Seismic Data Processing

for KH98-1 LEG 2, Ontong Java Plateau

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Introduction

The Ontong Java Plateau (OJP for short) is the world's largest oceanic plateau which is located in the west-central Pacific Ocean and covers ~1.86 x 10^6 $km.^2$ (Phinney, E. J. etc, 1998). To investigate the relationships between sedimentary and igneous stratigraphy in OJP, a two dimensional, multi-channel seismic survey project was conducted in OJP (Wiederspahn, M, 1998), during February 1998. This project was called KH98-1 Leg 2 which includes 10 lines and covers 2,111 km. There were 27000 shotpoints(50 + Gbytes) of 48-channel data collected. The OBS data and Sonobuoy data were also acquired on some lines. The seismic data were processed in The Institute for Geophysics, The University of Texas at Austin with Geovecteur Plus processing software on SGI computer, from June 1998 to December 1998. The processing was divided into two stages: 1) quick briefly processing, 2) conventional processing of all data. To meet the requirement for deciding the drilling site before July 1998, the selected parts of data, which were relative to drilling site, were briefly processed through simple procedures. This processing took one month. The drilling site determined according to the result of briefly processing was used by the Ocean Drilling Program.

Data Acquisition

The seismic boat R/V HAKUHO was used for the data acquisition with OYO DAS-1 recording system. The sources were air guns combination with AutoSync I WC as gun controllers and the maximal number of guns was three. The use of AutoSync I WC gun controllers caused significant air gun mistiming which gives a difficulty for following data processing. The receivers for line 401, line 402, line 403, line 404, line 501, and line 601 were 1200 m ITI solid streamer with 48 channels, while 300 m ITI solid streamer was for line 101, line 102, line 103, and line 201 with 24 channels. Although designed minimum offset for 48 channel lines was 115 meets, the actual minimum offset was variable from line to line and even it was not same in one line. The 24-channes lines were in same situation but the designed minimum offset was 300 m. The designed shot interval was 50 m, while the actual shot interval was variable from shot to shot, which causes zero fold for some partial sections of the lines. The trace interval for 48-channel lines was 25.0 m and 12.5 m for 24-channel lines.

Quick Briefly Processing

The Ocean Drilling Program required drilling site before July 1998. To meet the requirement, the quick briefly processing was conducted on partial sections from line 401, line 403, line 404, line 501, and line 101, during June 1998. At that time, the navigation data were not available. The geometry for line 401, line 403, line 404 and 501 was determined according to the designed shot interval, minimum offset and trace interval and the CMP interval was defined as 25.0 m. As to line 101, common shot gather stack was applied, because it was difficulty to get velocity information from line 101, due to less maximum offset. The tests were concentrated on deconvolution methods and parameters. Various deconvolution methods were tested such as single and multi-channel predictive deconvolution, cascade of predictive and spike deconvolutions. To attenuate seafloor multiple reflection and bulb and also to improve the resolution , multi-channel predictive deconvolution and multi-channel spike deconvolution were applied respectively. Firstly, the two time windows , multi-channel predictive deconvolution was used. Then the spike deconvolution followed the predictive. The parameters were tested on every line. The quick briefly processing went through F-K migration with constant velocity.

Conventional Processing

The conventional processing covered every shot gather from the project. Based on quick briefly processing, there were two problems needed to pay special attention in this project. The first problem was definition of geometry because of variable shot interval and variable minimum offset for each line. The second problem was mistiming. To resolve these two problems is critical for successful processing.

