HR 3D-3C Design for reservoir monitoring, Brooks

Davood Nowroozi
Donald Lawton

Outline

- Designing concepts and example
- Background
  - Geological prospects
  - Geophysical prospects
- 4D design case studies
- Attribute analysis

Introduction

4D Seismic Design

- **Considerations:**
- **1- Repeat with the same Bin**
- **2- Same offset and azimuth distribution for each Bin**
- **3- Finally : for a reasonable 4D acquisition ,we require to repeat survey with the same shot and receiver points**

General recipe for 3D survey design
(assuming P-wave survey, orthogonal geometry)(Vermeer)

- Establish objective of survey
- Make inventory of existing knowledge in the area of interest
- Select type of geometry to be used
- Identify main targets and required fold in each target
- Establish resolution requirements
- Establish representative velocity function
- Establish maximum stretch factor or mute function
- Establish maximum dip angles
- Determine spatial sampling interval
- Determine line intervals and maximum offset
- Determine geometry parameters that satisfy all requirements
- Choose field arrays on basis of noise problem
- Determine migration rim for survey
- Select type of source
- Establish most efficient way of implementing nominal survey
- Translate nominal geometry to field conditions
- Implement rules for obstacle avoidance

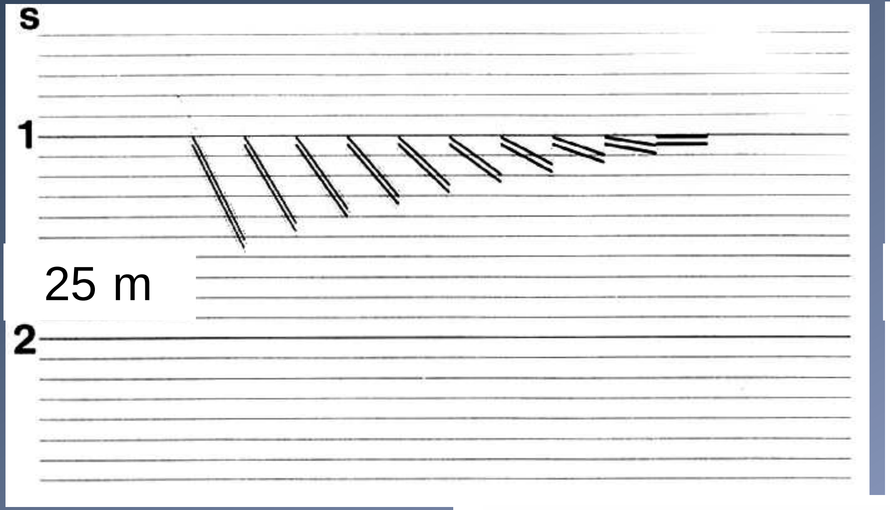
Acquisition parameters for AVO (Castagna,2000)

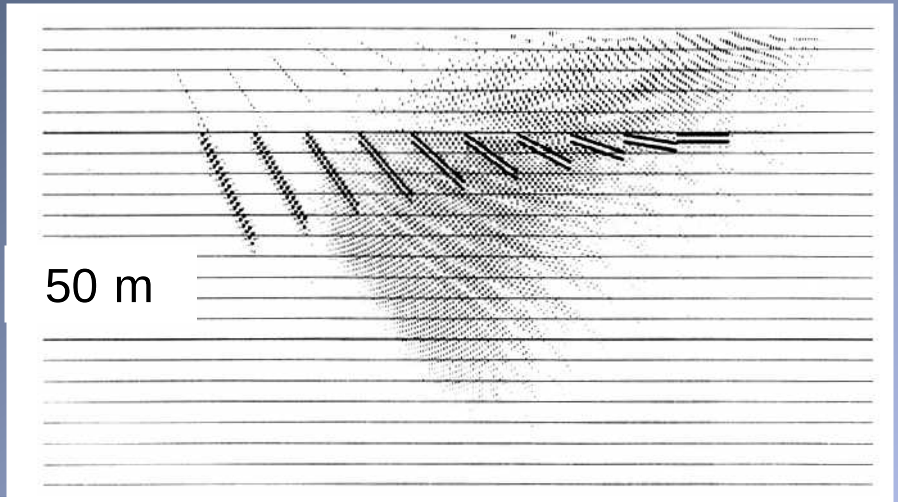
- **Designed for high pre-stack S/N**
- **Large dynamic range (noise suppression)**
- **High bandwidth**
- **Small spatial sampling increment**
- **Consistent source signature**
- **Wide aperture for imaging**
- **Wide angle distribution**
- **Azimuth distribution (wide or narrow?)**
- **Short arrays or point sources and receivers (omnidirectional)**
- **Regular geometry – minimize pre-stack footprint**
- **Consistency of distribution – fold, offset coverage, azimuth**
- **High effective fold (within the mute range)**

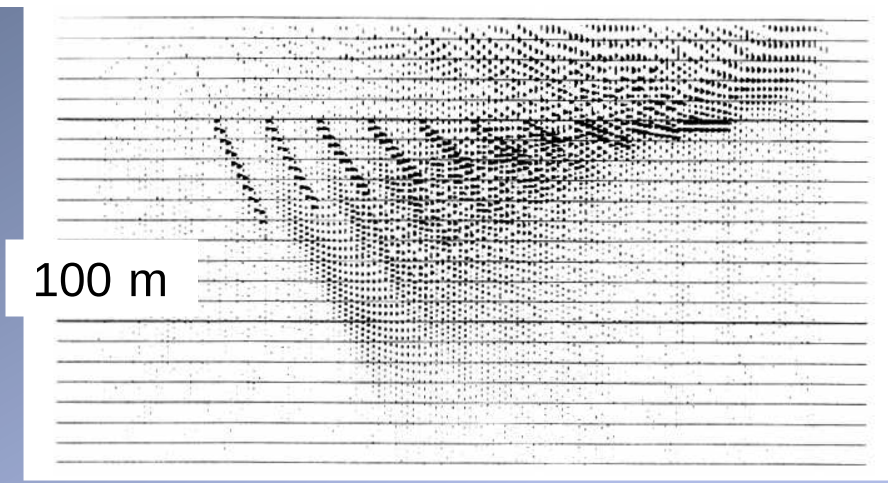
Background Information

- Geology of area (surface, subsurface and structural condition as layers dip angle)
- Terrain conditions (topographic, permit ...)
- Frequency contents (max and dominant) in the targets and required resolution
- Velocity and velocity as a function of depth
- Objective of acquisition (image, reservoir study,...) and main targets (the shallowest and deepest)
- Full fold Image zone for structural or reservoir studies to estimate acquisition boundary and area by calculating migration aperture and fold taper
- Seismic data (raw shots for a better frequency analysis and sections for interpretation and evaluation and both for controlling quality of data and problems)
- Technical part and technological capability (recording system)
- Financial conditions and limitations

Migrated dipping event for different trace spacing



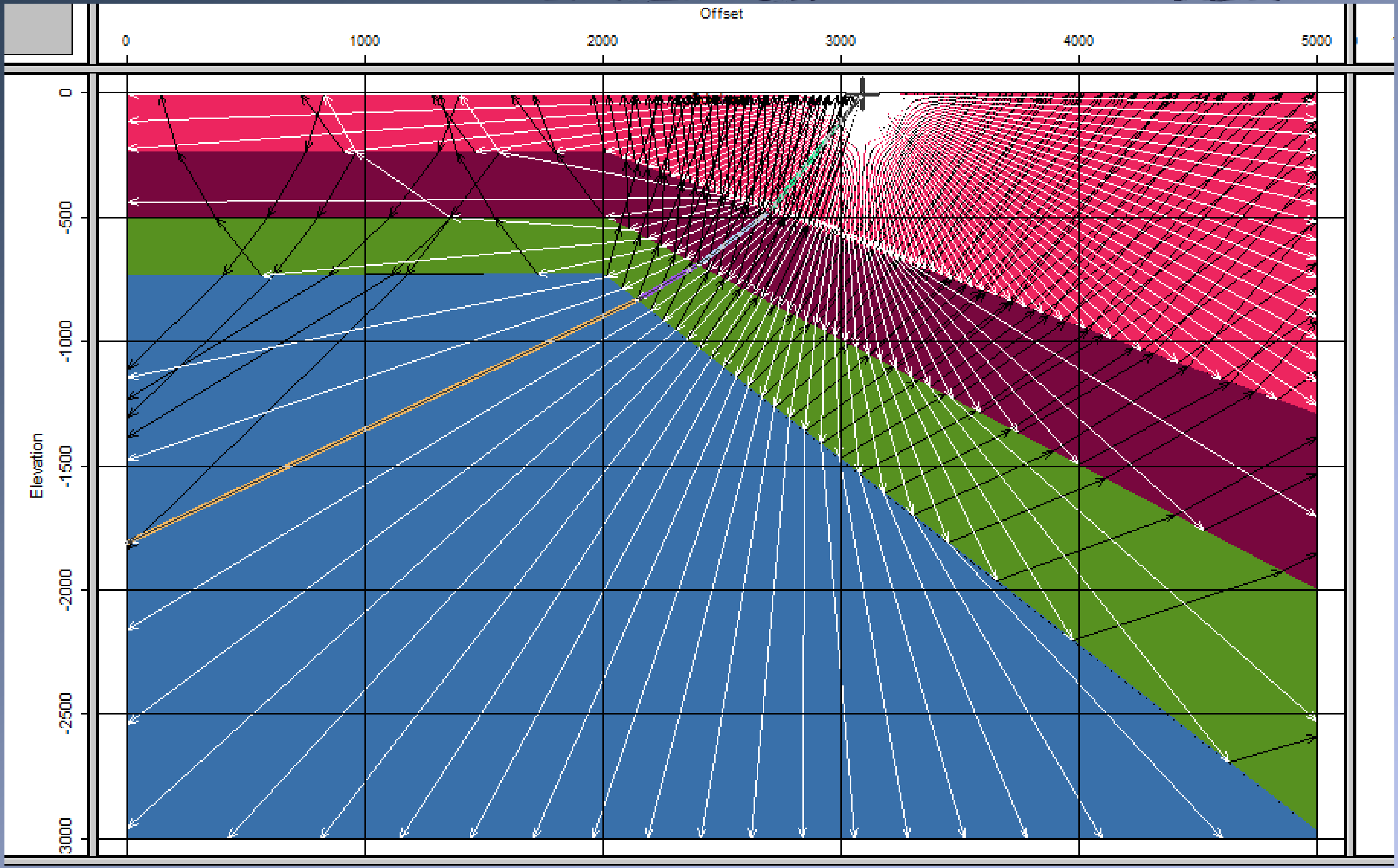




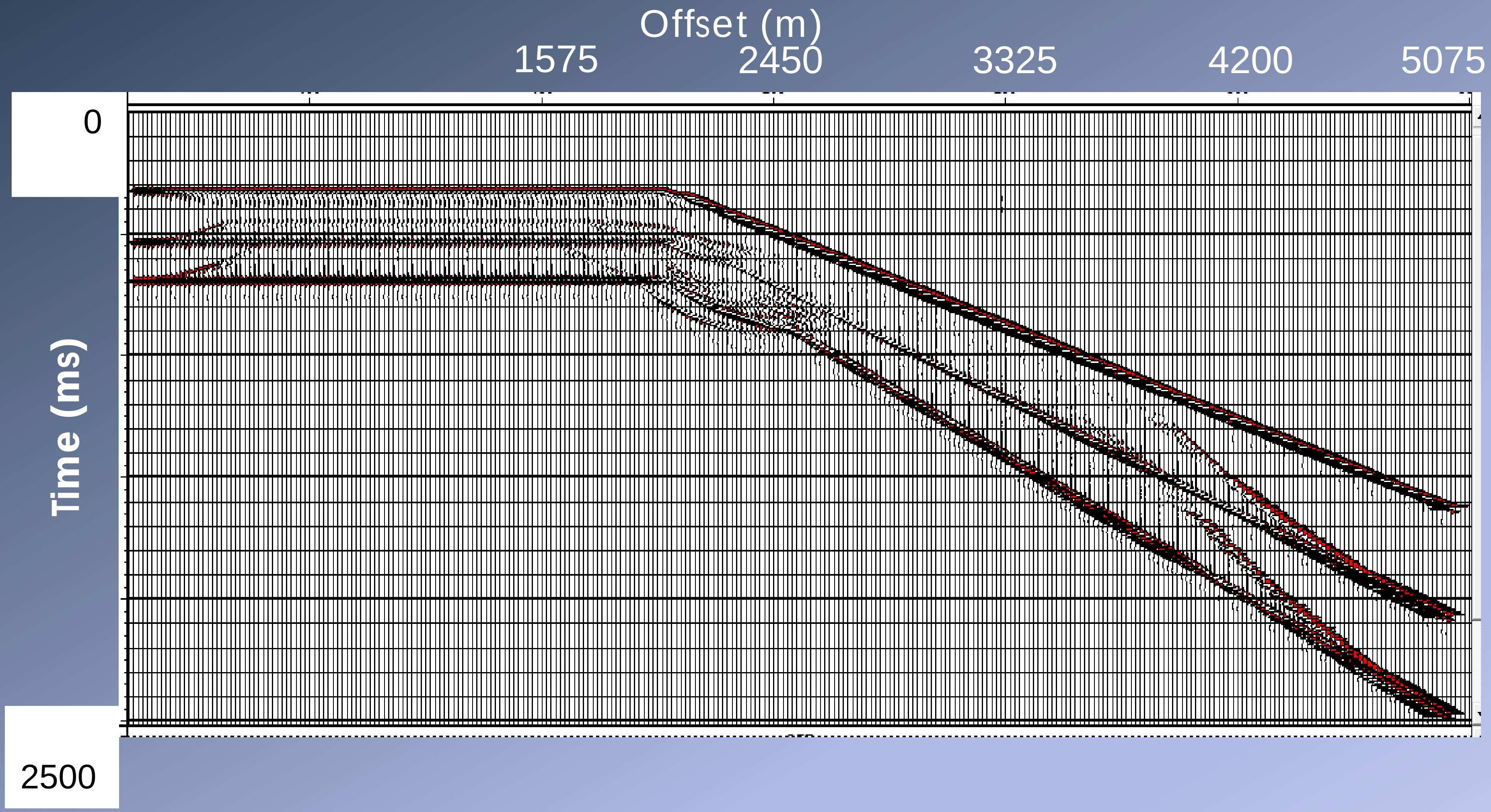
Kirchhoff migrations of the zero offset sections on the previous slide with trace spacings annotated

(Courtesy PGS)

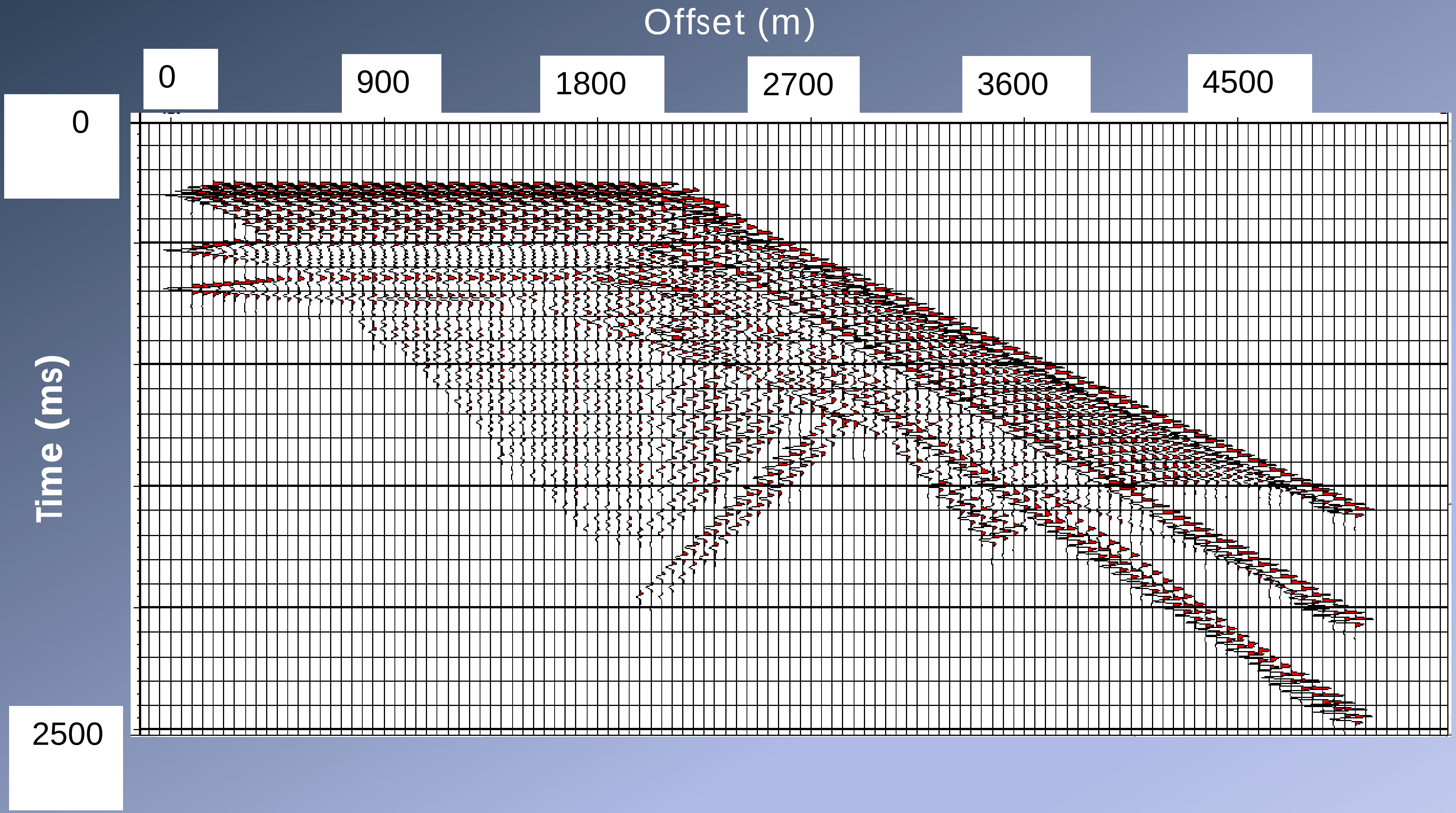
Ray tracing method



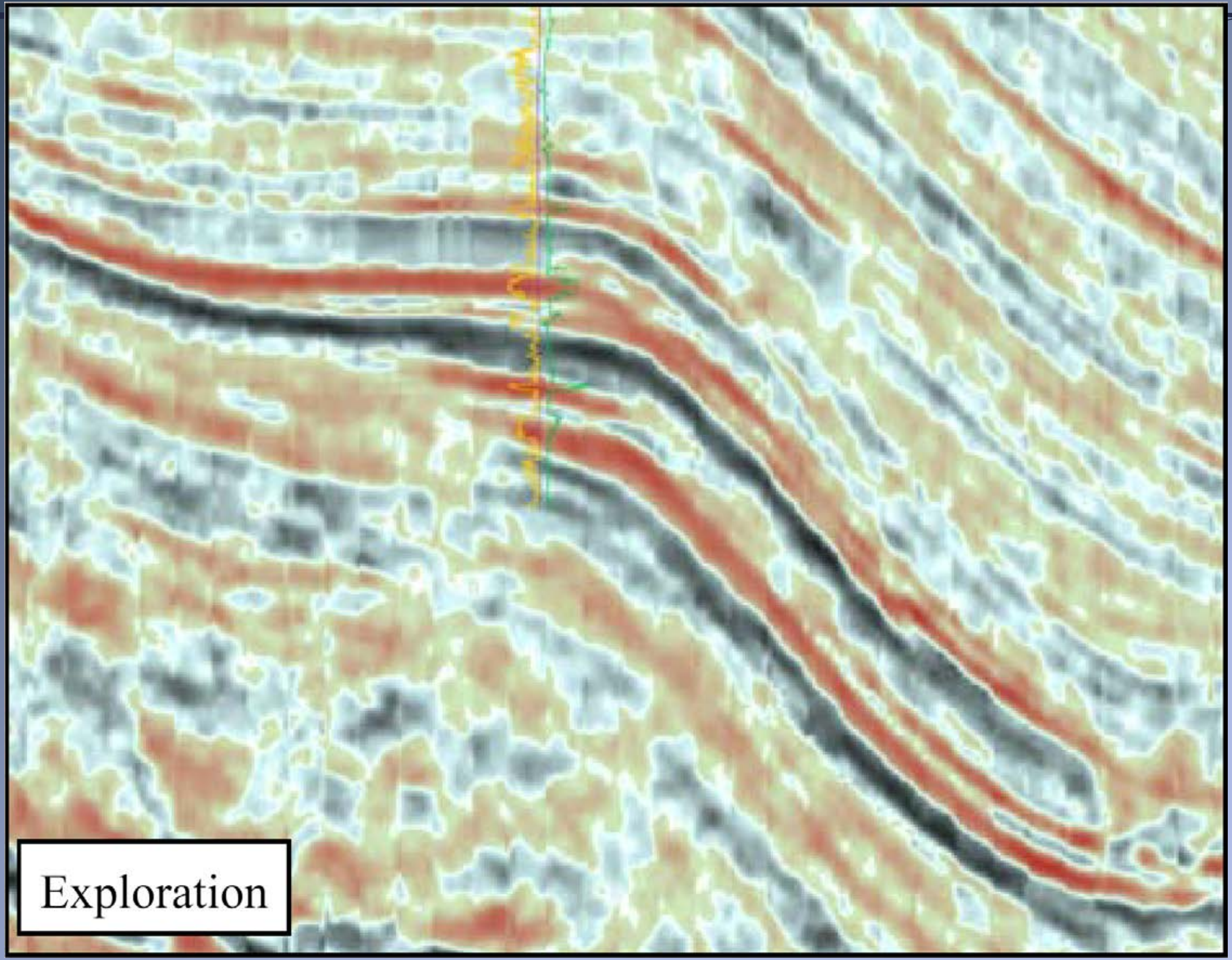
Pattern B – Stack (35m)



