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Offshore mapping and modeling of Miocene-Recent extensional basins adjacent to metamorphic gneiss domes of the D'Entrecasteaux Islands, eastern Papua New Guinea

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Offshore mapping and modeling of Miocene-Recent extensional basins adjacent to metamorphic gneiss domes of the D'Entrecasteaux Islands, eastern Papua New Guinea

by

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Thesis

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Chapter 4

Processing of *RV Maurice Ewing* cruise 9203 seismic reflection data

This chapter outlines the processing sequence for multichannel seismic (MCS) reflection data acquired during March-April 1992 on the *R/V Maurice Ewing* (cruise EW9203), a vessel owned by the U.S. National Science Foundation (NSF) and operated by the Lamont-Doherty Earth Observatory of Columbia University. Cruise EW9203 MCS data were originally collected as part of the NSF Division of Ocean Science's Woodlark-D'Entrecasteaux Project: "Deep seismic imaging and seismotectonics of extensional processes in a province of active rifting" (principal investigator: John Mutter of Lamont-Doherty Earth Observatory).

The objective of this previous NSF study conducted in the 1990's and completed in 2000 was to investigate active continental breakup and initiation of seafloor spreading by studying lithospheric extension in the Woodlark basin area where westward propagating seafloor spreading transitions into active continental extension in basins surrounding the D'Entrecasteaux Islands. Cruise EW9203 collected 2D MCS reflection data in varied tectonic settings in the Woodlark basin, including active seafloor spreading, the Woodlark rise and Pocklington rise conjugate margins, the seafloor spreading-continental rifting transition area near the Moresby Seamount, and continental extensional in Trobriand basin, Goodenough basin, and the Goshen strait surrounding the DEI (Fig. 2.1). Published interpretations of these data include the Fang (2000) PhD thesis from Columbia University and Mutter et al. (1996).

For this study only 2D MCS reflection data from Trobriand basin, Goodenough basin, and the Goshen strait were processed. The raw shot data from the cruise were acquired through the Academic Seismic Portal at UTIG (http://www.ig.utexas.edu/sdc/). This chapter details data acquisition parameters from cruise EW9203 and the MCS reflection processing sequence I applied to the data, including pre-processing, modeling, and imaging steps.

4.1. SEISMIC DATA ACQUISITION

The seismic data processed for this study includes 21 MCS lines from the Trobriand basin, 17 MCS lines from Goodenough basin, and one MCS line from the Goshen Strait, covering 1,518 km (Fig. 2.1). During the 1992 cruise, the *R/V Maurice Ewing* used a 20-gun array with a volume of 8383 in^3 fired at 50 m intervals approximately every 20 s. The seismic data were recorded at a 4 ms sample rate. The survey used four different streamer lengths, with lines 1167 and 1169 using a 240-channel streamer, lines 1170-1179 using a 120-channel streamer, line 1180 using a 200-channel streamer, and lines 1181-1207 using a 220-channel streamer. All channels had a 12.5 m spacing and a source to near-channel offset of 250 m. Lines 1167-1169, 1180-1183 were recorded to 14 seconds while lines 1170-1179 and 1184-1207 were recorded to 15 seconds. Further seismic acquisition parameters can be found in the official report of cruise EW9203 archived at the Academic Seismic Portal at UTIG (http://www.ig.utexas.edu/sdc/).

4.2. Processing sequence

The cruise EW9203 MCS reflection data were processed for this project with Paradigm Geophysical's Focus® software using processing flows designed by Steffen Saustrup at UTIG (Table 4.1). The goal of the processing was to achieve the maximum resolution of the reflection data in order to make accurate interpretations of the data. The processing flow contained four general steps: pre-processing, source deconvolution, common-mid point (CMP) processing, and post-stack processing.

Pre-processing – Quality control checks on raw data, defining geometries, trace editing, filtering, trace balancing
Source Deconvolution
CMP processing – CDP sort, Parabolic Radon Multiple Attenuation, DMO processing, velocity analysis, NMO correction, offset mute, CDP stack
Post-stack processing – F/K migration, AGC Gain, SEG-Y output

Table 4.1: Processing flow applied to multi-channel seismic data acquired by cruise EW-9203.

4.2.1. Pre-processing of seismic data

Pre-processing of the EW-9203 data was done to reduce noise and enhance reflections. The main pre-processing steps included converting shot gathers into SEG-Y disk files to load into Focus®, quality control checks on the raw data, defining geometries, and trace editing, filtering, and balancing.

