Multi-channel Seismic (MCS) Processing

------Jinchang Zhang, Adrienne Oakley, Bridget Hass, Stephen Swift

On R/V Thomas G. Thompson cruise TN272, we used Matlab to convert navigation files from latitude and longitude into X and Y coordinates in UTM (Universal Transverse Mercator) so that we could set up geometry in ProMAX (2D Version 2003.19.1). Then we applied bandpass filter, trace editing, normal move-out correction, stacking, time migration, automatic gain control and top mute on the raw MCS data using ProMAX. When we had processed data in SEG-Y files, we used GMT (Generic Mapping Tool) to create annotated plots in black-and-white and in color, and printed them out on HP DesignJet 500PS plotter. And we also output X and Y coordinates of CDPs (Common Depth Point) and converted them back to latitude and longitude after processing, and then we applied GMT again to plot MCS lines on the map of study area. This report includes acquisition geometry information, MCS processing steps, parameters and flows, GMT plotting scripts, Matlab conversion script and data storage locations.

(1).Acquisition Geometry Information

Number of GI Guns: 2

Source Depth: 4 m

Shot Interval: 25 m (~12 sec, shot on time)

Receiver Depth: 4 m

Receiver Group Interval: 12.5 m

Number of Channels: 48

Sample Rate: 1 ms

Record Length: 11.5 s

Raw Data Format: SEG-D & SEG-Y

Distance from Center of Source to First Channel: 76.25 m

Distance from Center of Source to Last Channel: 663.75 m

Nominal Fold: 12 [=(48 * 12.5) / (2 * 25)]

Nominal CDP Bin: 6.25 m

(2).MCS Processing Steps

2.1 Geometry Setup

Geometry setup is important for taking account of recording failures, ship turns, and other issues when reading in navigation files. And correct geometry assigns correct CDPs (Common Depth Point) to each MCS line, necessary for as to get the data ready for later processing. We used Matlab to convert navigation files from Latitude and Longitude into X and Y coordinates in UTM. That helped ProMAX to have real positions for every shot location, and it also made it possible to output positions for every CDP after processing so we can plot them on map.

2.2 Bandpass Filter, Trace Kill, Velocity Analysis, NMO, Stack and Time Migration

By doing interactive spectral analysis on shot gathers, we found that the frequency range containing most of geological information is approximately to 200Hz. Using shot displays, we searched for common bad channels which were constantly noisy for the entire seismic lines, and then we killed them for later processing. We realized that the number of common bad channels averaged ~7% of total number of channels for each line. Velocity analysis was performed at a 200 CDP interval to create normal moved out gathers for CDP stacking. After NMO (Normal Moveout Correction) and CDP stack, the data were time migrated using Memory Stolt FK Migration. Because the Stolt algorithm is based on a constant velocity medium, unsmoothed and laterally-variant velocity fields may introduce spurious migration smiles. We tested migration velocities based on smoothed stacking velocities, but this introduced obvious errors. We found that velocity models with horizontal constant and gentle vertical-variant velocity fields worked best to generate the seismic images. Post-cruise data processing might include time-variant and multi-window bandpass filtering and deconvolution, specific frequency range filtering and detailed velocity analysis particularly in areas of interest, and depth migration using an accurate velocity model.

2.3 Processed Data and Header Value Output

We chose the best migration records, and then we applied automatic gain control of 500 millisecond operator length and picked a top mute to crop out the water column. After that, we output processed data in SEG-Y files and header values in text files for each MCS line.

2.4 Plotting Seismic Sections and Seismic Lines

We used GMT to create PostScript plots from processed SEG-Y data and CDP coordinates. Seismic sections can be plotted as both variable area black-and-white images and color gridded ones. A custom plot size was needed to plot seismic sections on HP DesignJet 500PS plotter. CDPs of each MCS line can be plotted on the bathymetry map of our study area.

(3).MCS Processing Information

MCS Line No.	Length (km)	First Shot	Last Shot	Shot Count	First CDP	Last CDP	CDP Count	Sail Azimuth	Start Day	End Day
1	59.131	1001	3327	(2327)	948	10409	(9462)	205	318	319
2_part1	45.144	3420	5185	(1766)	948	8171	(7224)	205	320	321
2_part2	160.613	5186	11737	(6552)	948	26646	(25699)	205	321	322
3	10.831	11738	12208	(471)	948	2681	(1734)	295	324	324
4	19.556	12209	13072	(864)	950	4079	(3130)	115	324	325
5	5.763	13073	13315	(243)	947	1869	(923)	25	325	325
6_part1	25.438	13316	14322	(1007)	948	5018	(4071)	295	326	327
6_part2	31.238	14326	15557	(1232)	948	5946	(4999)	295	327	327
7_part1	64.738	15558	18131	(2574)	948	11306	(10359)	205	331	331
7_part2	55.519	18132	20327	(2196)	948	9831	(8884)	205->213	331	331
8	167.381	20328	26970	(6643)	948	27729	(26782)	213	331	332
9	107.231	26971	31243	(4273)	948	18105	(17158)	213	332	333
10	79.181	31244	34367	(3124)	948	13617	(12670)	213	333	334
10a	55.406	34386	36573	(2188)	948	9813	(8866)	213	334	334
Total	887.17									

