Common Reflection Angle Migration

Next-Generation Imaging in the Local Angle Domain

A subset of Paradigm EarthStudy 360™ Imager, CRAM provides fast, target-oriented solutions for local analysis and imaging on a regional scale.

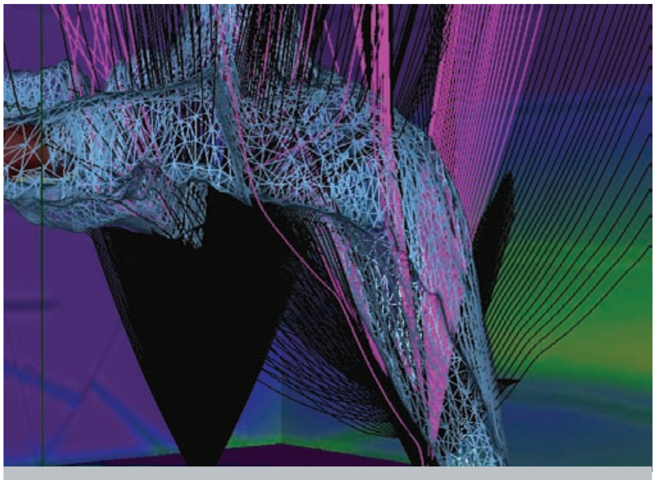
Imagine a migration solution that maintains all the flexibility of ray-based Kirchhoff and beam migrations while inheriting the desirable properties of full wave migrations. Paradigm has captured a new perspective on ray-based imaging and implemented it as a solution that can be applied to a broad range of exploration and development imaging objectives.

Referred to as the Common Reflection Angle Migration (CRAM), this prestack depth migration seeks an optimal illumination of the subsurface image points from the available recorded dataset with its given acquisition geometry. The migration is based on a special "bottom-up" ray tracing operator, where a set of dense rays are shot in all directions from every image point up to the acquisition surface. Directions can be set either with respect to the vertical axis or with respect to the Normal to the reflecting surfaces at the image points. Throughout the migration, all possible arrivals are taken into account to perform in situ reflection angle gathers, where kinematic and dynamic characteristics, accurately computed along the rays, ensure that amplitudes and phases of the migrated angle dependent reflectivities are preserved.

CRAM as a Beam Migration

CRAM is naturally a beam migration, but unlike conventional beam migrations where the beams are formed before the migration, the beam forming in CRAM is performed on-the-fly within the migration. For each central ray pair, scattered from a given reflected point (element) and arriving to the acquisition surface, a local slant stack operation is performed. The summation's slant is taken from the "source ray" and "receiver ray" directions at the surface, and the size of this operator is related to the computed Fresnel zones at the "source ray" and "receiver ray" locations. These optimal beams are then extrapolated along image points in the vicinity of the central image points, where the extrapolated volume is defined by subsurface Fresnel radii. This procedure enhances the imaging of primary events and substantially attenuates different types of multiples as well as various types of random and coherent noise.

With this new imaging perspective, CRAM is able to use the entire wavefield within a controlled directivity aperture, making it ideal for both full-volume and target-oriented migrations along specified exploration or development targets. More importantly, by formulating the migration in the local angle domain, the program is able to output true angle domain image gathers in depth, the natural domain for analyzing residual moveouts for velocity model determination and for performing seismic inversions.



▲ 3D CRP ray tracing in all directions and angles

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Benefits

Improved Imaging

CRAM is an anisotropic multi-arrival beam solution that uses the entire wavefield, making it ideal for solving complex imaging objectives, including overthrust and subsalt delineation.