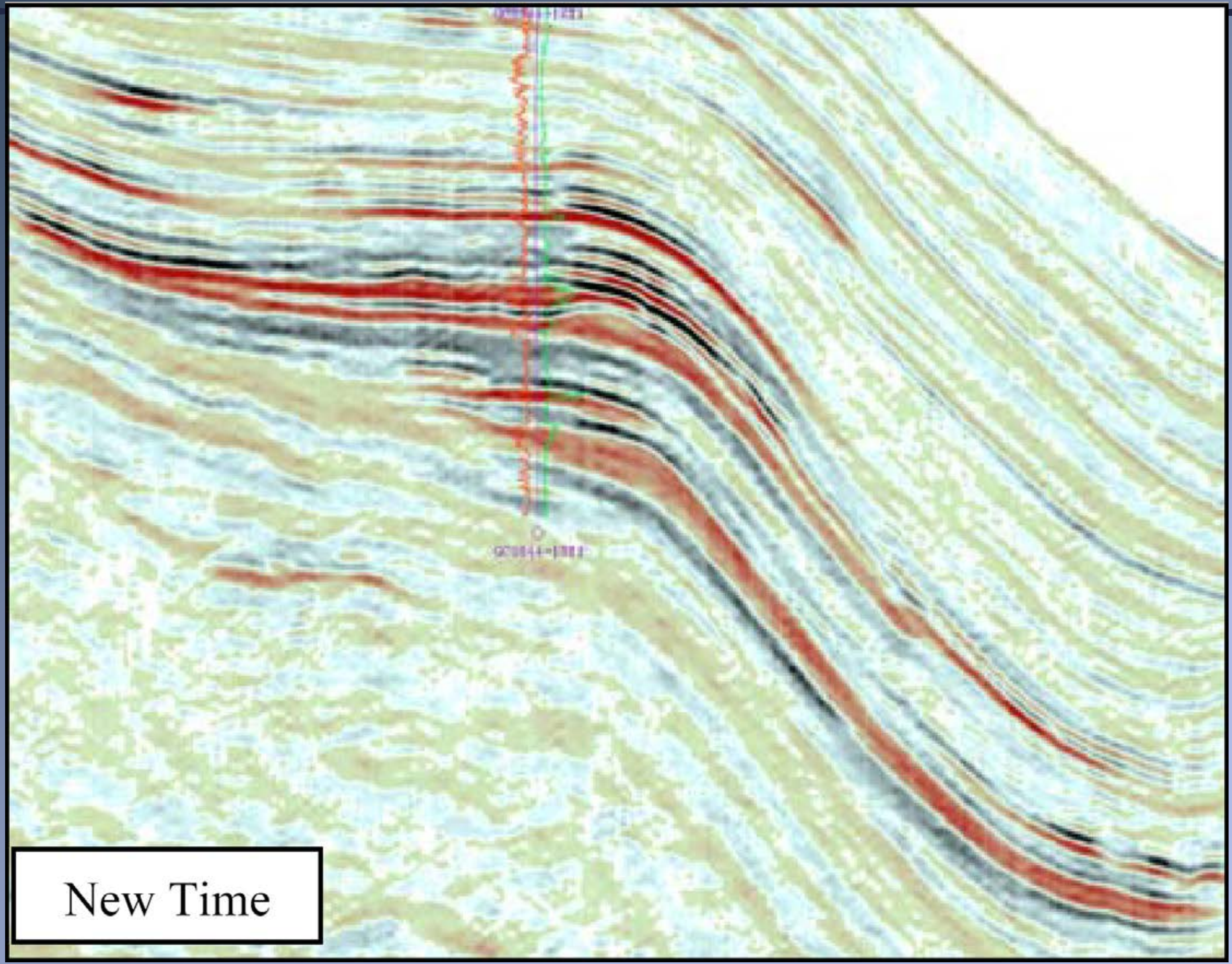
Pattern D – Stack (90m)



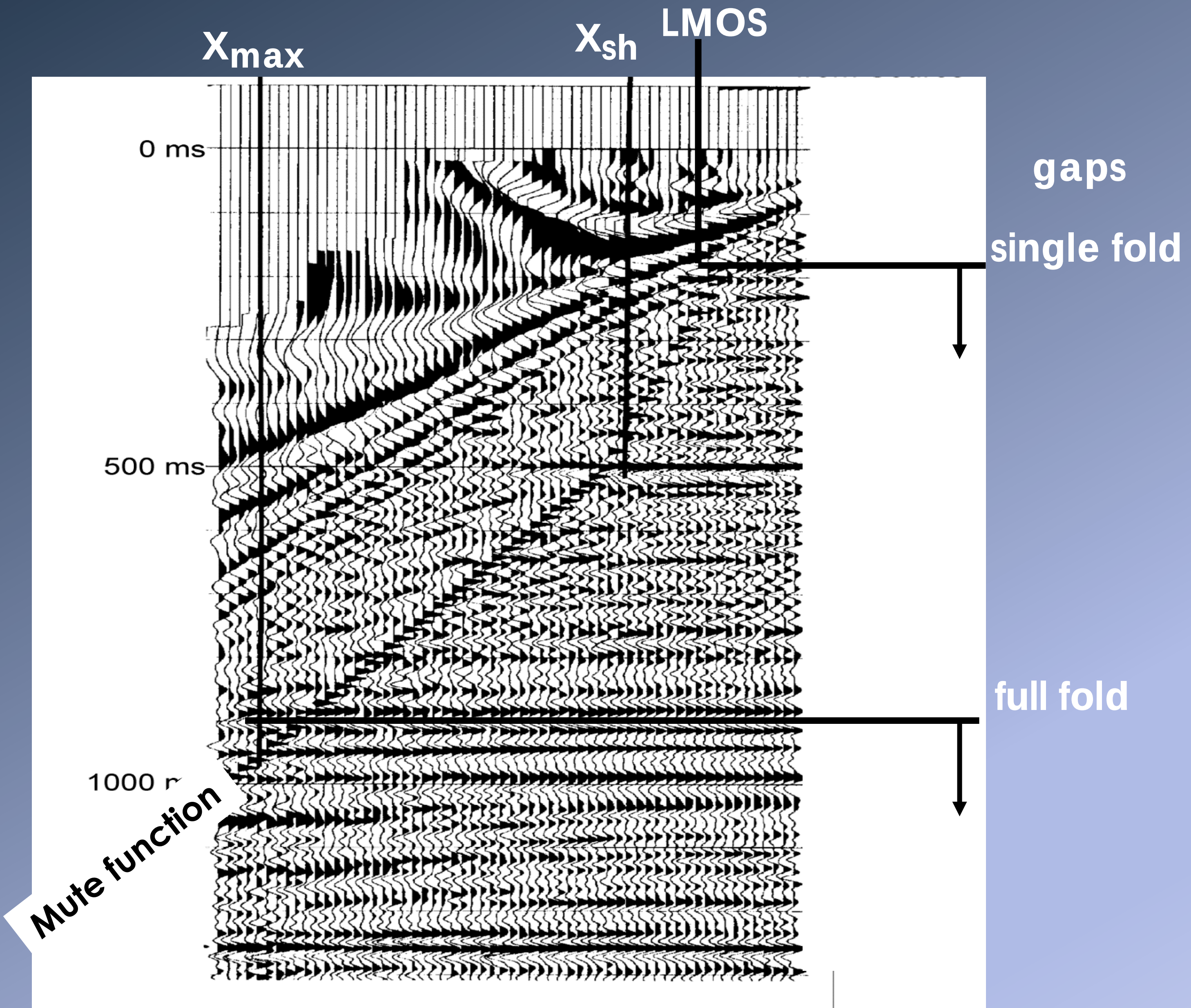
Conventional marine streamer acquisition result 7/10 m tow depth, 40 m crossline, 12.5 m inline, Calvert et al, 2003 SEG



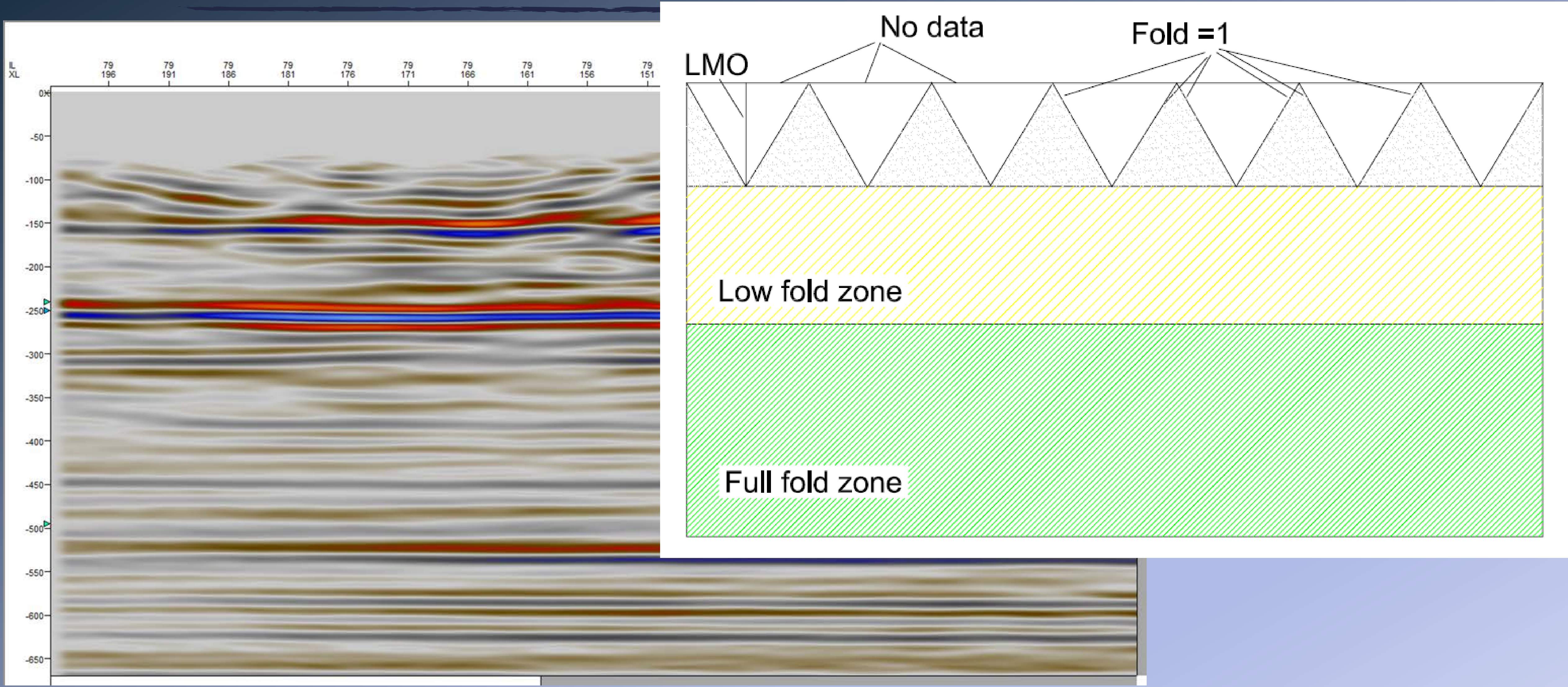
High-resolution result
5/5-m tow depth, 12.5 m crossline, 6.25 m inline



Mute function determines maximum offset as a function of time



Max and min offset (3D survey) - example



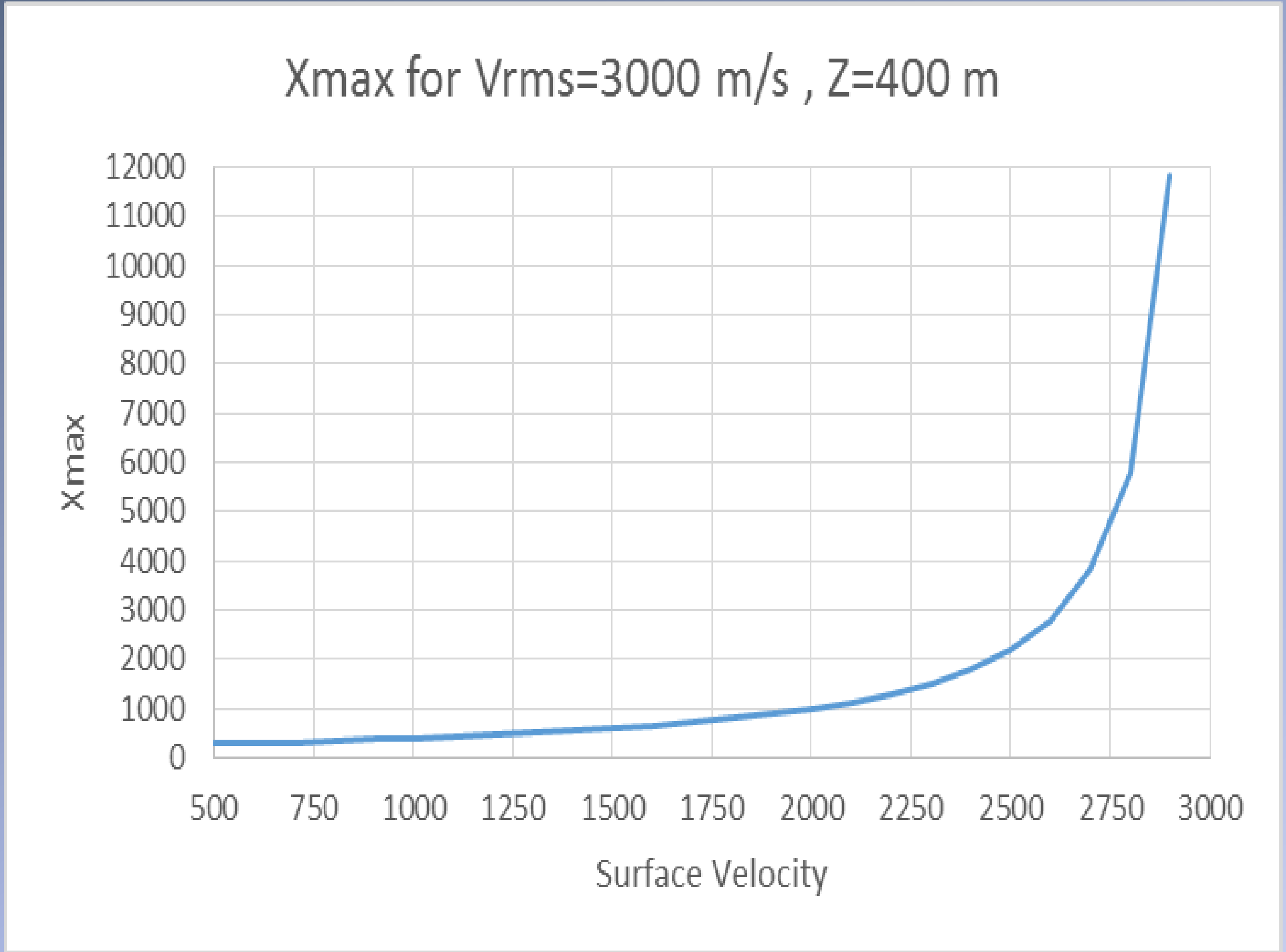
Maximum offset

X_{Max} > Deepest target

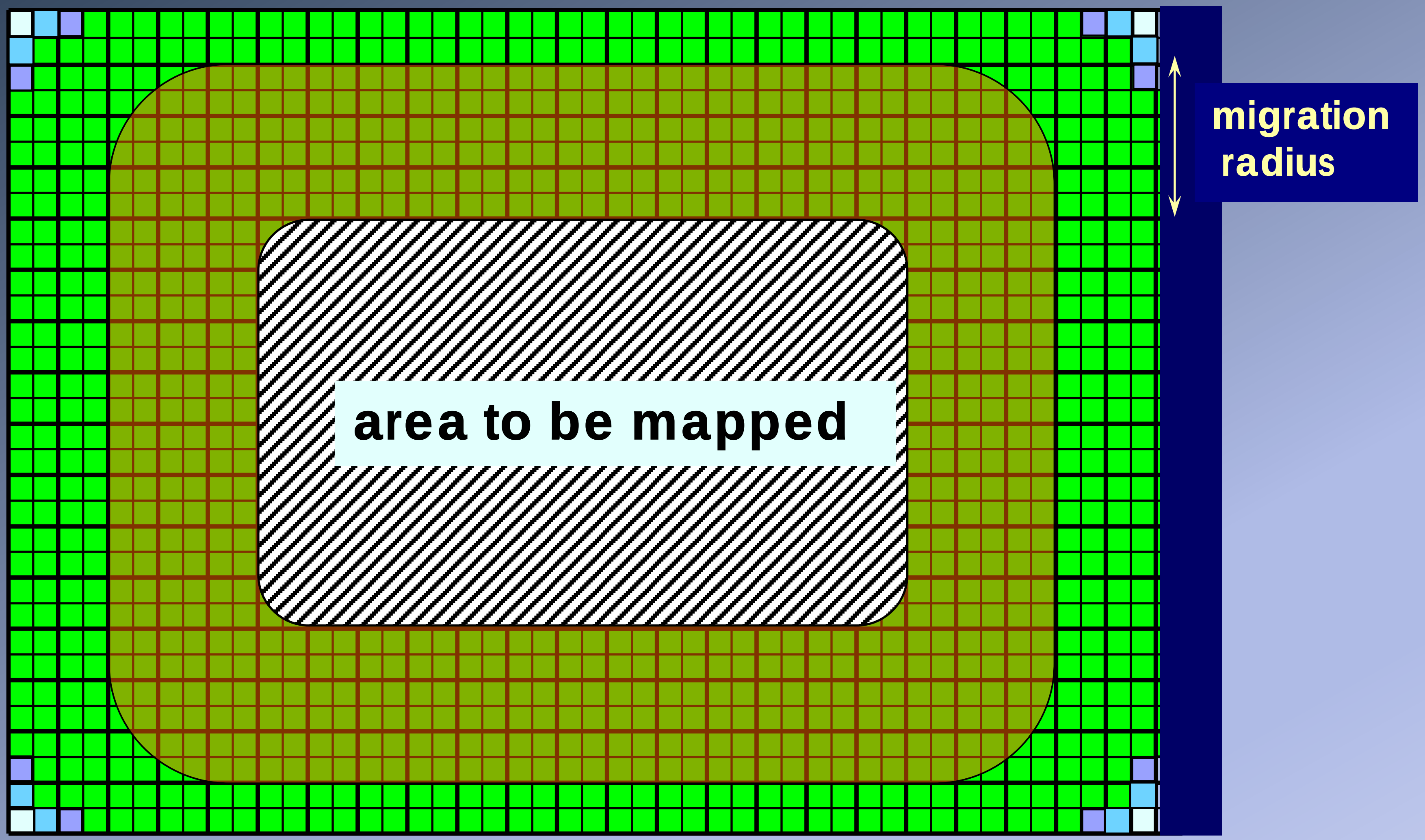
$$X_{Max} = \frac{1}{2} Z \left(\frac{V + V_s}{V - V_s}\right)^{\left(\frac{1}{2}\right)}$$

V : rms velocity
Vs : surface velocity

Is near surface important?

