PS 2-D Seismic Reflection Imaging of the Bennett Thrust Fault in the Indio Mountains of West Texas*

Alan Vennemann[1], Marianne Karplus[1], Galen Kaip[1], and Steve Harder[1]

Search and Discovery Article #30519 (2017)**
Posted October 9, 2017

*Adapted from poster presentation given at 2017 AAPG Annual Convention & Exhibition, Houston, Texas, April 2-5, 2017

[1]The University of Texas at El Paso, El Paso, Texas (atvennemann@miners.utep.edu)

Abstract

We will present results from a 1-km long, 2-D seismic reflection line across the Bennett Thrust Fault in the Indio Mountains of southwest Texas, 34 kilometers southwest of Van Horn at the UTEP (University of Texas at El Paso) Field Station. Active sources used in this survey included 100 one-third-pound explosions and a higher frequency dataset produced from 500 sledge-hammer blows at the same 100 source points (5 blows will be stacked at each source point). Receivers included 200 Reftek 125A ("Texan") stand-alone seismometers.

The dominant regional lithologies comprise a transgressive sequence nearly 2 km in total stratigraphic thickness, formed by extensional processes. The stratigraphic sequence is an analog for similar areas that are ideal for petroleum reservoirs, such as reservoirs off the coasts of Brazil and Angola. The area is highly faulted with multiple fault generations. The youngest fault is a large northwest striking, southwest-side down normal fault named the Indio Fault. The Indio Fault cuts a number of major thrust belts that formed during the northeast directed thrusting during the Laramide Orogeny. We will be imaging the Bennett Thrust Fault, a northwest striking fault with a dip to the northeast. We aim to determine the near-surface geometries of the Bennett Thrust Fault and accompanying rock units. While there are no petroleum plays in the Indio Mountains region, imaging and understanding subsurface structural and lithological geometries and how that geometry directs potential fluid flow has implications for other regions with petroleum plays.

2-D Seismic Reflection Imaging of the Bennett Thrust Fault in the Indio Mountains of West Texas

Alan Vennemann, Marianne S. Karplus, Galen Kaip, Steven H Harder
Department of Geological Sciences, The University of Texas at El Paso

Abstract

We will present results from a 1-km long, 2-D seismic reflection line across the Bennett Thrust Fault in the Indio Mountains of southwest Texas, 34 kilometers southwest of Van Horn at the UTEP (University of Texas at El Paso) Field Station. Active sources used in this survey included 100 one-third-pound explosions and a higher frequency dataset produced from 500 sledge-hammer blows at the same 100 source points (5 blows will be stacked at each source point). Receivers included 200 Reftek 125A ("Texan") stand-alone seismometers.

The dominant regional lithologies comprise a transgressive sequence nearly 2 km in total stratigraphic thickness, formed by extensional processes. The stratigraphic sequence is an analog for similar areas that are ideal for petroleum reservoirs, such as reservoirs off the coasts of Brazil and Angola. The area is highly faulted with multiple fault generations. The youngest fault is a large northwest striking, southwest-side down normal fault named the Indio Fault. The Indio Fault cuts a number of major thrust belts that formed during the northeast directed thrusting during the Laramide Orogeny. I will be imaging the Bennett Thrust Fault, a northwest striking fault with a dip to the northeast. I aim to determine the near-surface geometries of the Bennett Thrust Fault and accompanying rock units. While there are no petroleum plays in the Indio Mountains region, imaging and understanding subsurface structural and lithological geometries and how that geometry directs potential fluid flow has implications for other regions with petroleum plays.

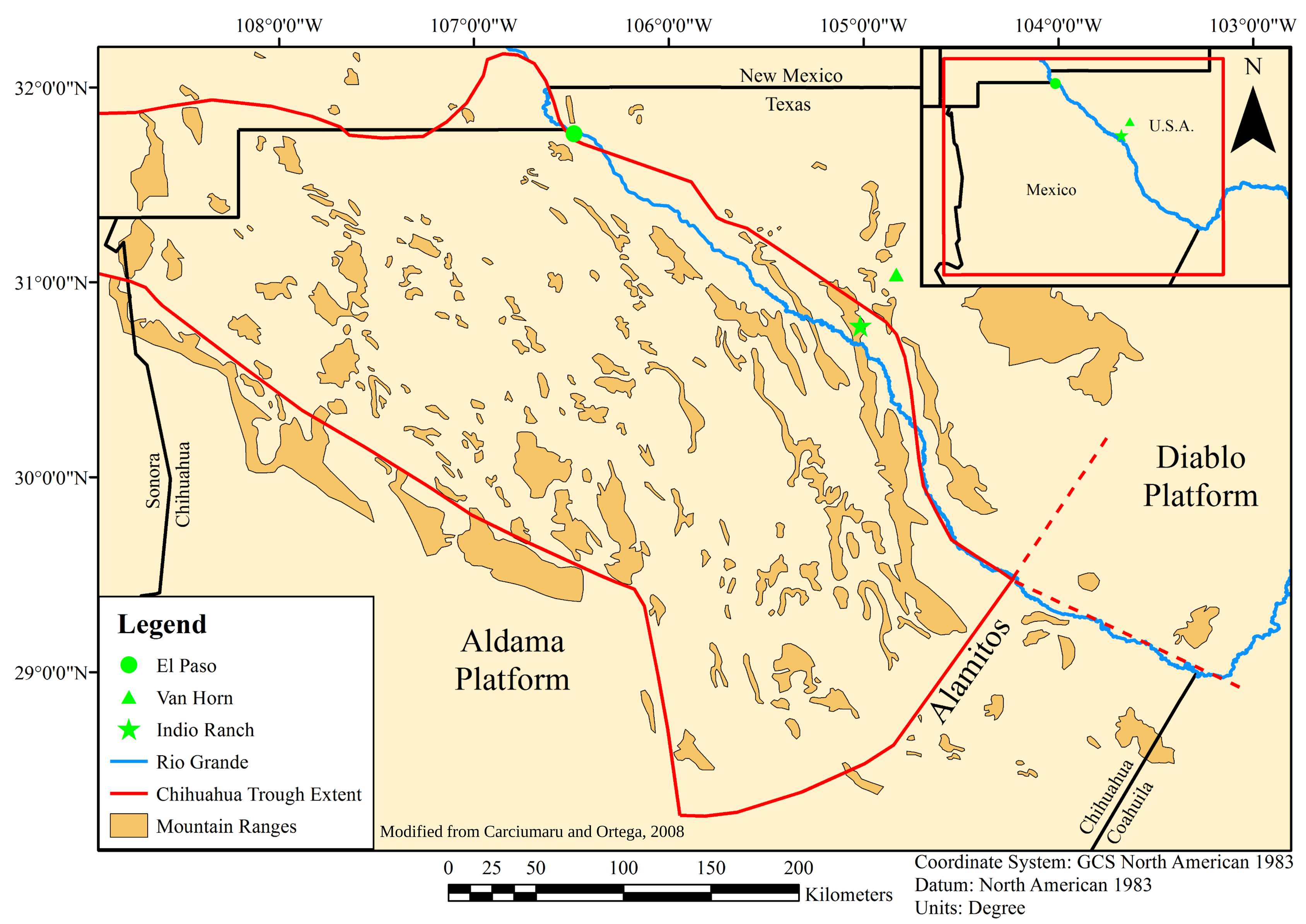
Objectives

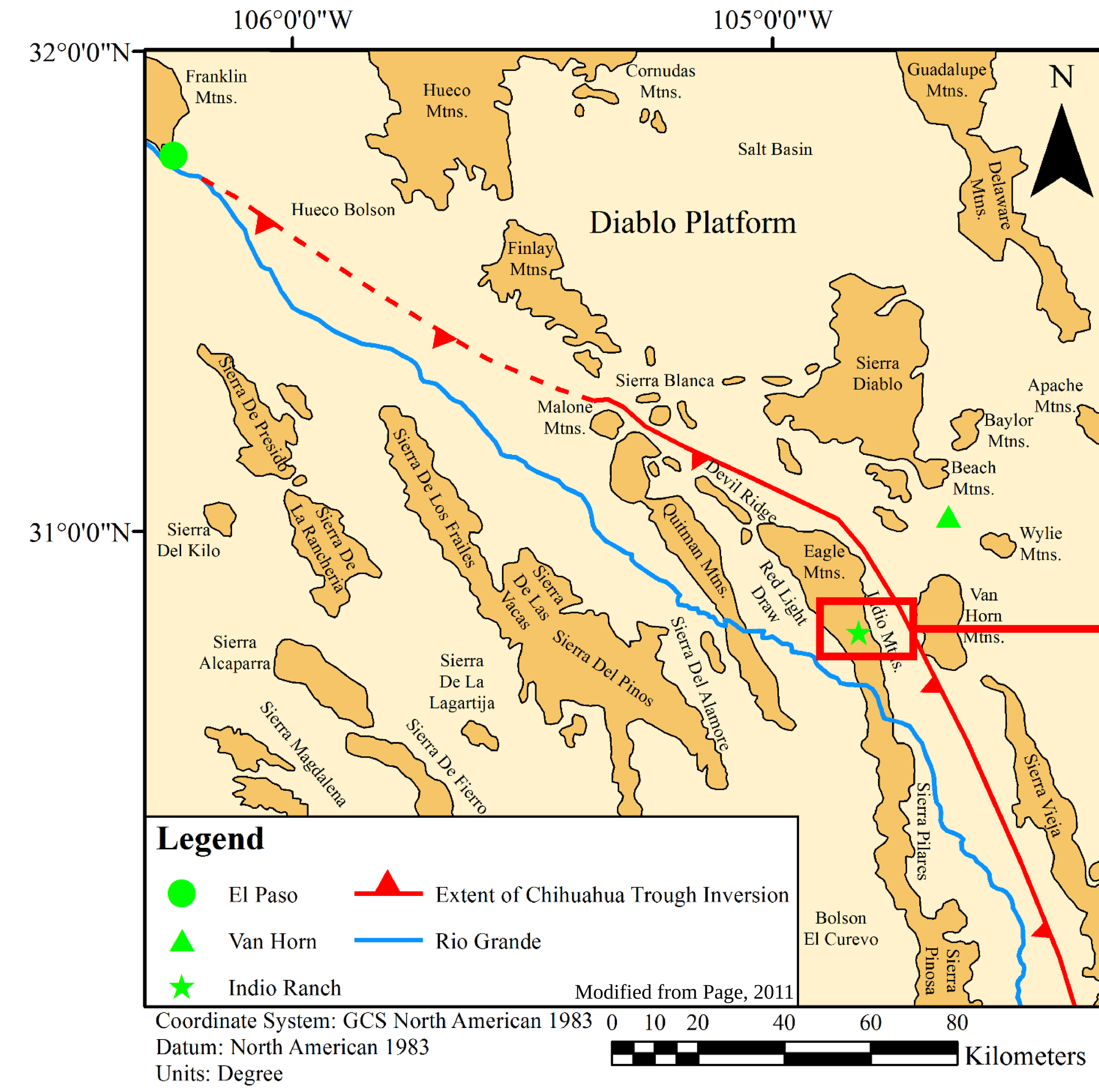
1. Process, analyze and interpret the structural and lithological geometries of the Bennett Thrust Fault and accompanying rock units.
2. Identify additional hypothesized imbricate faulting, as Page (2011) mapped previously unknown imbricate faults in the area at the surface.