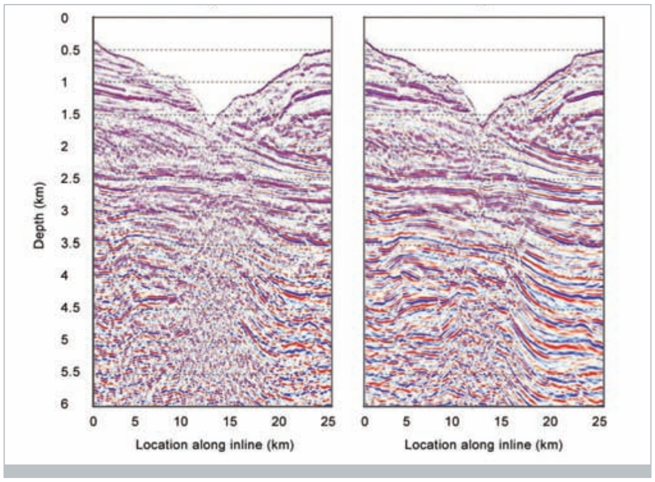
Improved Amplitudes

Amplitude preservation of the migrated angle dependent reflectivities depends on two main factors: subsurface illumination and the ability to account for energy loss throughout wave propagation. CRAM performs imaging in the local angle domain to accurately account for poorly illuminated subsurface areas and directions. Additionally, the required theoretical amplitude and phase characteristics are computed along the traced rays to be used as accurate summation weights within the construction of the final reflectivities. Support for Q Compensation during the imaging process improves resolution, amplitude balancing and image quality by compensating for dissipation and attenuation effects resulting from gas hydrates or gas clouds. Q Compensation enables amplitude and phase preservation and ensures higher-resolution imaging results.

The output common reflection angle gathers are ideally suited for seismic reservoir characterization objectives like AVA and amplitude inversions.

Improved Flexibility

CRAM is an output-driven migration with the ability to control and target its output along or at specific exploration or development targets. It can use additional background subsurface directivities (in situ dip/azimuth specular direction) to orient the ray tracing and the direction of the corresponding ray pairs in the proximity of the background directivities.



▲ Imaging a “hidden” structure in offshore Australia: Kirchhoff depth image on the left, full-azimuth specular weighted image on the right

New Opportunities

All of the properties of CRAM make it ideally suited for field development projects that use time-lapsed (4D) acquisition surveys.

Increased Technical and Operational Complexity

Exploration and Development geoscientists are required to generate subsurface images in areas of increasing technical and operational complexity. Imaging in the local angle domain provides a vehicle for dealing with this complexity. CRAM is ideal for the following types of imaging challenges:

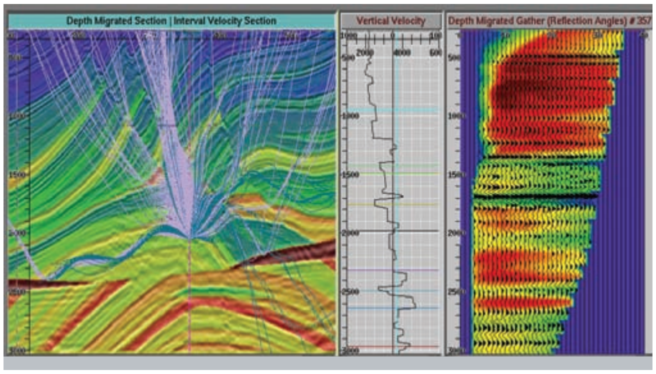
- Positioning of anisotropic overthrusts
- Qualifying subsalt reflectors
- Resolving stratigraphic or velocity detail
- Recovering reflectivities
- Predicting pre-drill pore pressure

Uniform Illumination

CRAM constructs true angle gathers by summing all seismic events with the same reflection/diffraction angle. By performing a uniform illumination of the image point, all arrivals are included and all amplitudes and phases are preserved. Using the information provided by the specular rays and the corresponding Fresnel zones, a count of the number of reflections contributing to each image point and each reflection angle can be made. These illumination factors can be posted (see image below) on the common image gather, an extremely useful diagnostic for understanding both amplitude behavior and the capacity of the recorded data to illuminate the subsurface.

Platform support

The Common Reflection Angle Migration is an add-on to the Paradigm GeoDepth™ velocity modeling and imaging solution. It is available on Linux clusters running 64-bit Red Hat® Enterprise Linux® 6.8 and subsequent minor releases, and 7.1 and subsequent minor releases.



▲ RMO analysis using CRAM angle gathers

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