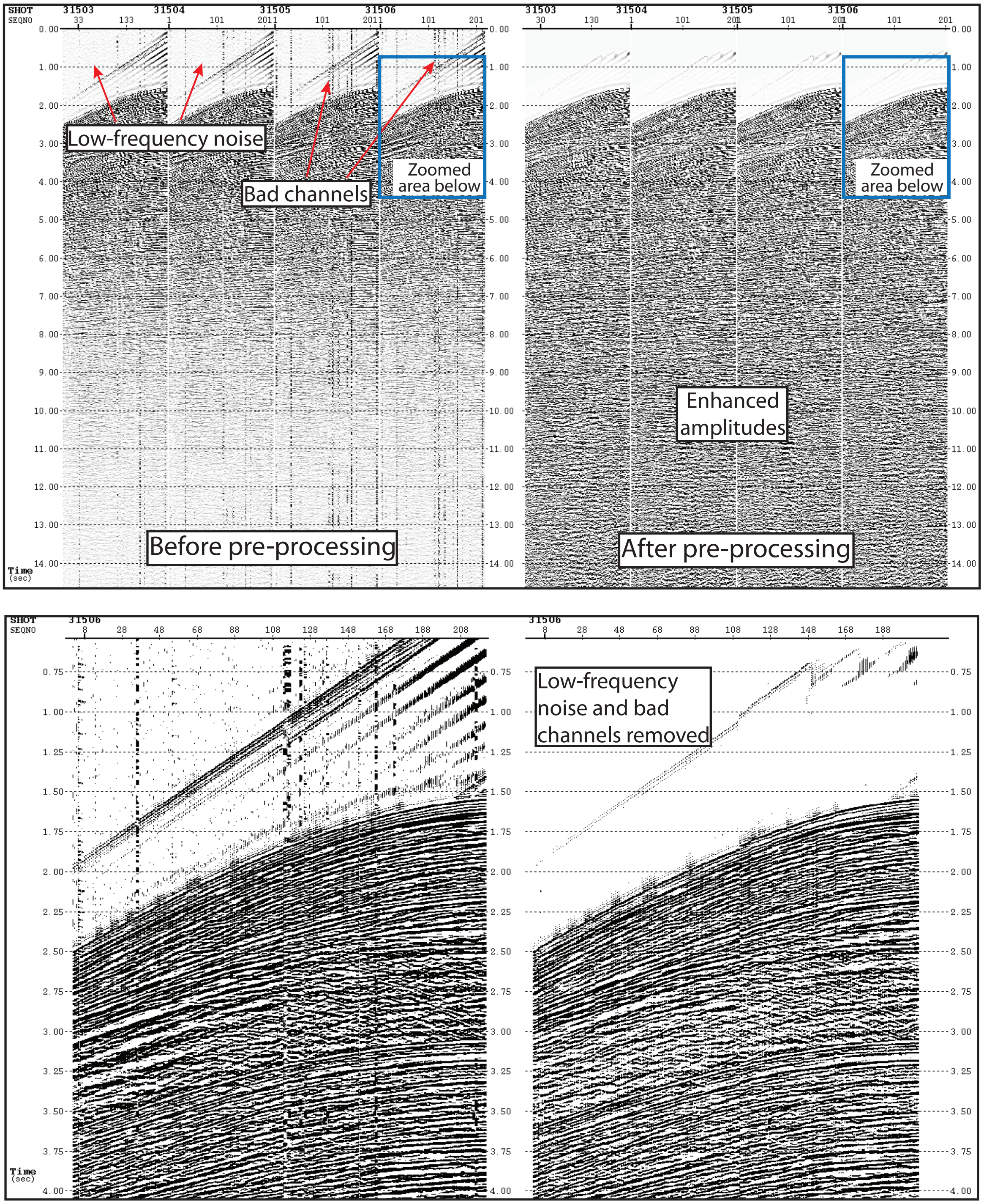

Figure 4.1: Comparisons of shot gathers before and after pre-processing of MCS Line 1191 from cruise EW9203. Low-frequency noise in traces and bad channels are removed and amplitudes are enhanced in deeper sections during the pre-processing stage.

Line geometries were defined by streamer length, source-receiver offsets and shot spacing. The different line geometries were then stored in trace headers for later use in common depth-point gathers (CDP) processing steps. Certain channels of consistently poor quality were deleted during trace editing (Fig. 4.1).