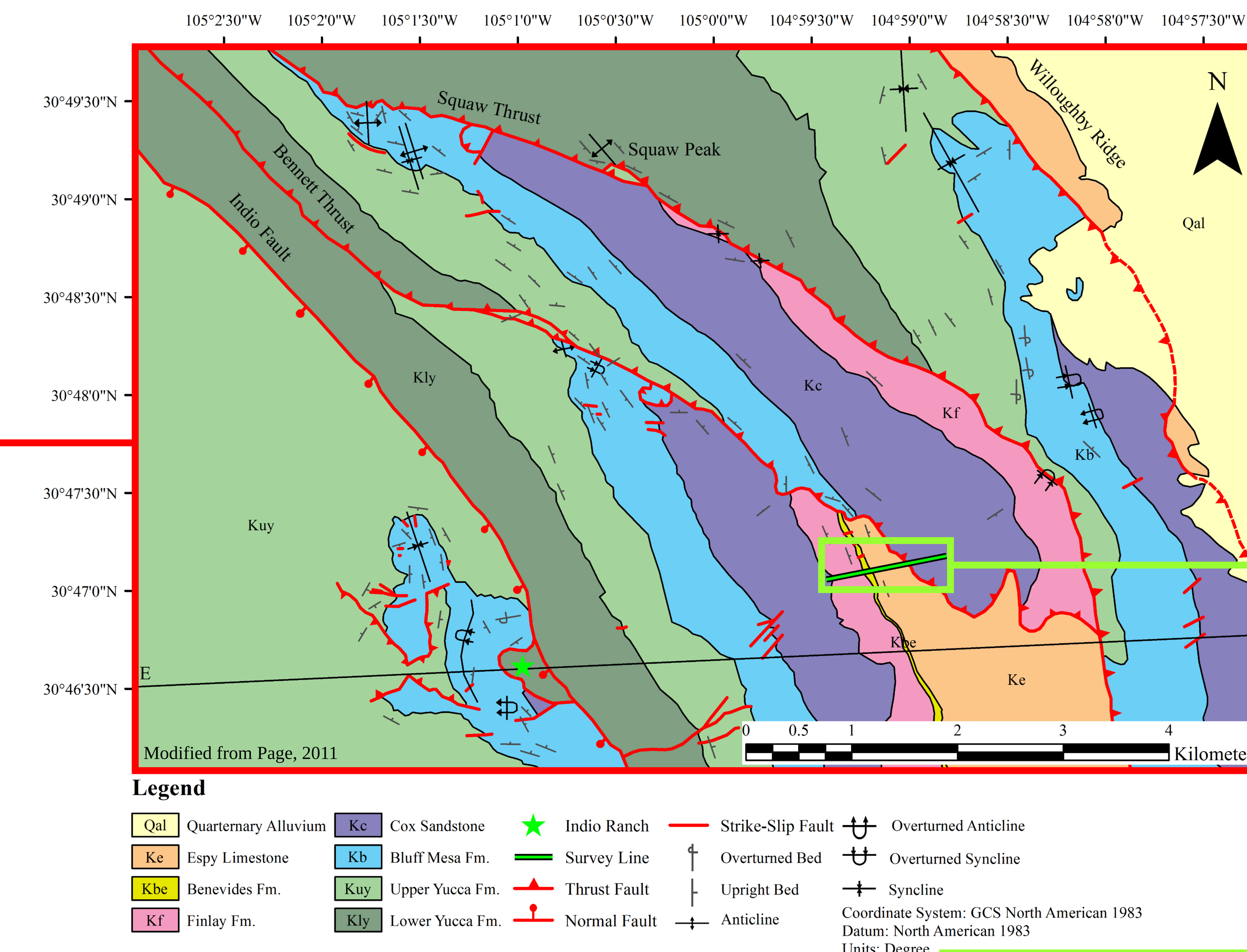
Field Methods

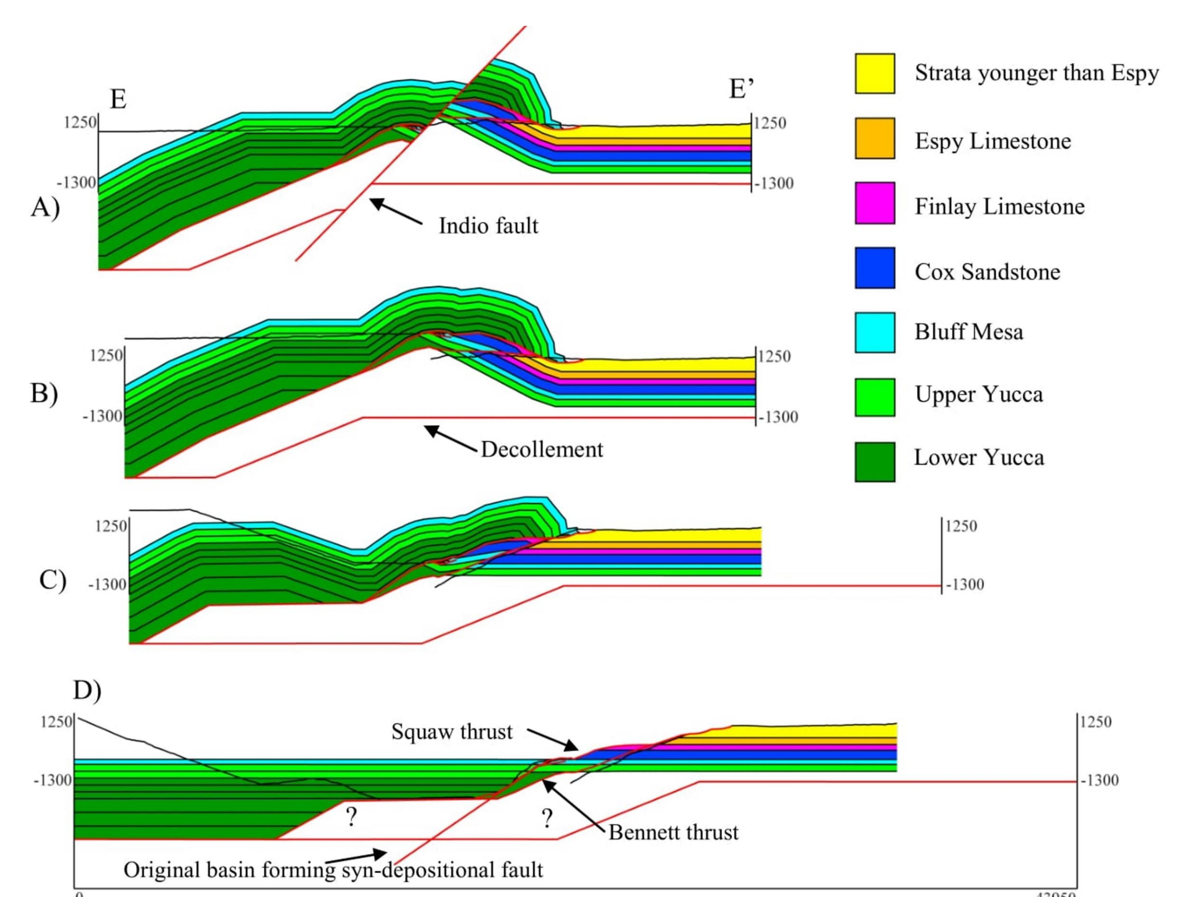
- Deploy 200 4.5 Hz seismometers attached to Reftek Texan Data Recorders at a sampling rate of 2 ms along the 1.0 km line at 5.0 m intervals.
- Deploy 100 one-third-pound Trojan Booster explosives along the 1.0 km line at 10.0 intervals at approximately 1.0 m below the surface, and 5 sledge hammer blows at each shot location prior to detonation.

