A modeling study for imaging in structurally complex media: Case History
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Summary

Two dimensional finite difference seismic modeling of a complex geologic structure on the Muskwa area (See figure 1) was used to aid in seismic interpretation and the optimization of future acquisition and processing parameters. The depth/velocity model was derived from a balanced geological section in North Eastern British Columbia foothill inferred from a 1998 2D-seismic line (See Figure 2), acquired by Husky Energy Corporation, and 5 adjacent wells drilled from 1981 to 2003. The model contains a velocity inversion, rough topography and characteristic structures found in North Eastern British Columbia.

Both acoustic and elastic finite difference modeling techniques were used to simulate waves propagating in the complex medium and the most difficult structural styles to image were investigated. Eight locations in the model (see Figure 3) were studied, using single event Prestack Kirchhoff migration for both first arrival and maximum energy event criteria. The synthetic shot gathers were prestack depth migrated to investigate which migration algorithms would produce the best images in such a complex environments. Long offsets gave a better migrated image when the complexities of the near surface geology were minimal. When the near surface geology becomes more complex, the value of the long offset information in enhancing the image was more limited. Additionally, fine source & geophone spacing gave a somewhat better image, but reasonable images could still be obtained providing the spatial sampling was adequate and the known velocity/depth model was used for the migration. The synthetic model contains three noteworthy geological features: a box-fold on the west separated from a fault propagation fold on the east by a central syncline. To test if expanding the aperture could aid in imaging steep dips in the presence of the inverted velocity profile, the model was expanded a few kilometers to the west (See Figure 2). Imaging the more complex geology in the central part of the model, has to date only been successful in imaging geological dips of less than 30°.

The imaging potential of prestack depth Kirchhoff migration using maximum energy or maximum energy event criteria can be predicted. Inadequate aperture or spatial sampling will distort the point diffractors on a depth section. We will demonstrate the effectiveness of prestack depth Kirchhoff migration using first arrival and maximum energy traveltimes in processing the Husky line.

Introduction

Numerous modeling approaches can be distinguished by using the assumptions regarding the seismic data and subsurface structures in an attempt to simulate the seismic response to the subsurface structures. One of those approaches that can be used is the prestack depth Kirchhoff migration using first-arrival traveltimes. However, this approach has been shown to produce poor images in areas of complex structures. To avoid this problem, we used a vector wave migration Kirchhoff operator method and using new type of time field calculations called maximum energy time field that allows these models to be closer to the real geological conditions. Maximum energy traveltimes calculated in the seismic frequency band"
calculating the travel times that estimate the travel time of the
maximum energy arrival, rather than the first arrival time. This
method estimates a travel time that is valid in the seismic
frequency band, but not in the usual high-frequency
approximation. In other words, instead of solving the Eikonal
equation for the traveltime solving the Helmholtz equation to
estimate the wavefield for a few frequencies, then it was
necessary to perform a parametric fit to the wavefield to
estimate a traveltime, amplitude, and phase. The images
created by using these parameters as an example of using
maximum energy time field method using 80 shots at the
surface. In a Kirchhoff imaging algorithm it can be comparable
in quality to those created using a full-wavefield and finite
difference migration.

Theory and/or Method

Comparison between two pre-stack Kirchhoff depth
migrations of the synthetic model of the Husky Federal line in
North Eastern British Columbia were done by a different
method of generating traveltimes and different modeling types.
Maximum energy time field calculations revealed that more
parts of the syncline formations were more difficult to image
using the first arrivals (See Figures 4, 5). Additionally, fine
source & geophone space should give a better result, but
because of time computations and disk space this phase of the
project will be done on the second phase and the elastic
modeling requires more time and disk space while producing
the hatch patterns in the shot gathers. Maximum Energy time
field calculated from the twenty three shots showed the general
shape of the deeper part of the model where the energy is
coming from.

Conclusions

The imaging potential of the prestack depth Kirchhoff
migration using a maximum energy can be predicted, and the
opportunity exists to greatly enhance the accuracy of
interpretation in the structurally complex areas. One must take
great care in order to avoid the increasing runtime by
considering the above-mentioned summary table of estimated
run time which will make the method justified economically.
Furthermore, not having enough apertures will distort the point
diffractors into frowns on a depth section. Finally, it is our
intention to demonstrate the use of prestack depth Kirchhoff
migration using maximum energy, maximum rotor, and a
maximum vertical flow in processing the Husky line that has a
wide variation in surface elevations and a complex geology of
deformation pattern predominately box folds along with the
fault propagation folds and multiple detachment surfaces.

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FIG. 2. (a). Compressional velocity model where
velocities range 3600-6050 m/s, section length = 25
km, section depth = 6 km. (b). Shear velocity model
where velocities range 1500-3551 m/s, section length
= 25 km, section depth = 6 km. (c). Density model
where densities range from 2-2.75 kg/m³, section
length=25 km, section depth=6 km.
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FIG. 3. Colored-overlay plot of velocity model on the Kirchhoff PreSDM section, model size = 29 x 6 km, letters corresponds to eight locations analyzed in this study.

FIG. 4. (a) LithoTech Balanced Geologic/velocity Model of North Eastern British Columbia created from Husky seismic line, using the velocities from five wells on or near the line which is expanded to the east and the structural complexity was removed on the west to help in imaging. (b) Kirchhoff Pre-stack depth migration with Migration Aperture 5500m, using Acoustic modeling on first arrival travel time for 80 Shot points with source interval 270m, and 966 Receivers with group interval 30m, 25 Hz Ricker wavelet, 2ms sample rate.

FIG. 5. Kirchhoff Pre-stack depth migration with Migration Aperture 5500m, using Acoustic modeling on Maximum Energy travel time for 80 Shot points with source interval 270m, and 966 Receivers with group interval 30m, 25 Hz Ricker wavelet, 2ms sample rate.
References


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