A 4-8-65-80 Hz preliminary trapezoidal bandpass filter was applied to the edited shot gathers to maintain the intergrity of the data while eliminating obvious noise such as low frequency ship noise (Fig. 4.1). The filtered shot gathers then were treated with a t^2 gain to account for amplitude decay and energy absorption due to geometric spreading.

4.2.2. Source deconvolution

The multichannel deconvolution technique was used to collapse the source wavelet and to attenuate short-period multiple energy that interfered with reflections in many seismic lines in the EW-9203 data set. The multichannel deconvolution design based on the Weiner-Levinson algorithm attenuates predictable signals in the seismic data and increases temporal resolution by compressing the source wavelet (Yilmaz, 2001). The deconvolution process forms groups of 31 trace and designs a filter using averaged autocorrelations of these traces. A predictive operator was used for deconvolution that included a filter length of 75 ms and a gap length of 24 ms. Following deconvolution, a trace balance was applied to normalize lateral amplitude variations in

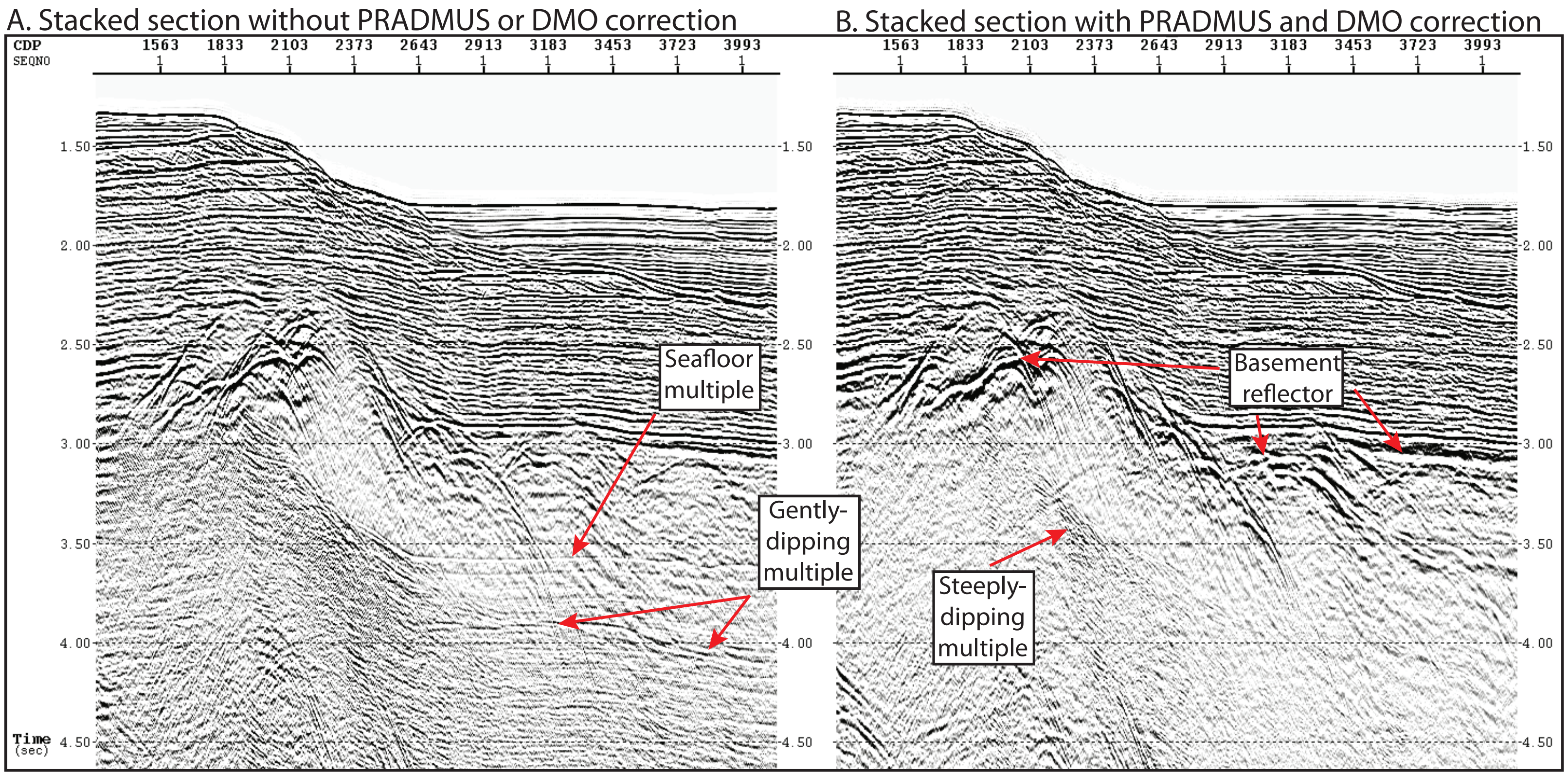

Figure 4.2: Comparison of unmigrated stacks. (A) Stacked version of MCS Line 1195 without parabolic radon multiple suppression (PRADMUS) and dip moveout (DMO) correction showing a subhorizontal seafloor multiple, a gently-dipping sedimentary contact multiple, a steeply-dipping seafloor multiple, and a poorly imaged basement reflector. (B) Stacked version of MCS Line 1195 with PRADMUS and DMO correction applied. PRADMUS was most effective at reducing the subhorizontal and gently-dipping multiples, and less successful at reducing steeply-dipping multiples. The DMO correction improved the resolution of the rugged basement reflector.

the lines. A brute stack was created after this step to pick the seafloor and make preliminary observations and interpretations of the data.

4.2.3. CDP processing

After pre-processing the raw data to enhance the signal-to-noise ratio and applying multichannel deconvolution, modeling was done to reduce the effect of the seafloor multiple and create a velocity model. This began by sorting the shot gathers by offset into NMO-corrected CDP gathers.

1. Parabolic Radon Multiple Attenuation

In many of the seismic lines from EW-9203, a strong seafloor multiple interfered with primary reflections, which would lead to difficulty during velocity analysis and the stack process. The best multiple attenuation technique tested to reduce the effects of this multiple was the parabolic radon multiple suppression ("Pradmus") method in Focus®.

Parabolic radon transform was applied to the NMO-corrected common shot gathers (Fig. 4.2). After the NMO correction, the primary events of the seafloor were flattened while the strong seafloor multiples seen in some areas often displayed residual moveouts. Parabolic radon transform distinguished and separated the primary and multiple events based on their moveout differences, then subtracted the multiple reflections. This technique was most effective in areas of continuous and horizontal reflectors with high signal-to-noise ratios, such as areas with relatively undeformed