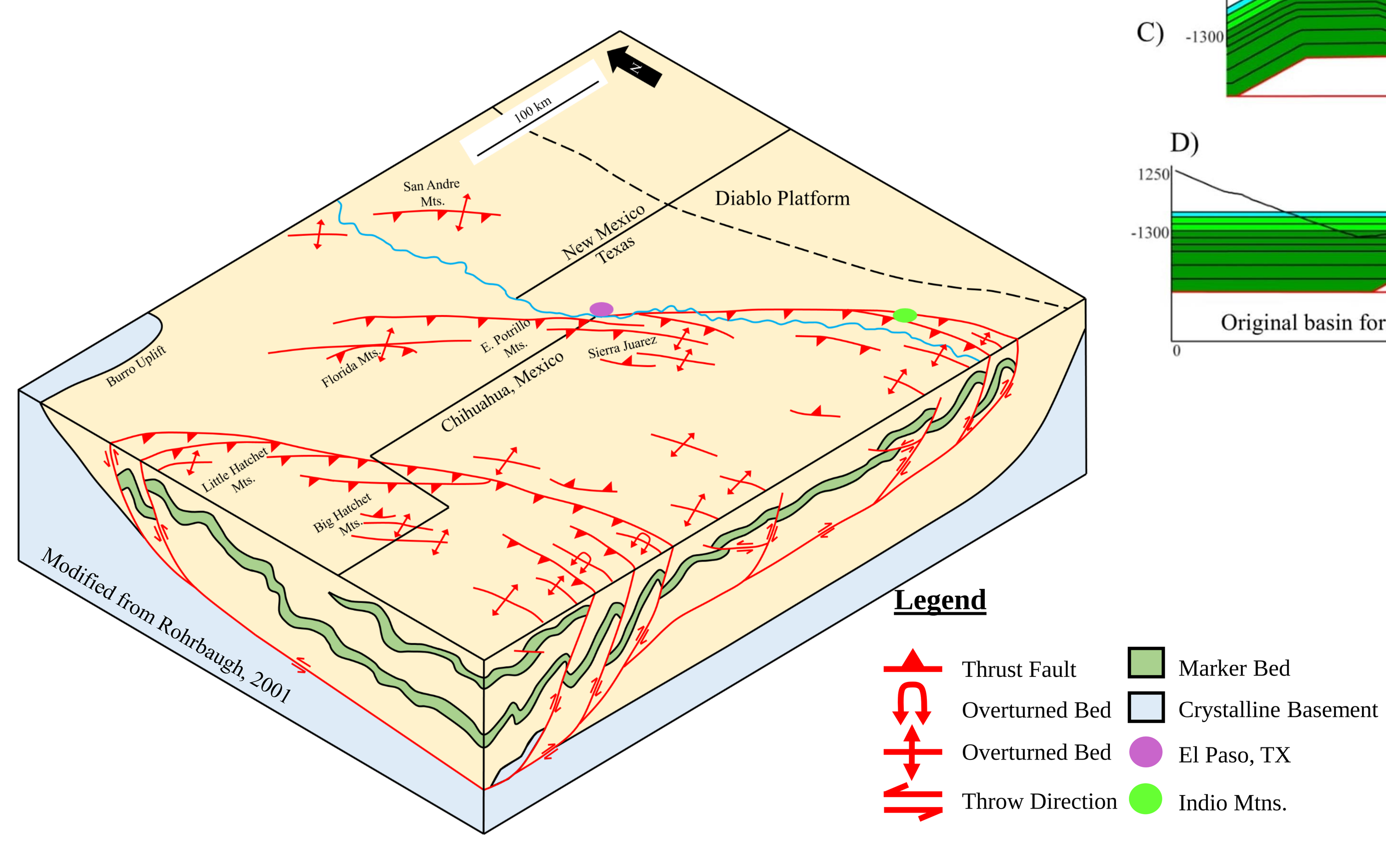
Study Area and Regional Geology

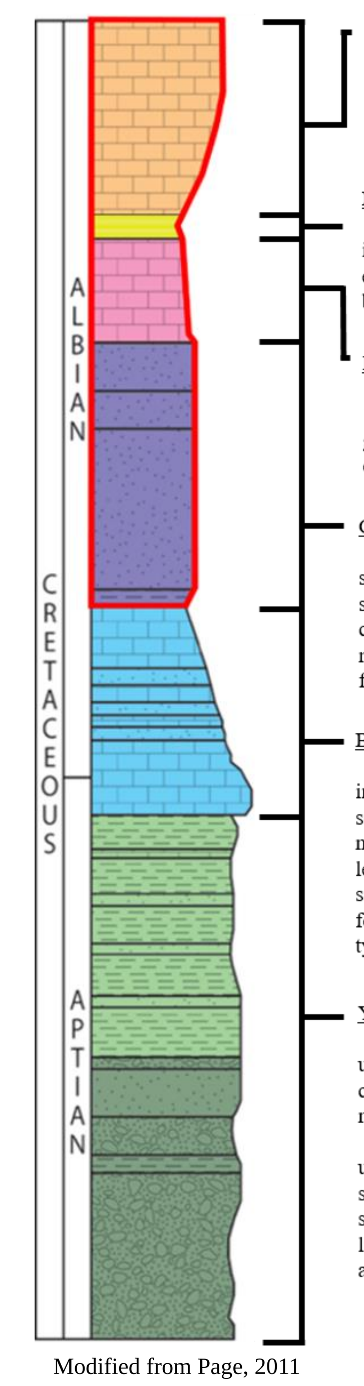












Espy Limestone
The Espy Limestone is composed predominantly of medium to dark gray limestone. The lower section is characterized by shale with interbedded nodular limestone and marl. Fossils are predominantly bivalves with a small frequency of gastropods. Fossils are abundant in the lower section and diminish in meter scale beds of the upper section.

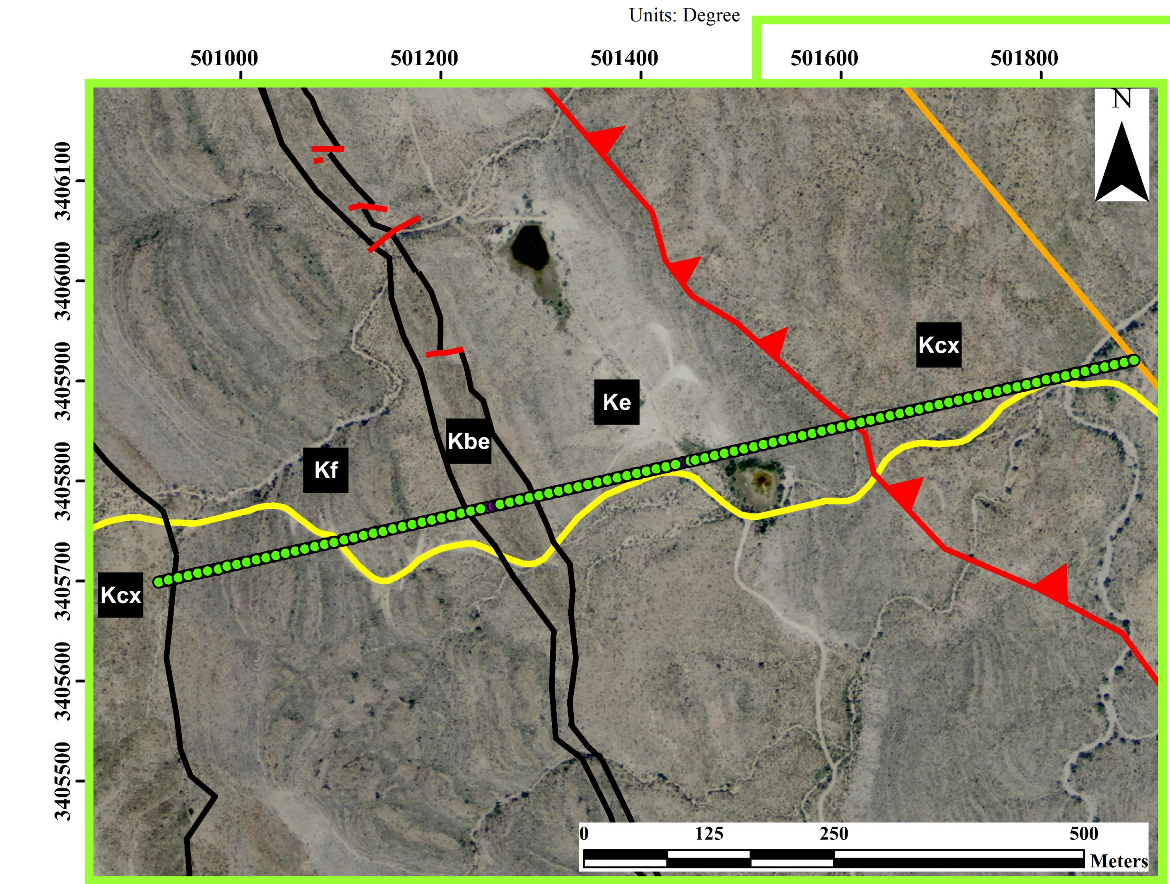
Benevides Formation
Visible outcrops of the Benevides are usually limited to the orange-brown sandstone in the upper unit. The lower section is non-resistant, shaley siltstone. The upper exposed portions is characterized by its cross-bedding and intersecting fossilized burrows.

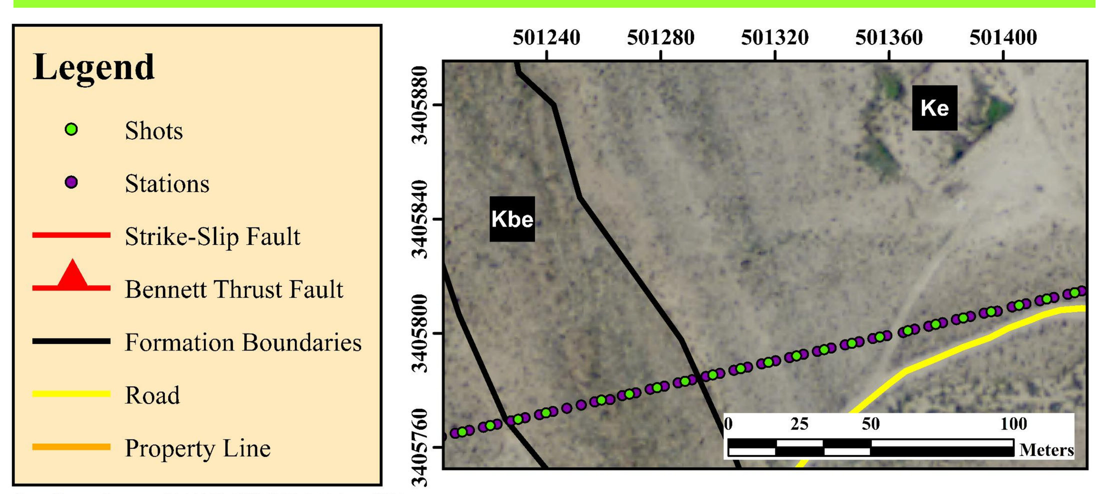
Finlay Formation
The Finlay formation is a fine-crystalline, gray limestone consisting of massive beds 1-3 m thick. The Finlay formation is composed of dense fissil hash and identifiable gastropds and bivalves. Abundant silicified pelycpod shells on the jagged and weathered exposures are common.

