MCS Reflection Data Processing and Subbottom Profiler (3.5kHz) Data Processing

From Funk, J.O., 2007, Cenozoic Tectonics of the Nicaraguan Depression, Nicaragua, and Median Trough, El Salvador, Based on Seismic Reflection Profiling and Remote Sensing Data, M.S. thesis, University of Texas at Austin, p. 19-26.

2.2 MCS REFLECTION DATA PROCESSING

2.2.1 Preprocessing and quality control. The NicLakes MCS data was processed with the Paradigm Geophysical's Focus® software using processing flows designed primarily by Steffen Saustrup and Kirk McIntosh, with additional assistance from Tom Hess at UTIG. Pre-processing steps were applied during the cruise to produce a brute stack which helped identify possible zones of geologic interest. Further processing and modeling focused on water bottom multiple attenuation techniques in order to recover any subsurface events.

Pre-processing and quality control were done in the field using a portable UNIX system. Steps for this included reading the SEG-Y disk files into Focus®, assessing raw data quality control, defining geometry, trace editing, applying trapezoidal band-pass filters, implementing statics corrections, and executing basic normal moveout (NMO) correction to create a brute stack.

Raw data quality control was done in the field to ensure the seismic system and recording system were both functioning properly. Quality control on the raw shot gathers also led to identification of a reverberating bubble pulse with an amplitude and arrival time directly related to the firing pressure. The acquisition geometry was defined based on source-receiver offsets and shot spacing, and then stored in the trace headers for later use in common midpoint (CMP) processing steps. Trace editing was needed towards the end of the survey due to the increased number of bad traces. All 24 channels were operational for the first 35 lines. By the end of the Lake Nicaragua survey channels 6, 8, and 18 were malfunctioning due to twisting of the cable when it was rewound onto the spool. By the end of seismic acquisition and multiple streamer recoveries on Lake Managua channels 2, 6, 8, 10, 14, 18, and 24 were also malfunctioning and had to be edited.

2.2.2 Filtering. A static correction was applied to the seismic traces. A 40-60-400-500 Hz trapezoidal band-pass filter was then applied, capturing the peak frequency of ~220 Hz. Brute stacks were created for initial interpretations during acquisition using an estimated water velocity (1385 m/s) NMO correction.

2.2.3 Post-cruise processing done at UTIG. Further processing done at UTIG included MCS data modeling of seafloor multiples. Due to the lack of seismic penetration, an extensive velocity analysis did not prove useful and therefore most of our attention focused on water bottom multiple attenuation techniques; the most promising method being the Focus® module for surface related multiple attenuation (SMAC) (Verschuur, 1991; Verschuur et al., 1992).

Brute stacks were used to pick the water bottom arrival time used in later processing steps. The shot gathers were sorted into common midpoints (CMPs) which included all offsets, and an automatic gain control (AGC) was applied with a 200-millisecond gate. Velocity analyses were performed using CMP supergathers of 12 adjacent, summed CMPs. Due to the surprisingly flat overall character of both lake bottoms, analyses were only performed every 200 CMPs.

Surface related multiples were a constant problem across both lakes because of: 1) extremely shallow water depth (often less than 15 meters); 2) relatively short streamer (74.1 meters); and 3) an impenetrable water bottom (most likely due to gas-charged sediments likely produced by high organic content and geothermal heating related to proximity of active volcanoes). The technique that seemed to work most effectively for multiple reduction was SMAC because it does not require a distinct moveout difference between primaries and multiples, nor does it require any previous knowledge of the subsurface geology (Verschuur, 1991; Verschuur et al., 1992).

The SMAC module utilizes pre-stack shot gathers to remove kinematically-predicted surface related multiples in two steps (Fig. 2.4). First, an outside mute in the shot gathers is placed just above the WB to eliminate the direct-wave and any other noise.

The SMAC module recognizes the first event as the water bottom and computes several terms of Taylor expansion of the multiple prediction operator. The Taylor terms are then used to attenuate recorded multiples by subtracting them from the input shot gathers (Verschuur, 1991; Verschuur et al., 1992). Figure 2.5 is an example from the processed line NLS23 showing the effectiveness of SMAC on multiple attenuation.

2.3 SUBBOTTOM PROFILER DATA PROCESSING

The SBP was used to image high resolution features on both lake bottoms and their shallow subsurface stratigraphy. Unfortunately, both lake bottoms proved to be impenetrable surfaces that revealed very few subsurface reflectors occurring in isolated and relatively small (~100 km^2) windows of penetration (the total area of the lakes is ~9000 km^2). The main goals of our processing sequence for these data were to improve WB imaging and increase the signal-to-noise ratio (SNR) at depth in limited areas showing acoustic penetration.

These data were recorded to a disc in the field and converted to SEG-Y format primarily using the DR GEO software. Those data collected using the recording software Audacity were later converted to SEG-Y using Matlab scripts written by Dr. Tom Pratt of the USGS/Seattle, who accompanied us on the Lake Nicaragua part of the study. The smoothed navigation data were then attached to the trace headers and converted to Focus® format for processing.