The most important and the most time consuming part was geometry definition. There were two parameters to be determined. the coordinates of shot point and the minimum offset for every line. The available information from navigation data were the longitude, latitude and time for shot points without shot point number. The shot point number and the beginning time for recording were extracted from seismic data. According to the experience, every 50th shot was processed for the coordinates of shot The method was to match the time from seismic data with the time from navigation data and the coordinates of other shots were interpolated linearly by shot number. This method was tested on one line. After geometry definition, brute stack was performed. In stack section, unreasonable phenomenon was observed which was doubtfully caused by wrong coordinates of shots. To investigate the phenomenon, the shot number and time were extracted for every shot. Although the normal distance between adjacent shots should be 50 m , it was found that the distance between some adjacent shots was even greater than 3000 m and the distance was zero between some other adjacent shots, especially during switching of tapes. To deal with variable shot distance, the shot point number and time was extracted for every shot and the coordinates for every shot was defined according to navigation data. The brute stack was done on same line again and the unreasonable phenomenon disappeared. By investigating the directly arrived wave, it was found that the actual minimum offset varied from line to line, although the designed minimum offset was 115 m for 48-channel lines and 300 m for 24-channel lines. Because no navigation data was available for receivers, the minimum offset was determined by arriving tine of direct wave and the acoustic velocity of water for every 50 shot.

Mistiming was another serious problem in the data acquisition of OJP for some lines. The guns in the combination should be fired at exactly same time so that the wavelets from different guns can be stacked with same phase which makes the stacked wavelet enhance each other. During the acquisition, the jitter caused by mistiming was anywhere from a few ms to 20 ms (Wiederpahn, M. 1998). This mistiming caused serious out-phase stacking (Figure 1a). The amplitude of reflection events in stack section exhibited periodic variation from stronger to weaker and the time shift also periodically changed with maximum up to 10 ms. The static correction and dip moveout were tested to deal with the out-phase stacking. The dip moveout did a good job. After dip moveout, the quality of stack section was improved significantly (Figure 1b).

The multi-channel and two time windows predictive and spike deconvolutions were applied in cascade with the predictive first. The purpose of predictive deconvolution was to attenuate bulb and seafloor multiples, while the spike deconvolution was to improve resolution. Using multi-channels gave a stable estimation of wavelet from noisy data. The predictive distance for predictive deconvolution was determined according to auto-correlation of shot gather. There was compromise between suppressing bulb and seafloor multiples which requires the predictive distance should the common factor of bulb period and two way time of seafloor reflection. The parameters were tested for every line. The output phase from both deconvolutions was minimum phase.

After deconvolutions, the seismic data were sorted into CMP gathers with 25.0 m CMP trace interval. Then the velocity analysis was performed on every 200 CMP with extra velocity control points in some sections of complicated structures. To attenuate seafloor multiples, F-K filtering was applied on some lines. The dip moveout was performed on line 601 for dealing with mistiming. After the data were stacked, they were firstly migrated by F-K method with constant velocity and then followed by F-X residual migration. This procedure was summarized in figure 2.

Conclusions

The quick briefly processing was a timely task so that a compromise should be made between quality and time, according to the available computer and human resources. The drilling site, determined by this quick briefly processing, was used by the

Ocean Drilling Program which means the quick processing and following interpretation were successful. In the conventional processing, the problems caused by variable shot interval and minimum offset were resolved successfully through careful analysis of navigation data and seismic data. The thorough tests on deconvolution methods and parameters improved the resolution and S/N ratio of the data significantly. By extensive experiments, dip moveout was used to deal with mistiming problem as well as to enhance dip reflection. Throughout sophisticated analysis and processing, the final results exhibited reasonable quality and interpretable in certain extent and the following users expressed highly satisfied with the results.

Acknowledgment

I would like to give my special thanks to Dr. Millard Coffin who supervised the processing and was the following user of the data processing results. Mr. Steffen Saustrup gave me a lot of helps in the parameter testing and in running of jobs. I am very appreciated his helps. The meaningful discussions, carried out among relative staff of the Institute for Geophysics, helped me a lot in the data processing. Finally, I also gave my thanks to Dr. Paul Stoffa and Dr. Thomas Shipley for their advice.

References

Phinney, E. J., Mann, P., Coffin, M. F. and Shipley T. H. (1998), Sequence stratigraphy, structure, and tectonic history of the southwestern Ontong Java Plateau adjacent to the North Solomon Trench and Solomon Island Arc, Internal report, Institute for Geophysics, the Universuty of Texas at Austin.

