Geophone azimuth consistency from vertical seismic profile data

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CREWES Sponsors Meeting

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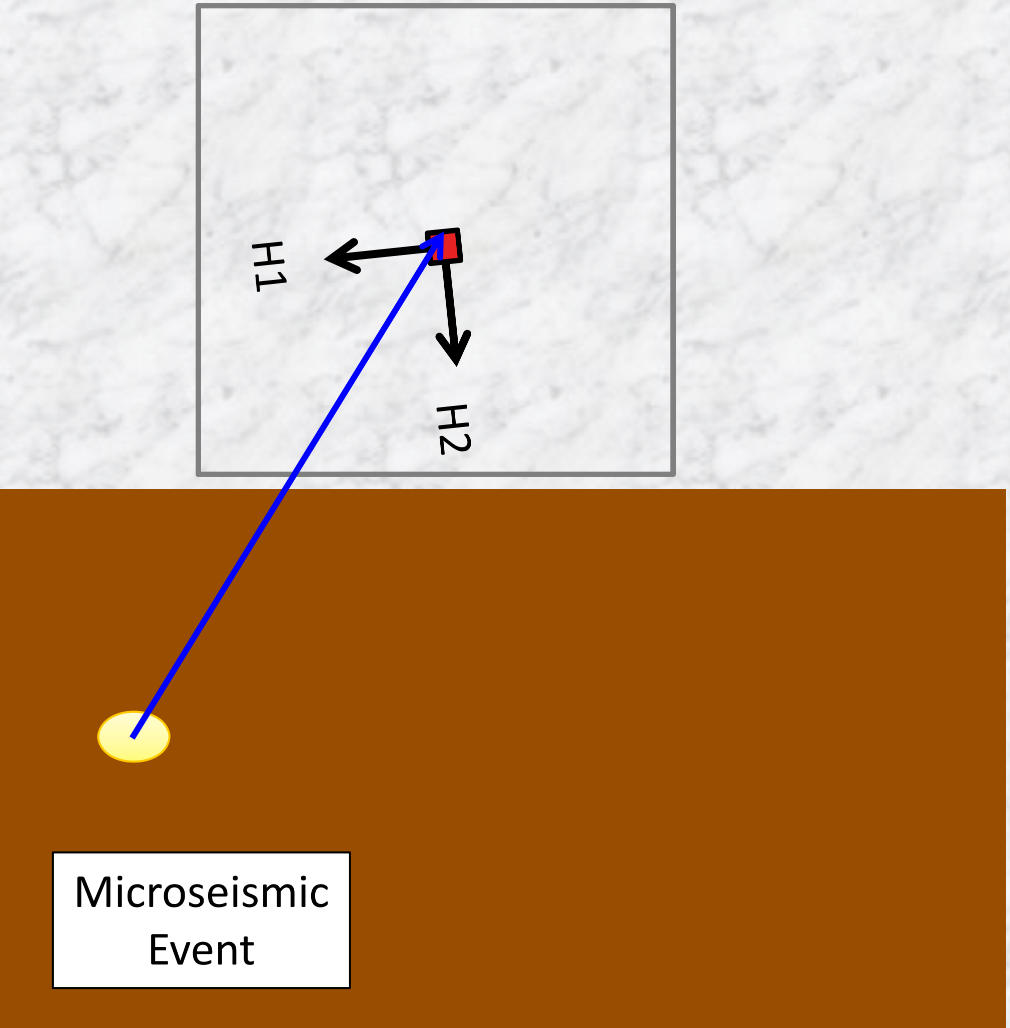
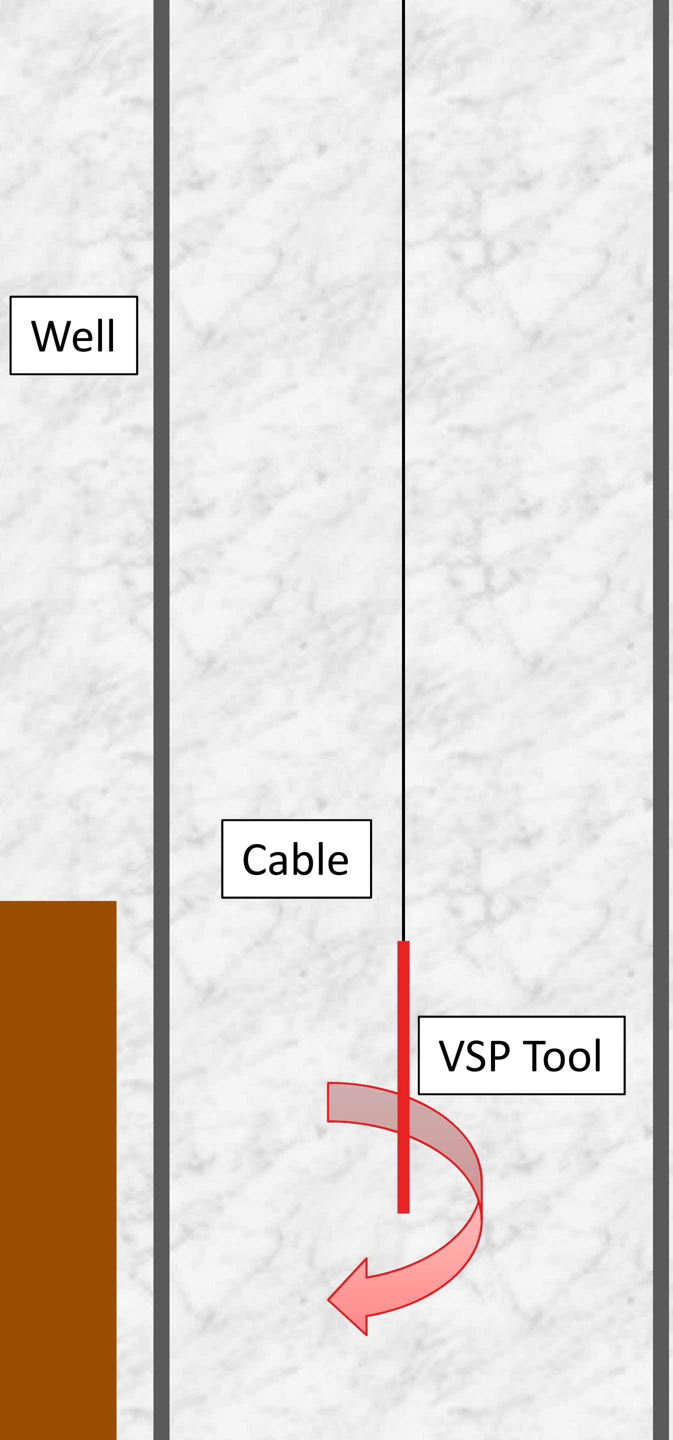
Geophone orientation calibration

Overhead View





Side View

Outline

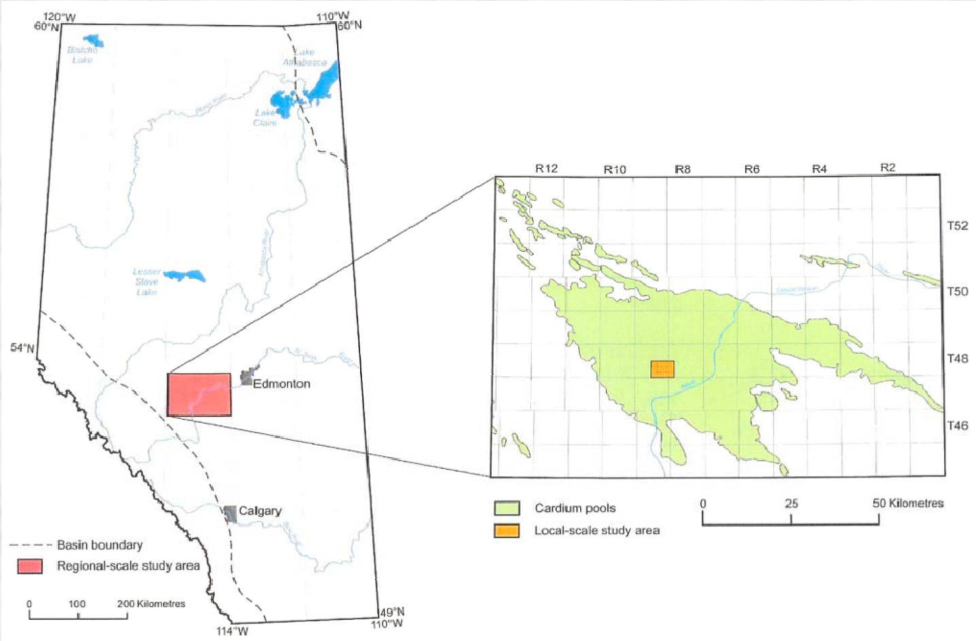
- Objectives
- Methods
- Results
- Conclusions
- Future work

Objectives

- Develop a method for determining geophone orientation in a deviated well
- Perform an analysis of orientation azimuths in a deviated well
- Examine the effects of noise and anisotropy on orientation analysis