*Notes: MSC line length is calculated by CDP number multiplied with CDP bin size of 6.25m. The gap in shot numbers between line 1 and line 2 was caused by duplicate shot locations. The gap in line 6 was caused by the ship too far off the programmed line. The gap between line 10 and line 10a was caused by gun issue. The CDP at the first shot point is set to CDP 1000. First CDP number changes due to changes in actual distance between source and first group. Sail azimuths are estimated. Days are in GMT Julian Day.

MCS Line No.	Type of Line	First CDP	Location (Lat. Long.)	Last CDP	Location (Lat. Long.)	Note
1	In-line	948	22.580533 N 166.644025 E	10409	22.154224 N 166.298096 E	
2_part1	In-line	948	22.156000 N 166.299416 E	8171	21.825042 N 166.043964 E	Gap in between ~1750m
2_part2	In-line	948	21.817545 N 166.028407 E	26646	20.678138 N 165.069802 E	
3	Cross-line	948	22.086522 N 166.262896 E	2681	22.146114 N 166.179626 E	~CDP 1111 of line_3 across ~CDP 2248 of line_2_part1
4	Cross-line	950	22.117012 N 166.159037 E	4079	21.993151 N 166.294159 E	~CDP 2588 of line_4 across ~CDP 3069 of line_2_part1
5	Cross-line	947	22.002638 N 166.313070 E	1869	22.046559 N 166.343049 E	
6_part1	Cross-line	948	21.727936 N 166.049304 E	5018	21.869739 N 165.855698 E	Gap in between ~750m, ~CDP 2234 of line_6_part1 across ~CDP 1981 of line_2_part2
6_part2	Cross-line	948	21.874286 N 165.850425 E	5946	22.048004 N 165.612037 E	
7_part1	In-line	948	20.671098 N 165.064831 E	11306	20.190869 N 164.710443 E	Gap in between ~500m, Ship turn at ~CDP 8117 of line_7_part2
7_part2	In-line	948	20.189409 N 164.708726 E	9831	19.788488 N 164.389558 E	
8	In-line	948	19.790540 N 164.390949 E	27729	18.743847 N 163.241336 E	
9	In-line	948	18.744504 N 163.241141 E	18105	18.070489 N 162.512386 E	
10	In-line	948	18.071384 N 162.512613 E	13617	17.571274 N 161.979133 E	
10a	In-line	948	17.569795 N 161.976826 E	9813	17.219312 N 161.605196 E	

(4).MCS Processing Parameters

MCS Line No.	Common Bad Channels killed	Single Ormsby Bandpass Filter(Hz)	Memory Stolt FK Migration (RMS) Velocity (m/s)	Note
1	20, 21, 22, 41	5-8-180-200	0-1480,7750-1520,8150-1600	(1) For common bad channels, on average about 7% of total 48 channels killed.
2_part1	17, 27, 45, 46	5-8-180-200	0-1480,7680-1520,8150-1600	
2_part2	27, 44, 45, 46, 48	5-8-180-200	0-1480,7400-1500,7800-1540,8000-1580	