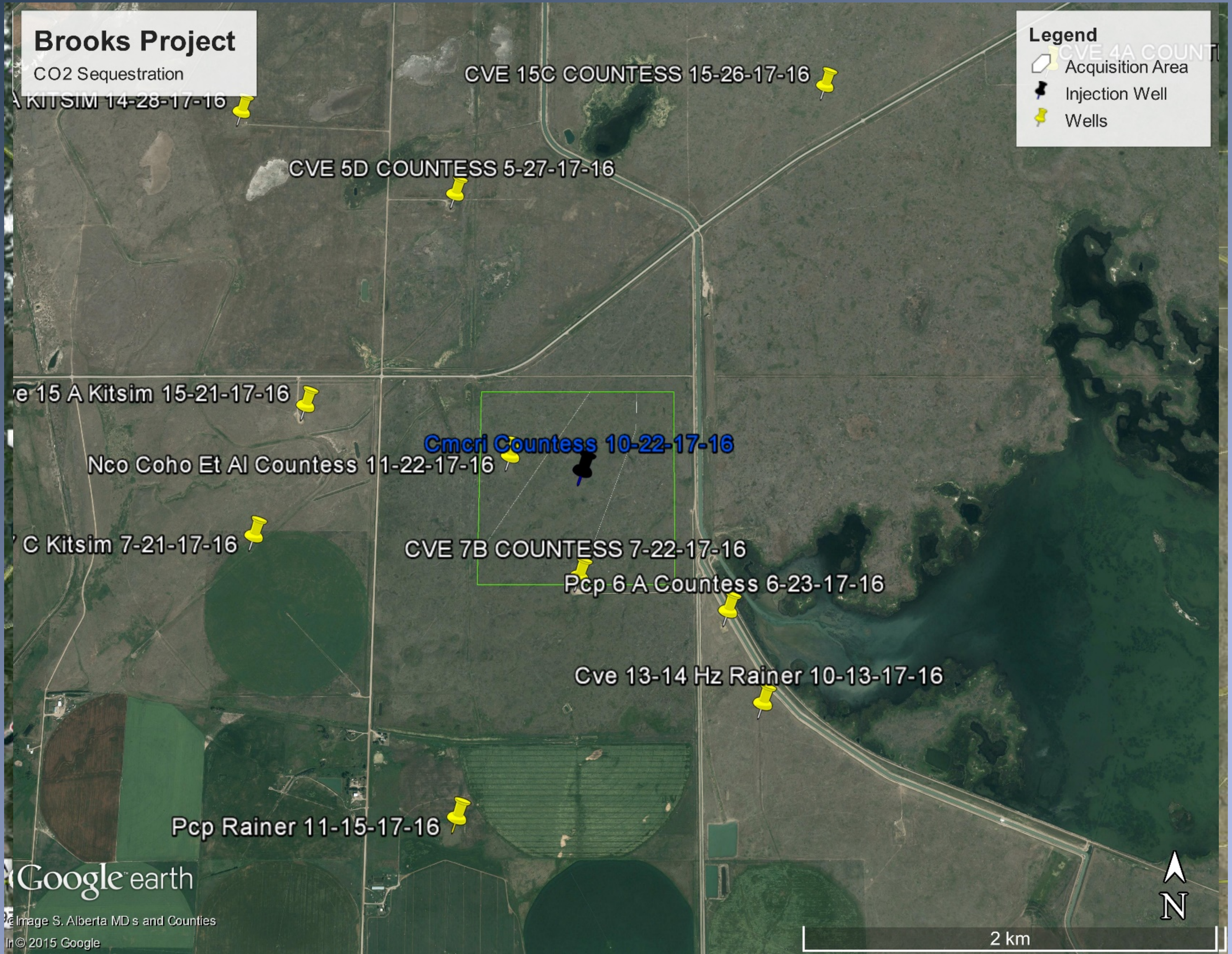


If only full-fold gives adequate quality:
Survey area =
area to be mapped + migration rim + fold taper zone (Vermeer)



Background information

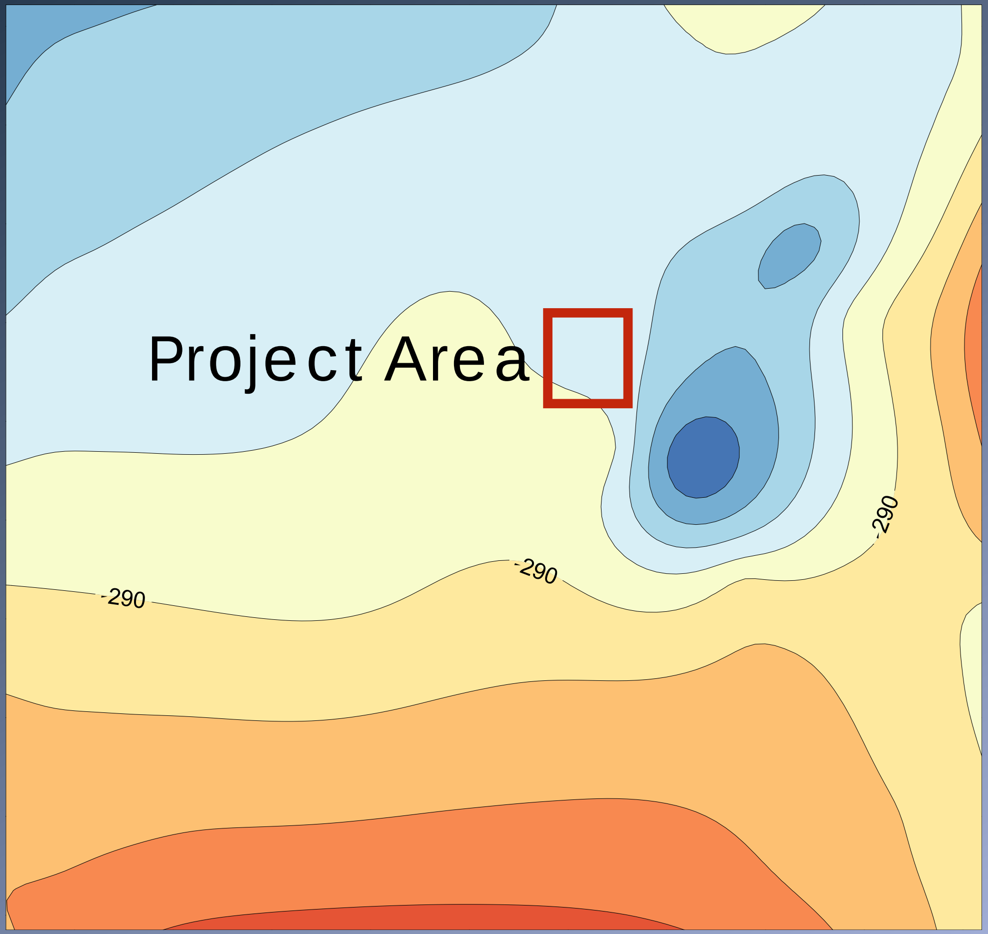
Project Area

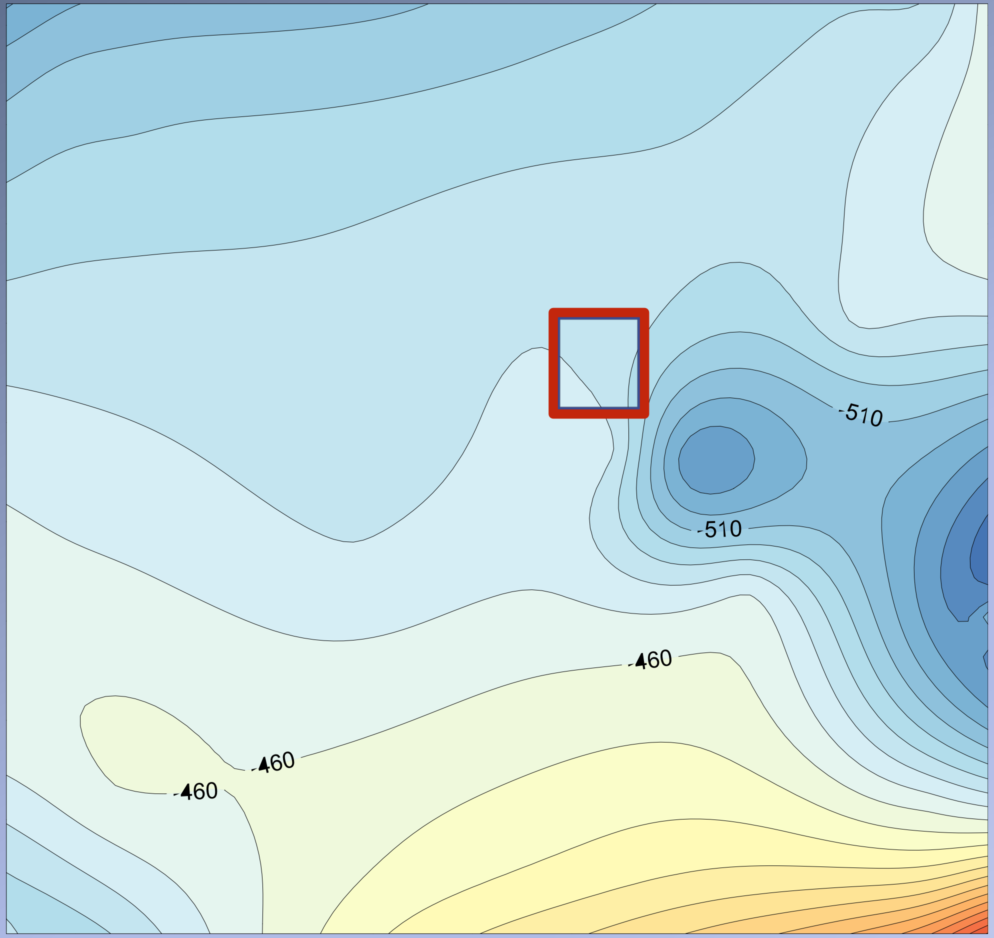


Targets

Depth (m)	Formation Top	Period		
189.74	*Top of log data*	Upper	Cretaceous	
296.5	*PAKOWKI*	Upper	Cretaceous	Target
357	*MILK RIVER*	Upper	Cretaceous	Target
441.5	*COLORADO SHALE*	Upper	Cretaceous	Target
478.5	*MEDICIN HAT SANDSTONE*	Upper	Cretaceous	Target
711	*SECOND WHITE SPECKLED SHASLE*	Upper	Cretaceous	
785	*FISH SCALES*	Upper	Cretaceous	
826	*BOW ISLAND*	Lower	Cretaceous	
938.5	*MANNVILLE*	Lower	Cretaceous	
1036	*GLAUCONITIC*	Lower	Cretaceous	
1059	*OSTRACOD*	Lower	Cretaceous	

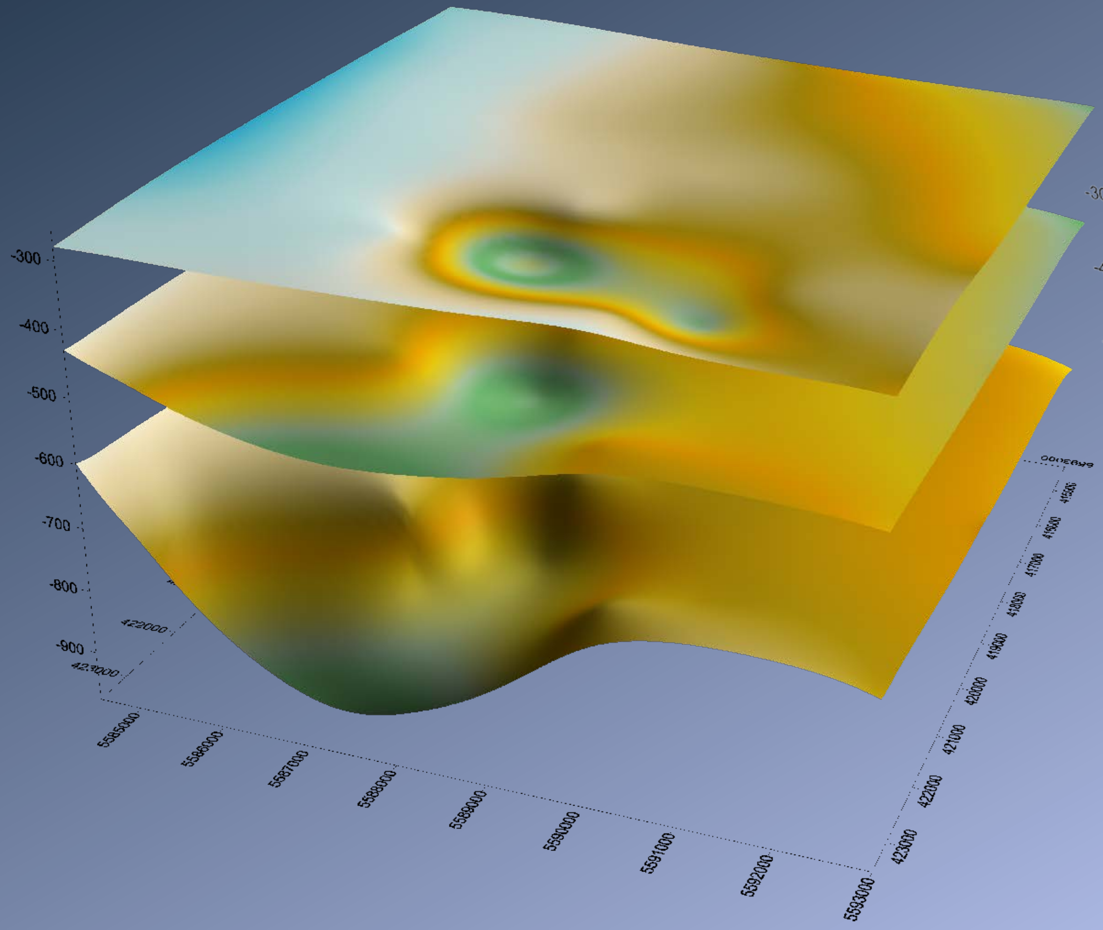
Top of Pakowki and Medicine Hat Formations



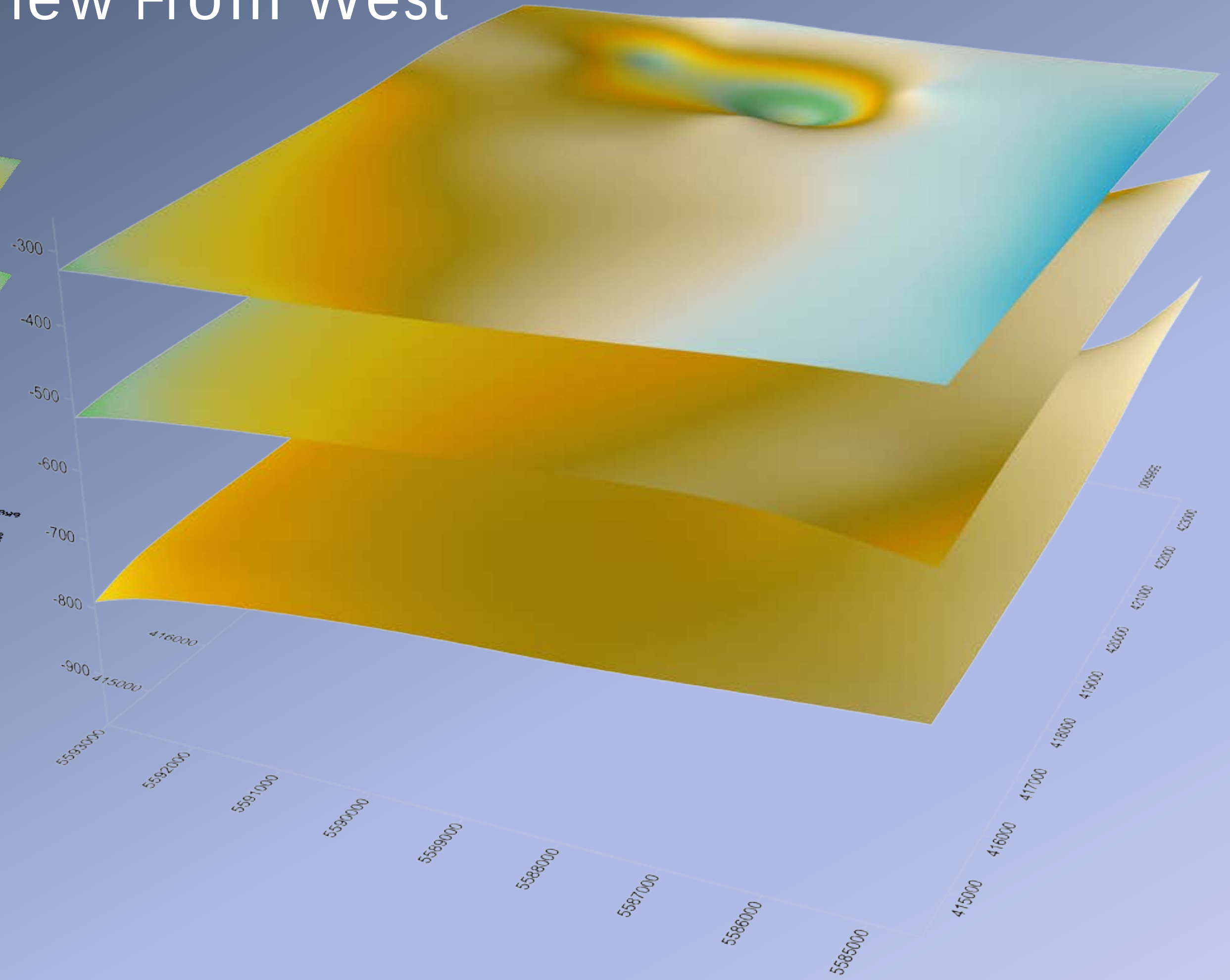


3D View for Pakowki, Medicin Hat, 2WSPK

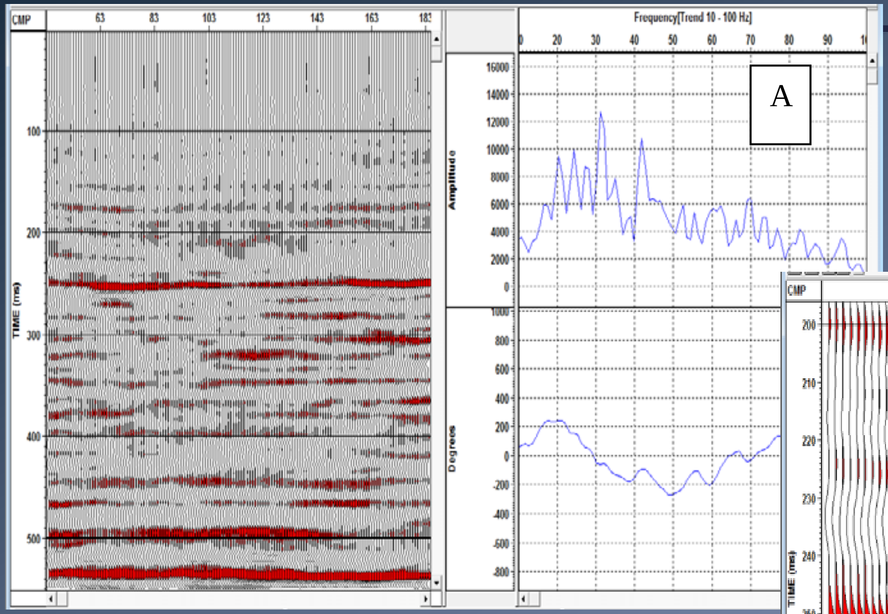
View From East

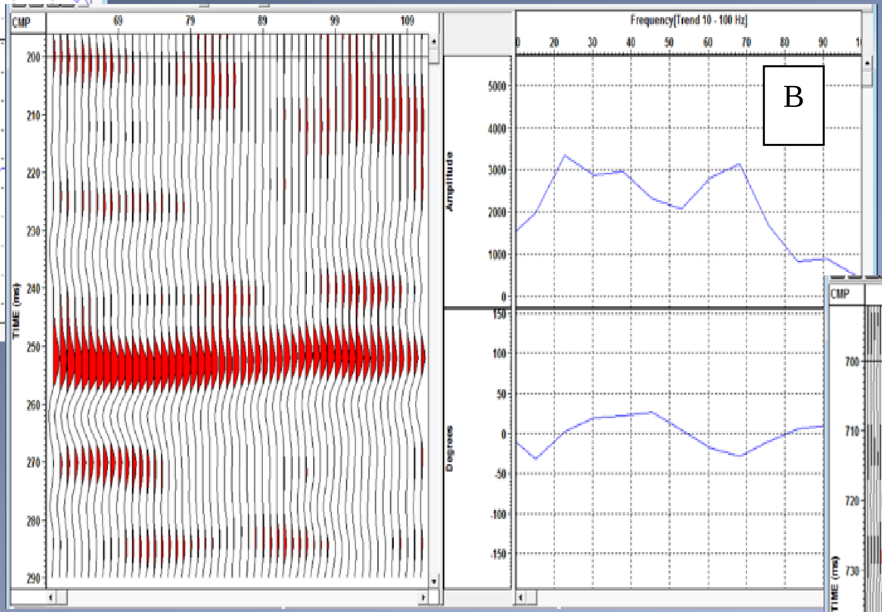


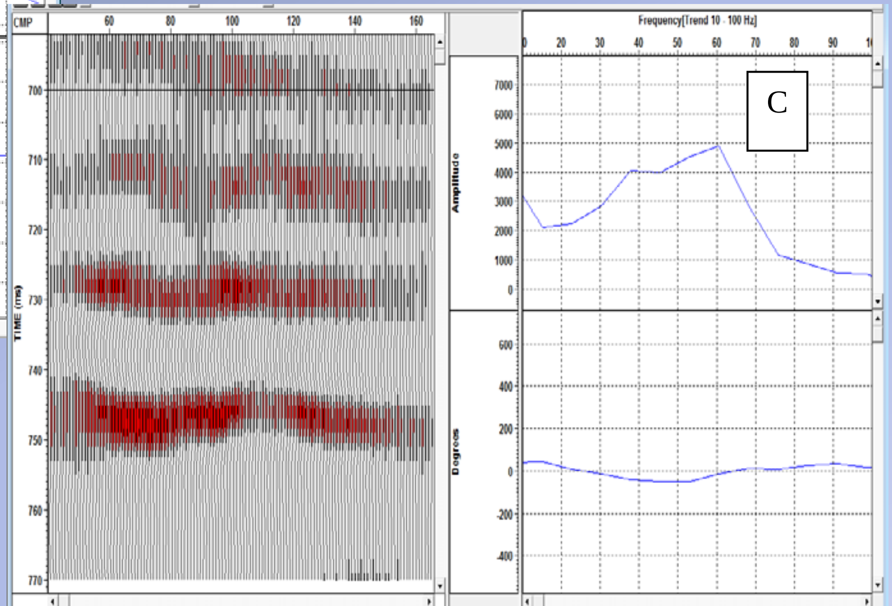
View From West



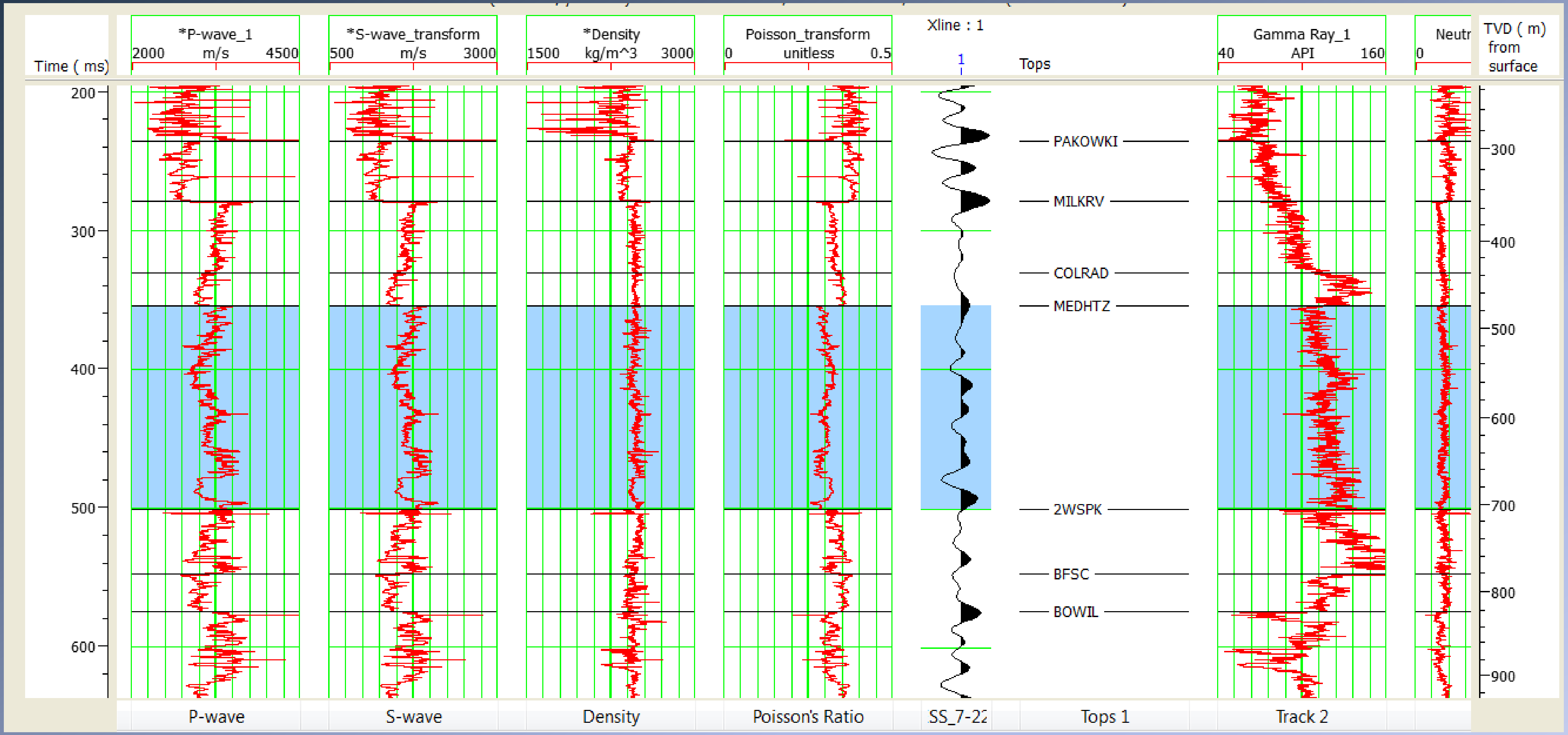
Frequency analysis on the whole seismic section