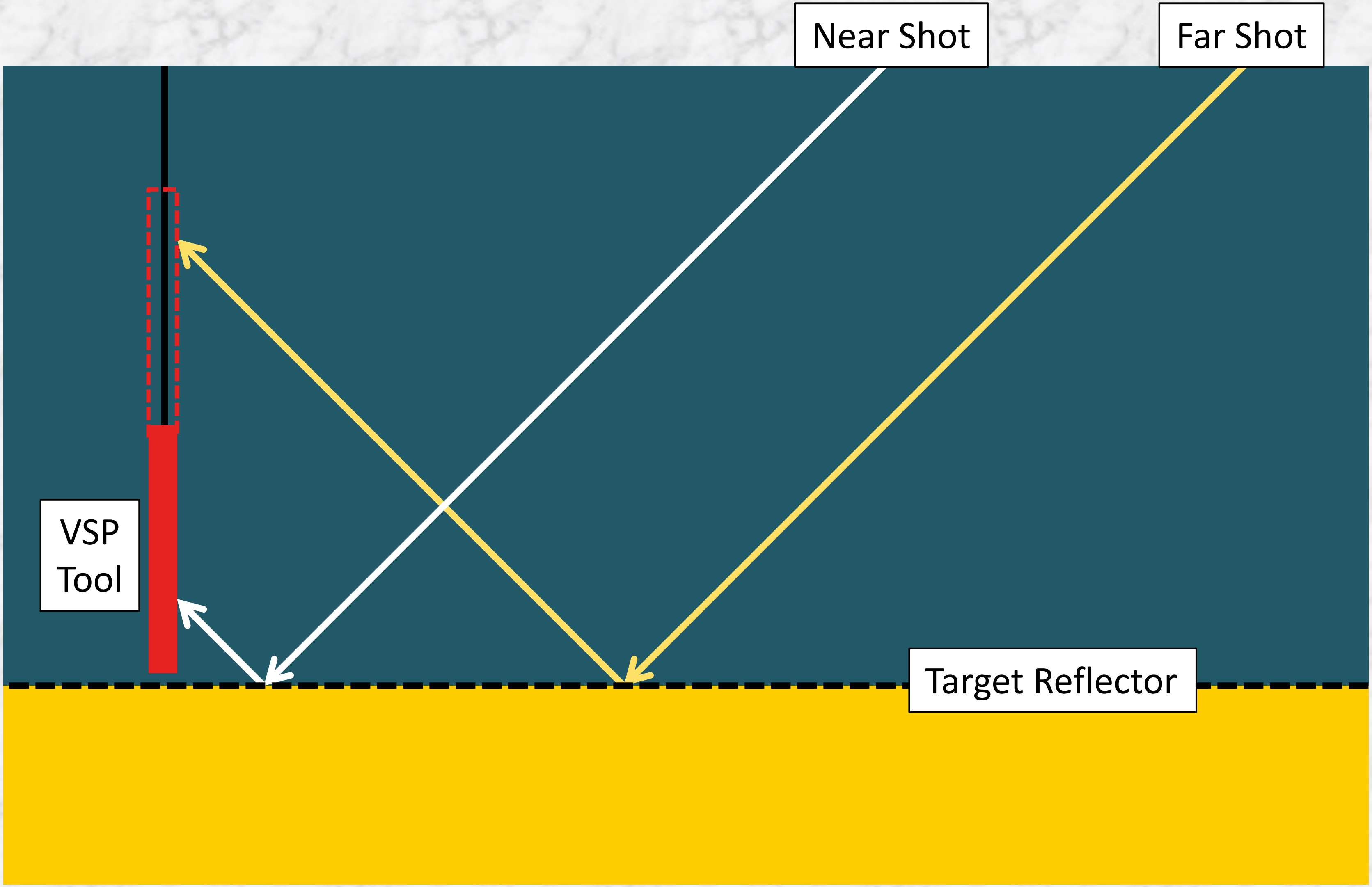
Pembina 16-level – VSP

- 16 3-C receivers
- Receiver spacing of ~15 m
- Three tool positions:
  - Shallow (798-1025 m)
  - Mid (1038-1265 m)
  - Deep (1278-1505 m)
- Deviated Well: PennWest 102-10-11-48-9W5

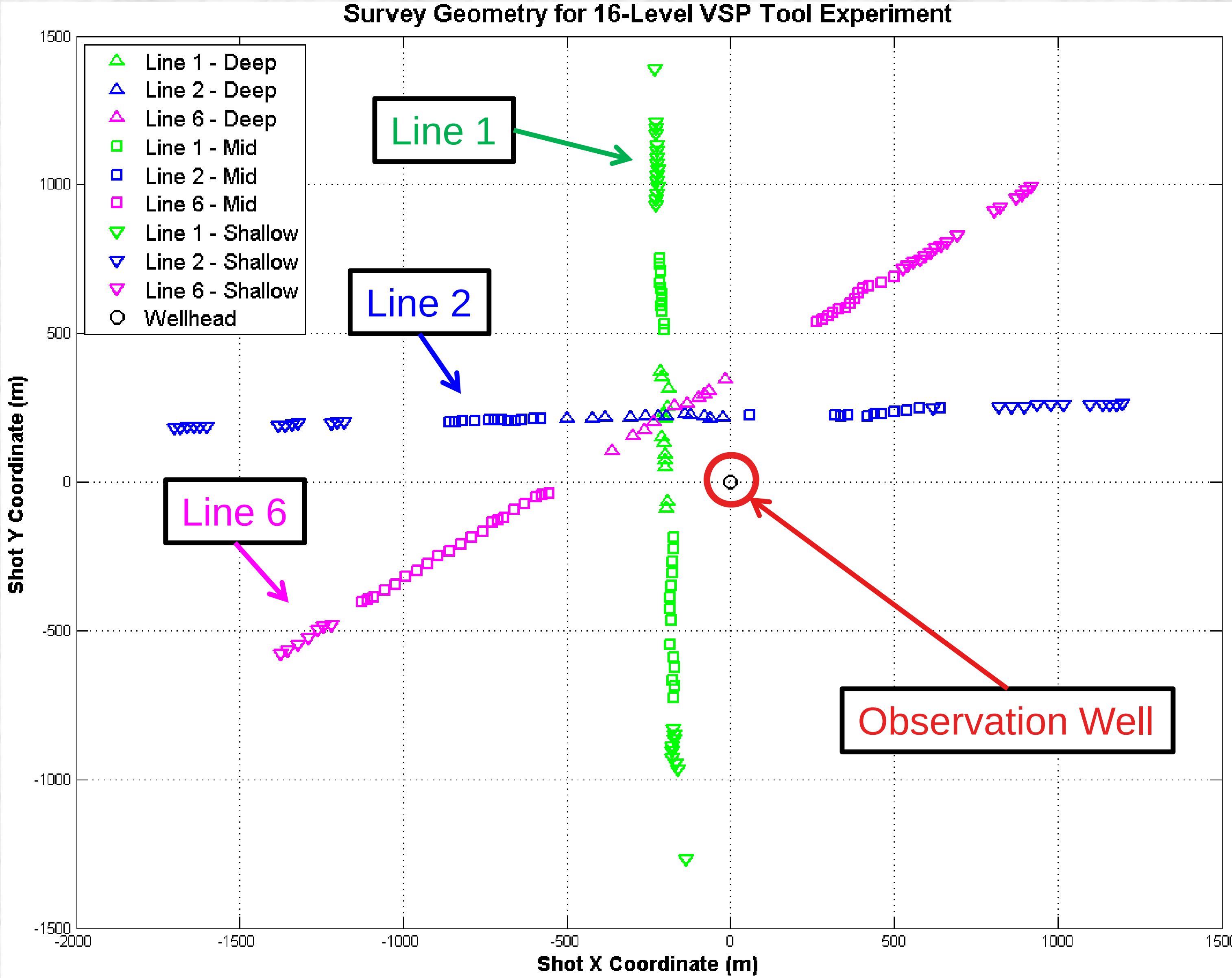


From Dashtgard et al. (2006)