<table>
<tr><td>3</td><td>45, 46</td><td>5-8-180-200</td><td>0-1480,7750-1500,8150-1580</td><td rowspan="11">(2) For frequency bandpass filter, besides 5-8-180-200, we also have a set of 20-30-180-200 for potential use.
(3) For migration, 1600m/s in RMS velocity equals to ~4307m/s in interval velocity.</td></tr>
<tr><td>4</td><td>44, 45, 46</td><td>5-8-180-200</td><td>0-1480,7750-1500,8000-1540,8150-1580</td></tr>
<tr><td>5</td><td>44, 45, 46</td><td>5-8-180-200</td><td>0-1480,7750-1500,8000-1540,8150-1580</td></tr>
<tr><td>6_part1</td><td>44, 45, 46</td><td>5-8-180-200</td><td>0-1480,7000-1500,7800-1540,8000-1580</td></tr>
<tr><td>6_part2</td><td>44, 45, 46</td><td>5-8-180-200</td><td>0-1520,7750-1600</td></tr>
<tr><td>7_part1</td><td>17, 33, 45, 46</td><td>5-8-180-200</td><td>0-1480,7450-1550</td></tr>
<tr><td>7_part2</td><td>17, 33, 45, 46</td><td>5-8-180-200</td><td>0-1480,7500-1550</td></tr>
<tr><td>8</td><td>17, 33, 45, 46, 48</td><td>5-8-180-200</td><td>0-1480,7500-1580</td></tr>
<tr><td>9</td><td>45, 46, 48</td><td>5-8-180-200</td><td>0-1500,7400-1600</td></tr>
<tr><td>10</td><td>45, 46, 48</td><td>5-8-180-200</td><td>0-1500,7400-1540,7450-1580,7500-1620</td></tr>
<tr><td>10a</td><td>45, 46, 48</td><td>5-8-180-200</td><td>0-1480,7500-1530,7600-1580</td></tr>
</table>

(5).MCS Processing Flows

1. Geometry Setup
   1) 2D Marine Geometry Spreadsheet
      1. Setup:
         a. Select: Matching pattern number in the SIN and PAT spreadsheets
         b. Station Intervals:
            i. Nominal Receiver Station Interval: 12.5
            ii. Nominal Source Station Interval: 25.0
            iii. Nominal Sail Line Azimuth: refer to processing information
            iv. Nominal Source Depth: 4.0
            v. Nominal Receiver Depth: 4.0
         c. Units: Meters
         d. Co-ordinate origin:
            i. X0: 0.0
            ii. Y0: 0.0
         e. Click OK
      2. Sources: Shot Pattern Spreadsheet
         a. Import FFID, X, Y coordinated and water depth from navigation files.

    b. Fill in source depth (4.0), and streamer azimuth (±180^0 from ship sail direction).
    c. Match up source, station and FFID numbers along the line.
    d. Click Save
    e. Click Exit
3. Patterns: Receiver Pattern Spreadsheet
    a. Min Chan: 1
    b. Max Chan: 48
    c. Chan Inc: 1
    d. Group Int: 12.5
    e. X Offset: 76.25
    f. Y Offset: 0.0
    g. Click Exit
4. Bin:
    a. Assign Midpoints
        i. Select Matching pattern number in the SIN and PAT spreadsheets
        ii. Click OK
    b. Binning
        i. Select: Midpoints, user defined OFB parameter
            1. Source station tie to CMP number: Use first shot number or FFID
            2. CMP number tie to source station: 1000
            3. Distance between CMPs: 6.25
            4. Offset bin center increment: 12.5
            5. Minimum offset bin center: 76.25
            6. Maximum offset bin center: 663.75
            7. Check: CMP numbers increase in shooting direction
            8. Click OK
        ii. Select: Receivers
            1. Receiver bin width: 12.5
            2. Check: Receiver numbers increase in shooting direction

3. Click OK

c. Finalize Database

i. Click OK

5. Trace QC: Check CDP coordinates, offset , fold, etc., when necessary

2. <u>Load SEG-D Data and Enter Geometry into Trace Headers</u>
    1) SEG-D input
    2) Inline Geom Header Load
        a) Primary header to match database: FFID
    3) Disk Data Output
3. <u>Interactive Spectral Analysis</u>
    1) Disk Data Input
        a) Primary trace header entry: Source
        b) Secondary trace header entry: Recording channel number
    2) Interactive Spectral Analysis
4. <u>Shot Display and Search for Common Bad Channels</u>
    1) Disk Data Input
        a) Primary trace header entry: Source
        b) Secondary trace header entry: Recording channel number
    2) Trace Display
5. <u>Velocity Analysis</u>
    1) Disk Data Input
        a) Primary trace header entry: CDP bin number
        b) Secondary trace header entry: Absolute value of offset
        c) Sort order list for dataset: 1-99999(200):*
    2) Bandpass Filter
        a) Type of filter: Single Ormsby bandpass
        b) Frequency values: refer to processing parameters
    3) Trace Kill/Reverse
        a) Primary edit list header word: Recording channel number
        b) Traces to be edited: refer to processing parameters
    4) Velocity Analysis
        a) Table to store velocity picks: Stacking velocity
6. <u>Bandpass Filter, Trace Kill, NMO, and CDP Stack</u>

1) Disk Data Input
    a) Primary trace header entry: CDP bin number
    b) Secondary trace header entry: Absolute value of offset
2) Bandpass Filter
3) Trace Kill/Reverse
4) Normal Moveout Correction
    a) Direction: Forward
    b) Stretch mute percentage: 30
    c) Long offset correction: None
    d) Velocities from database: Stacking velocity
5) CDP/Ensemble Stack
    a) Method for trace summing: Mean
    b) Root power scalar for stack normalization: 0.5
6) Disk Data Output

