on what external constraints are available. Automated higher order moveout picking is used to obtain the initial eta field that is input to the process. An orthorhombic tomographic solution is also available.

→ **Geological Flexibility**
The choice of purely gridded or hybrid gridded tomography is often geology dependent. In compaction driven environments or in poorly illuminated areas, where picking layers is inappropriate, the gridded tomographic solution is the best approach. The hybrid gridded method is the best in areas where we have stratigraphically bound rapid lateral velocity change.

→ **Quality Control**
Displays such as the original velocity field, the new velocity field, stack section before and after tomographic simulation with new velocities, pick quality indicators, and dip field sections allow the user to perform extensive quality control at every step of the iterative tomographic process.

→ **Efficiency**
Parallelized implementation of ray tracing and conjugate gradient inversion has enabled ION to undertake large 2D and 3D tomography projects efficiently and productively.

→ **Application**
Land and marine 2D and 3D seismic data, including multi-azimuth, wide-azimuth (see below), streamer and ocean bottom marine data.

Wide Azimuth Tomography

Wide azimuth (WAZ) tomography is a natural extension of narrow azimuth tomography. ION's WAZ tomography supports isotropic and anisotropic model parameter determination. For anisotropic models the tomography is used to determine not just velocity updates but also updates to the anisotropy parameters epsilon and delta. The input to the WAZ tomography program is migrated gathers. Several types of migrated gathers are supported. The choice of which type gather to use depends on the complexity of the depth velocity model being determined. For sedimentary basins and in areas above and around salt, the standard input is

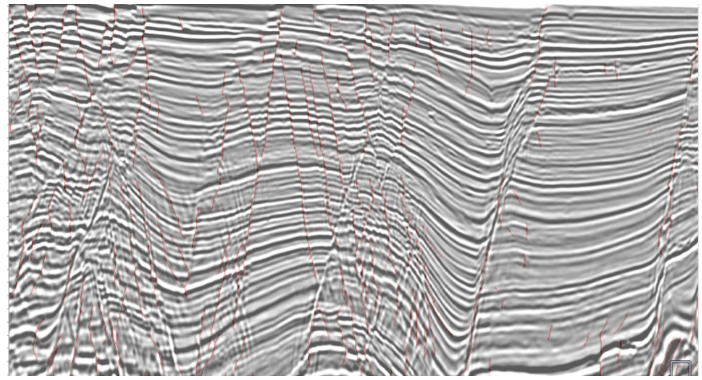
Kirchhoff or beam migration generated gathers. In areas below significant velocity complexity where multi-pathing is an issue, angle gathers generated with reverse time migration (RTM) migration are the best choice.

For WAZ data, the Kirchhoff gathers are parameterized by either offset and azimuth or offset vector tiles. The number of azimuths and offset vector tiles will depend on the input acquisition geometry. If offset and azimuth gathers are generated, residual move-out (RMO) is picked for each azimuth and input into the tomography update program as a separate RMO cube for each azimuth. If offset vector tiles are chosen, the two RMO cubes are input to tomography that best represent a 3D RMO surface for each migrated reflector. The angle gathers that are input to tomography for WAZ data are true 3D angle gathers that are parameterized by reflection angle and the reflection azimuth. Generating angle gathers with these two parameters allows for the tomography program to uniquely identify the 3D ray paths necessary to update the velocity model even when the velocity field is complex.

Updates to the velocity and anisotropy parameters are determined using 3D ray tracing and user controlled constraints. The constraints can be simple constraints that control the degree of model parameter variation in the model, i.e., smoothness constraints, or well type constraints that penalize updates to the model that drift away from well information or user input.

Structural Constraints & Automated Fault Detection

Our tomography incorporates the use of well constraints in multiple forms: e.g., check-shot travel time, depth point pairs and depth point, depth mis-tie pairs are supported. Due to the grid-based nature of our tomography, well constraints lead to localized velocity updates if they are supplied only at isolated well locations. In order to propagate mis-tie information away from wells in a geologically consistent manner, it is necessary to interpretively populate horizon maps with Δz values. Non-well geological information can also be incorporated using this mechanism; for example, we can use it to reduce velocity “push-downs” or “pull-ups” based on structural smoothness requirements as opposed to gather flatness requirements. This



offers the additional constraint of seeking a tomographic solution so to match a specific user defined horizon, such as an oil-water contact (which we may know to be flat and at a certain depth), or a smooth linear flat or dipping regional base salt glide plane.

ION uses structural tensors derived from our SOSE (Structural Oriented Smoothing) technology to constrain tomographically inverted velocity and anisotropy fields. The two key steps in this process are the automatic generation of 3D dip fields used in the smoothing, and the automatic detection of fault planes and other discontinuities in the structure where the smoothing is stopped. The latter capability also means that in low coherency zones the smoothing is applied along all directions, while in high coherency zones it is applied only along the bedding plane.

Using our structurally constrained GMO tomography method, we can resolve small-scale geologic features and preserve discontinuities across faults to create a velocity field that accurately represents the subsurface geology. The net result is a dramatic improvement in the resultant image quality. As a by-product of this fault-aware tomographic approach, we can also note the location of the fault discontinuities detected by the scheme, so as to provide an interpretational guide. The picture above shows an actual fault network detected on a marine RTM image. The fault network is used in the tomography to prevent smearing of velocity across fault boundaries.

Last updated June 2, 2021