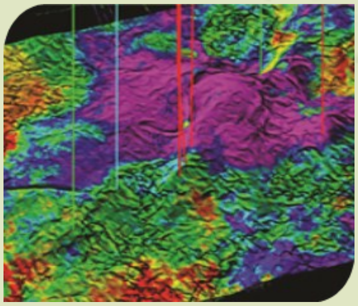
Beam Migration



Integral migration techniques such as Kirchhoff, equivalent-offset, and beam, set-out to solve a representation of the wave equation using a high frequency approximation, whereby each arrival is treated as a spike-like event, and the superposition of these events with appropriate amplitude scaling, reconstructs the final image through superposition of stationary phase components.

The greatest strength of integral techniques (in comparison to wavefield extrapolation techniques) is their cost-effectiveness. A fundamental feature of these techniques is that the image can be computed for a subset (e.g., for a gather, a depth slice, an image line, etc.). The dip limitation also is specified readily in integral techniques during travel time computation or during the summation step. In addition, integral techniques are very well suited to imaging the steepest dips.

The most widely used technique in this category is the single-arrival Kirchhoff integral, which usually is implemented in the time-space domain. In Kirchhoff migration, the migration process is separated into two stages: computation of the travel times along ray-paths through the velocity model, and summation of information associated with these travel paths.

For beams migration, we can conceive of there being three stages in the process: measurement of the time-dips present in the input data, computation of travel times associated with these time dips, and summation of information associated with these travel paths. In comparison with Kirchhoff migration, beam techniques have the advantages of dealing with multiple arrivals and of keeping costs down by computing operators only in the vicinity of a narrow trajectory. Depending on the beam scheme employed, this dip representation may be comprehensive or it may be sparse (designed to characterize only the significant features of the data).

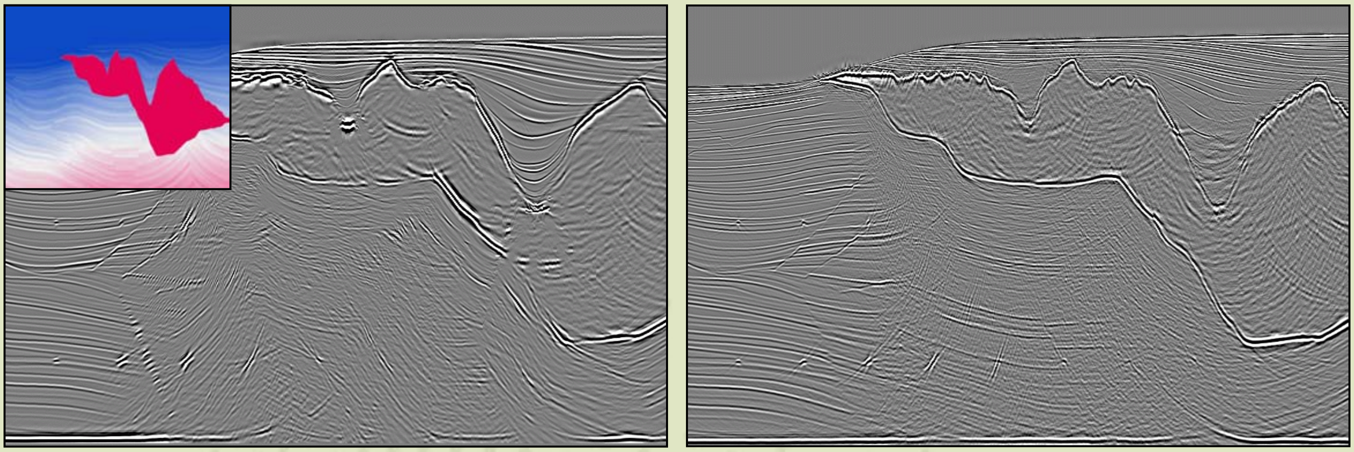
Although we may only need to compute the input time-dip fields once even when we are imaging with a collection of different velocity models, we still need to image the data in a manner consistent with the sampling of our dip fields. In the case of the sparser representations we may convert the time-dips into source and receiver position emergence angles (as a function of velocity).

For beam schemes, the objective is to link the surface take-off (emergence) angles at both the source and receiver locations to the possible ray paths that impinge on a given subsurface reflector segment. This is done for all subsurface segments, and an image computed using only contributions close (within a Fresnel zone) of this ray corridor. Implementations may simplify the picking by only defining dips in well sampled domains (for example offset) and then performing searches or integrals during the imaging, or an implementation can pick in a collection of domains to attempt to uniquely define the propagation for a given piece of data. Picking local time-dips in two directions for a given segment at a given arrival time on data in two distinct domains, for example both shot and receiver gathers, enables this objective to be accomplished, as long as we can identify and link the coherent event in both gathers. To convert the time-dips to angles, we need a velocity field, and this is updated in an iterative way, as for other migrations.

Once the travel times or ray angles have been computed, we then need to select samples that will contribute to each image point. For Kirchhoff migration, we collect the samples within some aperture and dip limit for which the travel times have been computed. For beam migration, we collect data samples in the vicinity of the computed ray tube, such that a Fresnel zone is encompassed, and only coherent energy thereby summed to form the image. In some beam schemes, a representative wavelet is used to emulate the data at each contributory picked dip segment, and these wavelet contributions summed to form the image.

In ION GX Technology's (GXT's) implementation of both 2D and 3D beam migration, we pick local time dips in the input shot and offset domains. Local tau-p measurements are made and combined with thresholding on amplitudes to select the dominant constituents of the data. Ray paths are computed from the surface source and receiver positions, and travel times along these paths analysed to determine the intersections of the path from the source and receiver sides, so as to find the image point for this particular ray path. Energy associated with this image element is then summed into the output image space taking account of the Fresnel zone.

GX Technology has implemented a version of beam migration tailored for either fast CRP gather production, or noise-restricted final images. The fast CRP option is best suited to aid in iterative velocity model update in producing clean gathers for auto-picking, but with restricted lateral resolution. Using a more demanding parameterization of the process can give a clean image whilst retaining acceptable lateral resolution: this latter option is useful for final image production.



Sigsbee synthetic data and model, with a comparison of a Kirchhoff (left) and beam migration result (right). Under a salt structure such as that seen in this synthetic example, multi-arrival events play a significant role in imaging sediments under the salt, and these are well-imaged by the beam migration, but are not addressed in a mono-arrival Kirchhoff scheme.

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