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Appendix Archived data list for final results

The final data were archived in SEGY, IBM 32 float point format with 4 ms time sampling interval and 8 s trace length. The data were recorded on the one exabyte tape by UTIG utility program xsegy from SEGY disk files. The SEGY files on the tape were in the following sequences.

1. L101 migration
2. L101 migration + filtering + agc
3. L101 stack
4. L102 migration
5. L102 migration + filtering + agc
6. L102 stack
7. L103 migration
8. L103 migration + filtering + agc
9. L103 stack
10. L201 migration
11. L201 migration + filtering + agc
12. L201 stack
13. L401 migration
14. L401 migration + filtering + spherical divergent correction
15. L401 stack
16. L402 migration
17. L402 migration + filtering + spherical divergent correction
18. L402 stack
19. L403 migration
20. L403 migration + filtering + spherical divergent correction
21. L403 stack
22. L404 migration
23. L404 migration + filtering + spherical divergent correction
24. L404 stack
25. L501 migration
26. L501 migration + filtering + spherical divergent correction
27. L501 stack
28. L601 migration
29. L601 migration + filtering + spherical divergent correction
30. L601 stack

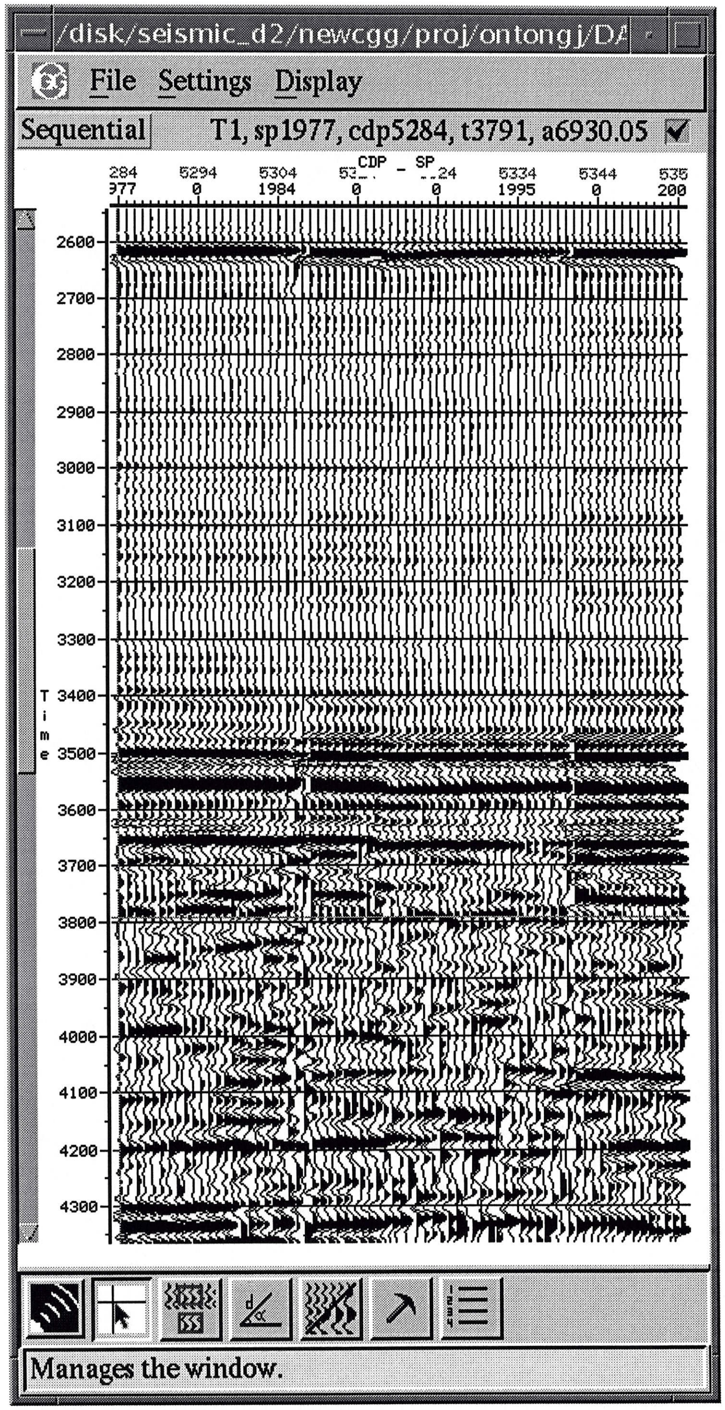

Figure 1a. Stacking after deconvolution, Note the periodical variation of amplitude and time shift caused by mistiming of air guns