Cox Sandstone
The Cox Sandstone is a cross-bedded, fine to medium grained, quartz-arenite. The sandstone is fairly resistant to weathering and is a ridge former. Pale yellow to white sandstone mixed with iron-oxide stained grains is characteristic. Several lenses of conglomerate-sandstone composed of rounded quartz, chert and limestone exist but are not pervasive. Dark red shale units exist in the lower column. A 3 m thick, light gray fossiliferous limestone is present.

Bluff Mesa Formation
The Bluff Mesa is a fossiliferous, fine-grained to crystalline, gray limestone interbedded with quartz-arenite sandstone and can be divided into 3 units. The lower section contains massive beds (up to 3 m) of fossiliferous limestone. Oolite rich beds are most abundant in this lower unit. The middle section consits of limestone beds 2 m or less in thickness. The limestone beds are interbedded by layers of quartz-arenite sandstone of a half meter or less in thickness and closely resemble the overlying Cox formation. The upper section consists of a fossiliferous, nodular, micritic limestone and is typically a valley former.

Yucca Formation
The Yucca formation can be divided into distinct upper and lower units. The lower unit is a conglomerate with clasts composed of gray limestone and black, pink and white chert cemented by a fine-grained maroon sandstone matrix. The clasts range from a few millimeters to approximately 20 cm in size.
A sudden fining upward sequence of sandstone in the Yucca defines the base of the upper unit, which consists of sandstone, shale, siltstone and limestone. The maroon shale layers are easily eroded and define slopes with an average thickness of 1-2 m. The siltstone is typically dark brown with an average thickness less than 1 meter. 2 limestone layers are in the upper portion of the Yucca column. The lower limestone bed averages 3 meters in thickness and the upper bed marks the Yucca-Bluff Mesa contact.





Coordinate System: NAD83 CSRS UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

2-D Seismic Reflection Imaging of the Bennett Thrust Fault in the Indio Mountains of West Texas

Alan Vennemann, Marianne S. Karplus, Galen Kaip, Steven H. Harder

Department of Geological Sciences, The University of Texas at El Paso

Processing Workflow

1. Geometry Assignment
2. Trace Editing and Parameter Selection
3. Elevation Static Corrections
4. Velocity Analysis
5. Normal Moveout Corrections (NMO)
6. Create Database Files
7. Dip Moveout Corrections (DMO)
8. PostStack Signal Enhancement
9. Velocity Manipulation
10. Time to Depth Conversion

2. Trace Editing and Parameter Selection

Editing Flow: shot_gathers

Add | Delete | Execute | View | Exit

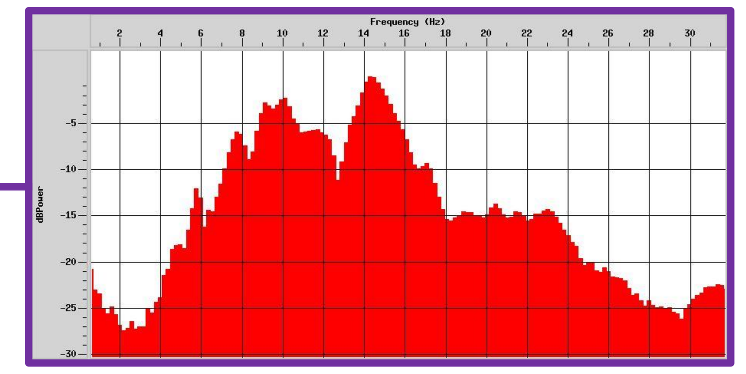
- Disk Data Input <- Shots_Geom
- Trace Muting <= TOP_MUTE
- Trace Kill/Reverse <= KILL
- Trace Muting <= R_AirWave
- Trace Muting <= L_AirWave
- Spiking/Predictive Decon <= decon_gate
- Automatic Gain Control
- Trace Display

Automatic Gain Control

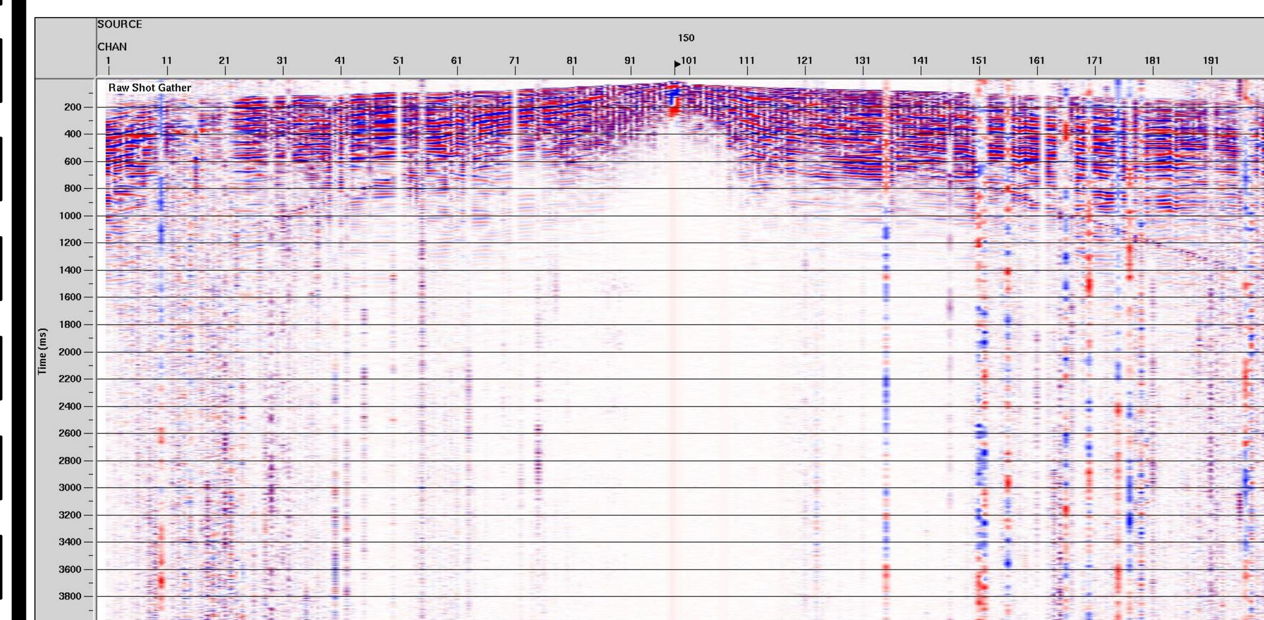
Application mode	APPLY
Type of AGC scalar	MEAN
AGC operator length	2100.
BASIS for scalar application	Centered
Exclude hard zeroes?	Yes No
Robust Scaling?	Yes No

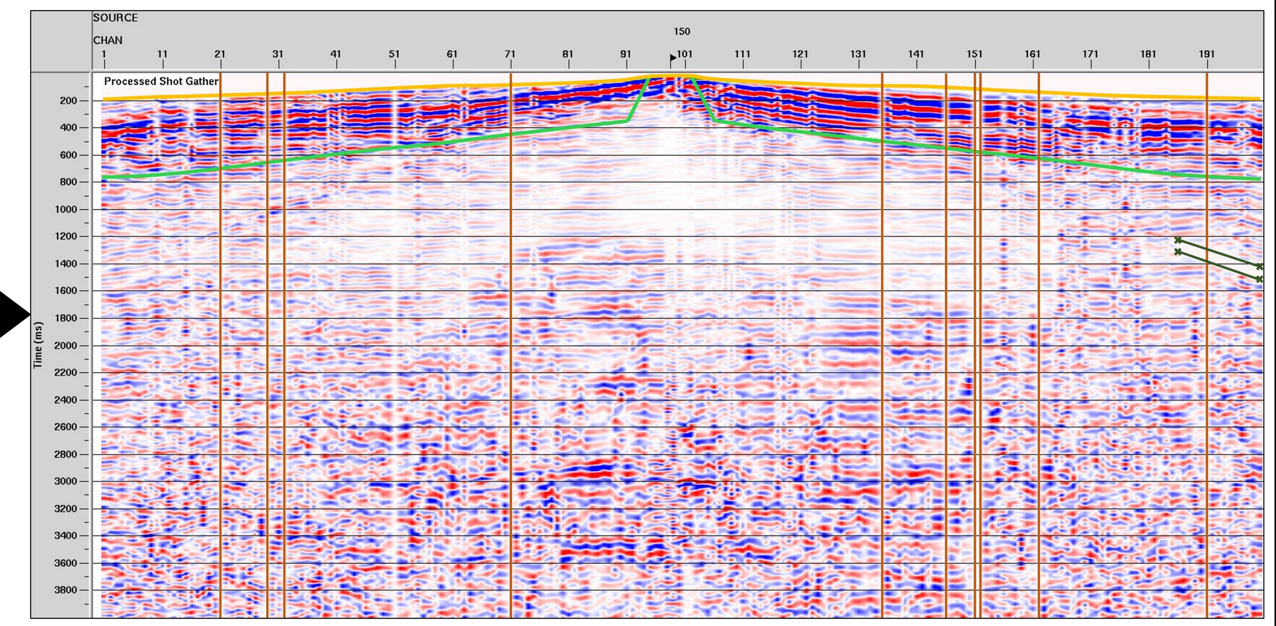
Spiking/Predictive Decon

TYPE of deconvolution	Minimum phase spiking
Decon operator length(s)	80
Apply user specified taper?	Yes No
Operator 'white noise' level(s)	0.1
Window rejection factor	2.
Time gate reference	Time 0
Get decon gates from the DATABASE?	Yes No
SELECT decon gate parameter file	decon_gate
Output traces or filters	Normal decon output
Apply a bandpass filter after decon?	Yes No
Bandpass filter frequency values	3-10-15-30
Re-apply trace mute after decon?	Yes No