7. <u>Time Migration</u>
    1) Disk Data Input
        a) Primary trace header entry: CDP bin number
        b) Secondary trace header entry: Absolute value of offset
    2) Memory Stolt F-K Migration
        a) RMS velocities for migration: refer to processing parameters
        b) Percent stretch factor: 100
        c) Stolt stretch factor: 0.6
    3) Disk Data Output

8. <u>AGC, Top Mute, SEG-Y Output and Header Values</u>
    1) Disk Data Input
    2) Automatic Gain Control
        a) Type of AGC scalar: Mean
        b) AGC operator length: 500
        c) Basis for scalar application: Centered
    3) Trace Muting
        a) Type of mute: Top
        b) Mute file from database: Top mute picks after migration
    4) SEG-Y Output

a) Type of SEG-Y: Standard

b) Trace format: IBM Real

5) Header Values

a) Specify header value output: CDP, CDP_X, CDP_Y, SOURCE, SOU_X, SOU_Y, SOU_H2OD, TIM_SHOT, DAY_SHOT, YER_SHOT

(6).GMT Plotting Scripts

a. GMT script for plotting black-and-white seismic sections:

```
gmtset PAPER_MEDIA=Custom_2800x3800
map=TN272_line_1_processed_final

psbasemap -JX126/-80 -R1/9462/7.6/9.2 -BNEWs500f100:"CDP No.(6.25m interval)":/.2g.2f.1:"TWTT(sec)"::."TN272--line-1": -X4 -Y7 -K > $map.ps
pssegy $map.segy -JX126/-80 -R1/9462/7.6/9.2 -V  -D.15 -B-.5 -F0 -N -O -M67000 >> $map.ps
```

b. GMT script for plotting color seismic sections:

```
gmtset PAPER_MEDIA=Custom_2800x3800
map=TN272_line_1_processed_final

psbasemap -JX126/-80 -R1/9462/7.6/9.2 -BNEWs500f100:"CDP No.(6.25m interval)":/.2g.2f.1:"TWTT(sec)"::."TN272--line-1": -X4 -Y7 -K > $map.ps
segy2grd $map.segy -G$map.grd -I1/0.001s -R1/9462/7.6/9.2 -V -M67000
grdimage $map.grd -Cseis.cpt -JX126/-80 -R1/9462/7.6/9.2 -O -K -V  >> $map.ps
psbasemap -JX126/-80 -R1/9462/7.6/9.2 -BNEWs500f100:"CDP No.(6.25m interval)":/.2g.2f.1:"TWTT(sec)"::."TN272--line-1": -O -V >> $map.ps
```

*GMT color map file: seis.cpt could be created by "makecpt -Cpolar -T-20/20/1 -Z".

c. GMT script for plotting seismic lines on map:

```
gmtset PAPER_MEDIA=A3
gmtset ANNOT_FONT_SIZE_PRIMARY=12
gmtset ANNOT_OFFSET_PRIMARY=0.2c
gmtset BASEMAP_AXES=WeSn
gmtset BASEMAP_TYPE=fancy
gmtset COLOR_NAN=255/255/255
gmtset PLOT_DEGREE_FORMAT=+DF
gmtset TICK_LENGTH=0.2c

grdgradient JQZ.grd -A315  -N10 -GJQZ_il.grd -V
psbasemap -JM20 -R164/167.5/19.75/23.5 -Ba.5f.25/a.5f.25 -P -K -V > JQZ.ps
grdimage JQZ.grd -Cwarm2.cpt -JM -IJQZ_il.grd -R -O -P -K -V  >> JQZ.ps
grdcontour JQZ.grd -A -C250 -JM -R -O -P -K -V >> JQZ.ps
psxy JQZ_line2.xy -R -JM -SqD20k:+LD+kred+n.1i -W8,red,solid -P -O -K -V >>  JQZ.ps
psxy JQZ_line1.xy -R -JM -SqD20k:+LD+kpurple+n.1i -W8,purple,solid -P -O -K -V >>  JQZ.ps
```

*GMT color map file: warm2.cpt, grid file: JQZ.grd and MCS line CDP xy files are needed.