Tool levels

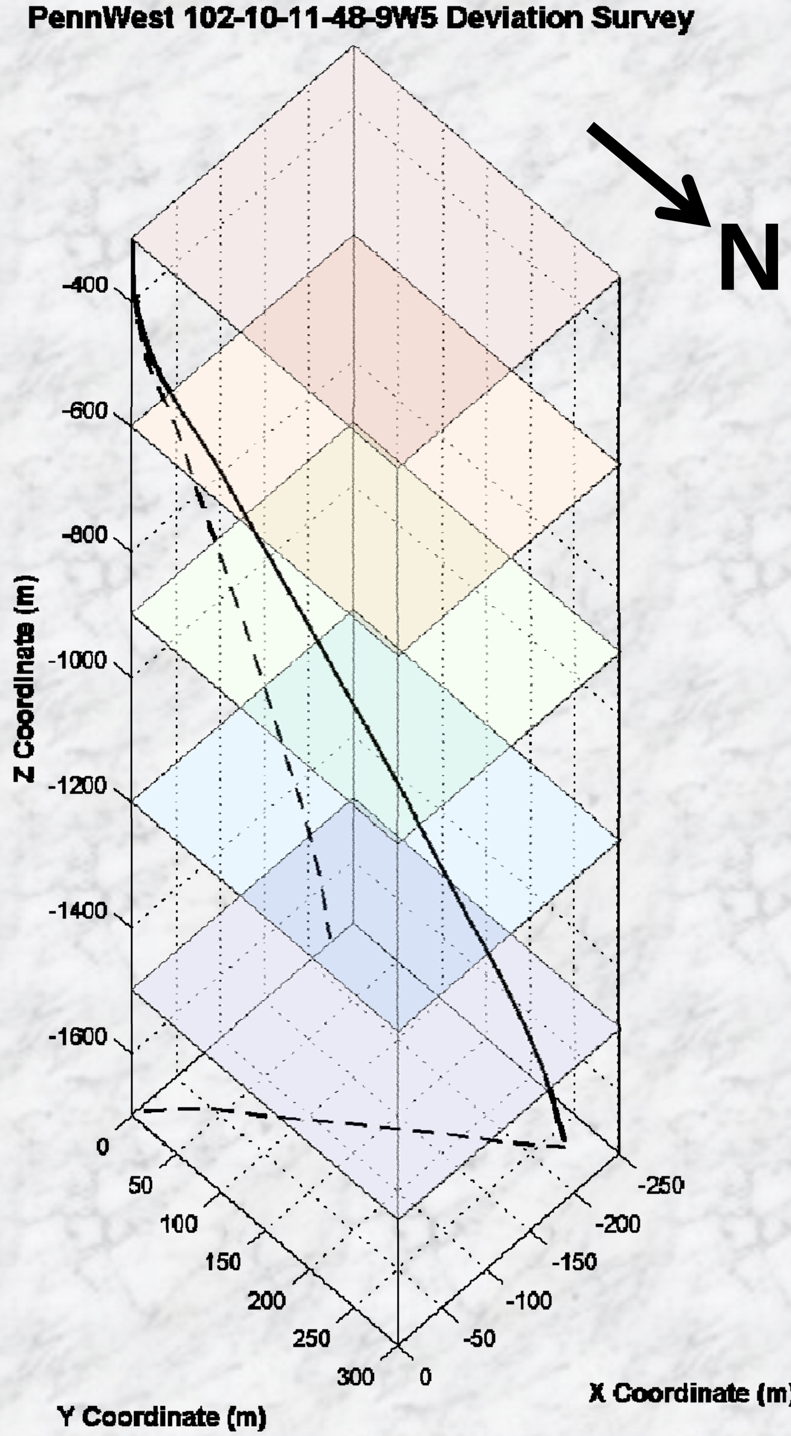


Survey geometry

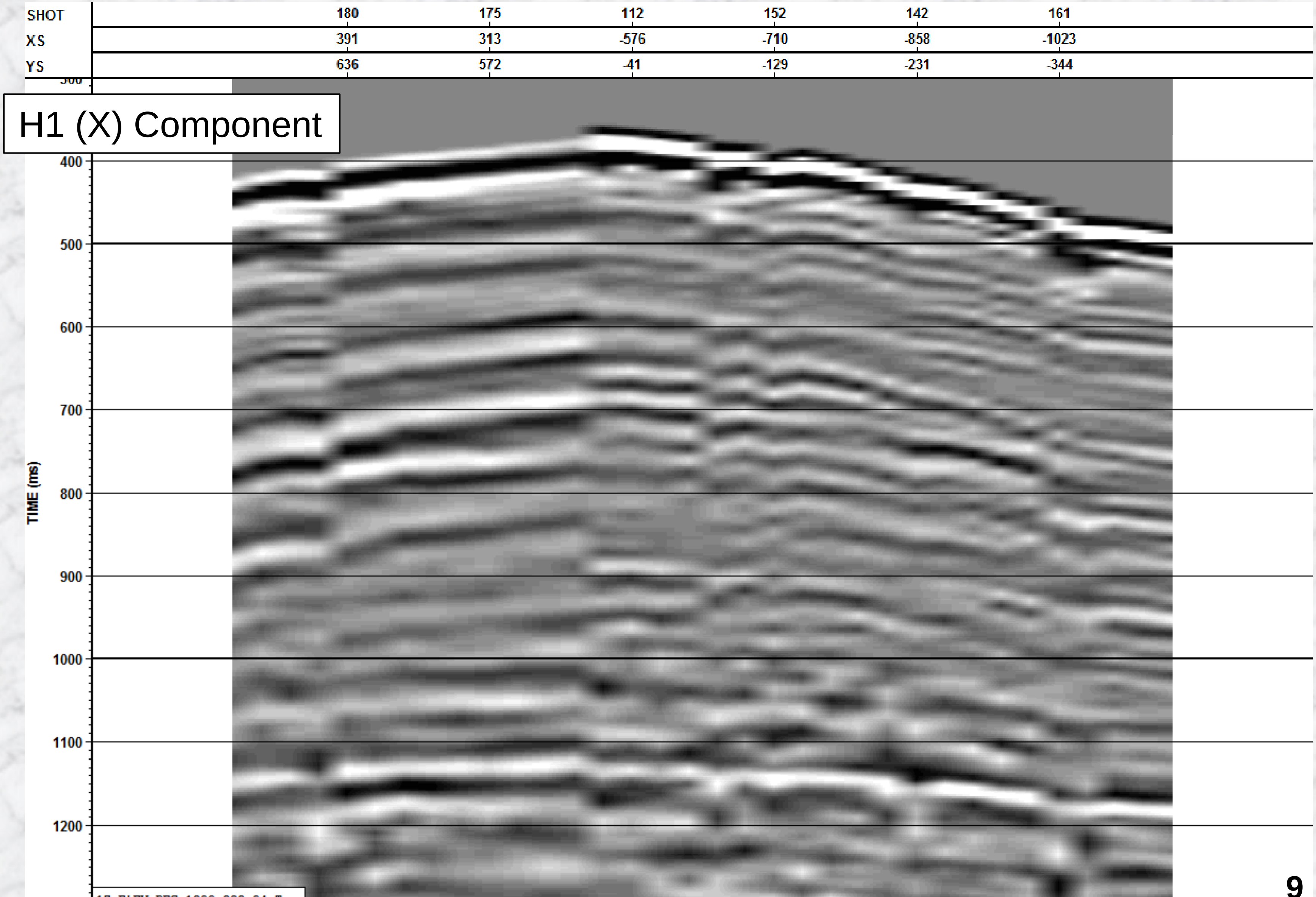


Deviation survey

- Well TD: 1644 m
- Max Deviation: 17°
- Dashed lines are projections onto x-y and x-z planes
- Linear interpolation between measurements



Receiver gather (1038 m, Line 6)



Geophone orientation – DiSiena method

- The equation used to analytically calculate rotation azimuths was (DiSiena et al., 1984)

$$\tan 2\theta = \frac{2X \otimes Y}{X \otimes X - Y \otimes Y}.$$

Deviated Well:

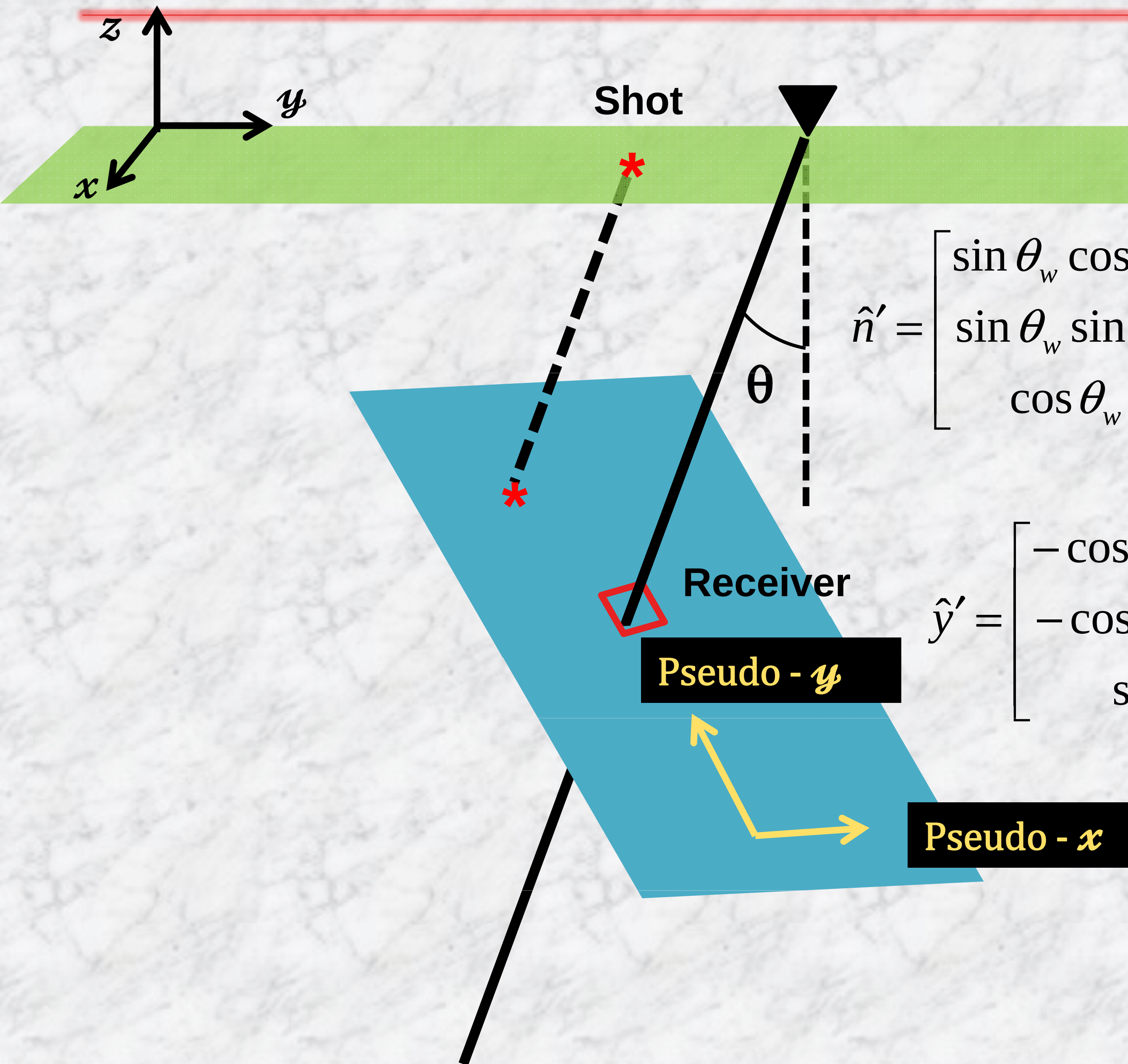
???

