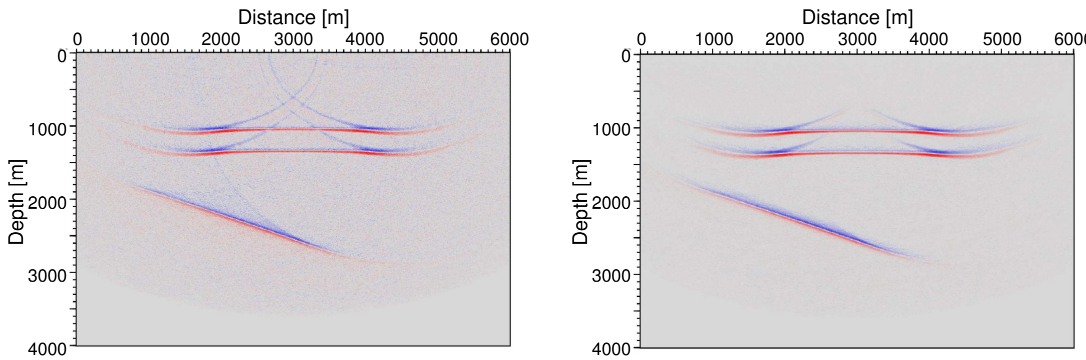
1 Introduction and motivation

Modern seismic imaging methods have been developed in the last decades to attain advantages with respect to two main problems: the improvement of seismic images and the reduction of computational costs. The latter was, thereby, of secondary interest since the computing power rapidly increases and the existence of parallel clusters enables the handling of large amounts of data with intensive algorithms in comparably moderate periods. Due to the decreasing natural reservoirs and the immense costs of production, especially in regions with a complex geology, the availability of reliable depth images is essential. This point is not only important in a small scaled point of view but also for the investigation of large scaled geological and tectonic formations to better understand global processes.

The appearance of noise plays an important role for the quality of depth images. While some coherent noise types as for example peg-leg multiples between two layers (e.g. Levin & Shah, 1977; Lumley *et al.*, 2001) or similarly ocean bottom multiples in marine data (Berryhill & Kim, 1985; Dragoset, 1990) are usually suppressed prior to the actual imaging, other events produce strong migration artifacts. The origins of the latter can be of different nature. A number of studies have been performed to investigate the influence of a limited aperture to the migration results (Takahashi, 1995; Sun, 2000) and the authors proposed strategies how to inhibit such kind of artifacts during the migration process. Other analyses were carried out with respect to the emergence of migration smiles due to a rough ocean bottom topography in marine reflection data (e.g. Larner *et al.*, 1983; Coltrin & Backus, 1989; Gragg *et al.*, 2001). Naturally, the morphology of the surface is three dimensional (3D) so that also 3D effects can cause poor images after processing (e.g. Gray *et al.*, 1999).

In contrast, as a basic principle of seismic imaging, random noise shall interfere destructively whereas reflected energy interferes constructively at the actual reflection points. This is not obtained when the aperture is strongly limited with respect to the volume of investigation. An obvious method to overcome this problem can be the restriction of the migration operator to the vicinity of the point of specular reflection. Milkereit (1987a) presented a slowness-weighted diffraction stack in which smearing of the amplitudes along the isochrons is reduced by including directivity to the diffraction stack integral. Other studies worked with methods based on ray tracing algorithms using different regions around the rays where the amplitudes have to be summed up. Besides some approaches using Gaussian beams (Hill, 1990; Gray, 2005), the physically most reasonable approach is to restrict the summation to the Fresnel zone.