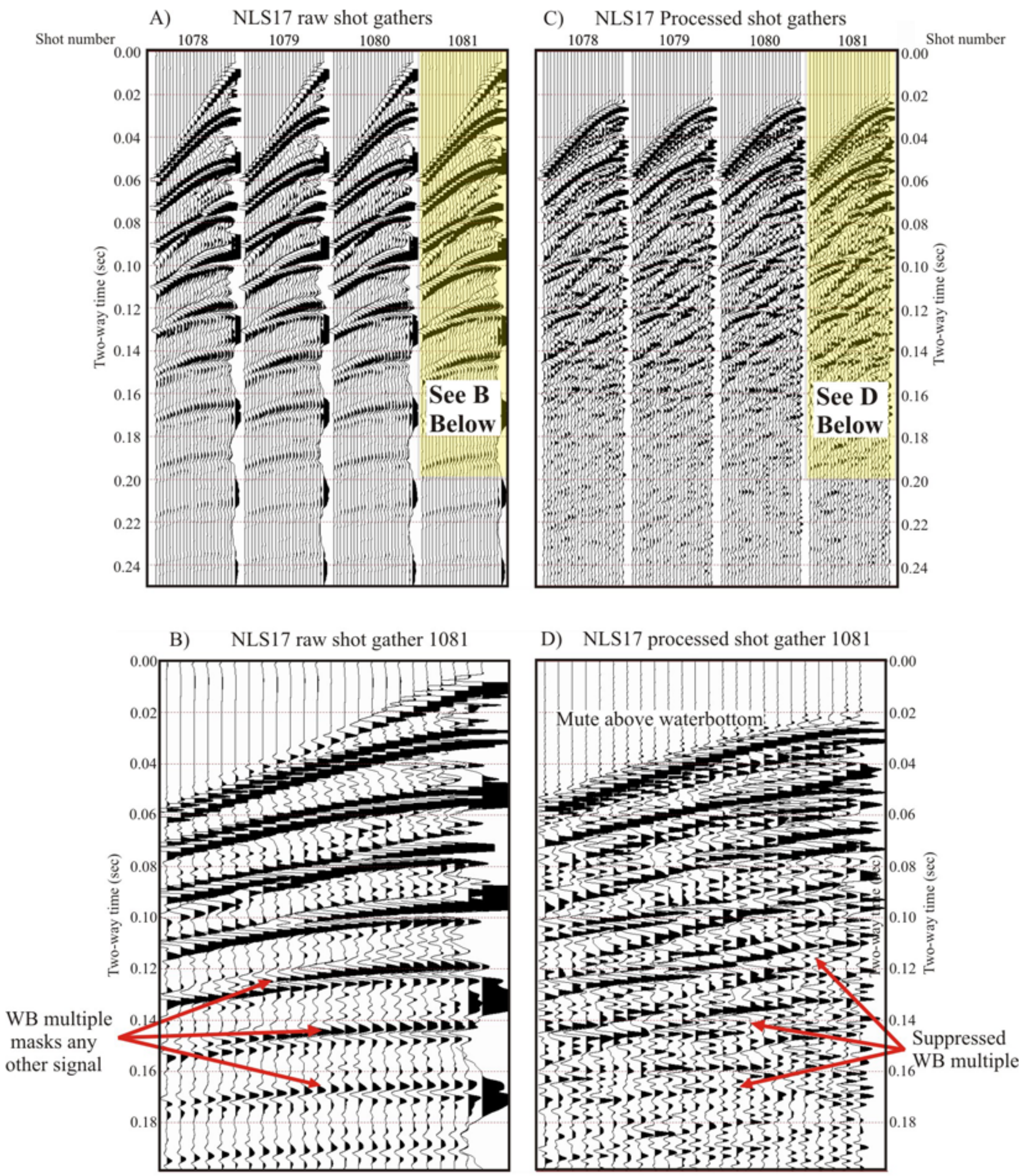
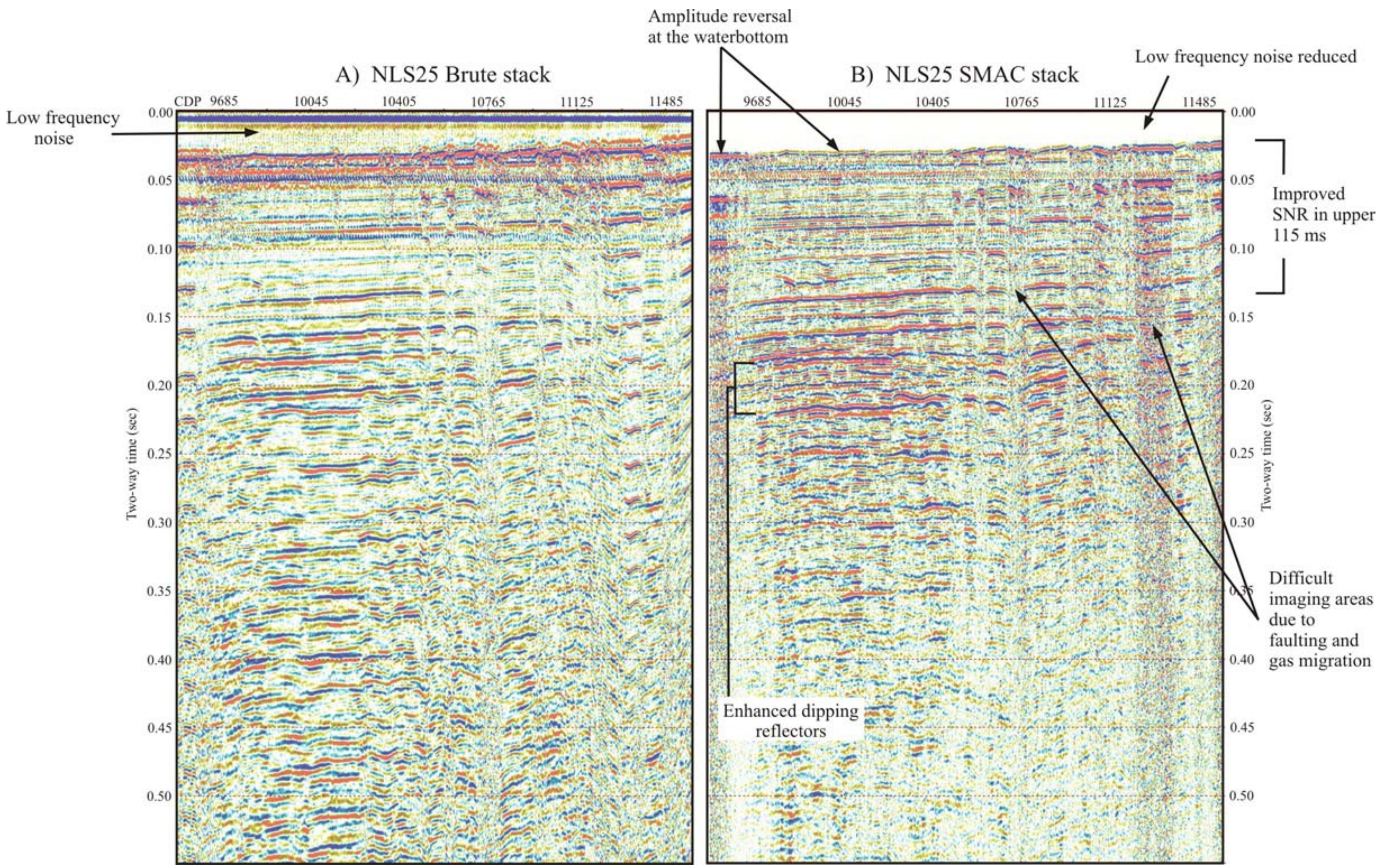