Vertical Well:

$$\phi_r = \phi_s + \theta$$

- $\otimes$ is a zero lag cross-correlation
- X and Y are the windowed data (100 ms)
- θ is the source-receiver orientation angle

Pseudo-coordinates

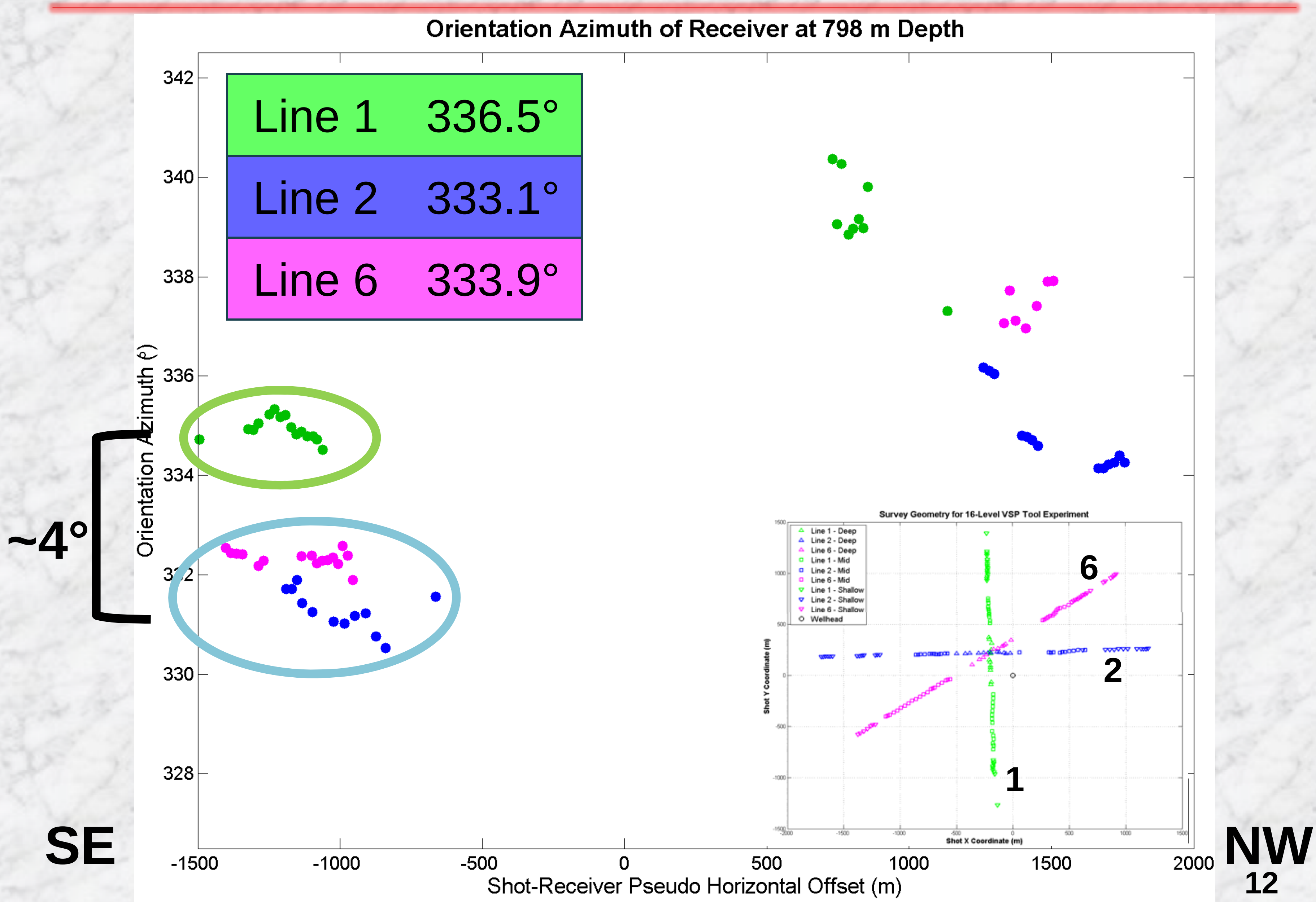


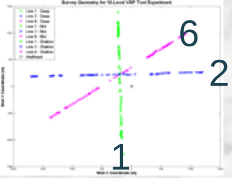
$$\hat{n}' = \begin{bmatrix} \sin\theta_w \cos\phi_w \\ \sin\theta_w \sin\phi_w \\ \cos\theta_w \end{bmatrix}$$

$$\hat{y}' = \begin{bmatrix} -\cos\theta_w \cos\phi_w \\ -\cos\theta_w \sin\phi_w \\ \sin\theta_w \end{bmatrix}$$

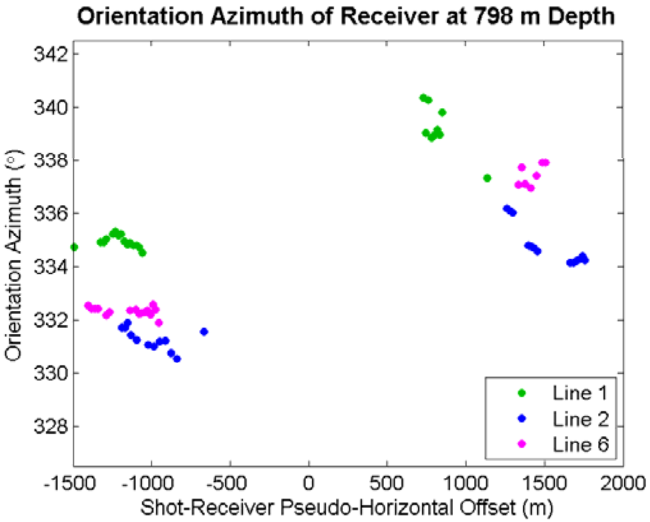
$$\hat{x}' = \begin{bmatrix} -\sin\phi_w \\ \cos\phi_w \\ 0 \end{bmatrix}$$

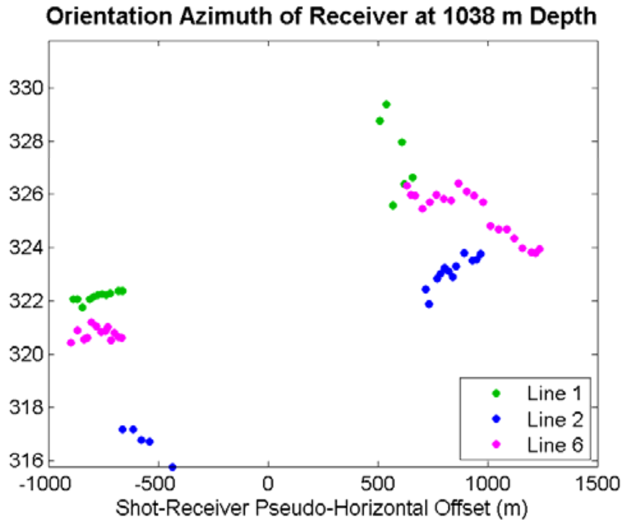
Orientation vs. pseudo-offset (798 m)