- AirWave Mute
- Top Mute
- Decon Gate
- Killed Traces





3. Elevation Statics

Disk Data Input

Read data from other lines/surveys?	Yes No
Select dataset	Shots_Geom
Propagate input file history	Yes No
Trace read option	Sort
Interactive Data Access?	Yes No
Select primary trace header entry	CDP bin number
Select secondary trace header entry	No trace header entry selected
Sort order list for dataset	*/
Presort in memory or on disk?	Memory
Read the data multiple times?	Yes No
Process trace headers only?	Yes No
Override input data's sample interval?	Yes No

Editing Flow: Calculate Datum

Add | Delete | Execute | View | Exit

- Datum Statics Calculation*
- Disk Data Input <- Shots_Geom
- Trace Muting <= TOP_MUTE
- Trace Kill/Reverse <= KILL
- Trace Muting <= L_AirWave
- Trace Muting <= R_AirWave
- Spiking/Predictive Decon <= decon_gate
- Datum Statics Apply
- Disk Data Output -> Statics_Sorted_3000

Datum Statics Calculation

Elevation or Refraction	Elevation
Final datum elevation	1316.526
Replacement velocity	3000
Database math method for elevation statics	Shot Holes Using Uphole Info
NMO static method	Elevations
Length of smoother	299
Processing DATUM	NMO DATUM
Run ID	01

4. Velocity Analysis

Editing Flow: velocity analysis

Add | Delete | Execute | View | Exit

- Supergather Formation*
- Automatic Gain Control
- Velocity Analysis Precompute <= TOP_MUTE
- Velocity Analysis <= vel_3000_NEW

Supergather Formation

Warning >> This menu is obsolete. Please use the new 2D Supergather Formation tool.

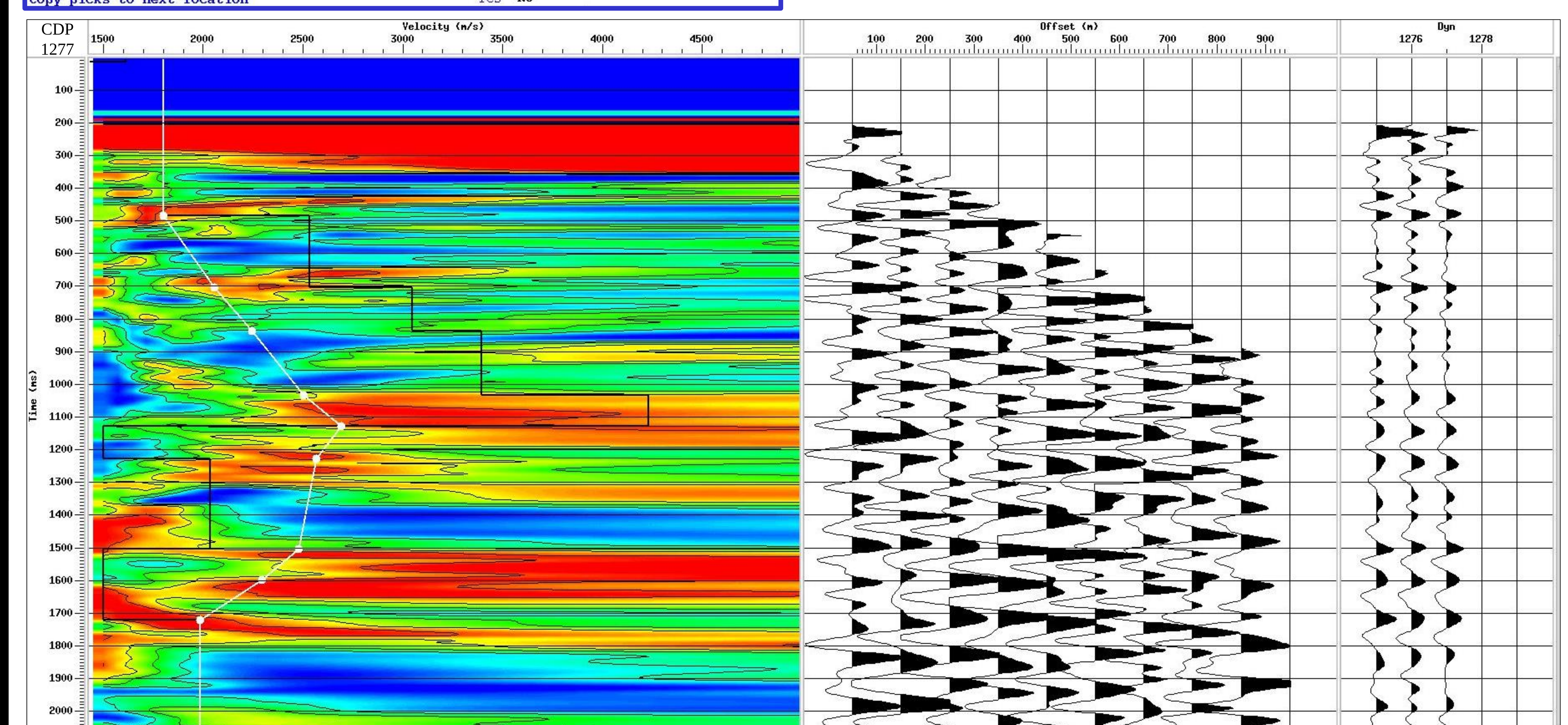
Read data from other lines/surveys?	Yes No
Select dataset	Statics_Sorted_3000
Presort in memory or on disk?	Memory
Maximum CDP fold	180
Minimum center cdp number	1102
Maximum center cdp number	1401
Cdp increment	5
Cdps to combine	3

Velocity Analysis

Select display DEVICE	This Screen
Table to store velocity picks	vel_3000_HIGH
Is the incoming data Precomputed?	Yes No
Perform residual velocity analysis?	NONE TIME DEPTH
Set which items are visible?	Yes No
Set semblance scaling and autosnap parameters?	Yes No
Pick/apply a mute?	NONE TOP BASE BOTH
Gather offset Top mute table	TOP_MUTE
Mute taper length	20.
Select/Display horizons?	NONE POP-MENU EXPLICIT RESET-EXPLICIT
Interact with other processes using PD?	Yes No
Get guide function from an existing parameter table?	Yes No
Guide minimum value	1500.
Guide maximum time value	4000.
Maximum stretch percentage for NMO	30.
Long offset moveout correction?	NONE ALCHALABI CASTLE HARLAN TSVANKIN
Interval velocity below last knee	0.
Copy picks to next location	Yes No

Velocity Analysis Precompute

Perform residual velocity analysis?	NONE TIME DEPTH
Number of CDPs to sum into gather	5
Apply partial NMO-to-binning	Yes No
Apply differential CDP mean statics?	Yes No
Absolute offset of first bin center	50.
Bin size for vertically summing offsets	100.
Maximum offset	1000.
Use absolute value of offset for stacking?	Yes No
Compute NMO for every velocity function?	Yes No
Minimum semblance analysis value	1500.
Maximum semblance analysis value	5000.
Number of semblance calculations	50
Semblance velocity axis	Equal Velocity
Semblance sample rate	20.
Semblance calculation window	40.
Number of stack velocity functions	11
Number of CDPS per stack strip	5
Scale stacks by number of live samples summed	Yes No
Method of computing velocity functions	Top/base range
Velocity variation at time 0	500.
Velocity variation at maximum time	1500.
Semblance normalization mode	No Scaling
Get guide function from an existing parameter table?	Yes No
Guide minimum value	1500.
Guide maximum time value	4000.
Maximum stretch percentage for NMO	30.
Long offset moveout correction?	NONE ALCHALABI CASTLE HARLAN TSVANKIN
Anisotropy correction parameter ETA	0.
Use a picked mute?	NONE TOP BASE BOTH
Gather offset Top mute table	TOP_MUTE
Mute taper length	20.