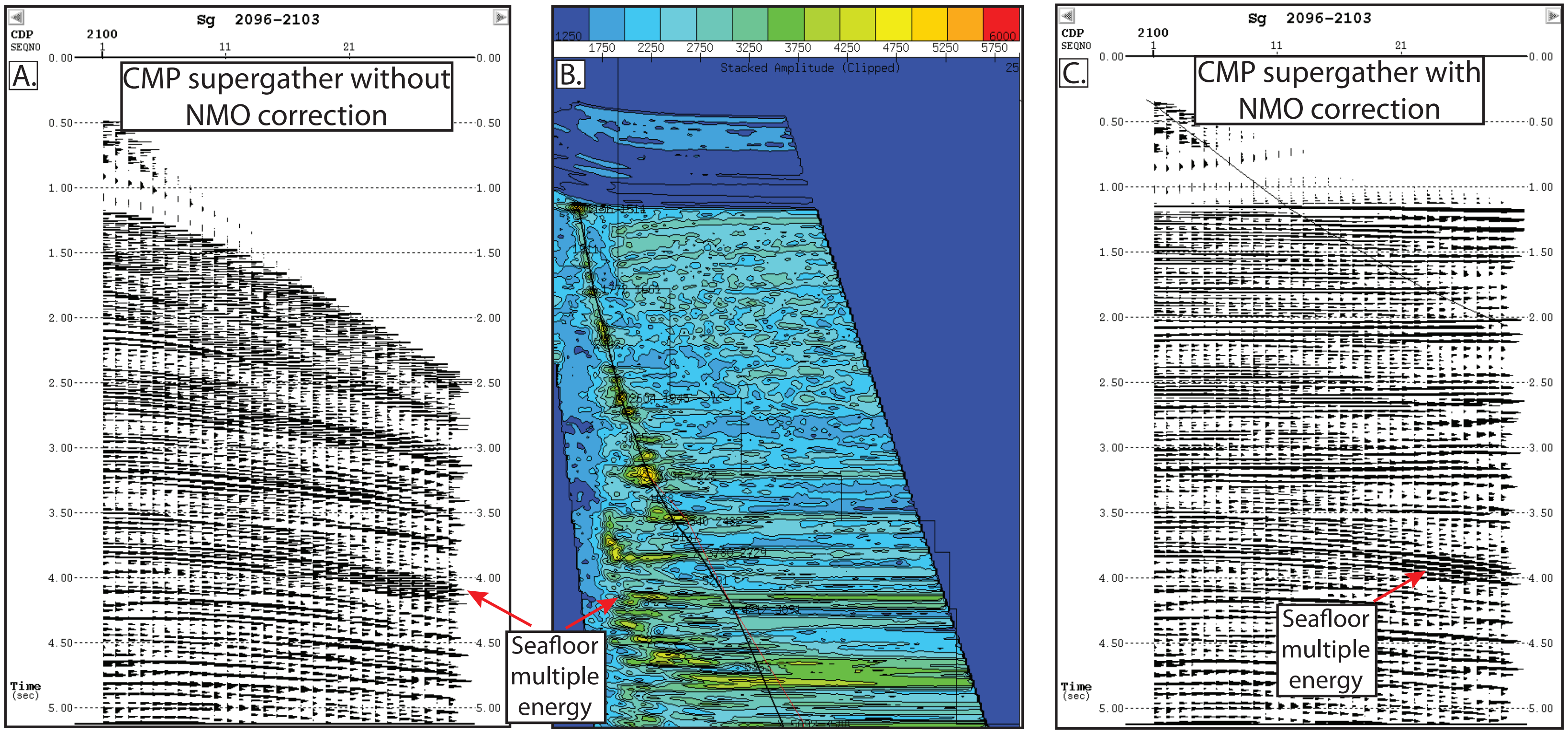

Figure 4.3. Comparison of velocity analysis windows. (A) CMP supergather prior to velocity anlysis and application of NMO correction. (B) Coherency plot showing stacked amplitudes and velocity picks of CMP supergather shown in Fig. 4.2A. Velocities are chosen based on areas with the greatest stacked amplitudes indicated by lighter colors. Multiple energy from the seafloor reflector is also shown on coherency plot. (C) CMP supergather with NMO correction shows flattened reflections. The multiple energy retains a steep dip at ~ 4 seconds and will not stack if the velocities have been picked correctly.

sediment beneath the flat seafloor. This technique was less effective reducing multiples in areas of steeply dipping reflectors (Fig. 4.2).

After the parabolic radon multiple attenuation technique was applied, a prestack, post-NMO dip moveout (DMO) was applied to image better dipping reflectors, including a rugged basement seen in many lines.

2. Velocity analysis

The extent of the EW-9203 data covers a wide range of geologic and tectonic settings with variations in basin architecture, sediment thickness, water depth, and basement composition. A velocity model was developed that attempted to take into account these variations.

Before performing velocity analysis, I applied a narrow bandpass filter designed to taper after 4000 ms, an automatic gain control (AGC), and front end mutes that eliminates distorted data to the pradmus-DMO CDP gathers. Velocities were picked on coherency plots based on supergathers of eight CDPs (Fig. 4.3). The plots displayed velocities that give the greatest stacking amplitudes. The NMO correction was applied to flatten the velocity model (Fig 4.3).

Velocity analysis was done every 500 CDPs, occasionally reducing the interval to 250 CDPs in structurally complex zones. Stacking amplitudes were clearest and velocities easy to pick in sedimentary sections. Areas of deformation and shallow limestone deposits interfered with stacking amplitudes, making velocity picking more difficult.