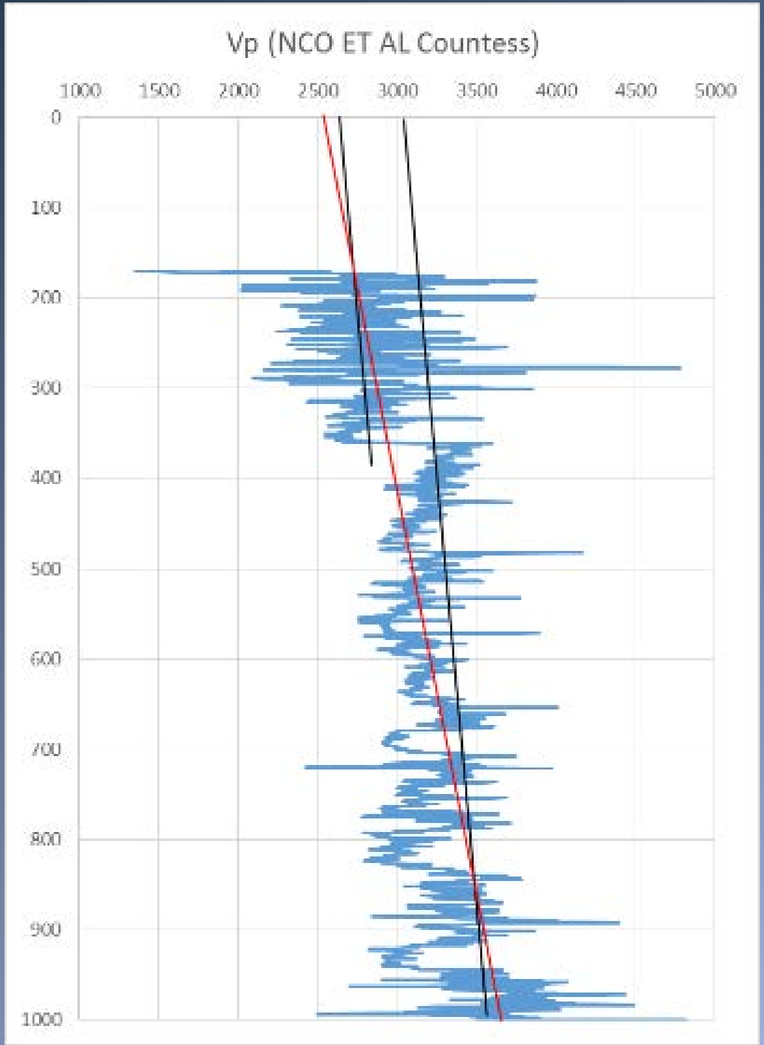


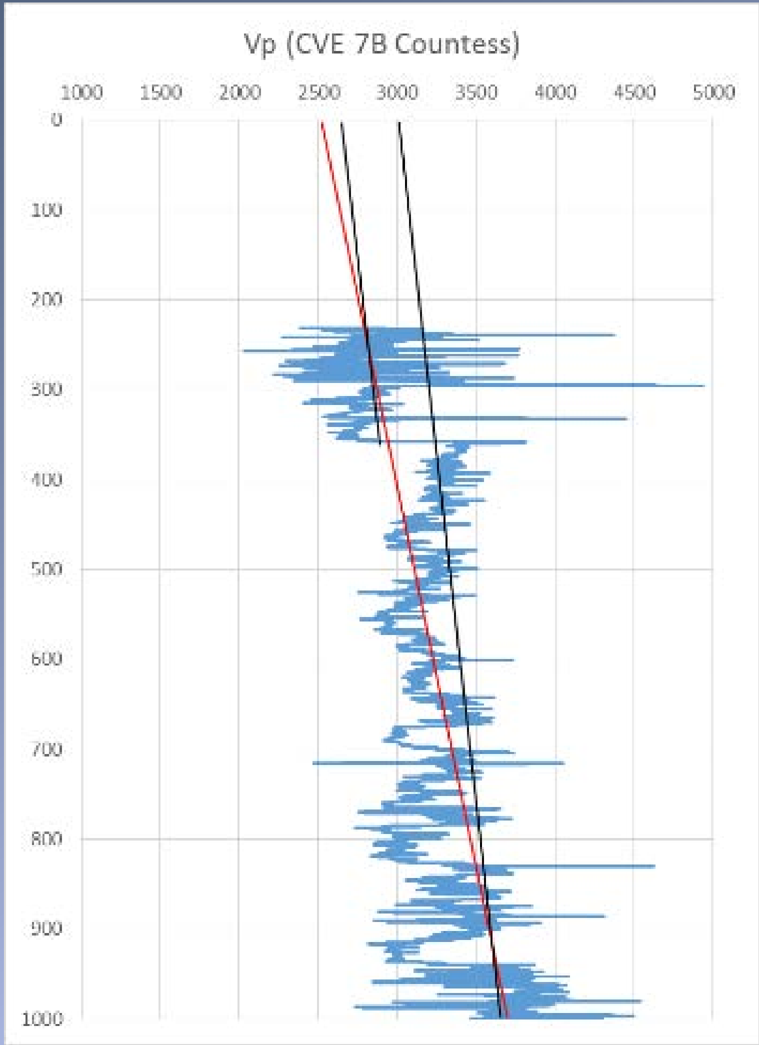


Well log data and synthetic seismogram



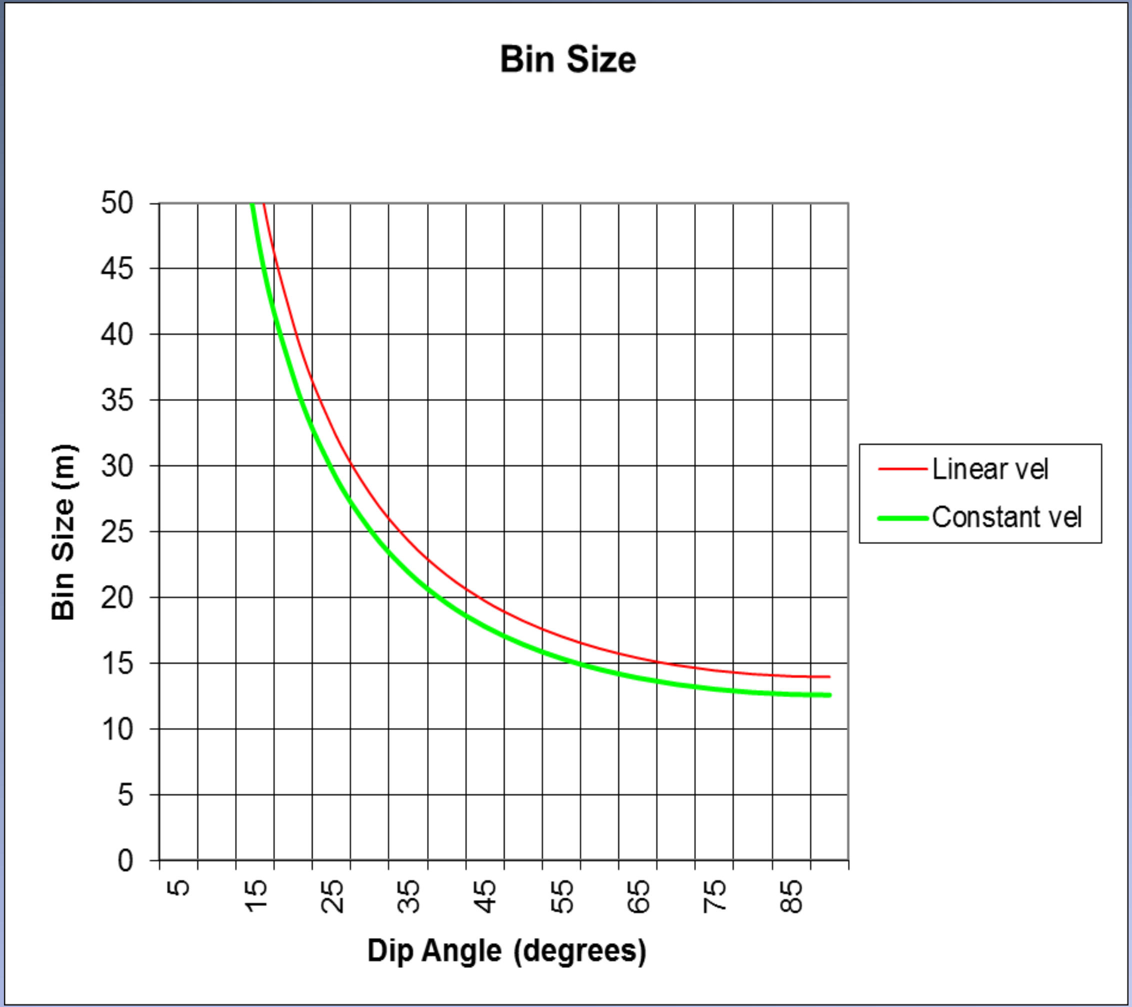
Velocity as a linear function of depth



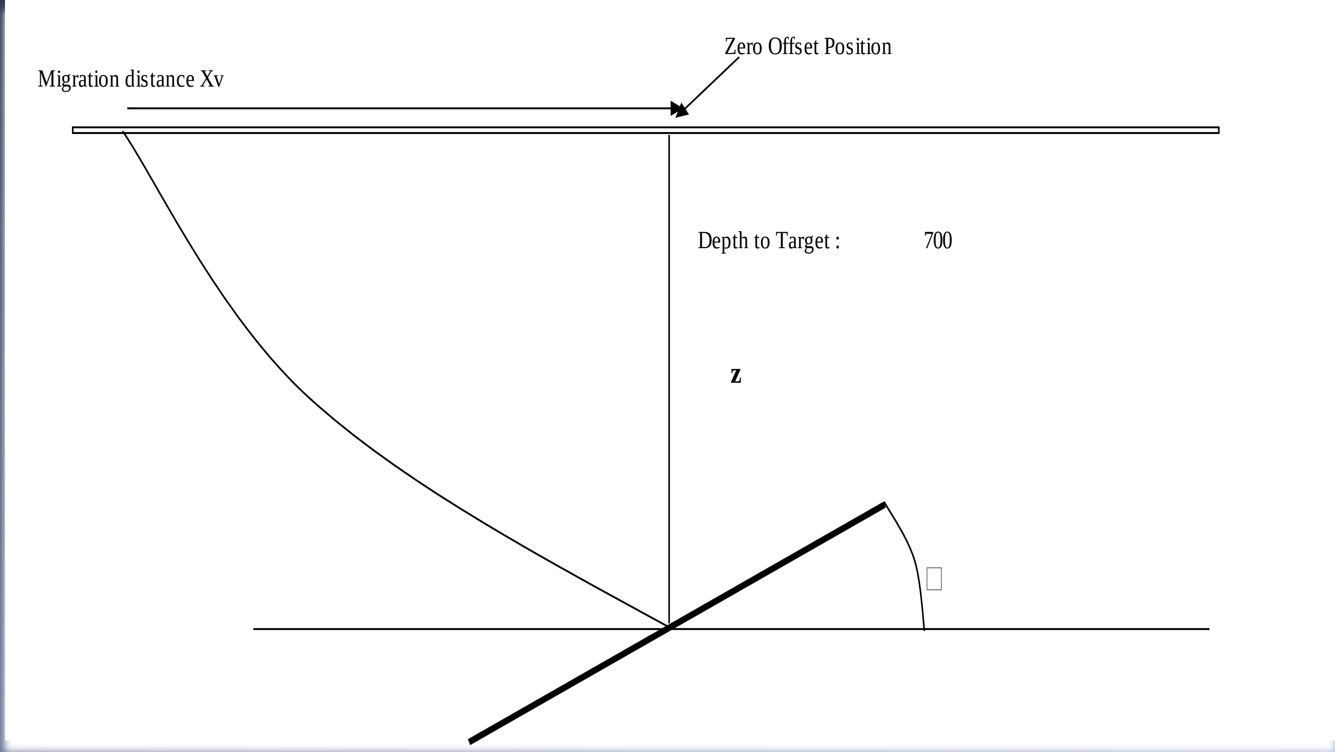


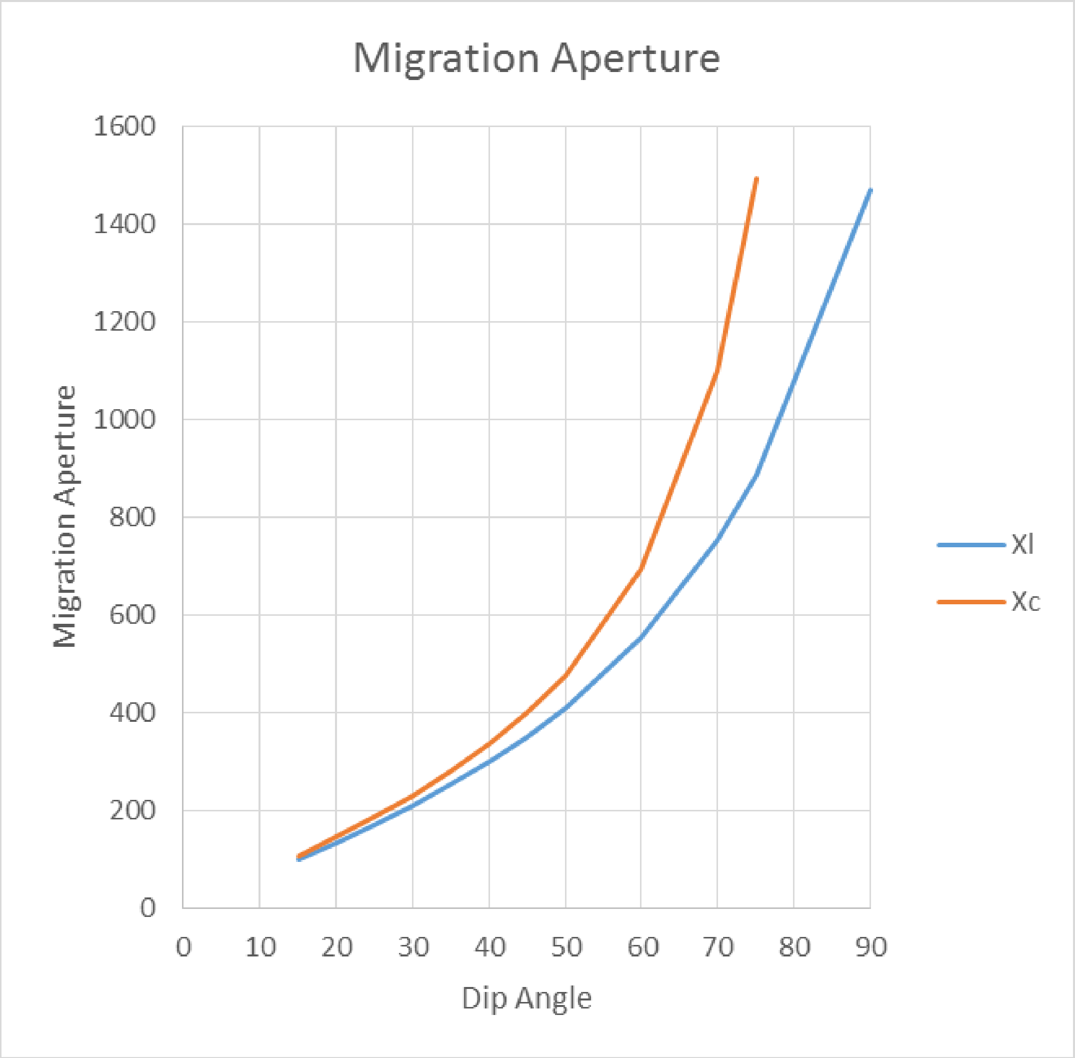
V=V0+kz
V=2500+1.1z

Bin size for the shallow target with 80Hz max frequency (left diagram) and for the deep target with 65Hz (right diagram)



