Seismic Data Processing for VB02 in ECHOS

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Introduction

The seismic line VB02 is part of the Valdivia Bank seismic survey in the southern Atlantic Ocean and it originates from the seismic cruise TN373. Valdivia Bank is a section of a larger conglomerate called Walvis ridge which sits outside the eastern shore of Namibia. The motivation of this study is to create seismic sections that can be used for geologic interpretation. In addition, this study is meant to articulate the preprocessing and processing steps for the seismic line VB02 and important findings from those steps.

The seismic line VB02 is marine seismic data located in the UTM 31° S 3° E WGS 1984 projection system. It contains the FFIDs 1001 to 6945 and there were 96 channels in the streamer. Channel 1 was the closest channel to the source and the tail end of the streamer was channel 96. The group spacing was 6.25 m and the shot spacing was 25 m. This means the CMP spacing was 3.125 m. Each channel recorded for 8 seconds per shot with a sampling rate of 1 ms. There were two 45 in^3 airguns that had a distance of 26.5 m behind the vessel. The near offset was 142 m between the source and the first channel, and the streamer length was 593.75 m, giving a far offset of 735.75 m. Lastly, the source and receiver depths were 3m and 4m, respectively.

Methods

The data was processed in the program Paradigm 18 which hosts a few powerful interfaces such as ECHOS and Integrated Canvas. The data was imported using the SEGY Import/Export loader as prestack CMP time gathers in SEGY full revision 1 format. The geometry was completed by a different processor using a seismic processing software called GeoEast. If the geometry were to be done in Paradigm 18, the user would use the interfaces BaseMaps and ECHOS in order to create the models and update the seismic data headers. Because the data being processed was marine data, not land data, it only needs a CDP model. First, the seismic data shot and receiver locations would be loaded into BaseMaps. To acquire the CDP model, the shot and receiver locations would be investigated and used to calculate scatter points, also known as CMP points. The scatter points would be binned and the fold map would be computed. The CDP model would be created via the fold map, and the cdpx, cdpy and cdp data headers would be updated. Each shot and channel was inspected to see if they should be omitted or muted. The airgun and receiver array temporarily stopped operation during the acquisition due to marine life near the vessel, so there are 12 shots in the seismic data that have no signal (FFIDs 2499 to 2510).

Since the shots occurred 50 ms after the channels started recording, a 50 ms static bulk shift was applied to the data. The swell noise was attenuated using a notch filter at .7 Hz and a time-variant band-limited noise suppression module called SUPPRES. SUPPRES decomposes data into good and bad signal bands, and time-variant noise suppression is applied by thresholding the noise envelope with the signal envelope. The noise frequencies specified in SUPPRES were between 0 and 20 Hz. Afterwards, the data was passed through a deghosting module called GHOSTX with the source depth at 3m, receiver depth at 4m and water velocity of 1500 m/s. At this point, velocity analysis was performed by picking time-velocity pairs every 1000th CDP. Normal moveout corrections were applied to the CDP gathers with an automatic stretch mute passing up to 65% stretch. The gathers were stacked and migrated using MIGRATX with a migration layer thickness of 20 ms. MIGRATX is a finite difference post-stack time migration module. The migration spatial filter length was 15 points and the maximum dip to migrate was 30 ms/trace with a subsurface distance of 3.125 m between CDPs and a maximum of 47659 traces migrated. Areas with steep dipping reflectors and diffractors were investigated in the stacked migrated section. The velocity model was updated with new time-velocity pairs every 50th CDP in the areas where the migration performed poorly.

Wavelet analysis was performed in this next part where a matching filter was created to remove the bubble from the source. In order to create the matching filter, there needs to be an input wavelet (a trace with the bubble) and an output wavelet (a trace without the bubble). An ideal input wavelet was created by reordering the data to channel 1 common receiver gather, muting the signal after 360 ms using the GAIN module and stacking the traces together. The GAIN module applied 0 db for the samples before 350 ms and -600 db for the samples after 360 ms. When the traces stacked, they formed a single stacked trace that was used as the input wavelet. The ideal output wavelet was created by muting the samples prior to 82 ms and after 92 from the stacked trace. To mute the samples prior to 82 ms, a gain of -600 db was applied to samples between 0 to 78 ms and a gain of 0 db was applied to samples after 82 ms. As for muting the samples after 92 ms, a gain of 0 db was applied to samples between 0 to 92 ms and a gain of -600 db was applied to samples after 96 ms. For all jobs using in the GAIN module, an exponential interpolation was used. In the Wavelet Utility, the input and output wavelets were used in the Matching function to create the matching filter. The matching filter created was 512 samples long (512 ms). The matching filter was convolved with all the seismic shot gathers using the FILTER module as a user defined filter.

