



REVERSE TIME MIGRATION: COLLAPSING CYCLE TIME

To make timely decisions, oil companies need both good quality images and fast turn around on projects. Typically both Kirchhoff and Reverse Time Migration (RTM) are used in the imaging cycle, which slows down the process and ultimately costs the company.

The solution is to collapse the imaging cycle. In order to accomplish this, we first take a look at the current imaging cycle. In comparing migration methods, it is not sufficient to compare the migration outputs alone. Instead, the entire processing flow must be analyzed. Table 1 shows a representation of traditional processing and imaging work flow for a typical depth imaging project in the Gulf of Mexico.

The typical flow consists of at least two iterations to define the salt – one for the top and one for the base. The base of salt iteration is typically done using a combination of Kirchhoff and wave equation migration (WEM) to overcome the limitations of each algorithm. For more complex or recumbent salt bodies, additional imaging iterations are required to define the salt, using a combination of Kirchhoff and WEM migrations. The last step is to generate WEM and Kirchhoff images with the final velocity model. The traditional flow uses a combination of Kirchhoff and WEM due to their respective deficiencies to build the salt model.

Generating understanding and forming a coherent model from two different images at each iteration is a lengthy process. As oil companies have limited staff to do this work, it puts significant strain on an exploration team, and model building slows the prospect generation process. In short, each migration takes a finite amount of time to run. It ultimately takes time to understand each image and build a coherent interpretation from two separate sets of images. Additional time is also spent readying the data for interpretation.

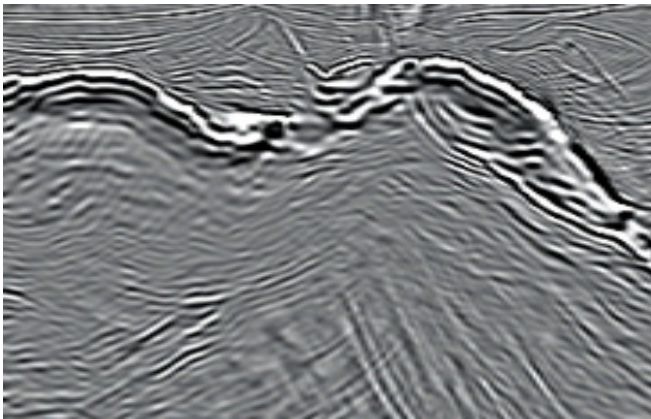
Table 1: Imaging work flow methods

Representative Imaging Flow	RTM Based Imaging Flow
3D SRME multiple attenuation	3D SRME multiple attenuation
Kirchhoff based tomography to establish sedimentary velocity field	Kirchhoff based tomography to establish sedimentary velocity field
Kirchhoff sedimentary flood migration for top salt	RTM top salt
WEM flood for base of salt + Kirchhoff for steeply dipping areas of salt	RTM for bottom salt
Repeat two previous for recumbent salt interfaces	Repeat two previous for recumbent salt interfaces
WEM based sub salt tomography or scans	RTM based sub salt tomography
WEM & Kirchhoff final migrations	RTM final Migration

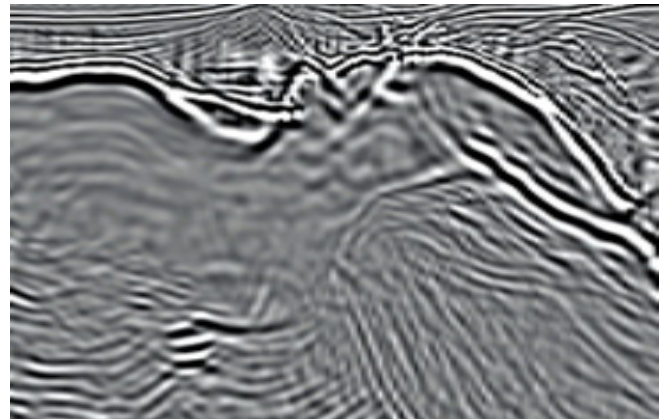
In contrast, the current RTM based model-building flow replaces two different migrations with a single imaging algorithm that is able to simultaneously resolve both complexity and steeply dipping interfaces. Not only is one migration run at each step, no time is required to understand how to combine the interpretation of the two separate images. In addition, the quality of the RTM image will be superior to either of the two Kirchhoff and WEM images, and this will reduce the project cycle time.



To help see the impact that RTM has on cycle time reduction in a real world context, lets consider a small 1200 sq km (approximately 50 OCS blocks) exploration project in the Gulf of Mexico.



A subsalt image generated with WEM technology, showing poor imaging of salt and subsalt reflections.



A subsalt image generated with RTM technology, showing significant improvement in imaging of salt and subsalt reflections.

First consider the base of salt interpretation phase for the traditional flow.

Let's assume that the WEM and Kirchhoff migrations both take one and a half weeks to run. For this analysis it is assumed that these runs are done sequentially one after the other. The total time for migrations is around three weeks. A typical base of salt based on WEM and Kirchhoff images will take about four weeks. Thus the total amount of time to image the base of salt is about seven weeks using the traditional flow. In contrast, the time to image the base of salt with RTM takes about the same amount of time as either a WEM or a Kirchhoff migration, but the time taken to interpret the image is typically only about two thirds of the time or in this case three weeks. Thus the total time for the RTM-based flow is four and a half weeks versus seven weeks for the traditional Kirchhoff and WEM flows. We can speed up the traditional flow by running the WEM and the Kirchhoff migrations in parallel, but the limiting factor in this process is the time it takes to interpret data. The key to reducing project cycle time is to reduce the time it takes to interpret and construct models.

At this stage it is worth adding an additional comment regarding the relative computational requirement of the imaging step for towed streamer wide azimuth geometries. The computer power needed for Kirchhoff migration only depends on the number of traces falling within the migration aperture. Standard exploration towed streamer wide azimuth surveys have a high fold, even though they have a relatively low shot count. This makes it very cost effective to image this type of data using shot based migration algorithms, such as shot domain RTM. As the objective of a survey moves from an exploration to a development phase, the fold count increases significantly while the shot effort still remains relatively low. For example, in rich azimuth acquisition techniques or node acquisition, the shot domain migration algorithms become significantly less expensive than Kirchhoff migration techniques. This makes RTM even more attractive than any trace-by-trace technique and there is no technical downside.

Reducing the time it takes to interpret the salt interfaces doesn't just depend on the quality of the migrated images. Most modern interpretation systems still assume that the top and base salt interfaces are relatively flat or nearly horizontal. In practice, salt interfaces are often steeply dipping, vertical or recumbent. Interpreting such salt interfaces is very difficult with modern interpretation systems. The current approach is to break the interfaces into a series of simple grids that are combined in the model construction process. Further, even though the steep salt flanks are clearly visible on the RTM images, auto picking software designed to pick 1D wavelets simply cannot interpret these interfaces that are visible on these more accurate images. In order to further reduce cycle time, better interpretation and model construction systems need to be developed.