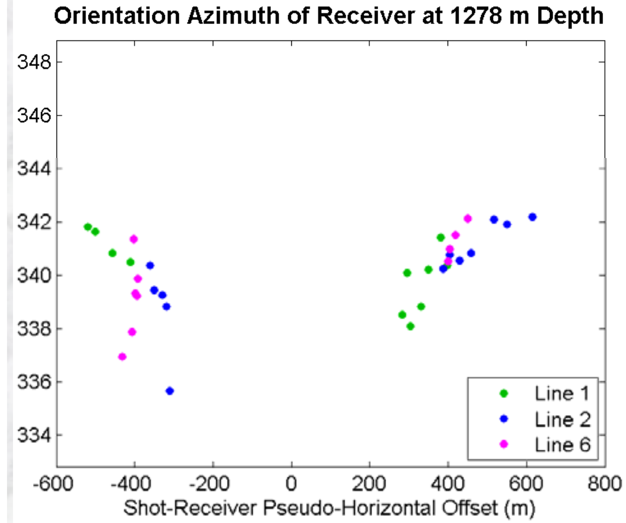




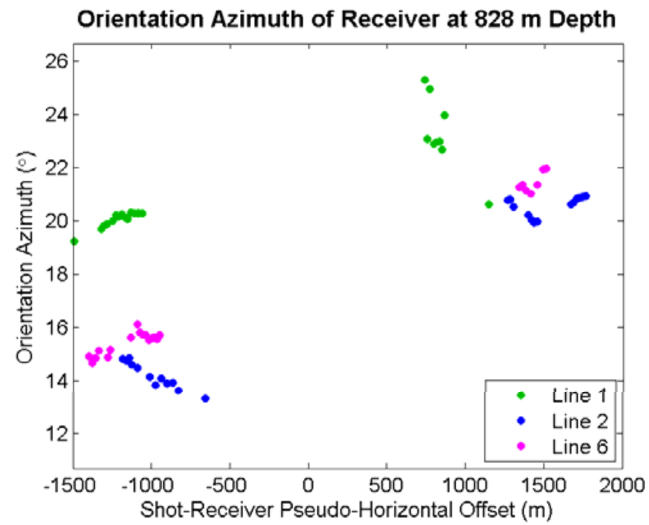
Orientation vs. pseudo-offset

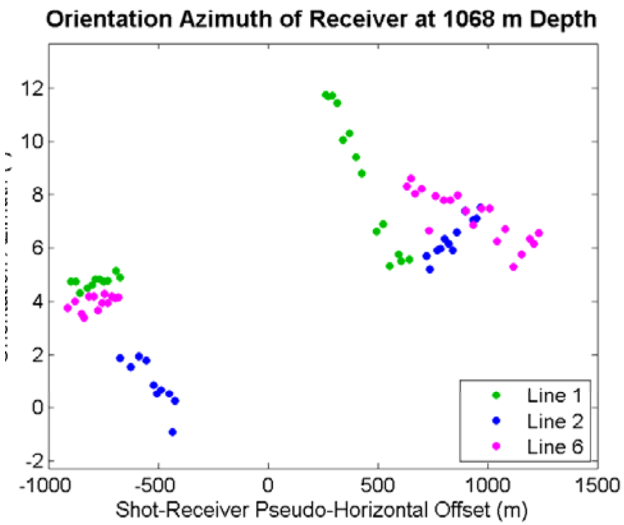


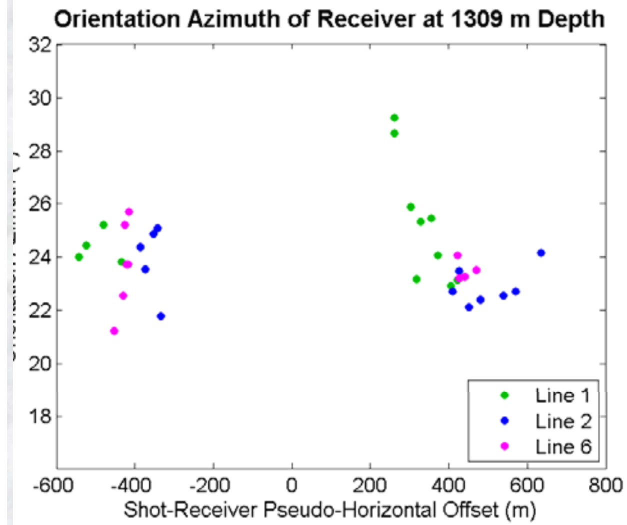


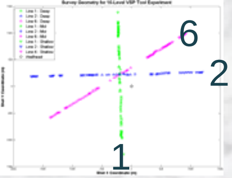


Shallow **Mid** **Deep**

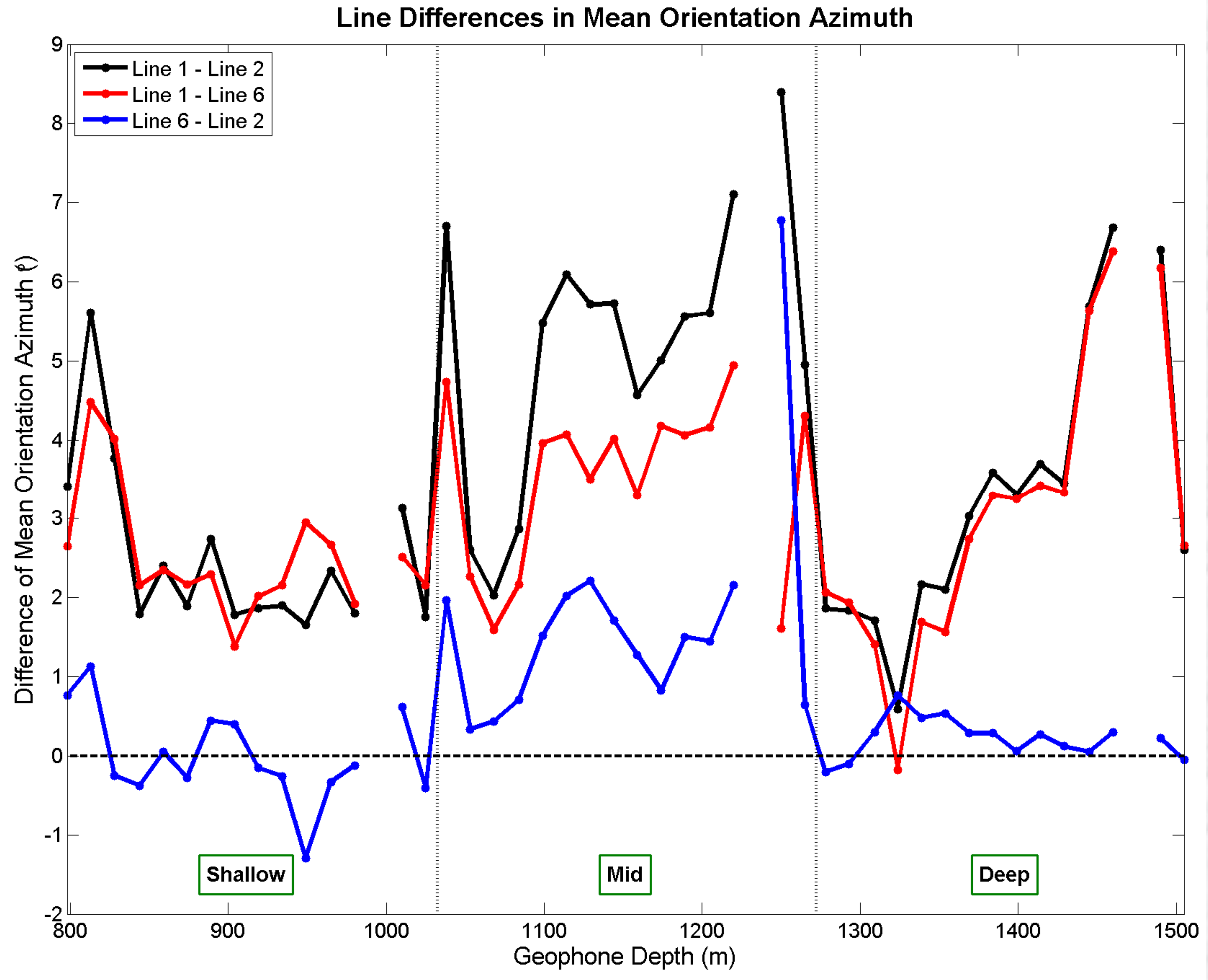


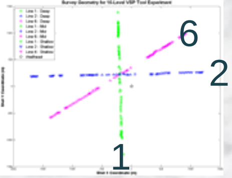




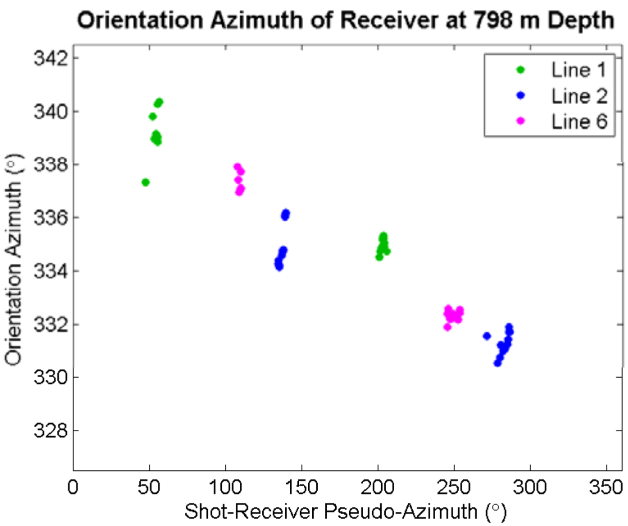


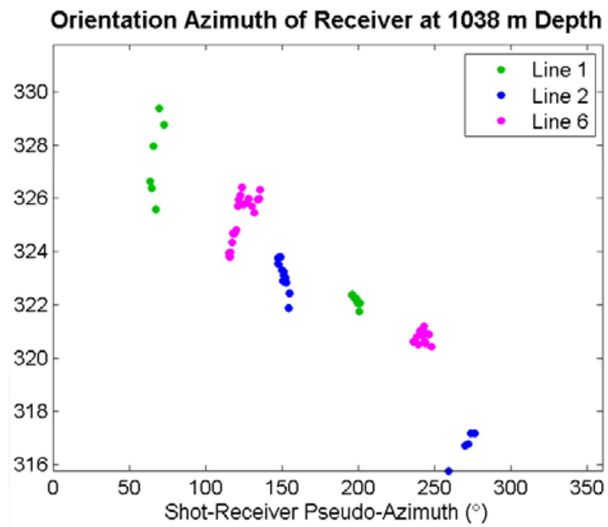
Differences in calculated orientation

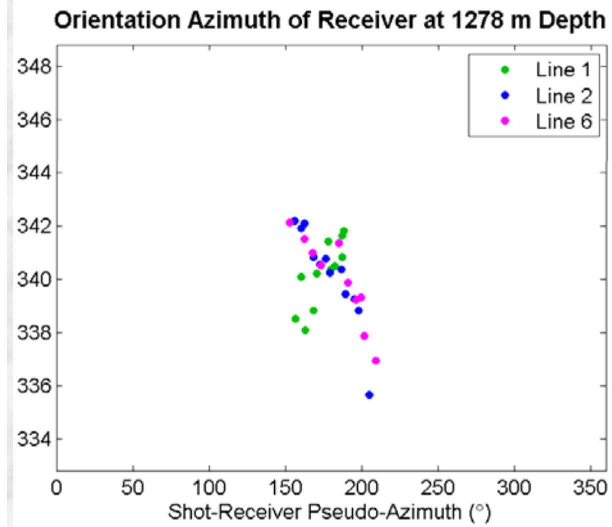




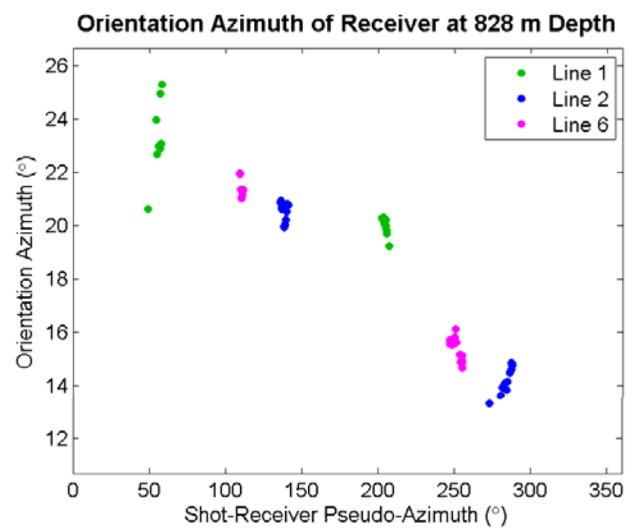
Orientation vs. shot-receiver pseudo-azimuth