The next step was to remove linear and random noise, to perform amplitude compensation, and to stack and migrate. Amplitude compensation was applied to the data using the spherical divergence function in the GAIN module. The spherical divergence function has time and velocity set to the power of 1 and 0, respectively. Next, a mute was applied above the sea floor to cancel out the direct wave. The data was reordered to CDP gathers and a normal move out correction was applied to those gathers. An automatic stretch mute with a maximum of 65% stretch was applied to the data before stacking the traces. The stacked section was passed into the migration module called MIGRATX (finite difference method) using the same parameters as mentioned before but using the updated velocity model (model has time-velocity pairs every 1000th CDP and every 50th CDP in certain areas). Since the migration added low frequency noise, a notch filter at .7 Hz was applied to the stacked migrated section. Afterwards, FXDECON was applied to the migrated stack with a time window and spatial window of 100 ms and 100 traces, respectively. FXDECON is a linear frequency domain signal enhancement module that transforms the data within a spatial and time window into the frequency domain and uses a deconvolution type algorithm to analyze the data. After the analysis, FXDECON applies an inverse transform to bring the data back into the time domain. This module is meant to remove random noise. The low and high frequency limits were 0 Hz and 500 Hz, respectively.

The final processing flow:

1. Load in data as SEGY full revision 1 prestack CMP time gathers
2. Inspect shot, receiver and cdp header values and locations as well as CDP model
3. Inspect for dead or noisy shots or channels
4. Static shift up 50 ms
5. Notch filter at .7 Hz

6. Time-variant band-limited noise suppression for frequencies between 0 and 20 Hz
7. Deghost with source at 3m depth, receivers at 4m depth and water velocity of 1500 m/s
8. Create first and updated velocity models via velocity analysis every 1000th CDP and every 50th CDP (in select areas)
9. Create a debubbling matching filter. Done by using the trace from stacking channel 1 common receiver gather with samples after 360 ms muted as the input wavelet and output wavelet with samples before 82 ms and after 92 ms muted.
10. Filter the data with the matching filter
11. Amplitude compensation using spherical divergence as a function of time and velocity to the power of 1 and 0, respectively
12. Water-bottom mute
13. Normal moveout, automatic stretch mute for stretching above 65% and stack
14. Finite difference post-stack migration using migration layer of 20 ms, CDP spacing of 3.125 m, migration spatial filter of 15 points, max dip of 30 ms/trace, and a max of 47659 traces to migrate
15. Notch filter at .7 Hz
16. Linear frequency domain signal enhancement using spatial and time windows of 100 traces and 100 ms. Low and high frequency limits were 0 Hz and 500 Hz.

Results

Figure 7 and 8 shows both the brute stack and final migrated stack. The final migrated stack used all the above processing steps and the updated velocity model for the normal moveout and migration. The brute stack was not migrated and it used the first velocity model (velocity model with time-velocity pairs every 1000th CDP) for normal moveout corrections. The processing steps performed prior to the brute stack were a static shift up 50 ms, a notch filter at .7 Hz, the time-variant band-limited noise suppression using frequencies 0 to 20 Hz, and deghost using a source depth of 3m and receiver depth of 4m, and a water velocity of 1500 m/s.