Migration Apron





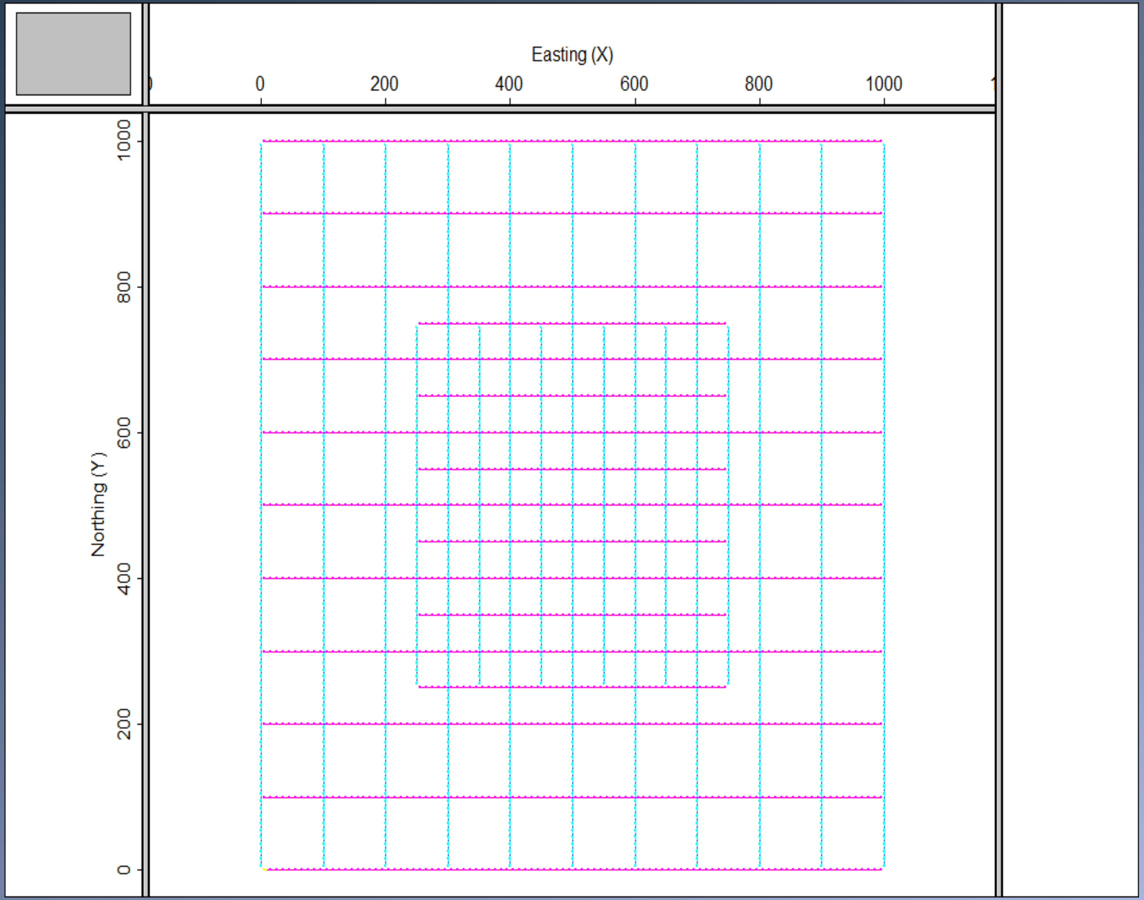
Design parameters

Suggested Options

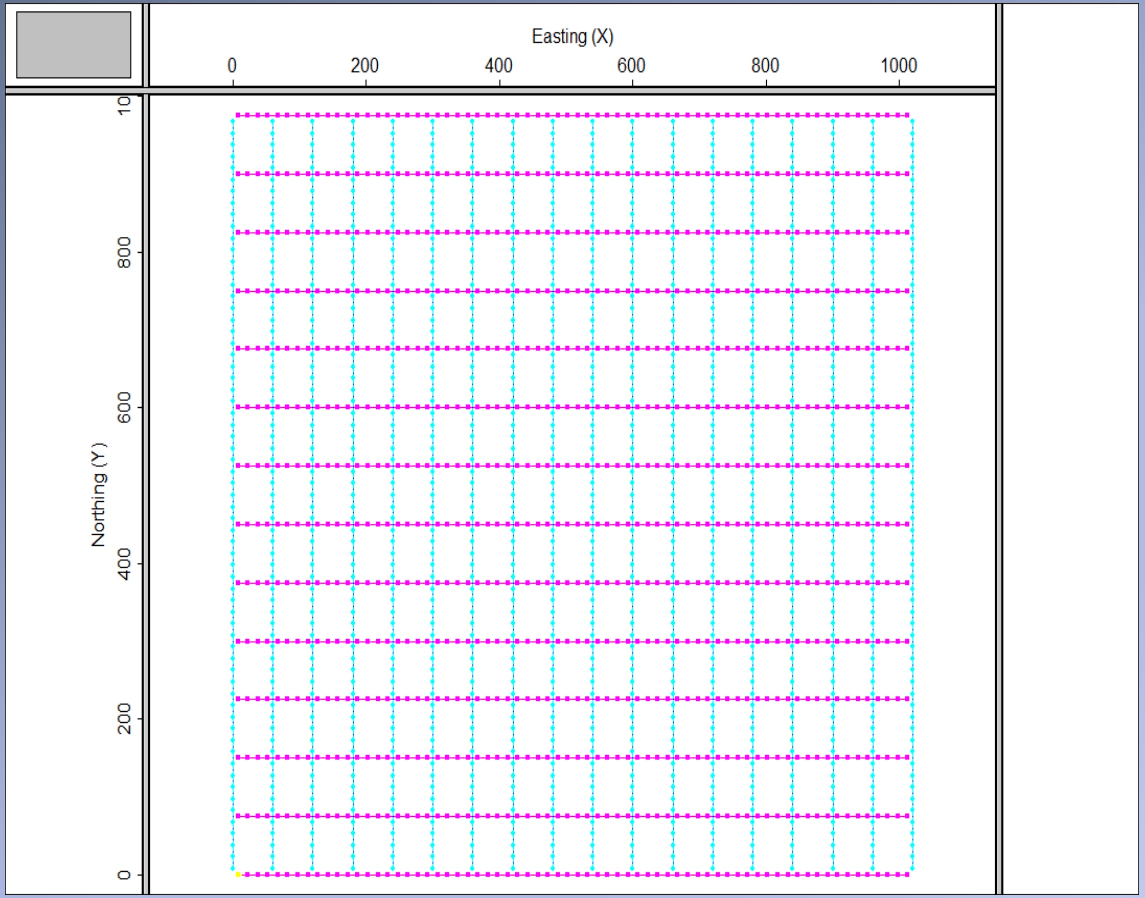
	Option A		Option B
Parameters	Main	Mid core	
Bin size	5	5	7.5 m
Receiver interval	10	10	15 m
Receiver line interval	100	50	60 m
Shot interval	10	10	15 m
Shot line interval	100	50	75 m
Total Survey area	1000*1000	500*500	1020*975 m
Maximum Offset	1407		1407 m
minimum offset	14	7	10.6 m
Largest minimum offset	134	64	85.5 m
Maximum fold	83	185	221
The highest fold (pp)	185		221
Maximum inline offset	1000		1020
Maximum xline offset	1000		975
Aspect ratio	100%		95.50%
Total shots	1600		952
Total live geophones	1600		1170