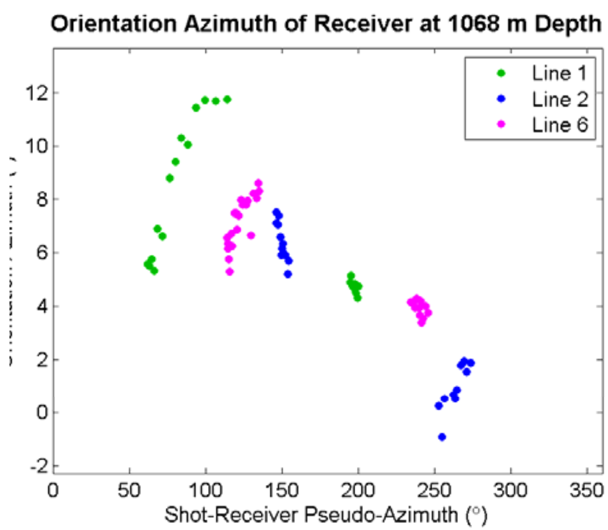


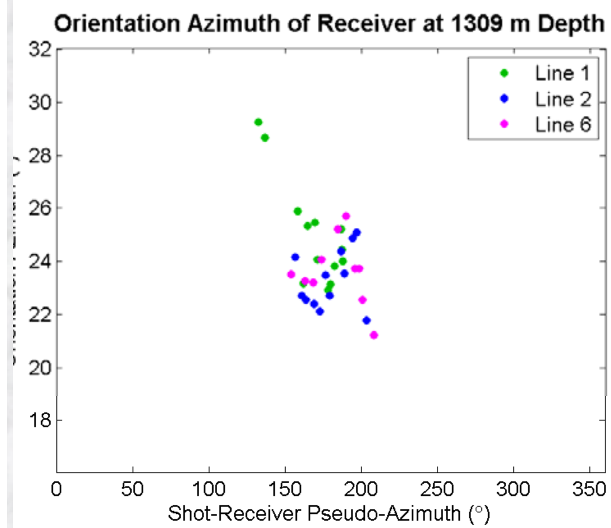


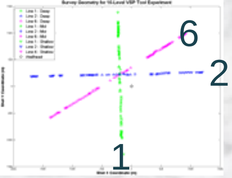


Shallow **Mid** **Deep**

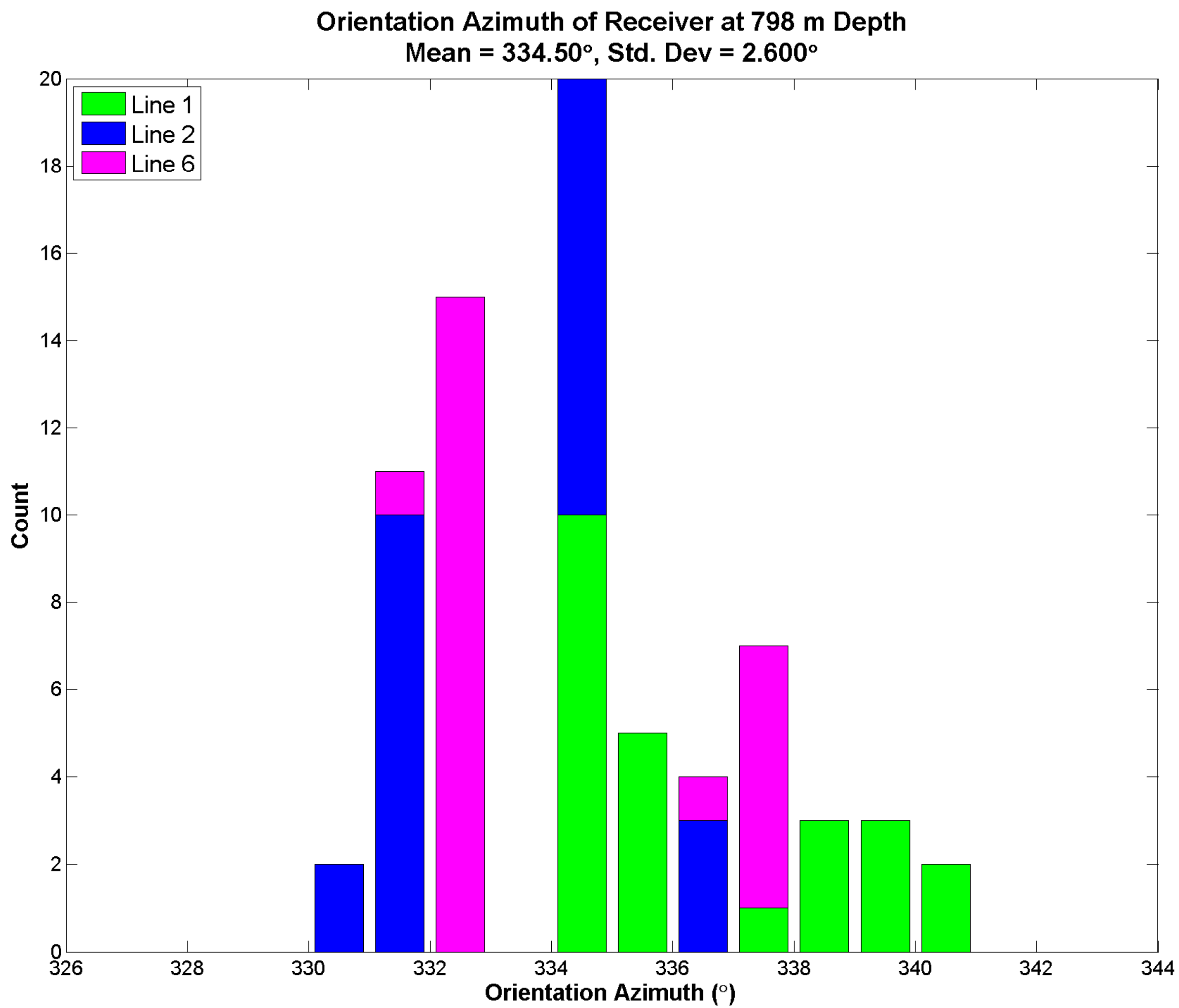