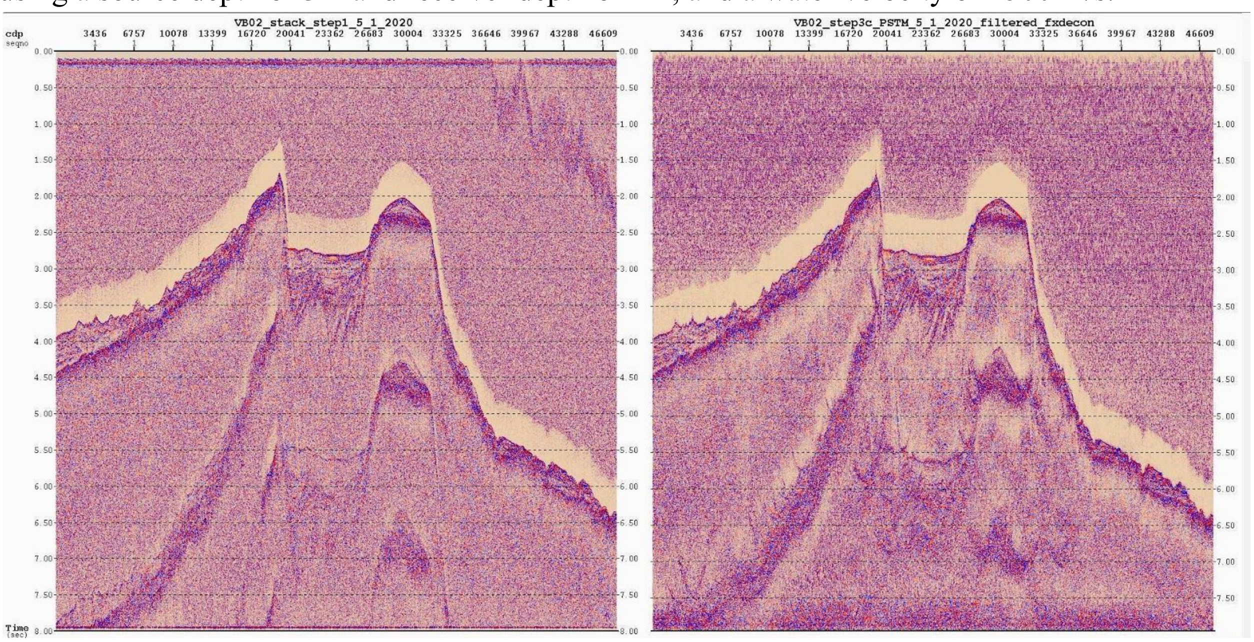

Figure 7. Shows the brute stack (left) and the final migrated stack (right). Both stacks are shown with automatic gain control (AGC) applied.

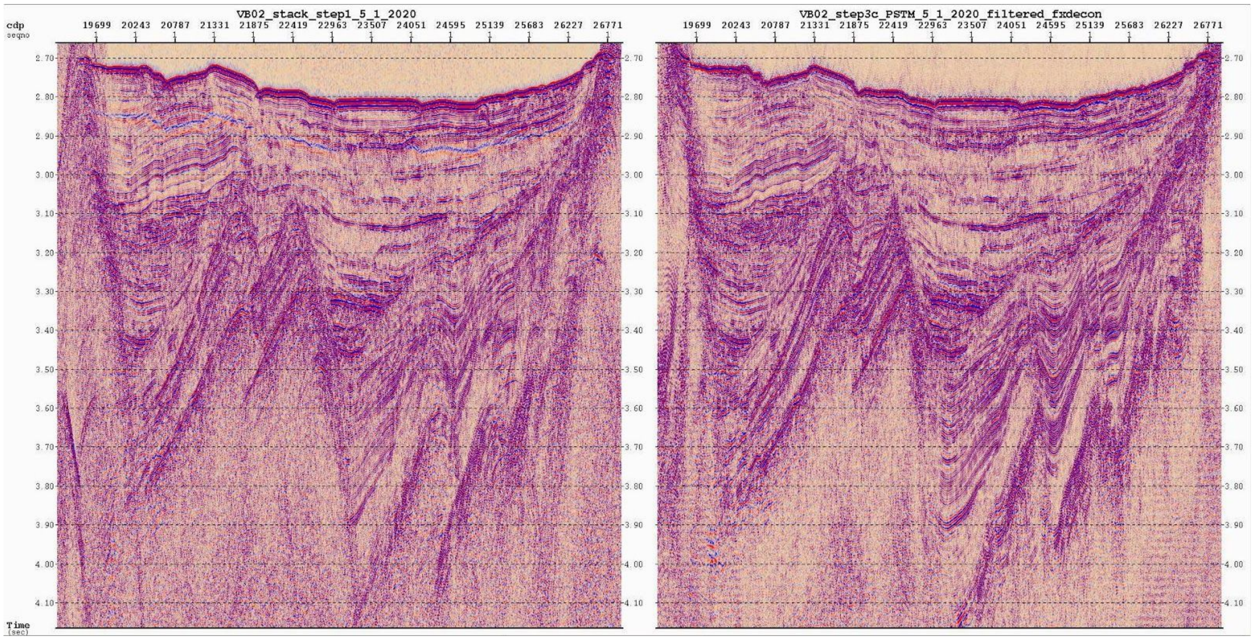

Figure 8. Shows the brute stack (left) and the final migrated stack (right) zoomed in between CDPs 19,000 and 27,000. Both stacks are shown with automatic gain control (AGC) applied.

Discussion and Conclusion

Several processing artifacts altered the processing flow. For instance, FK-Filtering was going to be used to remove the linear noise but the filter produced reverberations seen at the seafloor. Also, the matching filter added noise. The noise appears random so it disappears when stacking the traces. The MIGRATX module produced large “fingerprint” marks on the seismic sections which was due to the migration adding low frequency noise. Also due to the presence of the surface related multiples, the migration produced smiles in deeper sections since the velocities are too high for the multiple reflections.

Surface related multiple attenuation, also known as SRMA, was being investigated but the user was having trouble getting the merged data from the SRMA input and output data to work in the SMACMS module (surface related multiple attenuation subtraction module). There are several suggested future steps/tests: the velocity model needs to be updated again to better define weak areas in migration; use radon filtering to remove linear noise; finish the SRMA process on the data; mute the data above the seafloor after migration, not before; test more migration techniques and more migration parameters.

In sum, there’s a lot of work that still needs to be done but there are good results from this study. The seismic line VB02 has experienced significant improvements as seen between the brute and final stacks in figures 7 and 8. Using the preprocessing and the processing steps, the reader should be able to create similar results as the author. Although the processing flow given in this study produces an acceptable migrated seismic stack, there might be better techniques or better processing flows. Thus this study is meant to be a thorough guide to learn one way to process marine seismic data, and the author suggests the readers to take it upon themselves to add onto what the author has presented.