FIGURE 2.4. A) Four successive raw shot gathers from NLS17 on Lake Nicaragua showing dominance of water bottom (WB) multiples. B) Zoom of raw shot gather 1081 from part A. C) Processed shot gathers showing suppression of the WB multiple by the SMAC algorithm. The SMAC process was applied to all processed seismic data because of the strong WB multiple present in data from both lakes. D) Zoom of processed shot gather 1081 in part C. As part of the SMAC process which helps to suppress WB multiples, all signal above the WB is muted, effectively eliminating the direct wave.

FIGURE 2.5 A) An example of a brute stack used for preliminary interpretations during the NicLakes acquisition with an automatic gain control (AGC) applied. B) An example of a stacked section that has undergone surface related multiple attenuation (SMAC). Note also the amplitude reversal at the waterbottom. One possible explanation for limited seismic penetration is the presence of gas near the surface of the waterbottom which could produce amplitude reversals such as the one pictured here.


Amplitude reversal
at the waterbottom
Low frequency noise reduced
A) NLS25 Brute stack
B) NLS25 SMAC stack
Low frequency
noise
CDP 9685
10045
10405
10765
11125
11485
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Two-way time (sec)
Improved
SNR in upper
115 ms
Difficult
imaging areas
due to
faulting and
gas migration
Enhanced dipping
reflectors

The 3.5 kHz SBP performs as a single-channel seismic system with zero offset. Processing for this type of data included debias, bandpass filters, deconvolution, and applying an AGC before the final output. While each line was unique and required individual modification, the following sequence represents typical values for filters and deconvolution parameters.

Debias was applied first to remove DC bias from the data. A 1500-2200-5000-6000 Hz trapezoidal bandpass filter was then applied to increase target frequencies. Deconvolution was mainly used to compress the water bottom signature in order to more accurately image small offsets on the water bottom. A multi-channel, minimum phase, bandpass, spiking deconvolution was applied to seismic traces according to the Wiener-Levinson algorithm (Yilmaz, 2001). The filter was designed based on autocorrelations summed over 3 traces. An operator length of 35 points was used with an 800-5000 Hz bandpass filter. Before output, an AGC was applied to those lines showing possible subsurface reflectors. Final output to SEGY was then loaded into Landmark Seisworks® for interpretation and depth conversion.