Acquisition Pattern

Option A

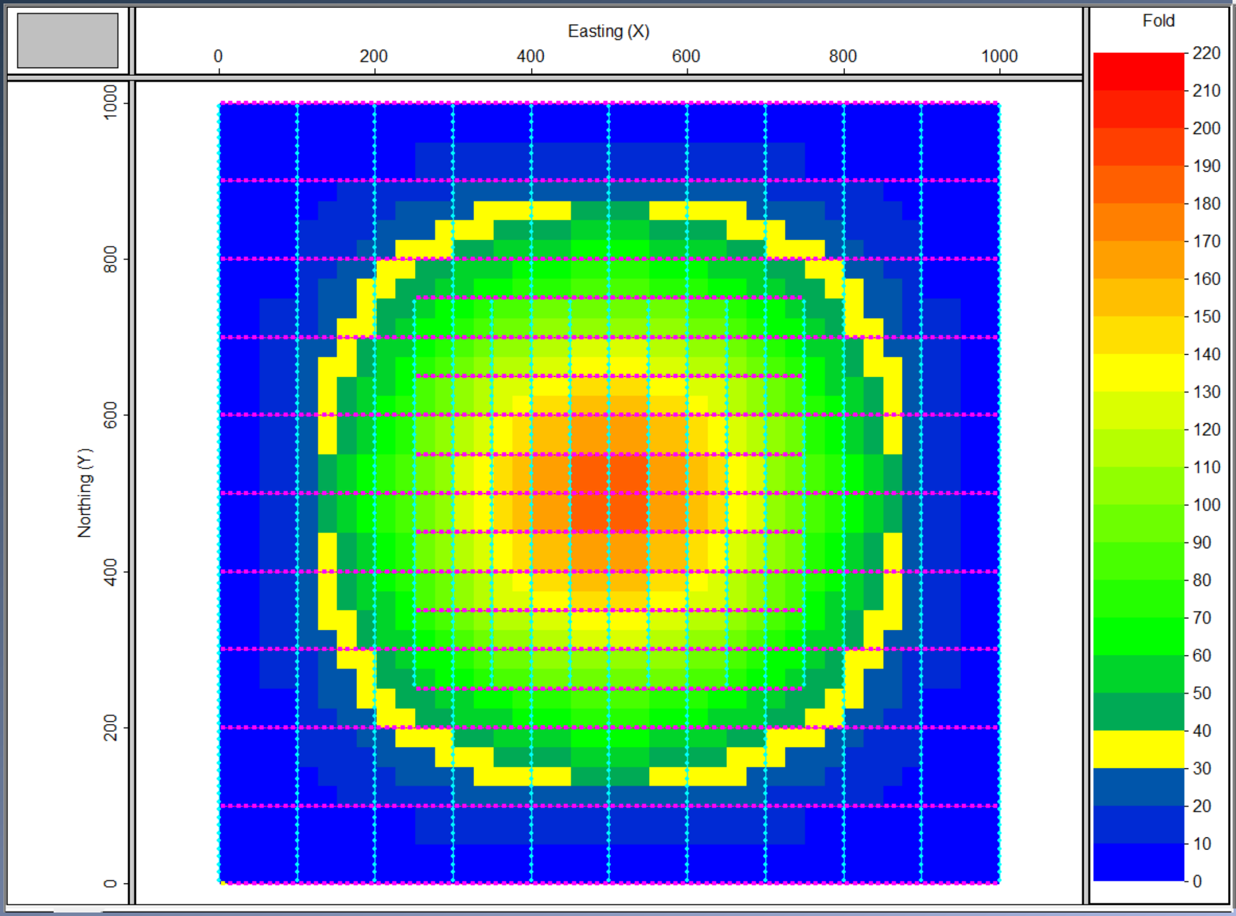


Option B

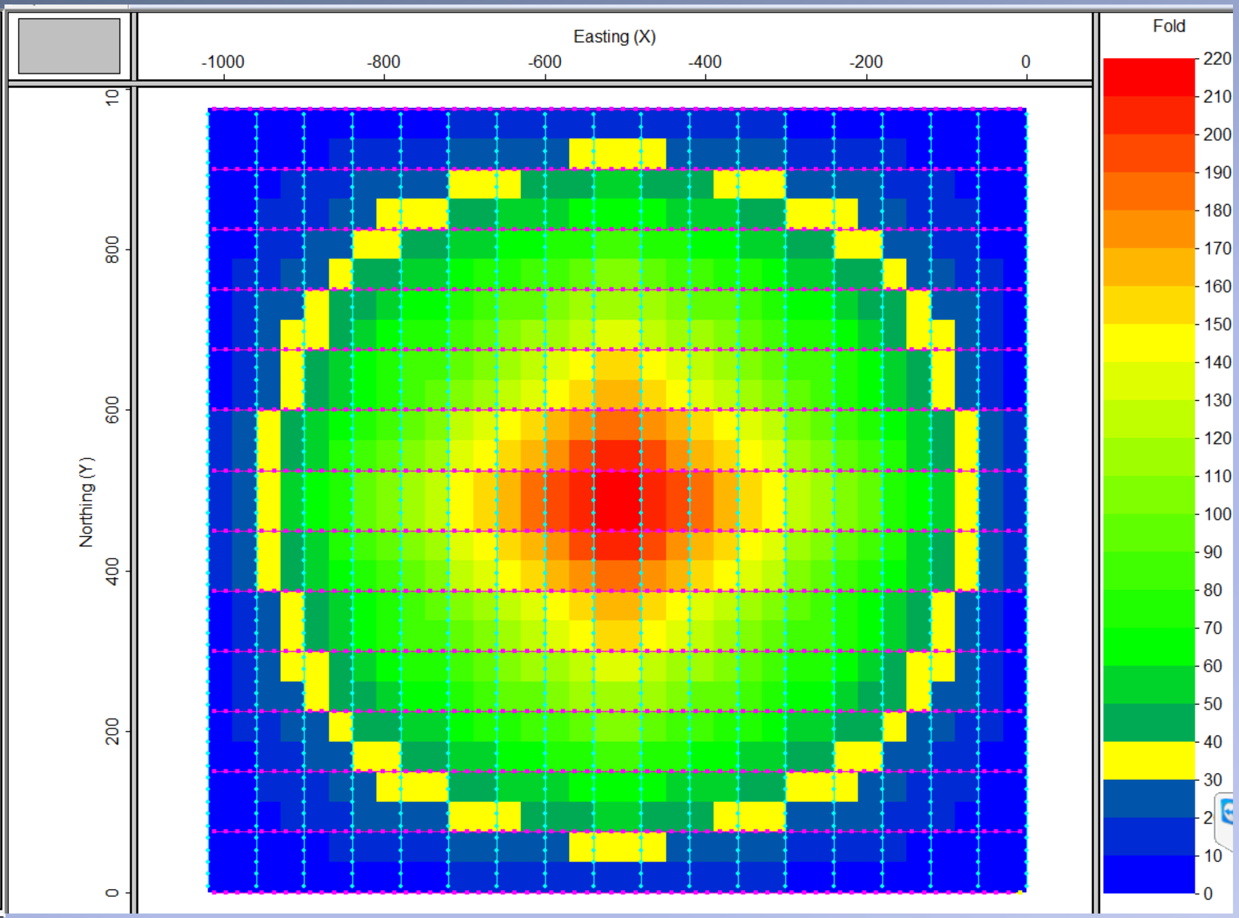


PP fold-All offset and azimuth ranges

Option A



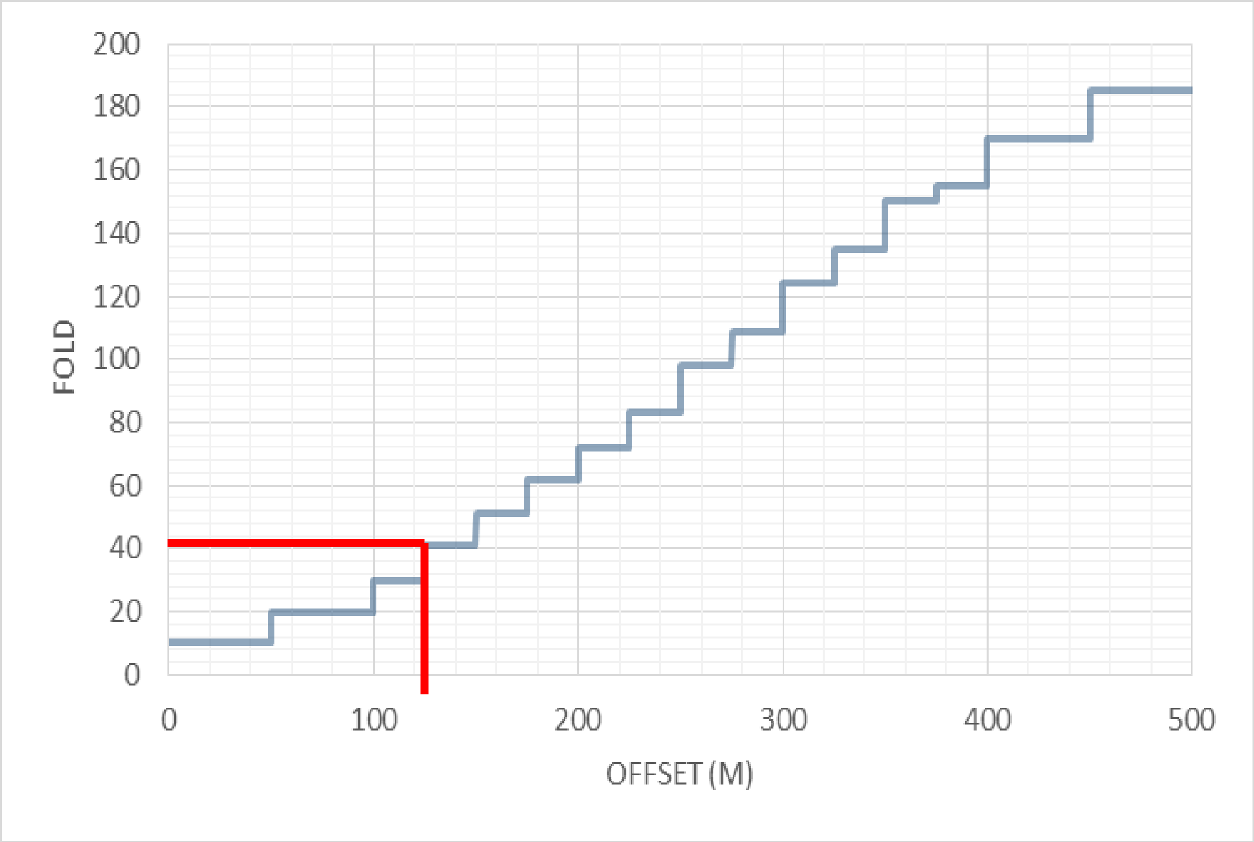
Option B

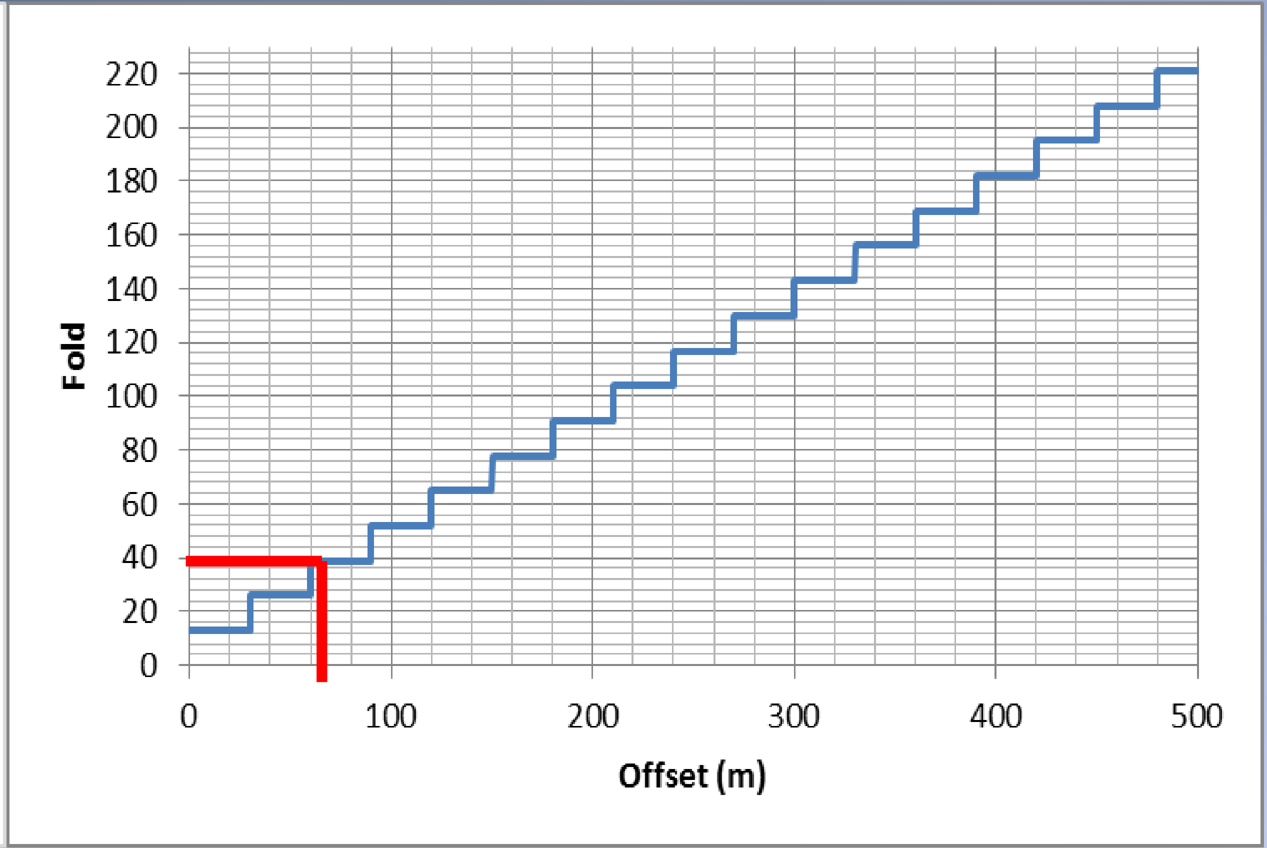


Fold increasing rate, Fold Taper

Option A

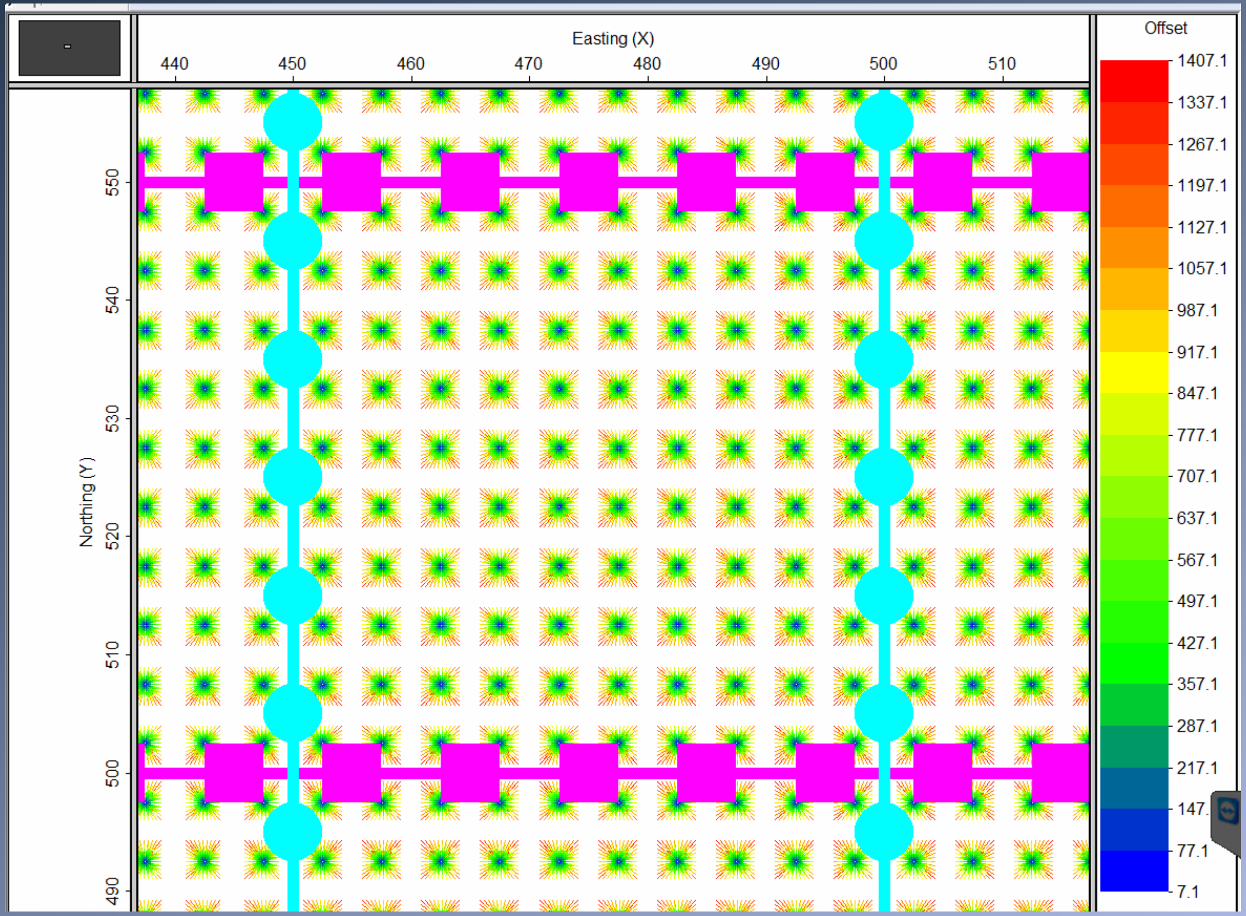
Option B



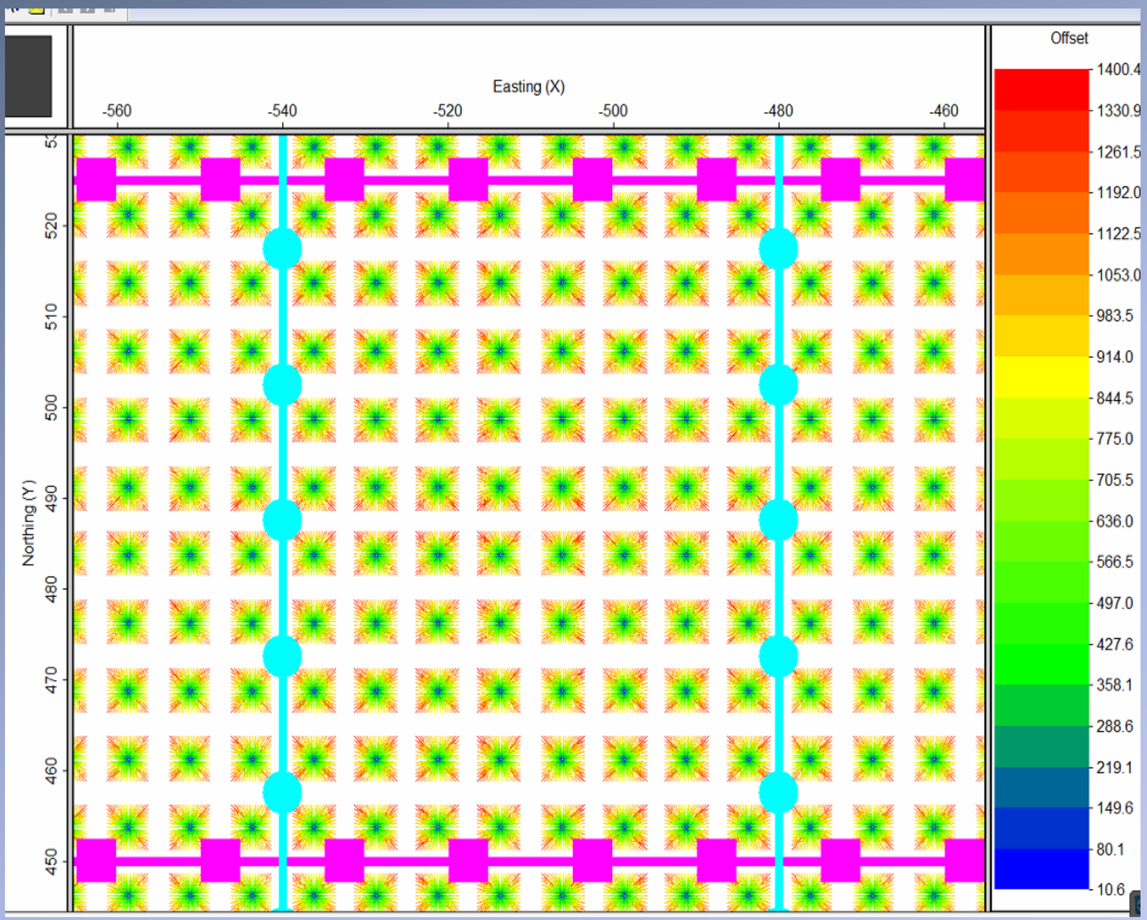


Azimuth distribution in high fold zone

Option A

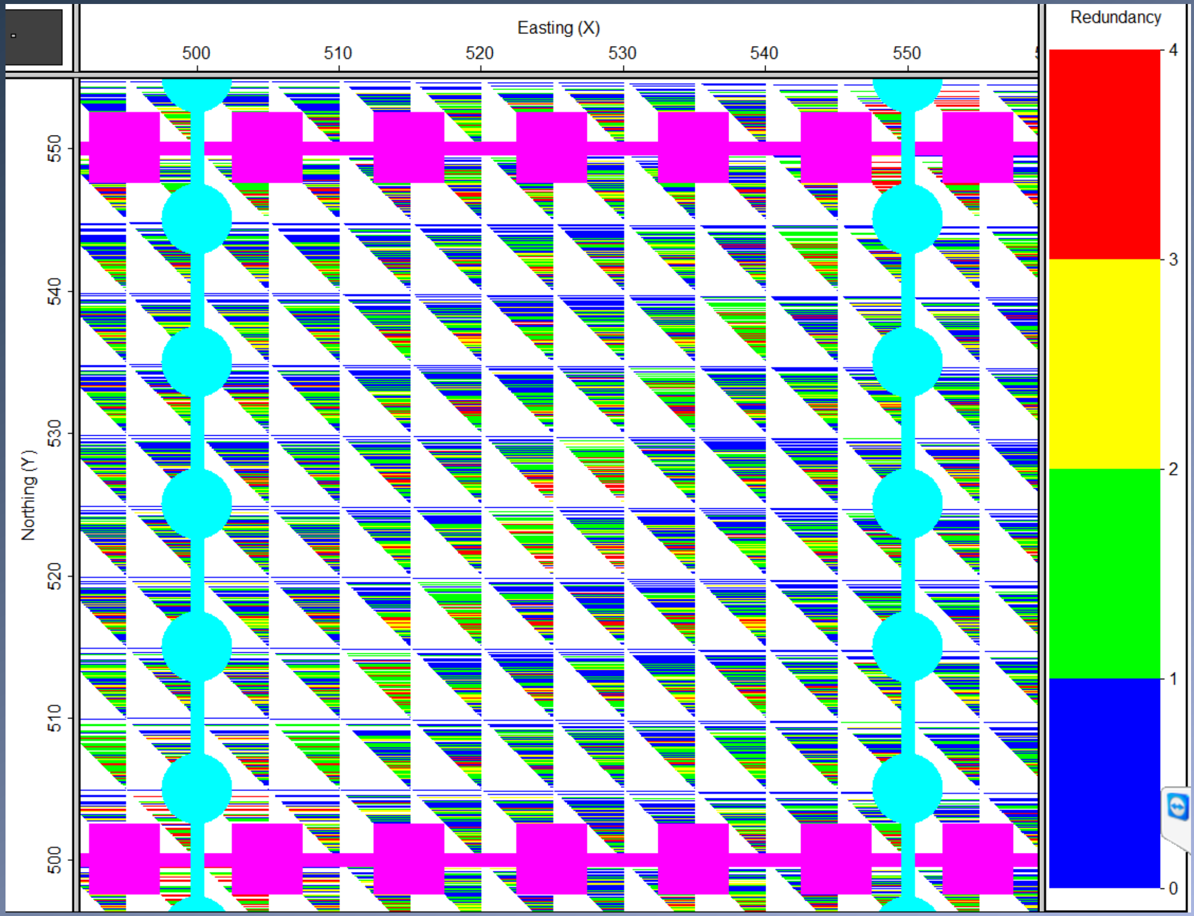