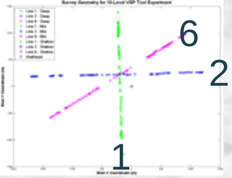




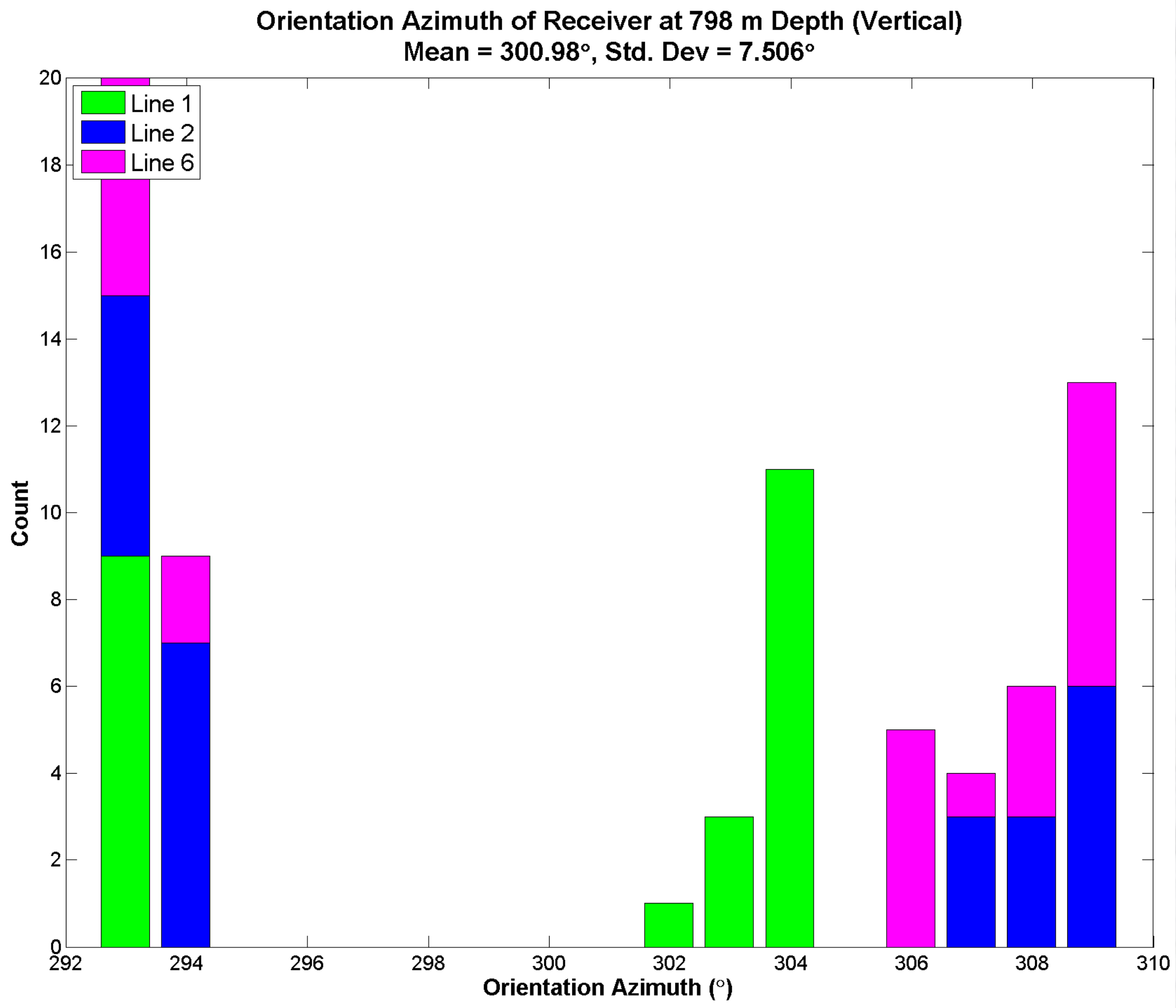
Deviated well result (798 m)



18° Range

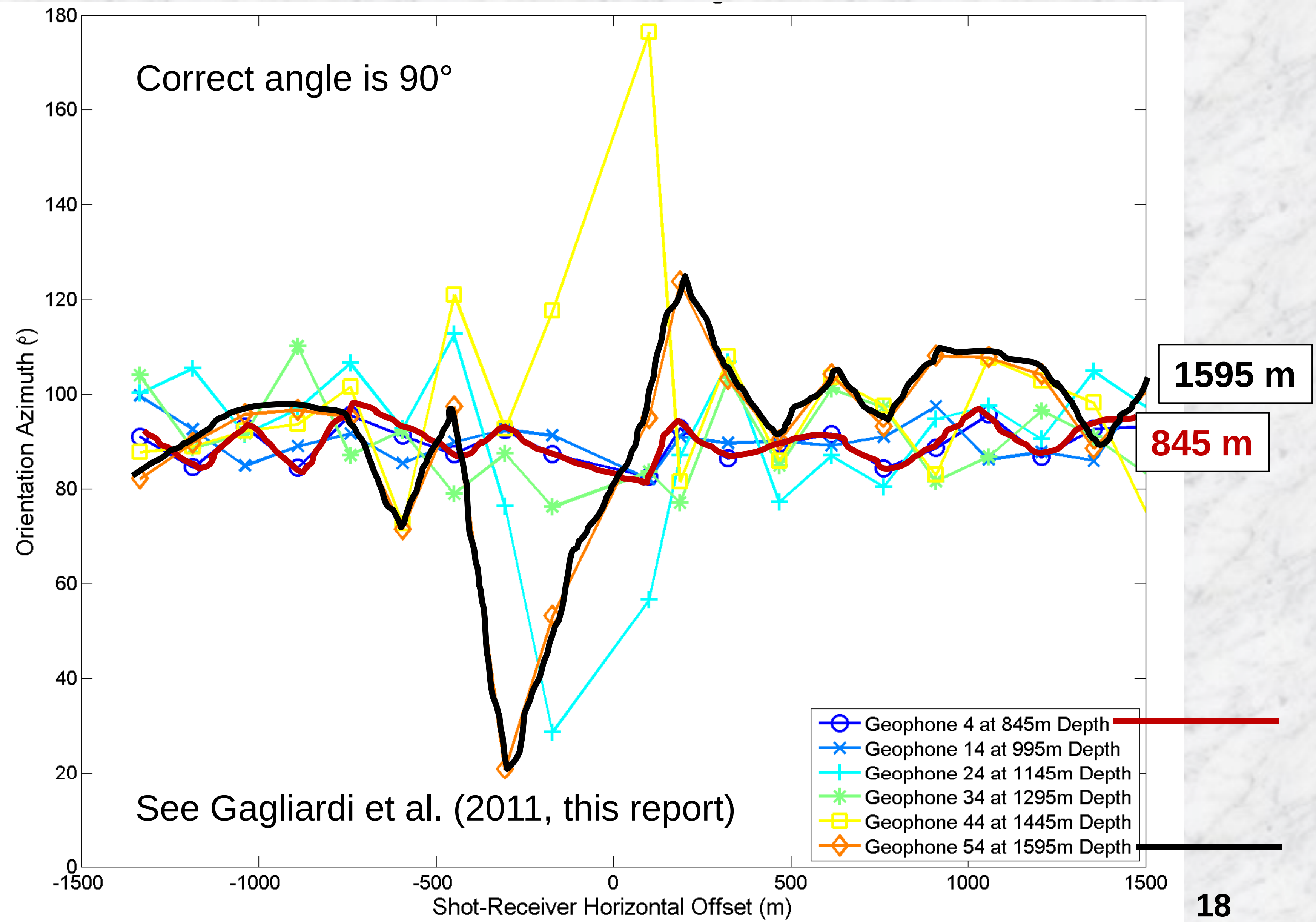


Assumed vertical well result (798 m)