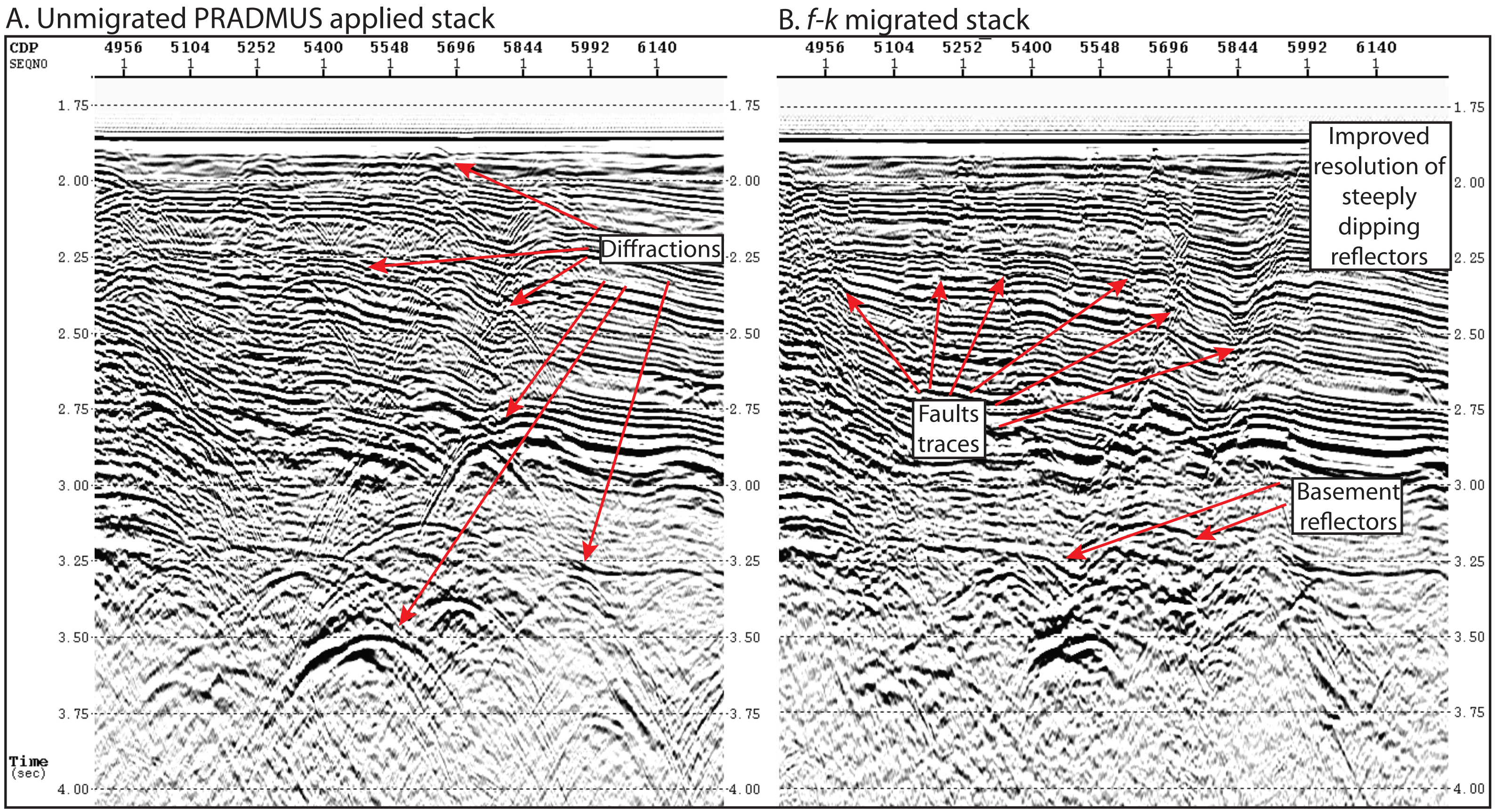

Figure 4.4. Comparison of unmigrated PRADMUS stack and F/K migration. (A) Unmigrated PRADMUS applied stack section with multipled diffractions obscuring image resolution. (B) The same section with an f-k migration applied that corrected diffractions and improved the resolution of steeply dipping reflectors making faults and the basement surface more easily distinguished.

Noise is also present in line 1168 due to contact of the streamer with the seafloor (Fang, 2000).

4.2.4. Post-stack processing

After completing modeling of the seismic data, DMO stack was employed using the PRADMUS-DMO corrected velocity model (Fig. 4.4). Unsatisfactorily imaged stacked sections resulted in further iterations of velocity analysis and multiple attenuation until acceptably imaged stacked sections were obtained. Front- end mutes were reapplied to eliminate noise in the water column, and stretch muting was done to mute the NMO correction stretch.

A post-stack *f-k* migration in the frequency-wavenumber domain also was applied to the stacked profiles to improve the resolution of steeply dipping reflectors obscured by diffractions (Fig. 4.4). Imaging of the rugged basement surface and fault traces became more distinct due to correction of diffractions.

The final output of the seismic images to SEG-Y format occurred after pre-processing, modeling, and imaging steps were applied to the data. The processed versions of the MCS reflection data from cruise EW9203 used in this study are archived at the Academic Seismic Portal at UTIG (http://www.ig.utexas.edu/sdc/).

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Mutter, J.C., Mutter, C.Z., and Fang, J., 1996, Analogies to oceanic behaviour in the continental breakup of the western Woodlark basin: Nature, v. 380, p. 333-336.