Option B

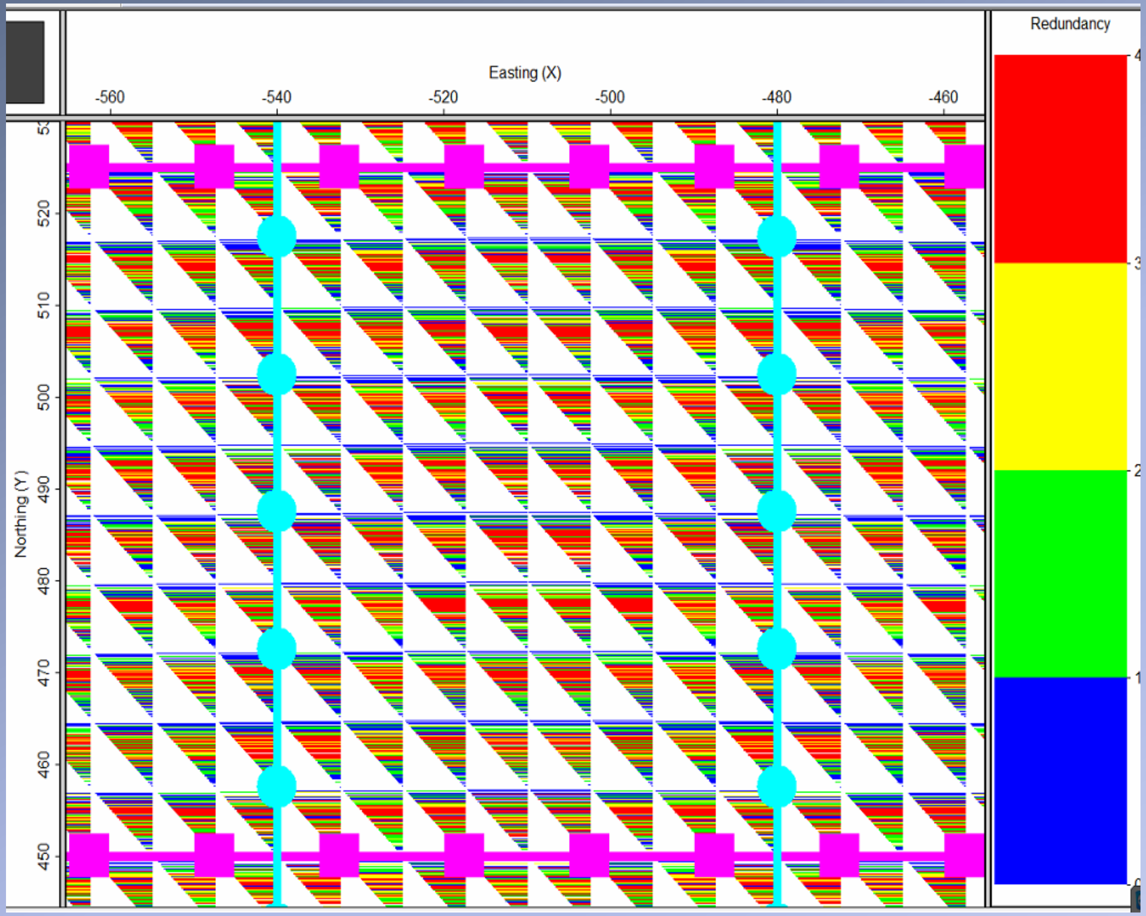


Offset distribution in high fold zone

Option A

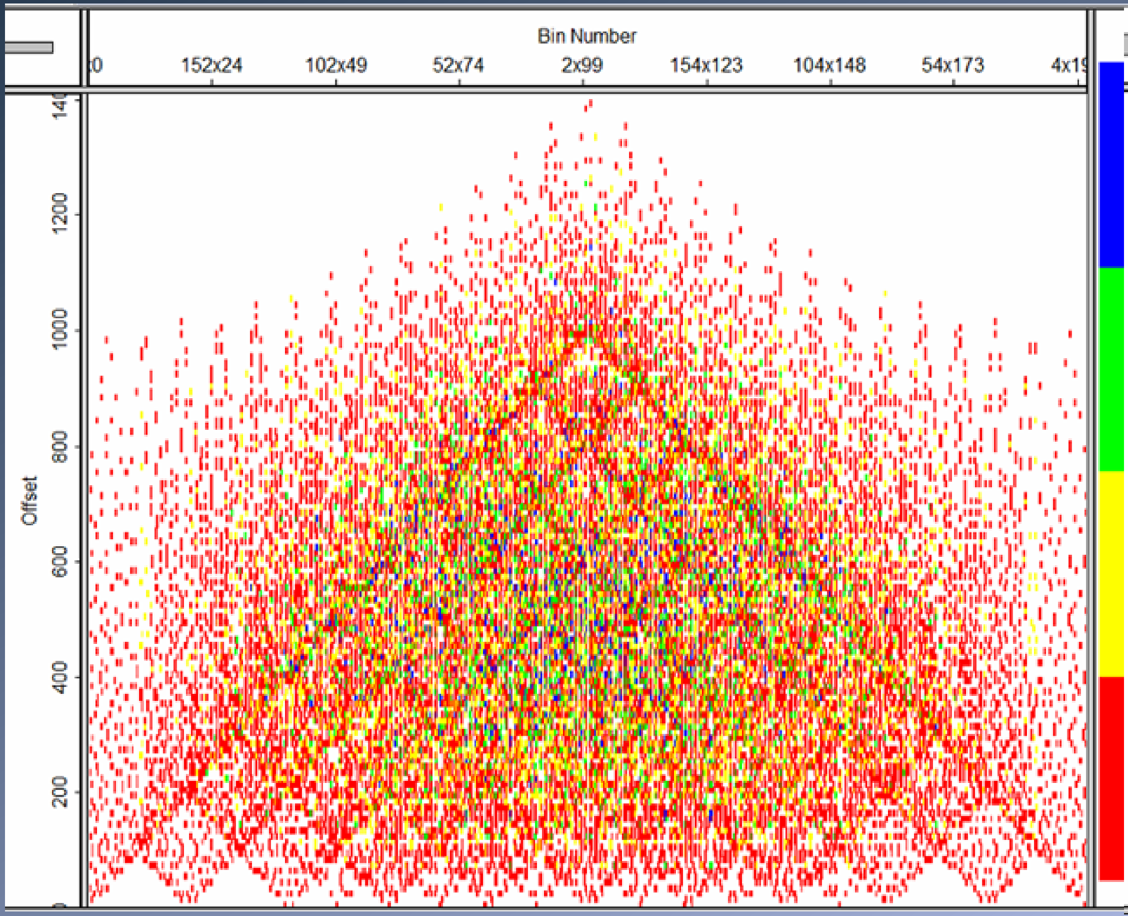


Option B

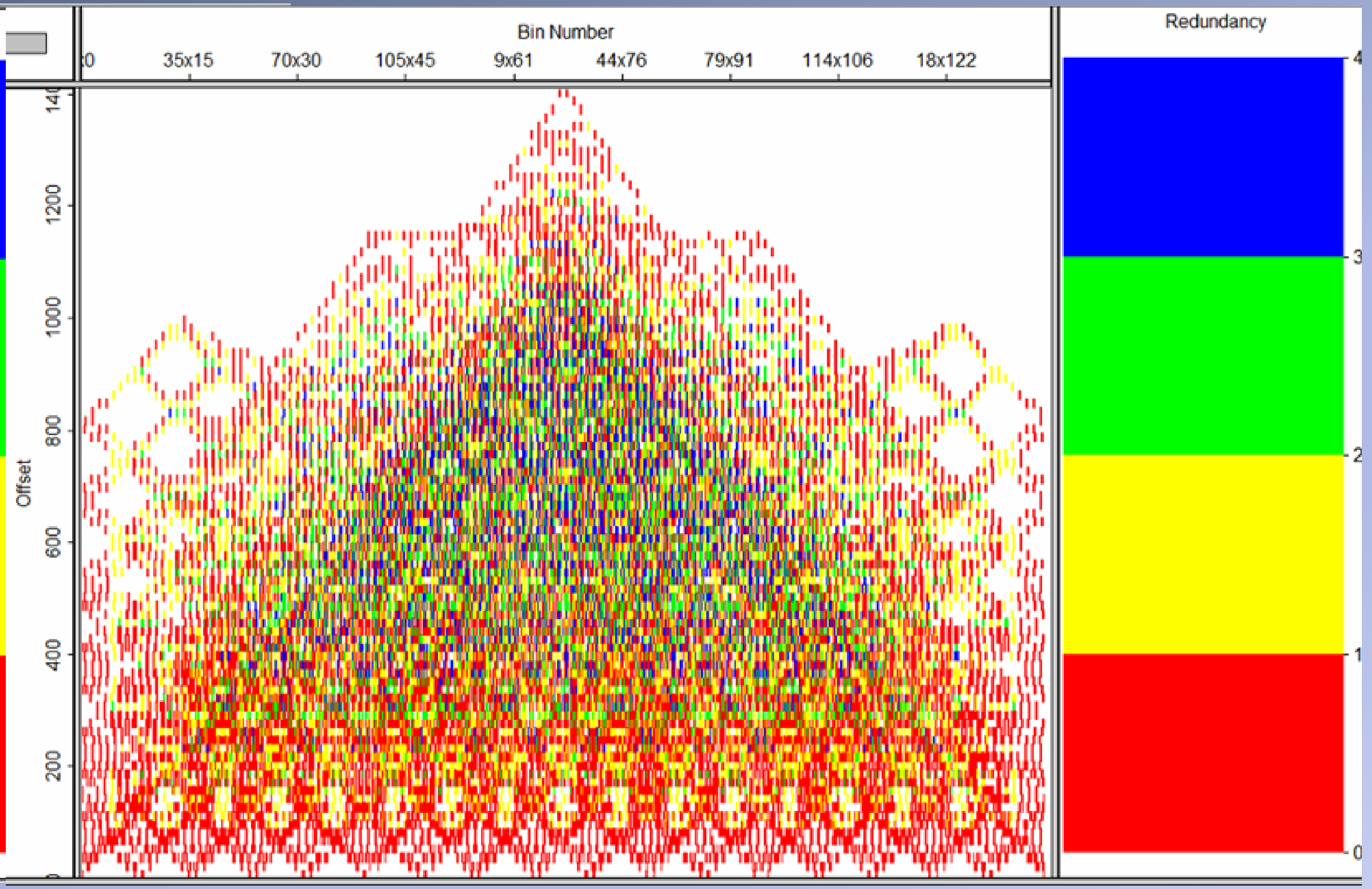


Offset redundancy

Option A

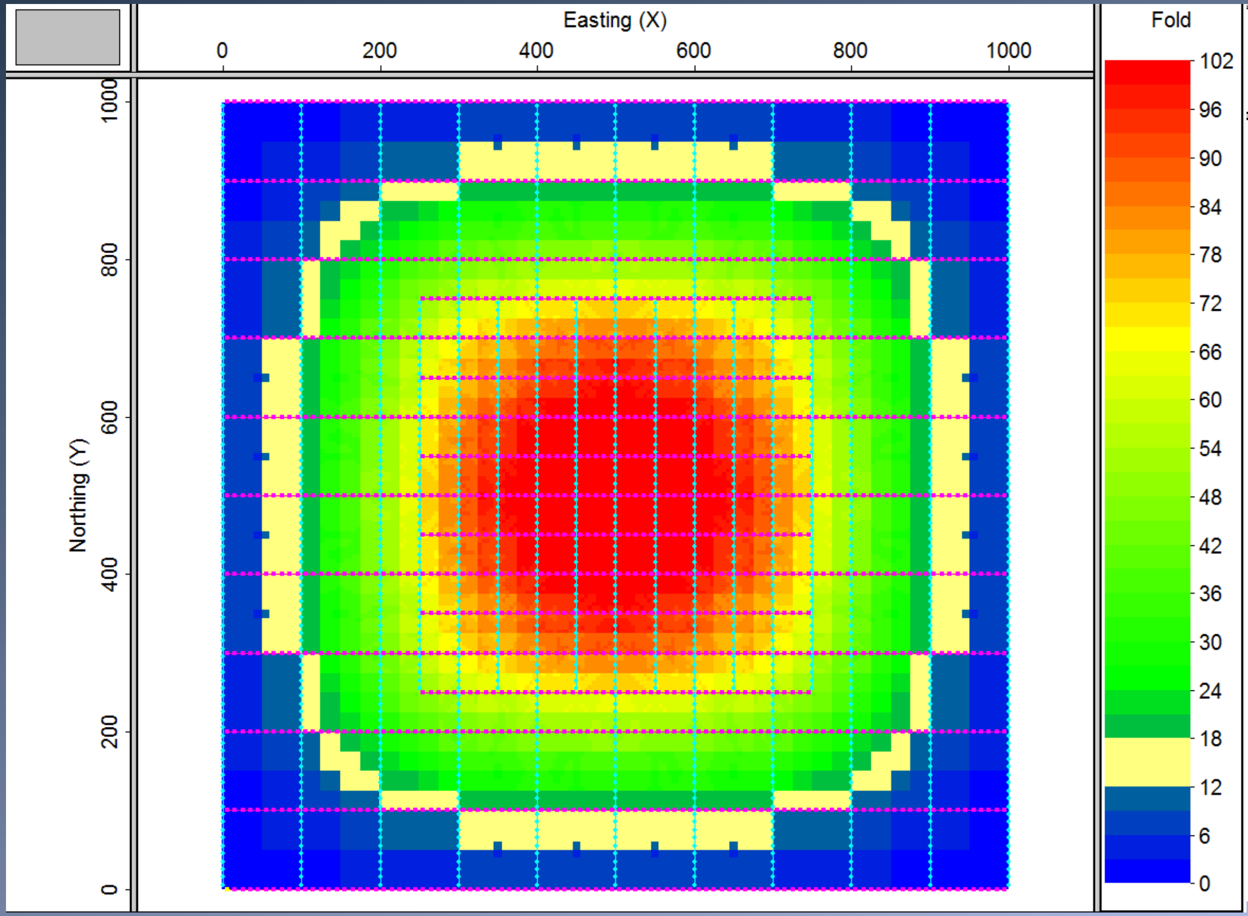


Option B

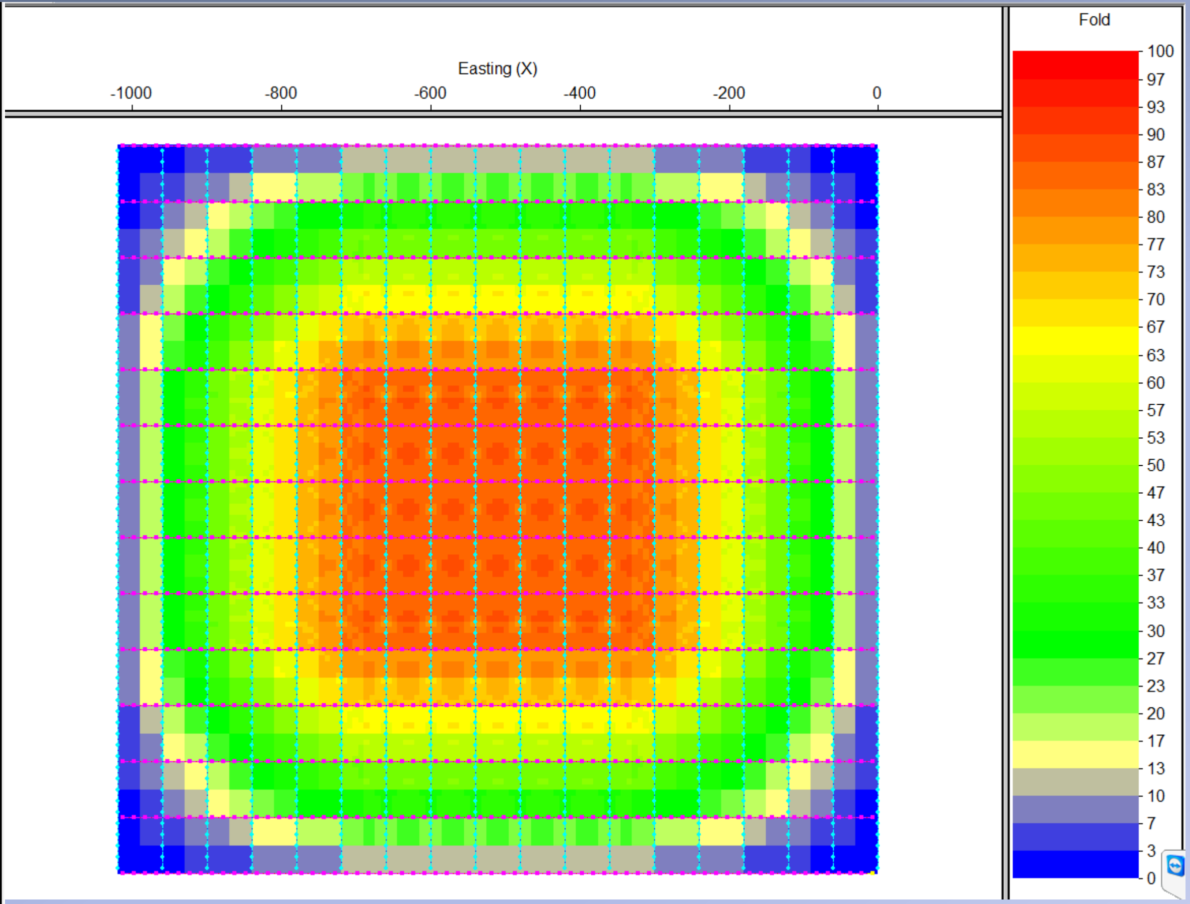


PP fold-For 0-700 m offset

Option A

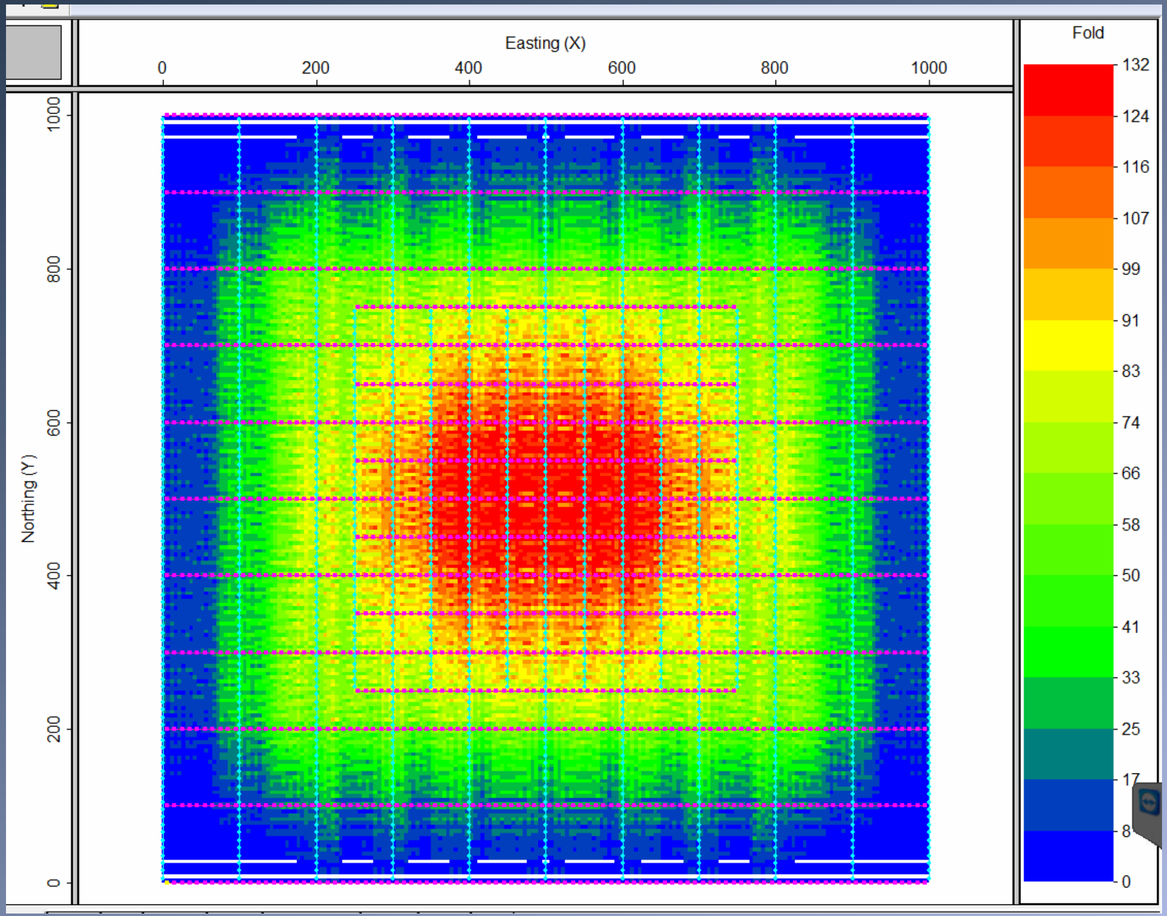


Option B

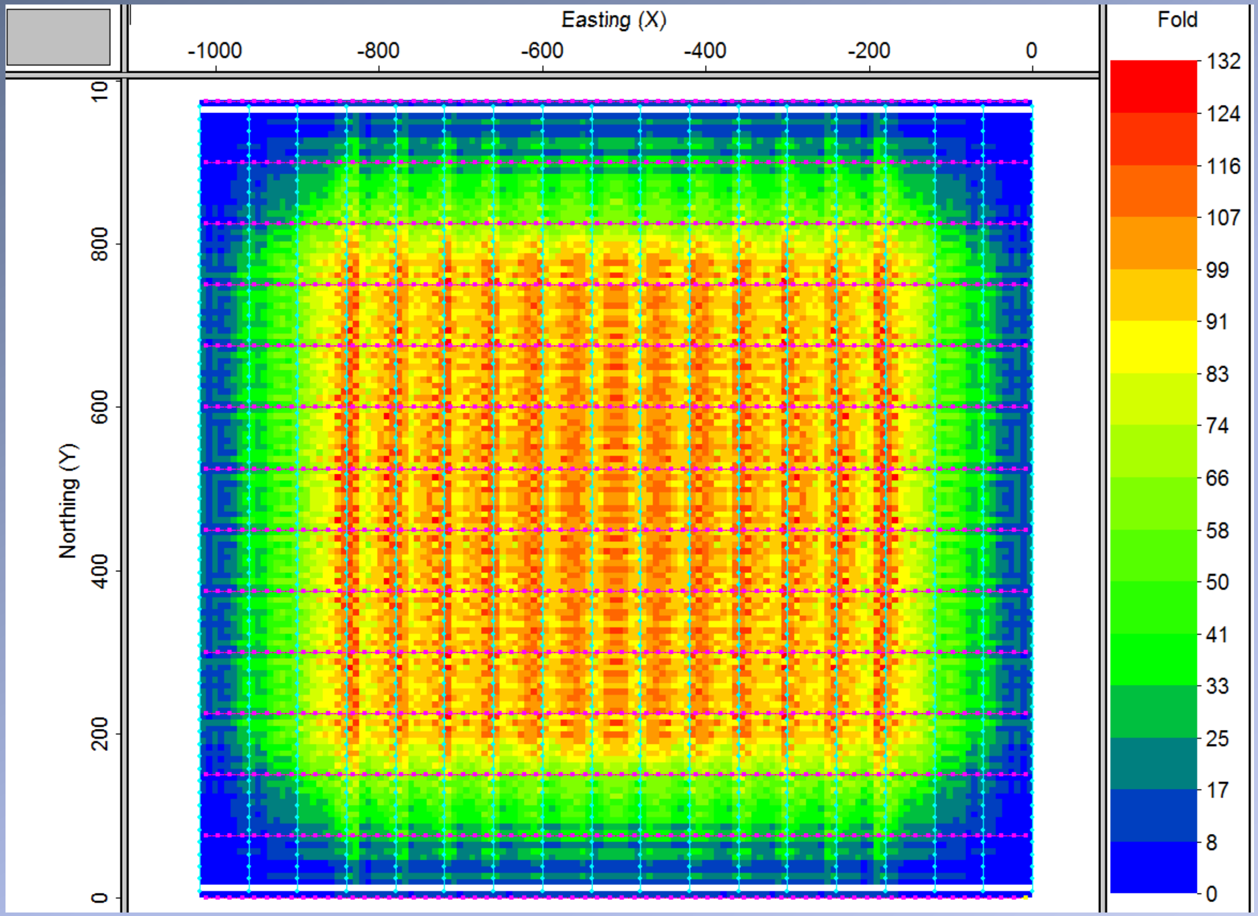


PS fold map for 400 m depth, (non-asymptotic method)