5. Normal Moveout Corrections (NMO)

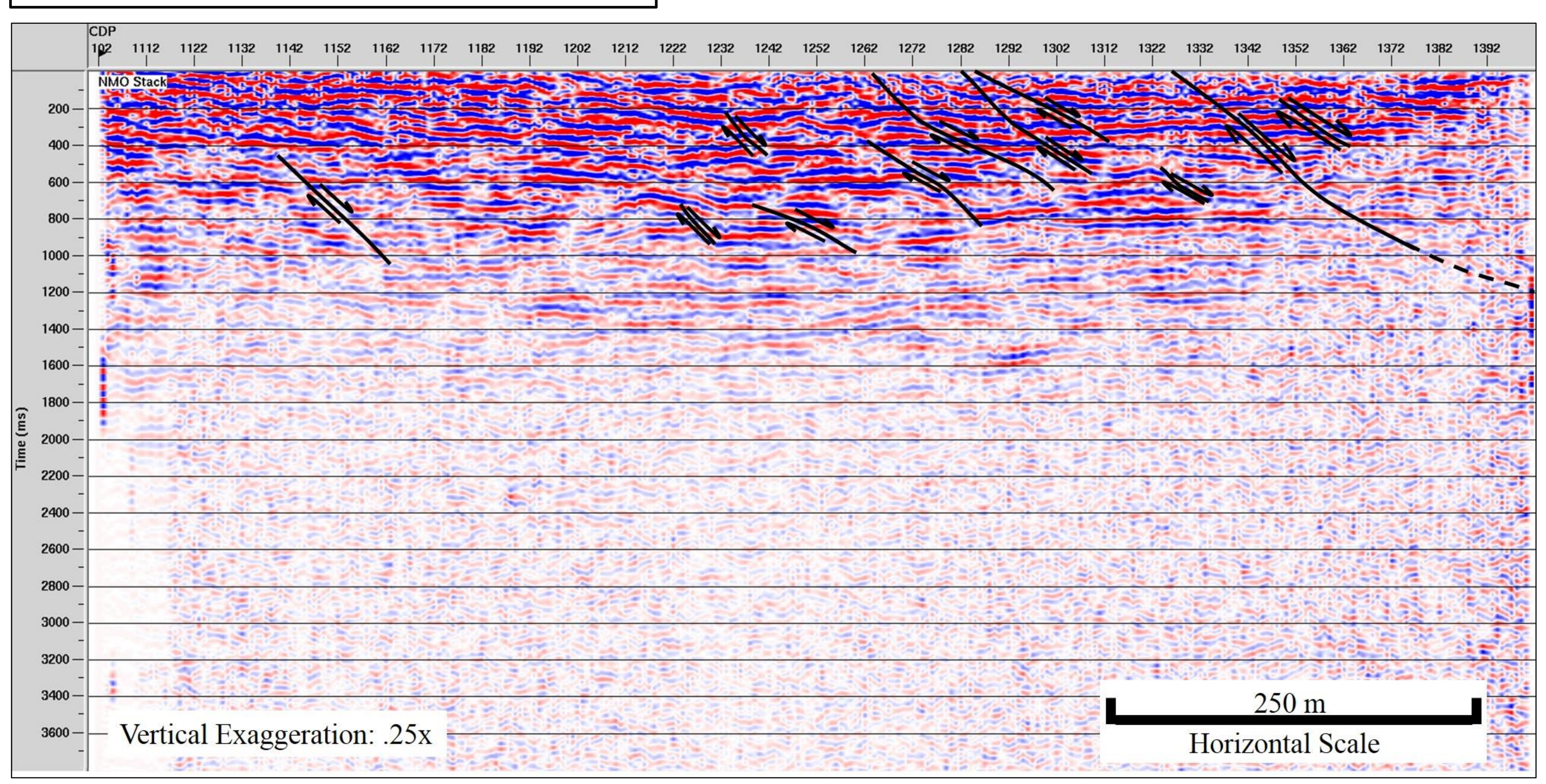
Editing Flow: NMO_OG

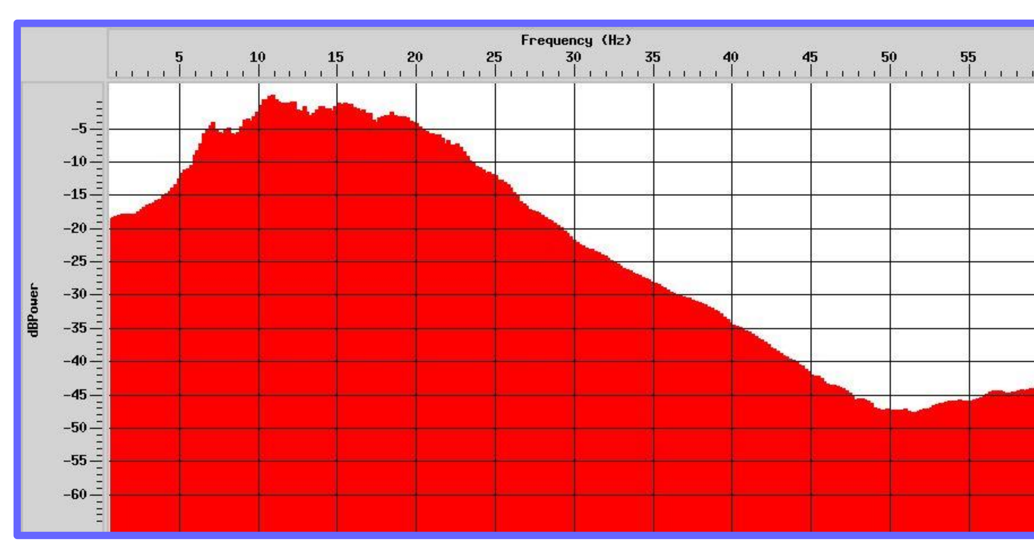
Add | Delete | Execute | View | Exit

- Disk Data Input <- Statics_Sorted_3000
- Trace Muting <= TOP_MUTE
- Trace Kill/Reverse <= KILL
- Trace Muting <= R_AirWave
- Trace Muting <= L_AirWave
- Spiking/Predictive Decon <= decon_gate
- Normal Moveout Correction <= vel_3000_HIGH
- Trace Equalization <= decon_gate
- CDP/Ensemble Stack
- Bandpass Filter
- Disk Data Output -> DMO_HIGH
- Trace Display Label
- Trace Display

Bandpass Filter

TYPE of filter	Single Filter
Type of filter specification	Ormsby bandpass
PHASE of filter	Zero
Domain for filter application	Frequency
Percent zero padding for FFT's	25.
Apply a notch filter?	Yes No
Ormsby filter frequency values	4.5-10-20-50
Re-apply trace mute after filter?	Yes No





6. Create Database Files

Editing Flow: create database files

Add | Delete | Execute | View | Exit

- Disk Data Input <- DMO_HIGH
- Extract Database Files
- Disk Data Output -> DMO_HIGH_w_DBFiles

2-D Seismic Reflection Imaging of the Bennett Thrust Fault in the Indio Mountains of West Texas

Alan Vennemann, Marianne S. Karplus, Galen Kaip, Steven H Harder
Department of Geological Sciences, The University of Texas at El Paso

7. Dip Moveout Corrections (DMO)

Disk Data Input	
Read data from other lines/surveys?	Yes No
Select dataset	DMO_HIGH_w_DBFiles
Propagate input file history	Yes No
Trace read option	Sort
Interactive Data Access?	Yes No
Select primary trace header entry	CDP bin number
Select secondary trace header entry	Absolute value of offset
Select tertiary trace header entry	No trace header entry selected
Sort order list for dataset	*:*/
Presort in memory or on disk?	Memory
Read the data multiple times?	Yes No
Process trace headers only?	Yes No
Override input data's sample interval?	Yes No

Trace Binning	
Header entry to bin	Absolute value of offset
Binned header entry	DMOOFF
Binned entry format	Real
Header entry bin centers	2.5-997.5(10)
Binned header entry values	2.5-997.5(10)
Set OFFSET and AOFFSET headers to bin center?	Yes No

Disk Data Input	
Read data from other lines/surveys?	Yes No
Select dataset	DMO_HIGH_w_Headers
Propagate input file history	Yes No
Trace read option	Sort
Interactive Data Access?	Yes No
Select primary trace header entry	Offset bin for DMO
Select secondary trace header entry	CDP bin number
Select tertiary trace header entry	No trace header entry selected
Sort order list for dataset	*:*/
Presort in memory or on disk?	Memory
Read the data multiple times?	Yes No
Process trace headers only?	Yes No
Override input data's sample interval?	Yes No

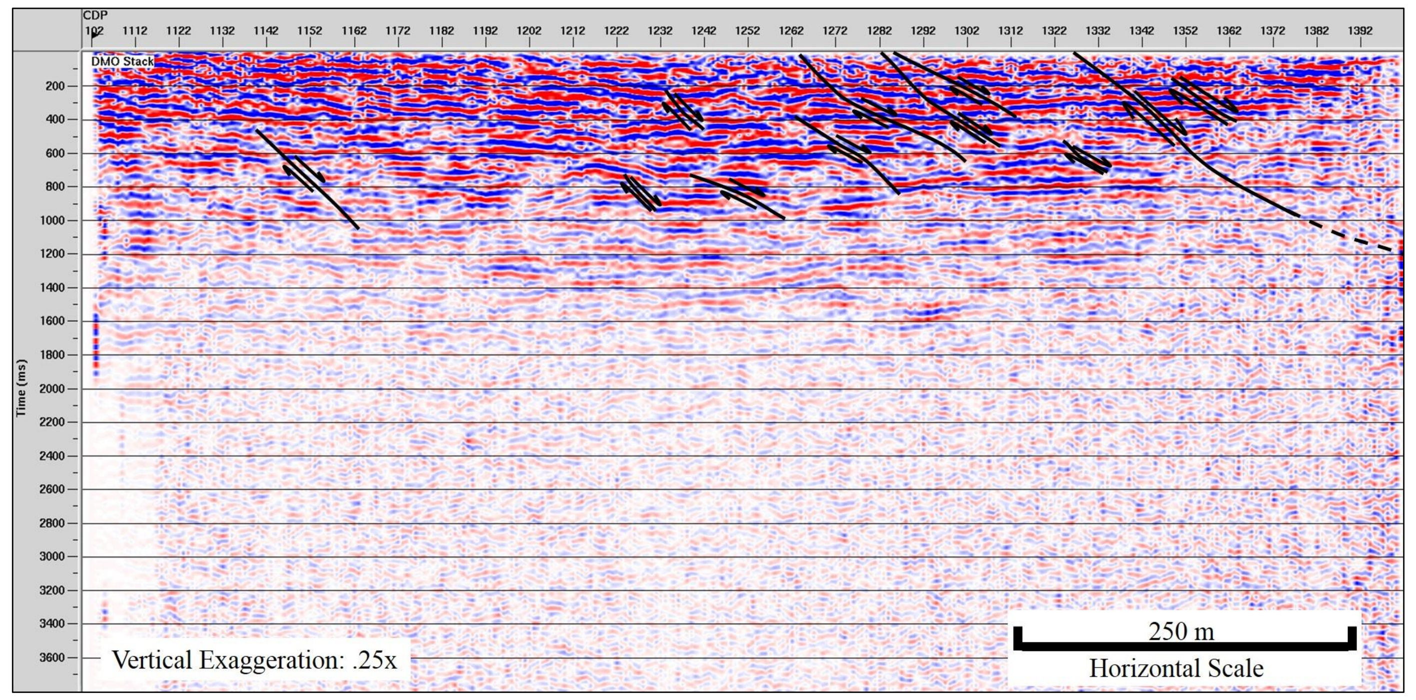
Editing Flow: DMO_OG

Add Delete Execute View Exit

```
Disk Data Input <- DMO_HIGH_w_DBFiles
Trace Binning
Database/Header Transfer
Disk Data Output -> DMO_HIGH_w_Headers
Disk Data Input <- DMO_HIGH_w_Headers
Common Offset DMO Binning
Disk Data Output -> DMO_HIGH_Binned
Disk Data Input <- DMO_HIGH_Binned
CDP/Ensemble Stack
Trace Display Label
Trace Display
Disk Data Output -> DMO_HIGH_Stack
```

