6 Summary and outlook

Noise and migration artifacts strongly affect the imaging results when standard Kirchhoff Prestack Depth Migration is used and thus complicate structural interpretation. Especially side events, which can occur in regions of rough ocean bottom formations, produce migration smiles which disable the detection of coherent reflection events within the data. In some cases, this led to poor images of the subsurface.

In this thesis, Fresnel Volume Migration was applied to two marine data sets. The resulting images were analyzed to study the influence of the restriction of the migration operator. Two different velocity models were used and discussed, each based on a different assumption. The input parameters for Fresnel Volume Migration was investigated with the aim to reduce the computing time but also to avoid possible errors due to the use of the wrong parameters. The obtained images were compared with the corresponding results from Kirchhoff Prestack Depth Migration.

The Fresnel Volume Migration revealed several additional structures which were interpreted and compared to the results from further investigations. A summary of the most important results is given in the following.

6.1 Summary

6.1.1 Velocity fields

The influence of two different velocity models on the resulting depth images was studied. One of them was an extension of an existing velocity field of the trench and the outer forearc region (IFM-model). The other model contained information about the seismic boundaries and mean velocities obtained from wide-angle observations (wide-angle model). Each velocity model resulted in different travel times and thus to different depth images of the investigation area. While the images obtained with the IFM-model exhibited a sediment thickness of less than 200 m, as proposed by several authors, the use of the wide-angle model led to oversized images of the sedimentary layers. Increasing migration smiles from a possible reflection event after the use of the wide-angle model indicated overmigration as a result of too high velocities in the upper part of the oceanic crust. Also a fault observed in the results from the IFM-model, which has been identified in earlier line drawings at nearly the same location, mapped outside the depth section when the travel times were calculated with the wide-angle model. At greater depth, the latter seemed to provide a more reliable depth section since a weak reflector has been identified at a depth where the oceanic Moho was expected. These events were not visible in the depth section obtained from the IFM-model.

During further investigations, comparably low velocities have been found directly below the sedimentary layer. These observations and the above mentioned features within the images suggested the use of the IFM-model for the uppermost part of the oceanic crust and to image deeper regions with the wide-angle model.

6.1.2 Influence of the input parameters

The main principle of Fresnel Volume Migration is the restriction of migration operator in a form that the resulting image of a recorded event is limited to the volume in the subsurface that physically contributes to the reflected signal. The paraxial ray method was used to calculate the required Fresnel volumes. A multichannel cross-correlation was performed to estimate the horizontal slowness used as an input parameter for the ray tracing algorithm. A few tests with respect to the frequency dependence of the cross-correlation method indicated a quite better quality of the resulting images when a lower dominant frequency was used.

Several input parameters were studied and tested in order to find the best combination with respect to the computing time and to obtain improved images of the subsurface within the investigation area. These input parameters were then used to perform Fresnel Volume Migration. Besides the input parameters, a method was implemented which enabled to significantly decrease the computing time. The Fresnel Volume Migration results obtained with this method showed no significant differences compared to the images computed without this method.

6.1.3 Fresnel Volume Migration of the CINCA data

Two marine data sets were processed. Both lines, line SO104-07 and SO104-13, were acquired during the CINCA experiment in 1995. The comparison of the results from Kirchhoff Prestack Depth Migration with the corresponding images obtained from Fresnel Volume Migration illustrated a significant improvement of the latter. A strong suppression of the migration artifacts due to the limitation of the migration operator was observed as well as the reduction of the noise level within the resulting Fresnel images. This enabled to identify several additional structures in the subsurface off Northern Chile.

Thrust faults was found in a region where normal faulting due to plate bending was expected. These features were only vaguely visible within Kirchhoff images but they were clearly identified after Fresnel Volume Migration, especially on line SO104-13. Small, seaward dipping normal faults were found within the frontal prism on line SO104-07 which pass into plate parallel orientation at greater depth. In contrast, the frontal prism on line SO104-13 exhibited folds below the seafloor which form a sedimentary ridge at the deformation front. The subducting Nazca plate in the trench region along line SO104-07 showed an ambiguous geometry. Several small bumps on the intra-plate boundary below the continental slope indicated a downward continuation of the rough ocean bottom topography observed to the west of the trench. The upper boundary of the subducted lithosphere was imaged down to about 12 km depth underneath the continental slope.

Probably the most important features for the understanding of the subduction mechanism in this area were found in the upper part of the continental crust. Plate parallel faults were observed and interpreted to mark the upper boundary of the subduction channel. They might be generated in the case of a horst-continent collision. In such a case, strong compressional forces occur, possibly resulting in an eastward movement of parts of the overriding plate. Their strong reflectivity might be a result of infiltration of fluids or material contrast or cataclastic fabric. The resulting images obtained from Fresnel Volume Migration provided an excellent and detailed insight into the normal fault systems located between 90 km and 113 km along line SO104-13. These normal faults merge into a slightly eastward dipping detachment.

6.1.4 Advantages and disadvantages of Fresnel Volume Migration

The Fresnel Volume Migration approach resulted in an obvious improvement of the depth sections and revealed plenty of additional structural information about the subsurface. The immense computing time of the algorithm, compared to Kirchhoff Prestack Depth Migration, necessitated the use of a cluster of parallel computers. Also the additional preparatory work, including the slowness calculation prior to the actual Fresnel Volume Migration, increases the computing time. However, the improved images indicate that Fresnel Volume Migration is a forward-looking method.

6.2 Outlook

The application of Fresnel Volume Migration to marine data sets showed that this technique enables to visualize certain details of the subsurface which are not visible in depth images resulting from Kirchhoff Prestack Depth Migration. Within this thesis, the main focus was set on the implementation of this new method for real data. The more or less smooth velocity structure and the advantages of marine data, as for example straight lined and equally spaced receivers and no elevation, nearly provided perfect conditions to test this new migration technique. More numerical tests are essential to study the influence of velocity fields with more complex layering. Seismic onshore experiments often deal with topography and crooked line geometries due to regional conditions. Also the geophones are often not equally spaced. This requires an explicite modification of the slowness calculation algorithm. In a few years, maybe, the computing time is no longer a problem since the computing power rapidly increases. Additionally, an update of the Fresnel Volume Migration routine would be helpful in order to find further possibilities to decrease the computational cost and thus to enable a fast Fresnel Volume Migration of 3D data sets.