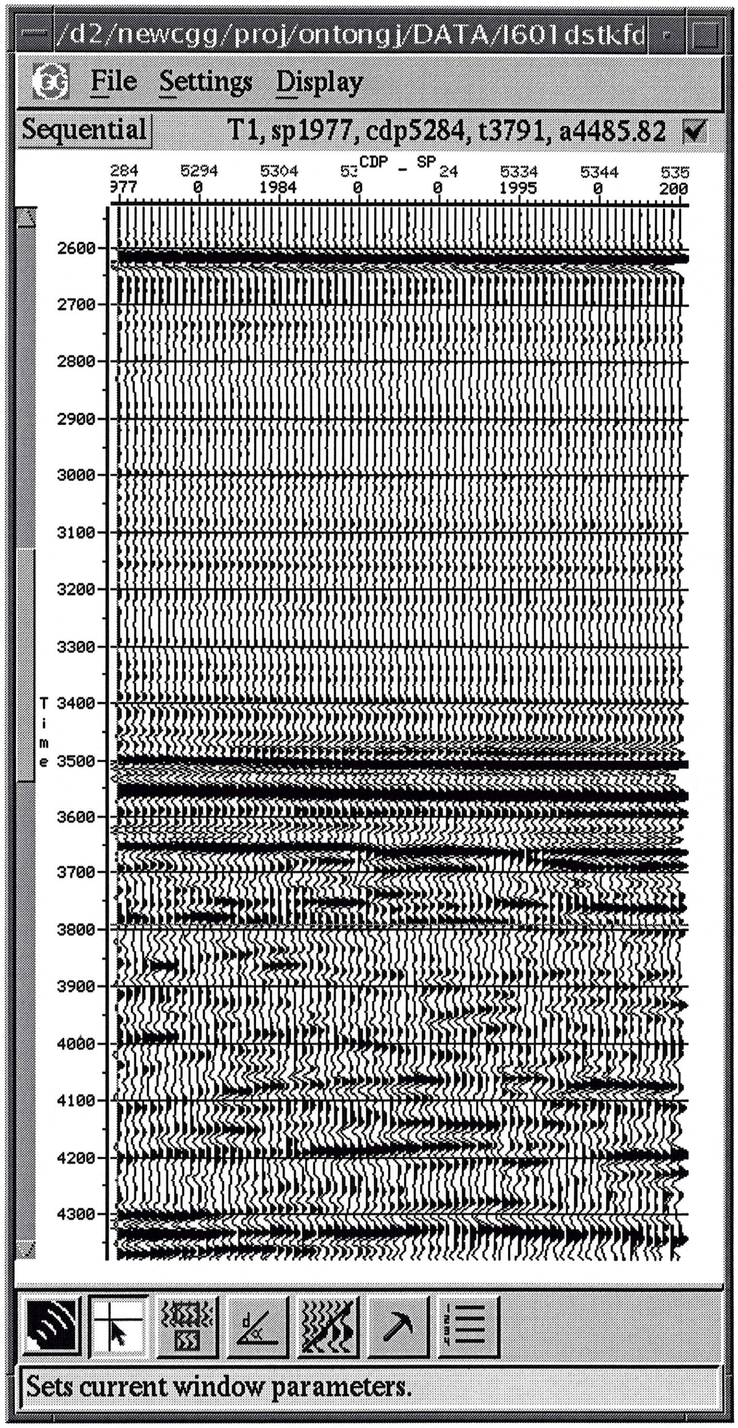

Figure 1b. Stacking after deconvolution and DMO, Note the periodical variation amplitude and time shift in figure 1a were overcome.

Figure 2. OJP Seismic Data Processing Flow