Lüth *et al.* (2005) proposed a method to implement this restriction to Fresnel zones within a Kirchhoff Prestack Depth Migration scheme. They suggested the use of the polarization angle of three component data as the directional input for the ray tracing procedure. The application of this so-called *Fresnel Volume Migration* to numerical data but also to three component tunnel data indicated a significant improvement of the resulting images. A study of this approach for 2D data sets was carried out by Heigel (2005). Since the use of the polarization is impossible in 2D, he focused on the calculation of the horizontal slowness to yield the necessary emergence angles. His modelling studies (Figure 1.1) illustrate the enhancement of the resolution of the images after Fresnel Volume Migration using the slowness approach according to Haslinger (1994). Migration artifacts are significantly suppressed, the overall signal to noise ratio is higher and the reflectors are obviously clearer imaged.



(a) Diffraction stack image. *(b) Fresnel image.*

Figure 1.1: Modelling studies for Fresnel Volume Migration in 2D. The initial model consisted of three layer interfaces.

The CINCA (Crustal Investigations off- and onshore Nazca/Central Andes) experiment provides examples for reflection seismic data of a region where a rough ocean bottom topography has been observed. These data sets were acquired to investigate the subduction related processes of an erosive continental margin within the trench region between 19°S and approximately 26°S off Northern Chile. The oceanic crust in this area is dominated by horst-and-graben-like structures which continue below the overriding forearc crust (von Huene *et al.*, 1999). Such surface structures facilitate frontal erosion and indicate a strong coupling between the oceanic crust and the forearc (Ranero & von Huene, 2000). Basal tectonic erosion also occurs beneath the coast and the frontally and basally eroded material is transported within the seismic coupling zone, defined by shallow earthquakes (< 50 km depth) (Scheuber & Giese, 1999), and subducts further into the mantle wedge (e.g. Pelz, 2000). Subducting graben-like structures indicated a transport of fluid saturated slope debris and frontally eroded material into the subduction channel. This results in an increasing pore fluid pressure which reduces the friction along the plate interface (von Huene & Ranero, 2003). The study of the data in the time domain by means of interpreted line drawings (Hinz *et al.*, 1995) gave first ideas of the complex structure in the subsurface of the investigation area. They illustrate that the continental slope exhibits landward rotated listric faults.

Two of these CINCA data sets are used for the application of the Fresnel Volume Migration approach. This new technique enabled to study the effects of migration operator restriction within the resulting images, especially in areas with a pronounced ocean bottom topography. Also, a comparison of the Fresnel images with standard Kirchhoff Prestack Depth Migration results is performed in this thesis. Due to the noise reduction and the suppression of migration artifacts, the Fresnel images extracted additional structural information from the reflection seismic data and suggested alternative interpretation of the subduction related processes in some areas.

In chapter 2 an overview of the investigation area and an introduction to the marine seismic experiments is given. The geology of the Nazca plate and the outer forearc as well as the tectonical setting are also subjects of this chapter. The presentation of the necessary preprocessing steps is done in chapter 3. Strong ocean bottom multiples disturb the imaging results at depth and also a large amount of migration artifacts due to rough ocean bottom formations results in bad quality imagery in some areas. Here, first strategies to suppress those unwanted signals are studied. Chapter 4 comprises the principles of Fresnel Volume Migration. Starting with the theory of Kirchhoff Prestack Depth Migration, including the basics of the travel time calculation and a presentation of the used velocity models, all additional steps prior to Fresnel Volume Migration are introduced. The computation of the horizontal slowness is one of the most important aspects since it provides the emergence angles as the initial parameter for the used ray tracing algorithm. The influence of different variations of input parameters, i.e. mainly the roughness of the velocity field, the implementation of Fresnel Volume Migration and a strategy to reduce the computing time is presented in the last few sections of this chapter. By means of two marine reflection profiles (line SO104-07 and line SO104-13) from the CINCA area, the resulting depth images obtained from both migration methods (Kirchhoff Prestack Depth Migration and Fresnel Volume Migration) are compared and discussed in a structural context in chapter 5. The re-processing of the data sets with two different velocity models enabled to study the influence of the velocity field to the depth images and the structural interpretation of the different results. A final discussion and a summary of the results will close this thesis in chapter 6.