Common Offset DMO Binning	
Near offset bin	2.5
Bin increment	20.
Maximum number of bins	3990
Use absolute value of offset?	Yes No
Set offset header to binned center?	Yes No

Disk Data Input	
Read data from other lines/surveys?	Yes No
Select dataset	DMO_HIGH_Binned
Propagate input file history	Yes No
Trace read option	Sort
Interactive Data Access?	Yes No
Select primary trace header entry	CDP bin number
Select secondary trace header entry	No trace header entry selected
Sort order list for dataset	*/
Presort in memory or on disk?	Memory
Read the data multiple times?	Yes No
Process trace headers only?	Yes No
Override input data's sample interval?	Yes No



8. Poststack Signal Enhancement

F-X Decon	
TYPE of filter	Wiener Levinson
Percentage of white noise	0.
Horizontal window length	299
Number of filter samples	7
Time window length	300.
Time window overlap	100.
F-X filter start frequency	4.5
F-X filter end frequency	50.
Number of times to apply F-X filter to each trace	1
Apply filter only to selected traces?	Yes No
Re-apply trace mute after filter?	Yes No

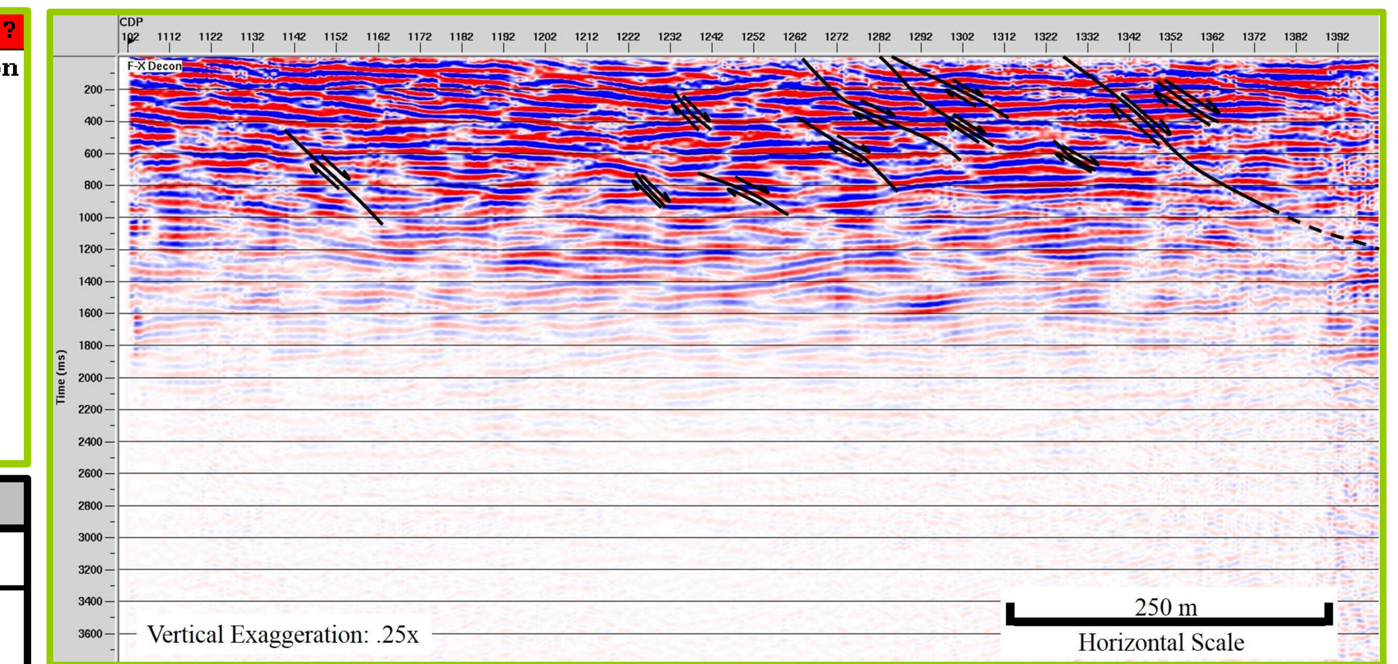
Editing Flow: Poststack_Enhancement

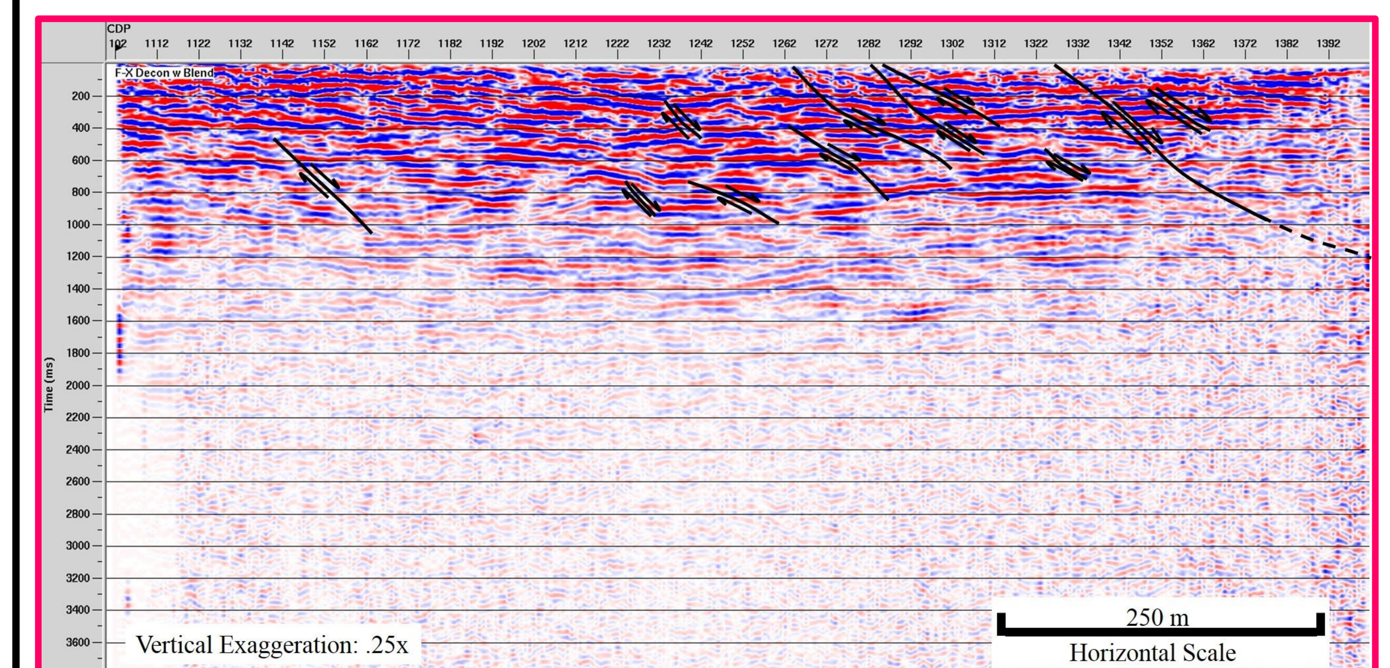
Add Delete Execute View Exit

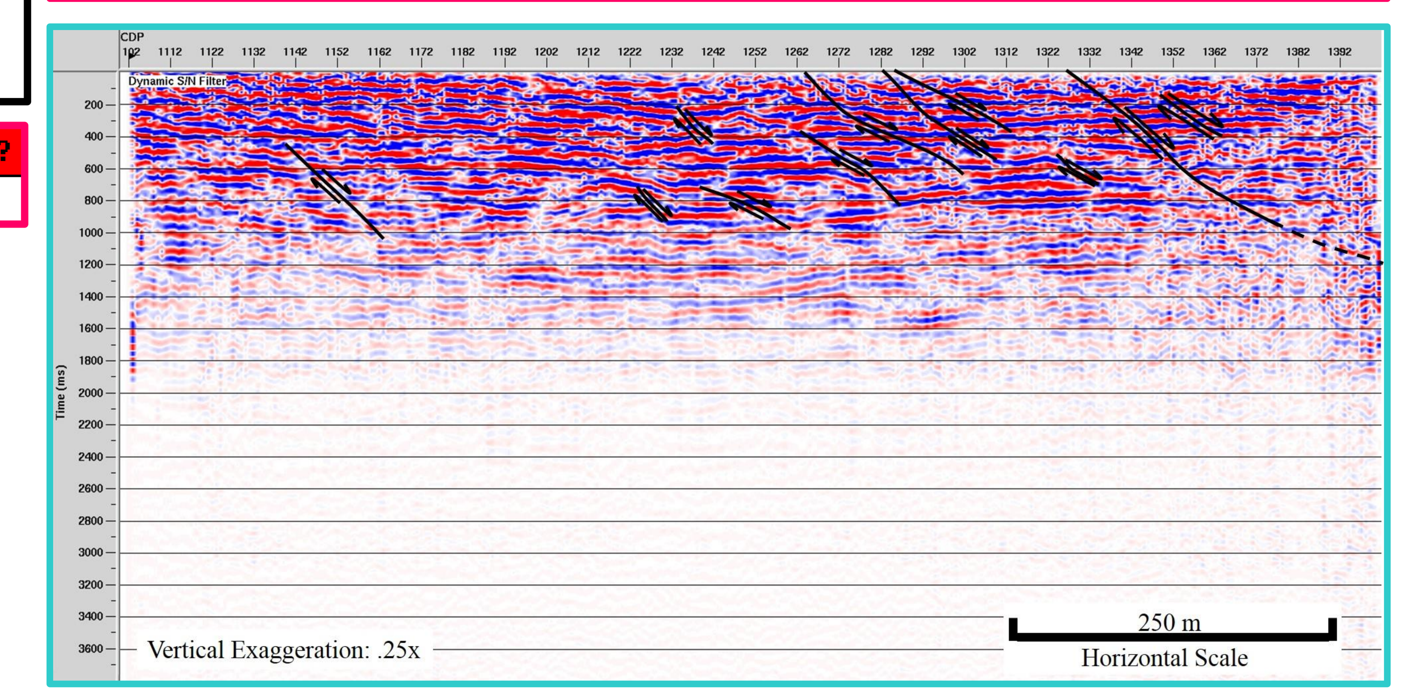
```
Disk Data Input <- DMO_HIGH_Stack
Reproduce Traces
IF
  Trace Display Label
ELSEIF
  Trace Display Label
  F-X Decon
ELSEIF
  Trace Display Label
  BLEND
  F-X Decon
  Automatic Gain Control
ELSEIF
  Trace Display Label
  Dynamic S/N Filtering
ENDIF
Trace Display
Disk Data Output -> Stack_FX_Enhance
```

BLEND	
Ratio of processed/original	1:2

Dynamic S/N Filtering	
Horizontal window length	299
Time window length	300.
Time window overlap	100.
F-X filter start frequency	4.5
F-X filter end frequency	50.
Re-apply trace mute after filter?	Yes No







9. Velocity Manipulation

Editing Flow: Velocity Manipulation

Add Delete Execute View Exit

```
Velocity Manipulation* <= vel_3000_HIGH
```

Velocity Manipulation*	
Type of velocity table to input	Stacking (RMS) Velocity
Get velocity table from database?	Yes No
Select input velocity database entry	vel_3000_HIGH
Combine a second velocity table with the first?	Yes No
Resample the input velocity table(s)?	Yes No
Shift or stretch the input velocity table?	Yes No
Adjust velocities to the final datum?	Yes No
Type of parameter table to output	Average Velocity in depth
Select output velocity database entry	vel
Type of RMS to interval conversion	Smoothed gradients
Spatially resample the velocity table?	Yes No
Output a single average velocity table?	Yes No
Smooth velocity field?	Yes No
Time step sizes for the output velocity table	30.
Adjust output velocities by percentages?	Yes No
Clip output velocities?	Yes No