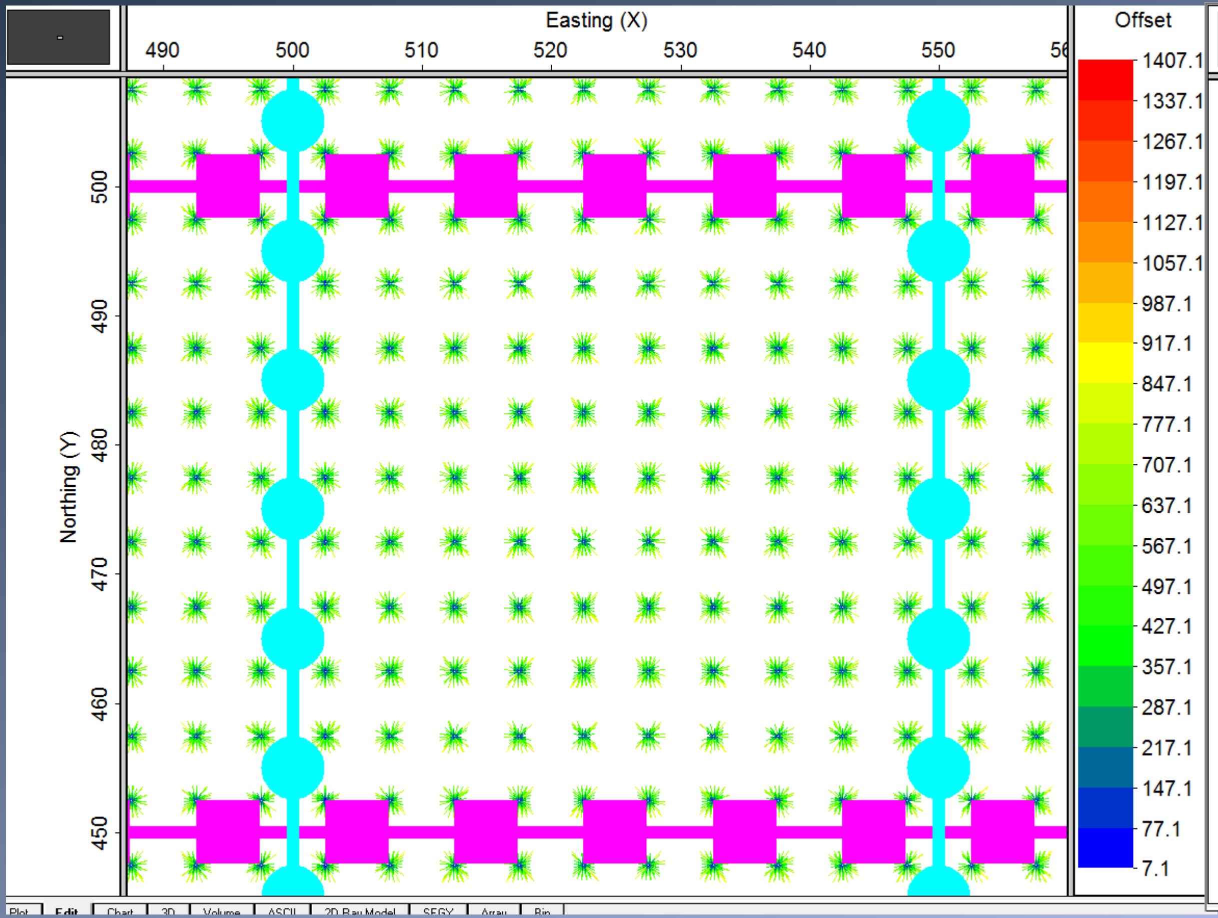
Option A

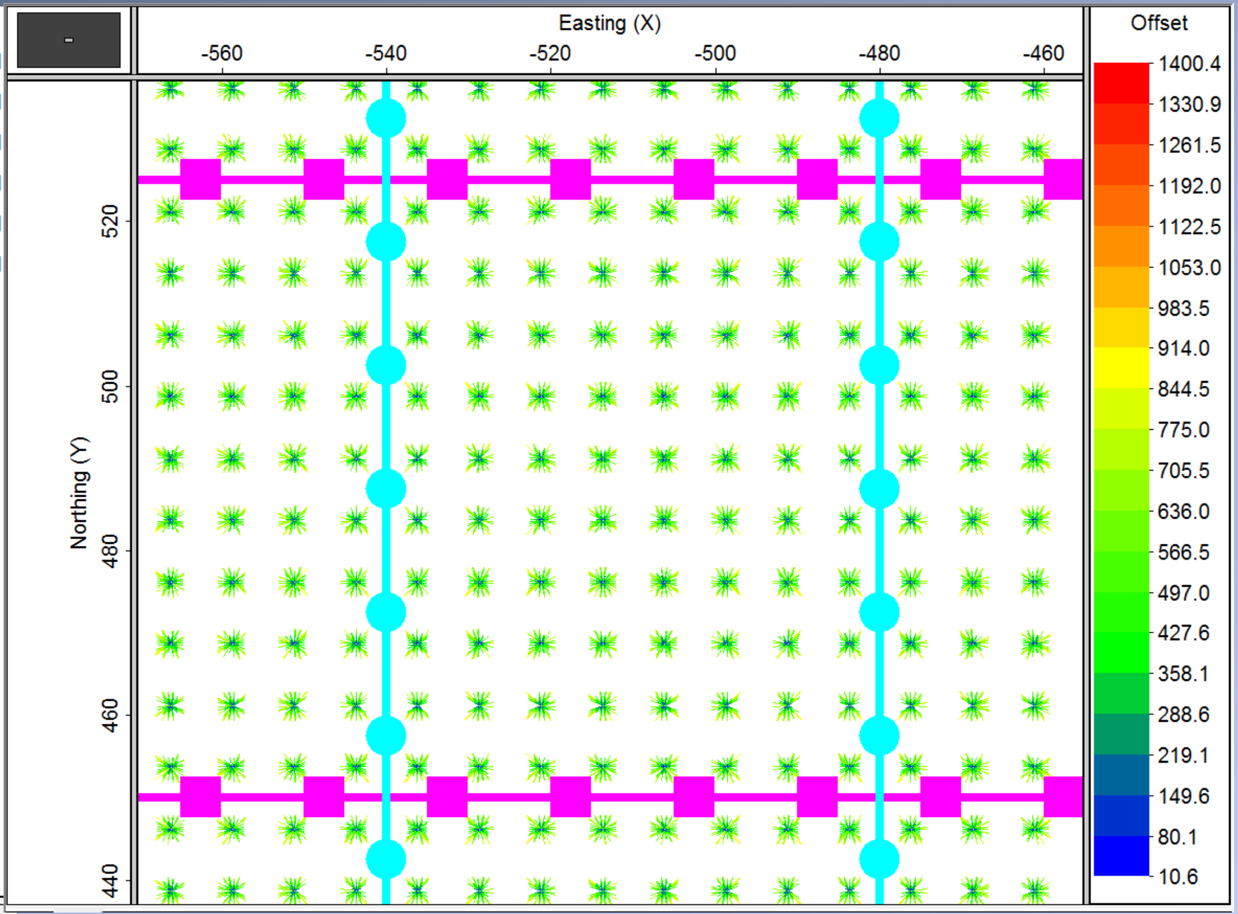


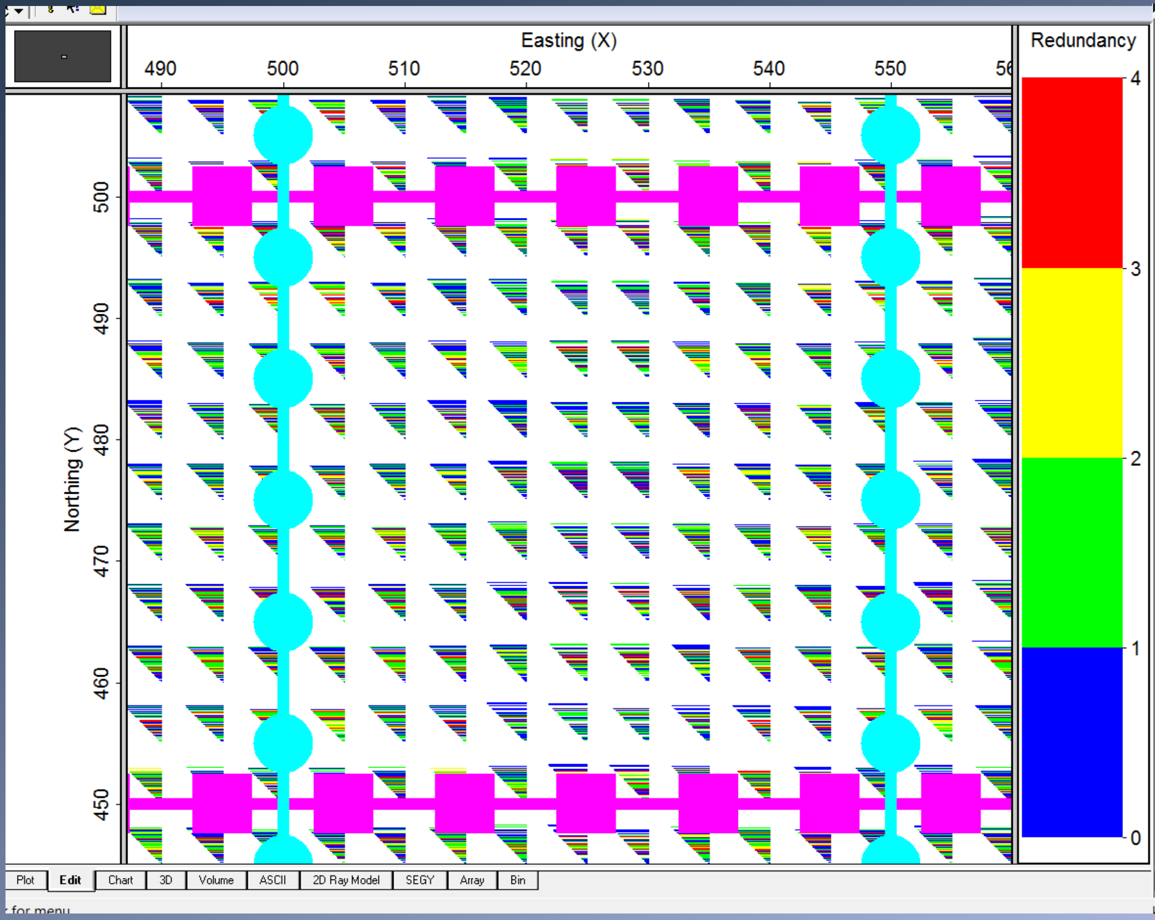
Option B

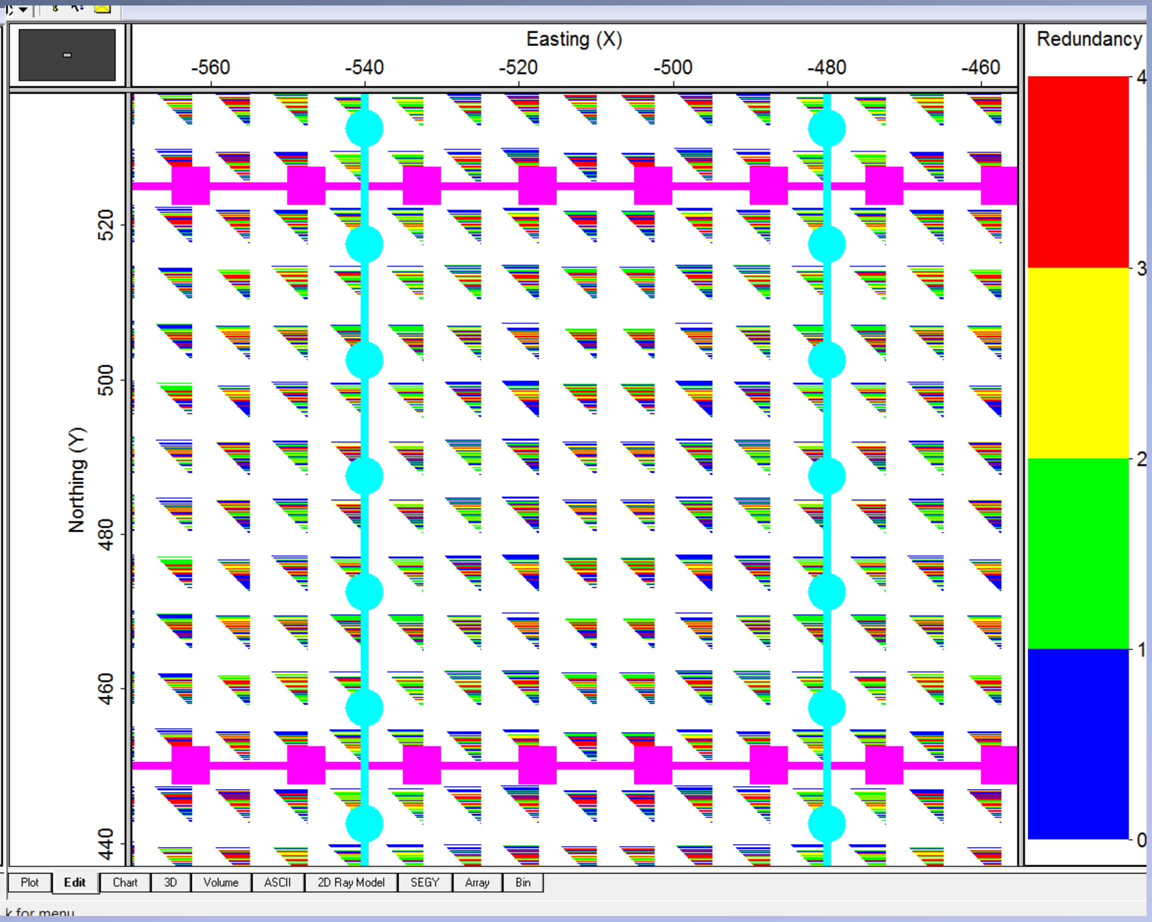


Azimuth distribution

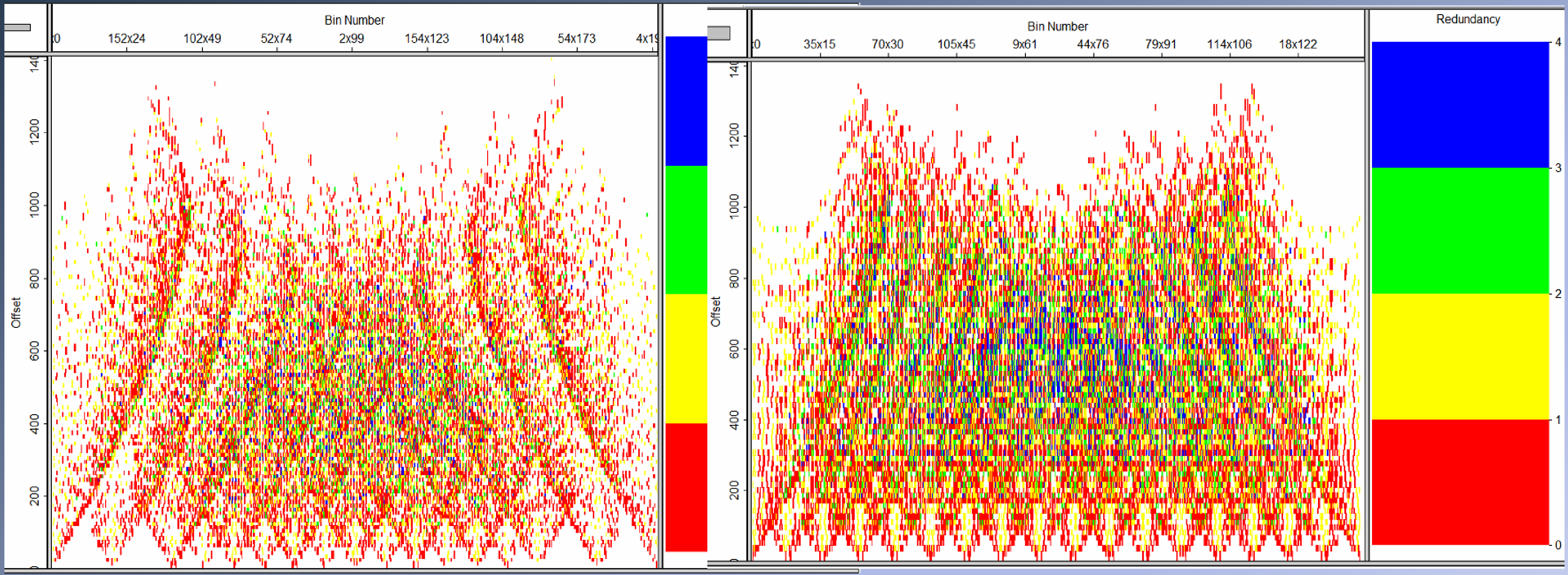




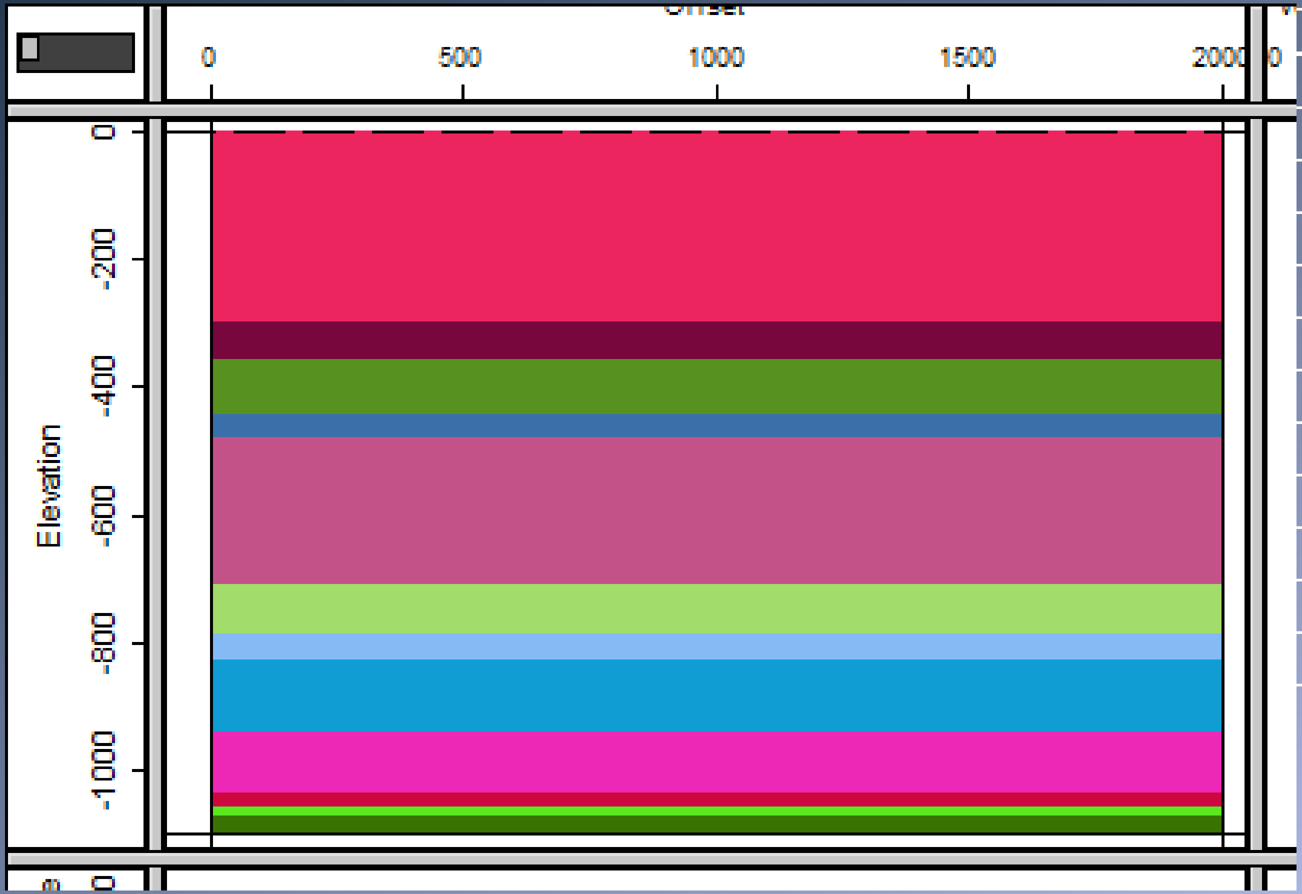

Easting (X)
490
500
510
520
530
540
550
Redundancy
4
3
2
1
0
Northing (Y)
500
490
480
470
460
450
Plot
Edit
Chart
3D
Volume
ASCII
2D Ray Model
SEGY
Array
Bin


Easting (X)
-560
-540
-520
-500
-480
-460
Redundancy
4
3
2
1
0
Northing (Y)
520
500
480
460
440
Plot
Edit
Chart
3D
Volume
ASCII
2D Ray Model
SEGY
Array
Bin

Offset redundancy for PS wave

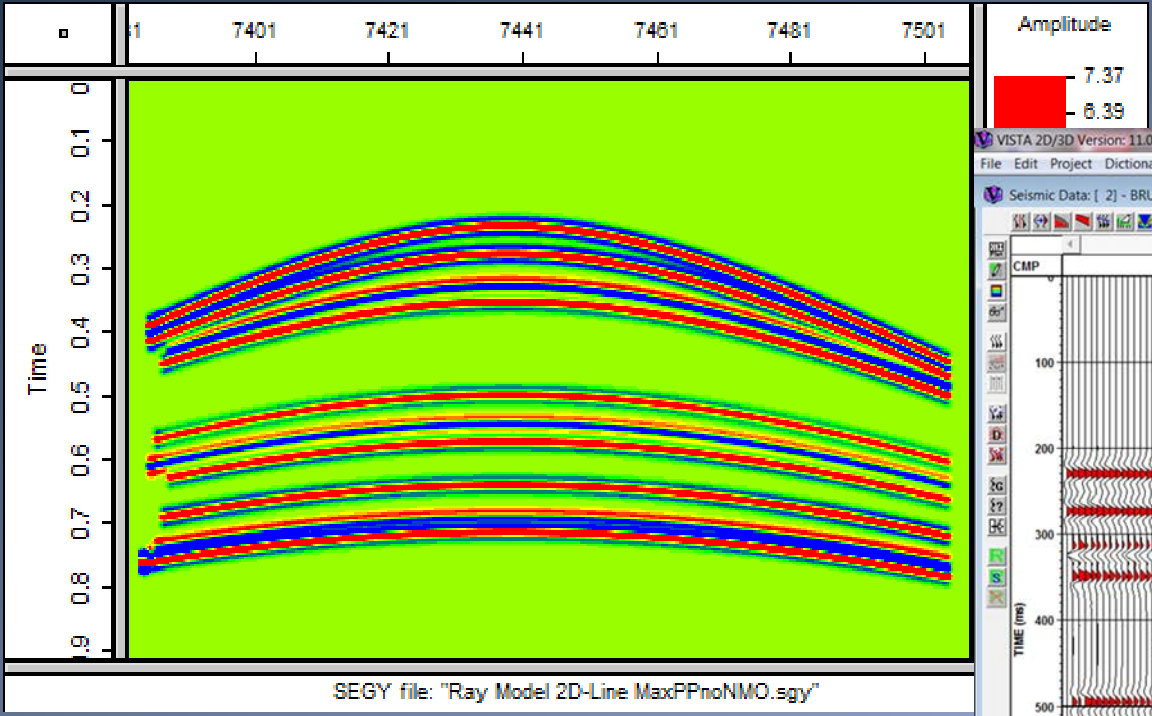


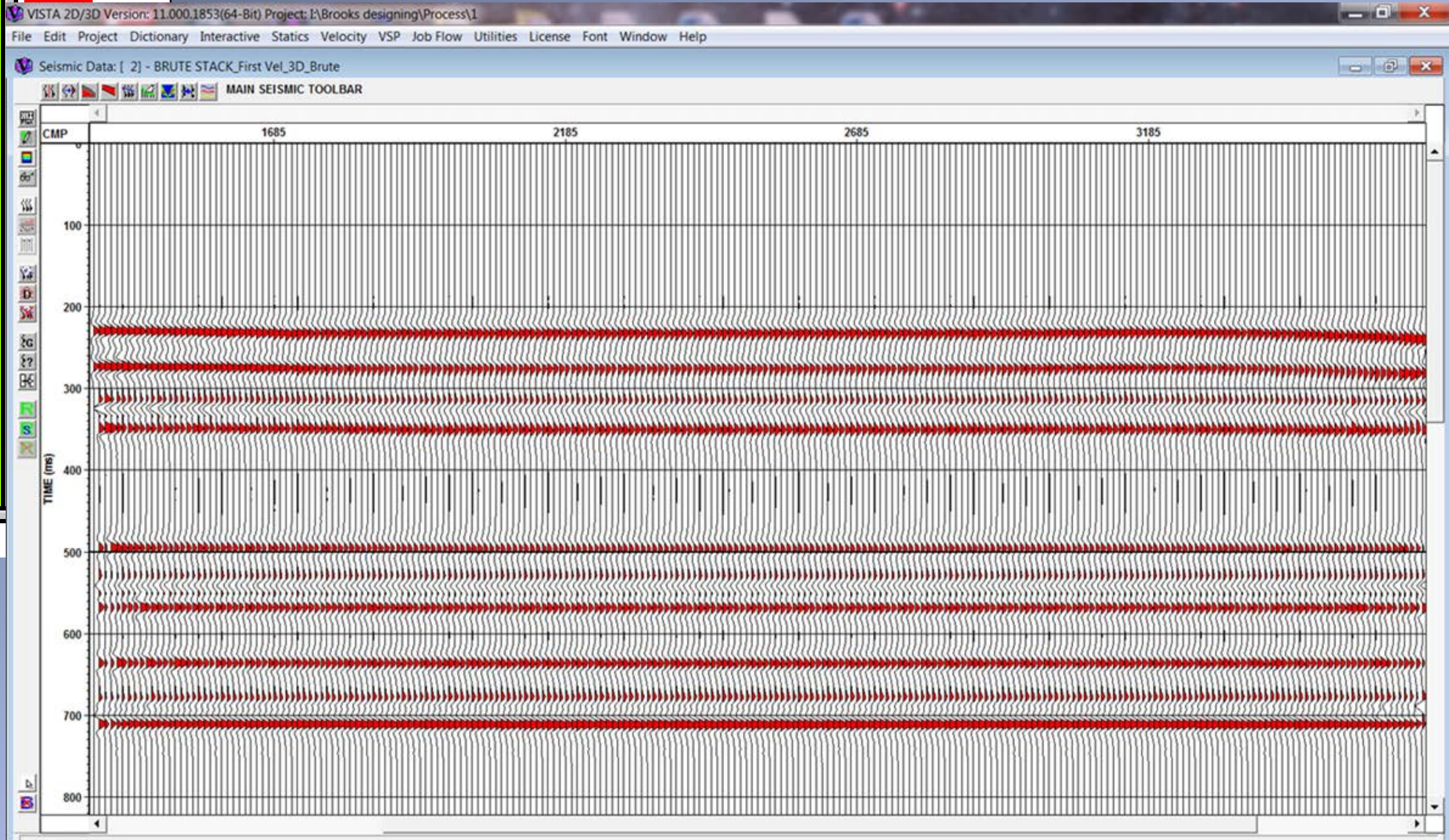
2D Model



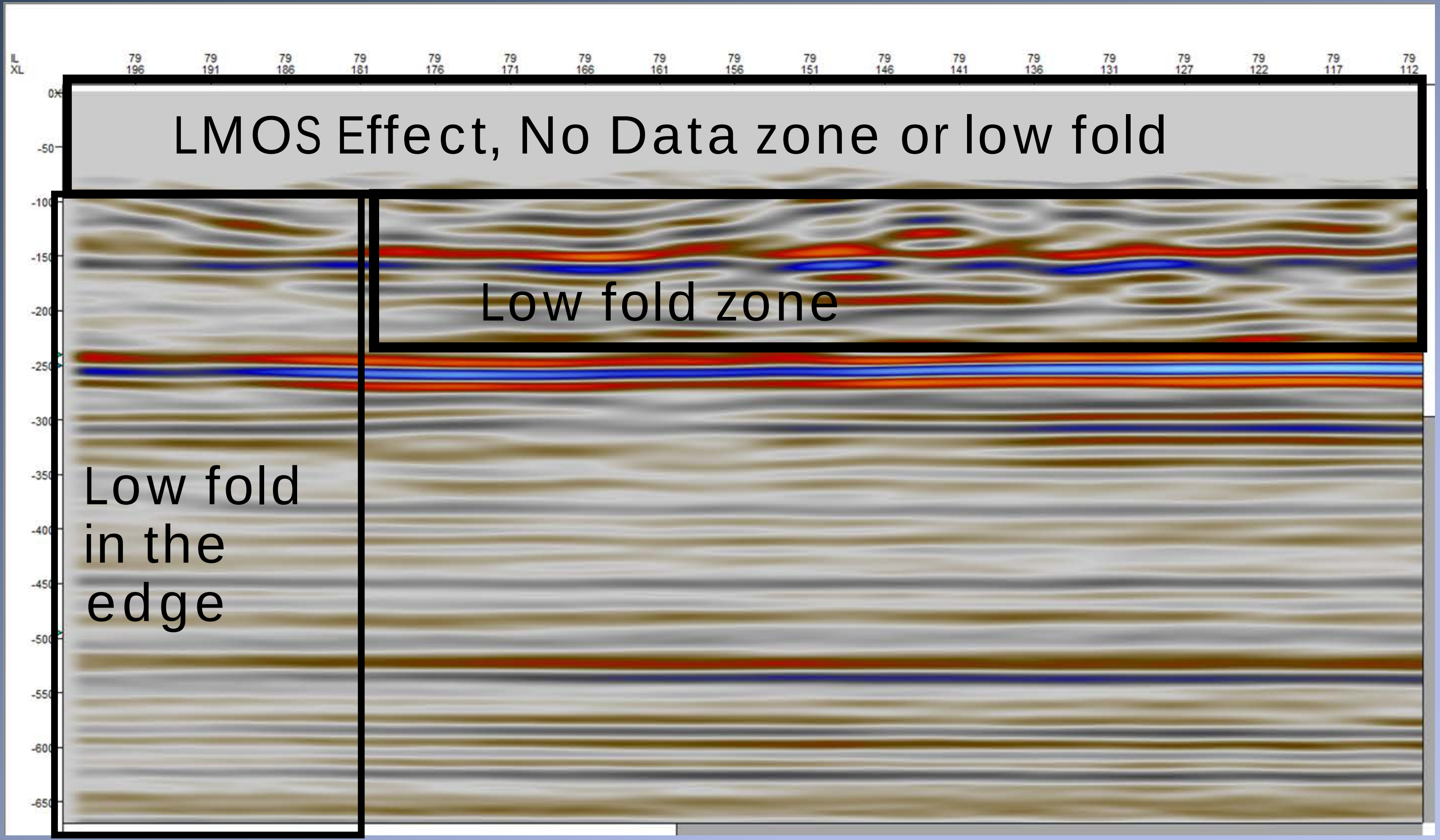
Formation Top	Depth (m)	Density	Vp(m/s)	2T(s)	Q	Z(m)
PAKOWKI	296.5	2387	2775	0.2136937	100	60.5
MILKRV	357	2472	3305	0.2648283	100	84.5
COLRAD	441.5	2477	3062	0.2889955	100	37
MEDHTZ	478.5	2473	3178	0.435314	100	232.5
2WSPK	711	2487	3224	0.4812197	100	74
BFSC	785	2443	2993	0.508617	100	41
BOWIL	826	2446	3326	0.5762658	100	112.5
MANN	938.5	2491	3688	0.62914	100	97.5
GLAUCSS	1036	2407	3602	0.6419107	100	23
OSTCZ	1059	2335	2882	0.6495442	100	11
ELLERSL	1070	2516	3942	0.6617208	100	24

PP synthetic row shot (ray tracing method,100 shots,134 traces)





Acquisition footprint



conclusion

- Option A has a better resolution because of smaller bin size, also it has higher fold for 0-700 m offset in the inner core.
- Option B has a better total fold distribution. Fold taper is small and increases fast so image condition can be much better in the margins. Because total shot points are 40% less than option A, acquisition cost is economical.

Questions & Discussion