(7).Matlab Conversion Script

```
%Convert UTM coordinates to Lat Lon given x y and zone number
%Use WGS 1984 Ellipsoid from NIMA
%-------------------------------------------------------
% Maurice A. Tivey October 25, 1991
% Use NIMA flattening
% Jul 24 2006 Mod for southern hemisphere (negative zones)
%-------------------------------------------------------
% constants:
% r  equatorial radius
% e2 eccentricity (e squared) or flattening
% k0 scale factor on central meridian of zone
```

```
% m  true distance along central meridian from the
%         equator to the specified latitude
%
% Usage: [dlon1,dlat1]=utm2ll(x,y,izone)

% Clarke 1866 ellipsoid
%      r=6378206.4; % rp=6356583.8;
%      f=1/294.9786982; e2 = 2*f - f*f;
% WGS 1972 ellipsoid
%      r=6378135.0; % rp=6356750.3;
%      f=1/298.26; e2 = 2*f - f*f;
% GRS80
%     r=6378137.0; % rp=6356752.3;
%     f=1/298.257222101; e2 = 2*f - f*f;
% WGS 1984 ellipsoid
      r=6378137.0;      % equatorial radius
%  rp=6356752.3;      % polar radius
%  f=(r-rp)/r;        % compute flattening
   f=1/298.257223563; % flattening
   e2 = 2*f - f*f;
      k0=0.9996;
%
[nx,ny]=size(x);
if ny>1, x=x'; y=y'; end
% remove 500000. from x for "false eastings" ?
     x=x-500000;
% check for negative zone and southern hemisphere
if izone < 0, y=y-10^7; end
% determine zone for calculation of longitude of
% central meridian
     dlon0=(abs(izone)-1)*6.-180.+3.;
%fprintf(' UTM zone is %6.0f\n',izone);
%fprintf(' Central Meridian Latitude is %10.2f\n', dlon0);
```

```
%
     e21=e2/(1-e2);
% spheroid calculation
     m=0.+y./k0;
     m0=0.;
     e1=(1.-sqrt(1.-e2))/(1.+sqrt(1.-e2));
     mu=m./(r*(1.-e2/4.-3.*e2*e2/64.-5.*e2*e2*e2/256.));
%
     s2=sin(2.*mu);
     s4=sin(4.*mu);
     s6=sin(6.*mu);
radlat=mu+(3.*e1/2.-27.*e1*e1*e1/32.)*s2+(21.*e1*e1/16.-
55.*e1*e1*e1*e1/32.)*s4+(151.*e1*e1*e1/96.)*s6;
%
     dlat=radlat.*57.2957795132;
%
     c=e21.*(cos(radlat)).^2;
     t=(tan(radlat)).^2;
     n=r./sqrt(1-e2.*(sin(radlat)).^2);
     ss=(1-e2.*(sin(radlat)).^2);
     ss=ss.*ss.*ss;
     r1=r*(1-e2)./(sqrt(ss));
     d1=x./(n*k0);
%
     d2=d1.*d1;
     d3=d2.*d1;
     d4=d3.*d1;
     d5=d4.*d1;
     d6=d5.*d1;
term1=n.*tan(radlat);
term2=d2/2-(5*3*t+10*c-4*c.*c-9*e21).*d4/24;
term3=(61+90.*t+298.*c+45.*t.*t-252*e21-3.*c.*c).*d6./720;
     rlat1=(term1./r1).*(term2+term3);
```

```
    dlat1=dlat-rlat1*57.2957795132;
%
terma=(d1-(1.+2.*t+c).*d3./6.);
termb=(5.-(2.*c)+(28.*t)-(3.*c.*c)+(8.*e21)+(24.*t.*t)).*d5./120.;
    radln=(terma+termb)./cos(radlat);
    dlon1=dlon0+radln.*57.2957795132;
% output values are in dlat1,dlon1
%     fprintf(' lat: %12.5f\n lon: %12.5f\n',dlat1,dlon1);
```

(8).Data Storage Locations

Ship Server:

Main Directory: smb://indian/cruiseshare/seismic

Geometry Files: smb://indian/cruiseshare/seismic/TN272_Geometries

Navigation Files: smb://indian/cruiseshare/seismic/Navigation_UTMxy

GMT Scripts: smb://indian/cruiseshare/seismic/gmt_script

Processed SEG-Y files: smb://indian/cruiseshare/seismic/processed_segy

Seismic Section Plots: smb://indian/cruiseshare/seismic/processed_segy/plots_pdf

Screen Prints of ProMAX: smb://indian/cruiseshare/seismic/processed_segy/screen_print

CDP Navigation Files: smb://indian/cruiseshare/seismic/processed_segy/CDP_navigation

TAMU Carina Computer:

Raw SEG-D&SEG-Y Files: /media/2011Thompson/TN272

ProMAX: /media/2011Thompson/promax

Scratch: /media/2011Thompson/scratch