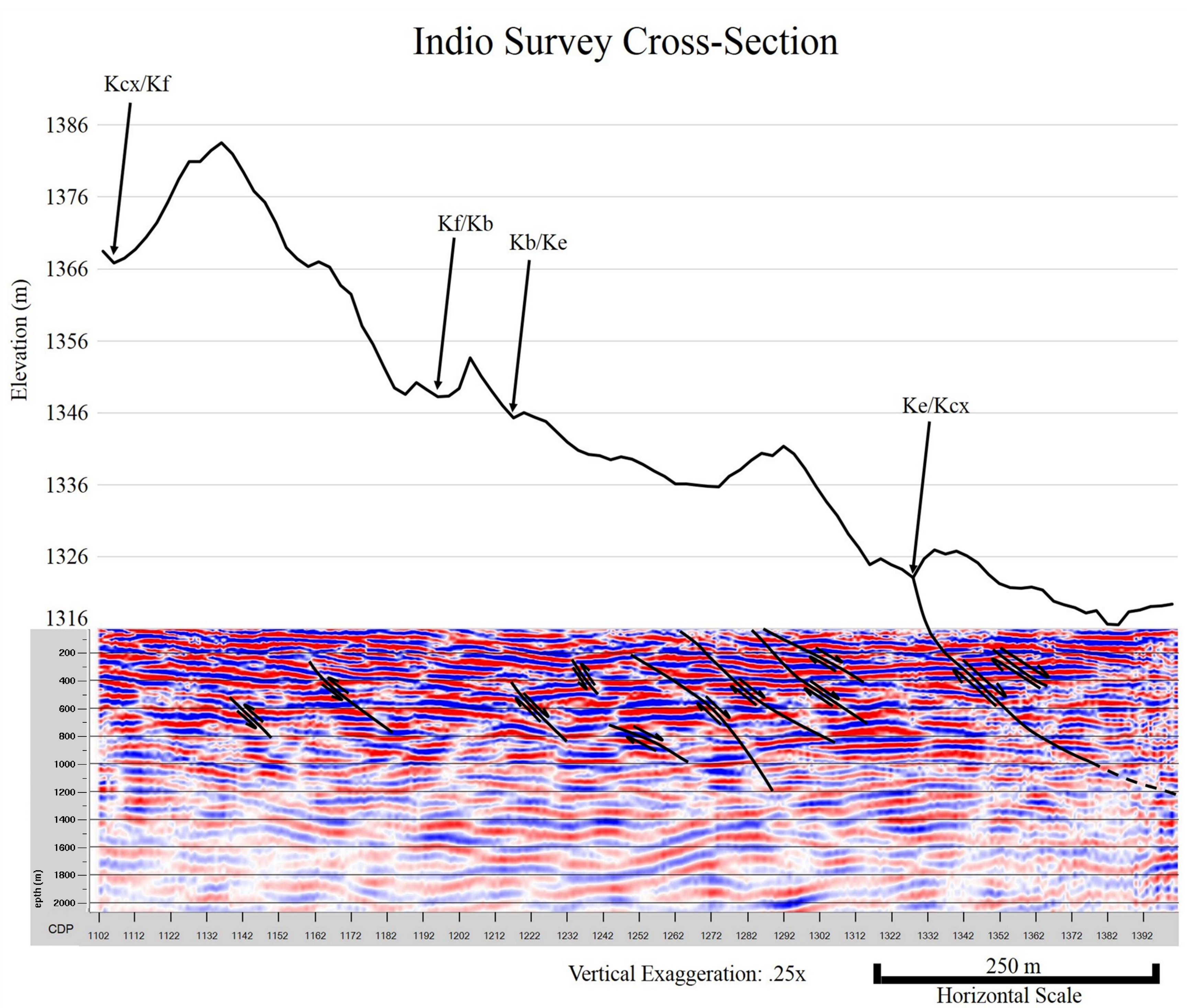
10. Time to Depth Conversion

Editing Flow: Time to Depth

Add Delete Execute View Exit

```
Disk Data Input <- Stack_FX_Enhance
Time/Depth Conversion <= vel
Trace Display Label
Trace Display
```

Time/Depth Conversion	
Conversion direction	Time-to-DEPTH
Maximum frequency of interest (in Hz)	50.
Percent velocity scale factor	100.
Type of velocity table to use	Average Velocity in depth
Get velocities from DATABASE?	Yes No
SELECT Velocity Parameter File	vel
Convert Mutes?	Yes No



Future Processing

- Process the higher frequency dataset comprising of the sledge hammer blows using the processing flow described.
- The region lacks a weathered-layer, therefore refraction static corrections may not be a necessary process. However, refraction statics could better constrain a subsurface image.

Selected References

- Carciumaru, D., and Ortega, R., 2008, Geologic structure of the northern margin of the Chihuahua trough: Evidence for controlled deformation during Laramide Orogeny: Boletín de la Sociedad Geológica Mexicana, v. 60, no. 1, p. 43–69.
- DeFord, R., 1969, Some keys to the geology of northern Chihuahua, in The Border Region (Chihuahua, Mexico, & USA), New Mexico Geological Society Field Conference Guidebook 20, p. 228.
- Haenggi, W.T., 2002, Tectonic history of the Chihuahua trough, Mexico and adjacent USA, Part II: Mesozoic and Cenozoic: Boletin de la Sociedad Geologica Mexicana, v. 55, no. 1, p. 38–94.
- Hart, B.S., 2000, Chapter 3. CHAPTER 3: SEISMIC ACQUISITION AND PROCESSING, in 3-D Seismic Interpretation: A Primer for Geologists, SEPM Short Course Notes, p. 23–40.
- Landmark Graphics Corporation, 1998, ProMAX 2D Seismic Processing and Analysis.
- Page, S.J., 2011, Fold-thrust system overprinting syn-rift structures on the margin of an inverted rift basin: Indio mountains, west Texas: THE UNIVERSITY OF TEXAS AT EL PASO.
- Reynolds, J.M., 2011, An Introduction to Applied and Environmental Geophysics: Wiley-Blackwell, Chichester, West Sussex ; Malden, Mass.
- Rohrbaugh, R., 2001, Contractional and Extensional Deformation Kinematics of the Southern Indio Mountains, Trans-Pecos Texas: The University of Texas as El Paso, 112 p.
- Underwood, J.J., 1980, Geology of the Eagle Mountains, Hudspeth County, Texas, in Trans Pecos Region (West Texas), New Mexico Geological Society Field Conference Guidebook 31, Kansas State University, p. 308.

Acknowledgements

I would like to thank my advisor, Dr. Marianne Karplus, Galen Kaip, Dr. Steve Harder, the UTEP Active Seismic Source Facility, the Incorporated Research Institutions for Seismology (IRIS) and all the students that assisted in data acquisition.

IRIS

Active Seismic Source Facility