Reverse-Time Migration for Borehole Seismic

High-resolution, near-wellbore depth imaging in areas of complex geology

APPLICATIONS
■ Deepwater exploration
■ Subsalt reservoir characterization
■ Other complex geological settings

BENEFITS
■ Enables simultaneous imaging of upgoing and downgoing energy
■ Improves earth model calibration using borehole tomography
■ Facilitates integration of surface and borehole seismic data
■ Provides higher-quality depth migration than ray-based methods
■ Enhances the vertical and lateral extent of 3D vertical seismic profile (VSP) images
■ Optimizes well placement and hydrocarbon production

FEATURES
■ Computes numerical solutions to two-way wave equations
■ Extends reverse-time migration (RTM) from vertical transverse isotropy (VTI) to tilted transverse isotropy (TTI) and vertical or tilted orthorhombic (VOR, TOR) anisotropy
■ Runs efficiently on high-performance parallel graphics processing unit (GPU) computing clusters
■ Uses the same industry-leading Omega® geophysical data processing platform RTM algorithm as 3D surface seismic processing
■ Refines structural boundaries in velocity model building
■ Accurately delineates subsalt and other complex reservoirs
■ Correctly handles kinematics in areas of complex anisotropy

Overcome uncertainty in spatial positioning of reflectors
As exploration and development activities expand into more complex geological settings worldwide, geoscientists face increasing difficulties in accurately imaging the subsurface using conventional 3D seismic acquisition and processing methods.

In environments with highly complex structure, velocity, and anisotropy—such as sedimentary basins with steep salt inclusions and subsalt reservoirs—traditional ray-based seismic imaging algorithms leave considerable uncertainty in the spatial positioning of target reflectors. Operators need more reliable velocity models and more rigorous imaging methods to properly delineate reservoirs, optimize well placement, and boost hydrocarbon recovery.

RTM is an ultra-high-end prestack imaging algorithm that computes numerical solutions to a two-way wave equation. It enables simultaneous imaging of both the upgoing and downgoing energy. RTM is not limited by steep structural dips or multipathing. It correctly handles kinematics in areas of complex anisotropy including VTI and TTI or VOR and TOR anisotropy.

Integrate 3D surface seismic with borehole seismic imaging
Historically, RTM was deemed impractical due largely to high computational costs. Over the past few years, increases in massively parallel GPU computing clusters and lower costs, coupled with more accurate velocity model-building workflows, have enabled RTM to emerge as the industry’s algorithm of choice for accurate 3D seismic imaging in structurally complex areas. Currently, RTM is applied primarily to 3D surface seismic data to image anisotropic reservoirs in subsalt plays. It has a proven track record for refining structural boundaries during velocity model construction and for generating more detailed final depth images.

Two 3D VSP RTM images from the same finite difference synthetic, one with 160 receivers and one with 20 receivers. The resulting SEG Advanced Modeling (SEAM) compressional-wave velocity ($V_p$) image on the left clearly illustrates the benefits that longer arrays can bring to 3D VSP RTM imaging.
Schlumberger provides RTM for processing high-end 3D VSPs with the same Omega platform used for surface seismic processing. Previously, the use of RTM with borehole seismic was limited due to short downhole receiver arrays, but longer arrays are making it an increasingly practical solution for 3D VSP imaging.

RTM is ideal for complex geological environments where operators need higher-resolution imaging in the vicinity of the wellbore than surface seismic can provide. 3D VSPs provide useful estimates of near-wellbore anisotropy and improve earth model calibration through direct wave, common image point (CIP) tomography, or both. Now geoscientists can use the same calibrated earth model for both surface and borehole RTM imaging.

The capacity of the large Schlumberger high-performance computing infrastructure maximizes the efficiency of RTM processing. In addition, Schlumberger software and acquisition technologies for borehole seismic and surface seismic provide comprehensive seismic services—from presurvey design and acquisition through model building, processing, and imaging.

**Enhance reservoir delineation and imaging of geological features**

In areas of high structural dip and relatively complex vertical or tilted anisotropy, RTM for 3D VSP can simultaneously image the upgoing and downgoing energy with minimal reprocessing. Field tests show that with large downhole arrays RTM provide a high-end borehole seismic imaging solution with far higher quality than traditional ray-based methods.

With full wavefield imaging, a specific advantage RTM provides is that it increases both the vertical and lateral extent of the 3D VSP image. This enables operators to improve the spatial positioning of reflectors, more accurately delineate reservoirs, and image finer geological features.

High-resolution images can even identify small-scale faults and channels in a deep subsalt reservoir. For example, building a 3D tilted TTI model of the reservoir incorporating these features, generating a high-frequency 3D VSP data set with TTI finite difference modeling, and imaging the data with RTM could successfully reveal such fine structural and stratigraphic details.