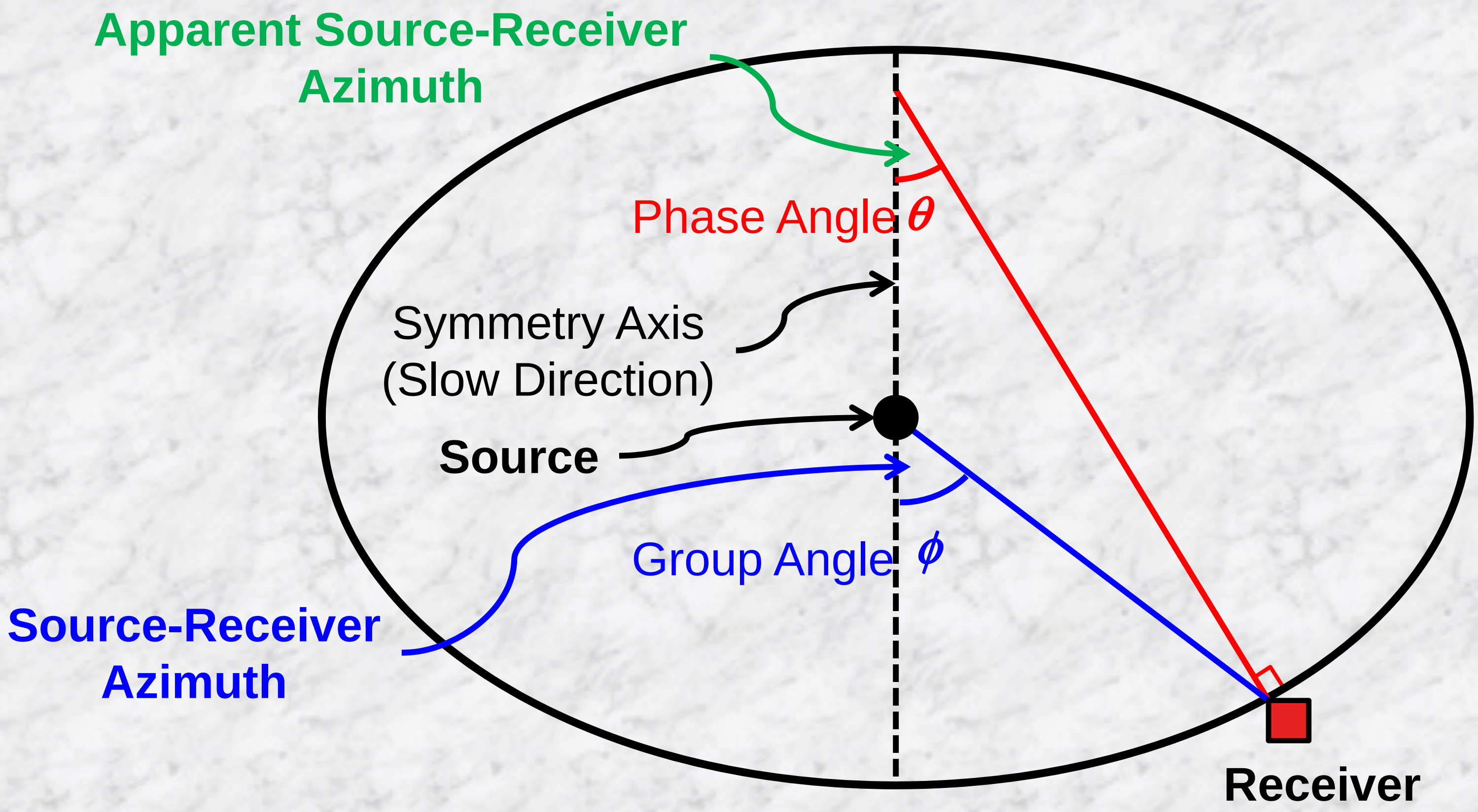


18° Range

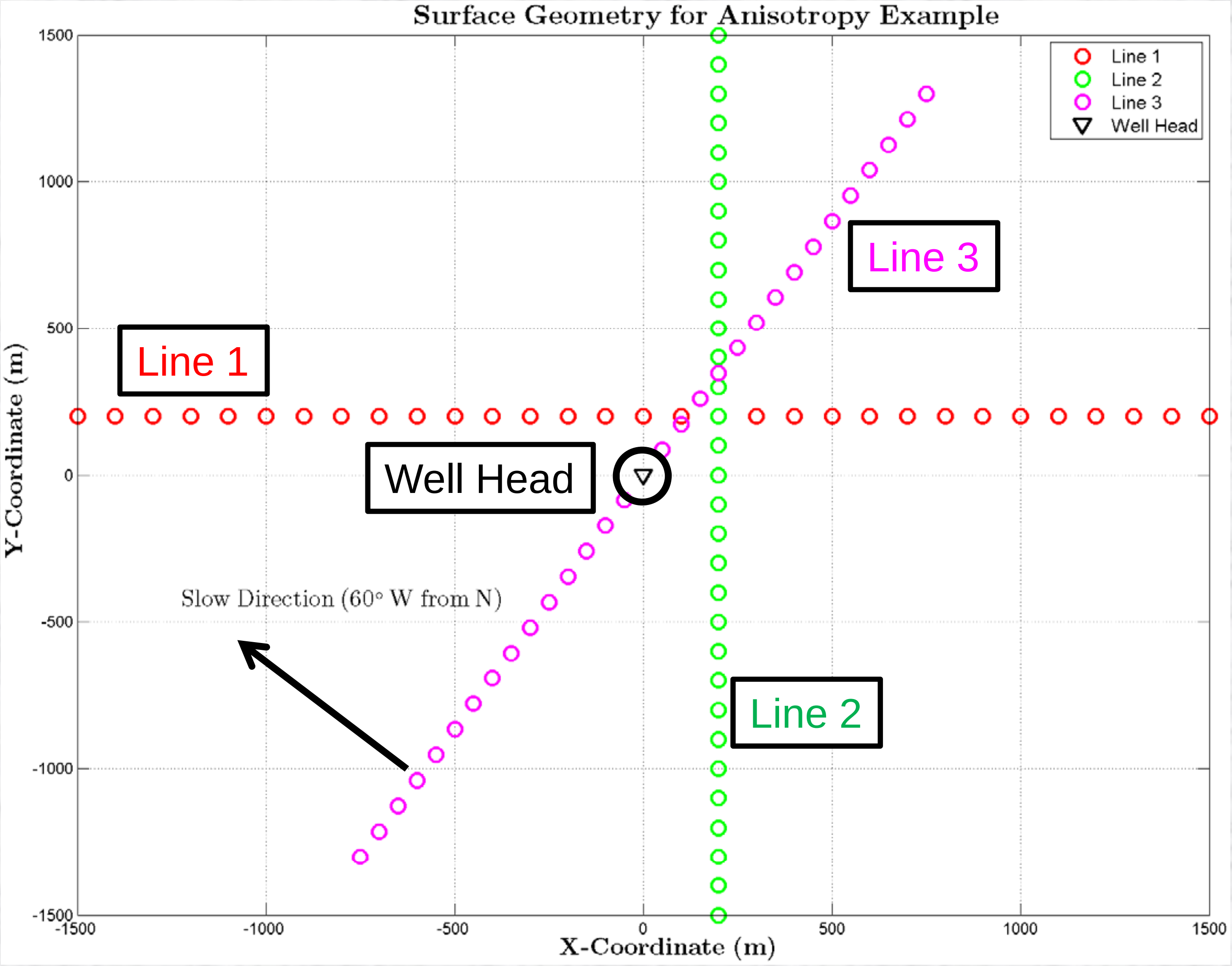
Modelling effects of noise



Anisotropy (HTI)

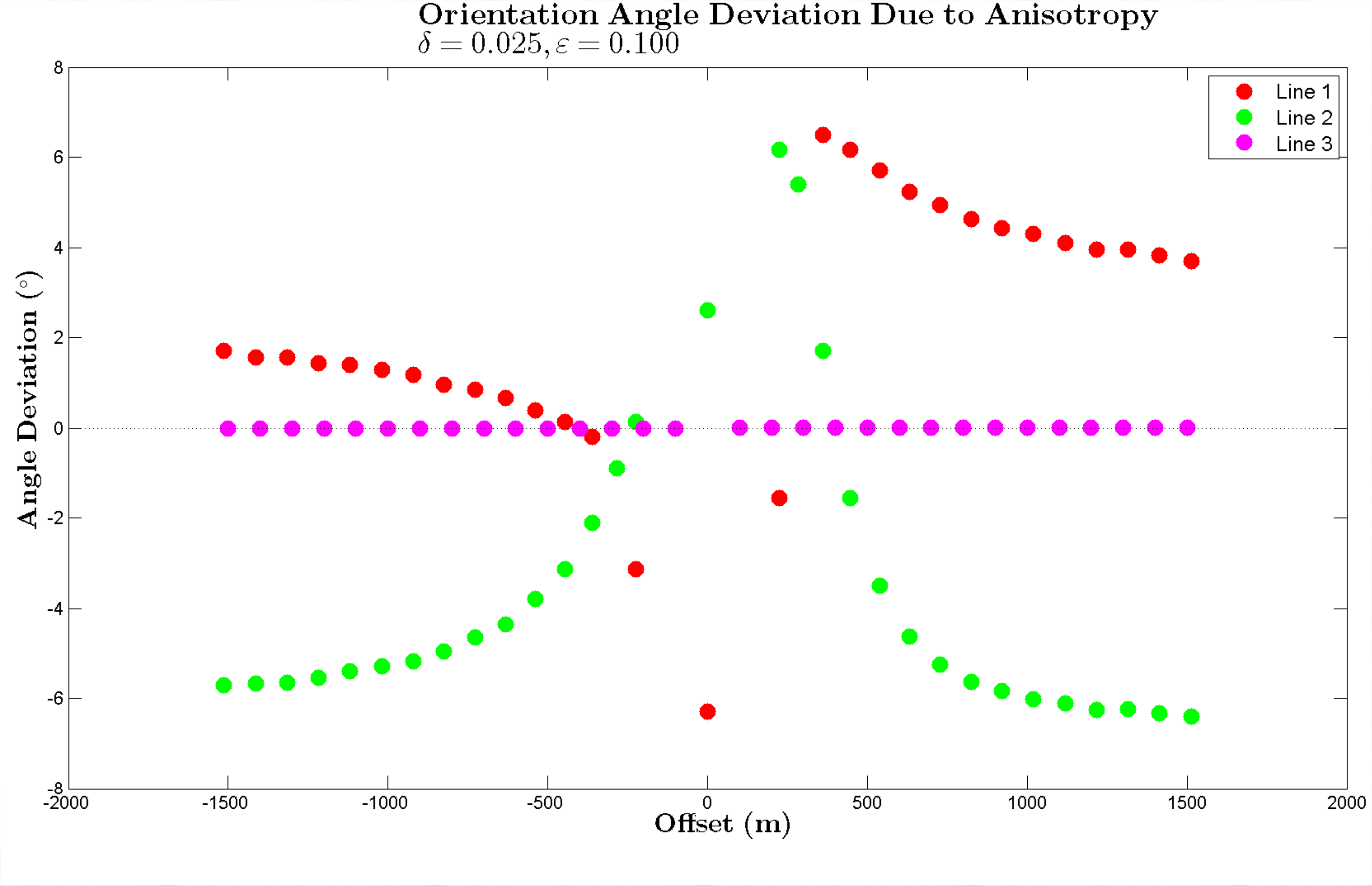


Modelling effects of anisotropy (HTI)



See Gagliardi and Lawton (2011, this report)

Modelling effects of anisotropy (HTI)



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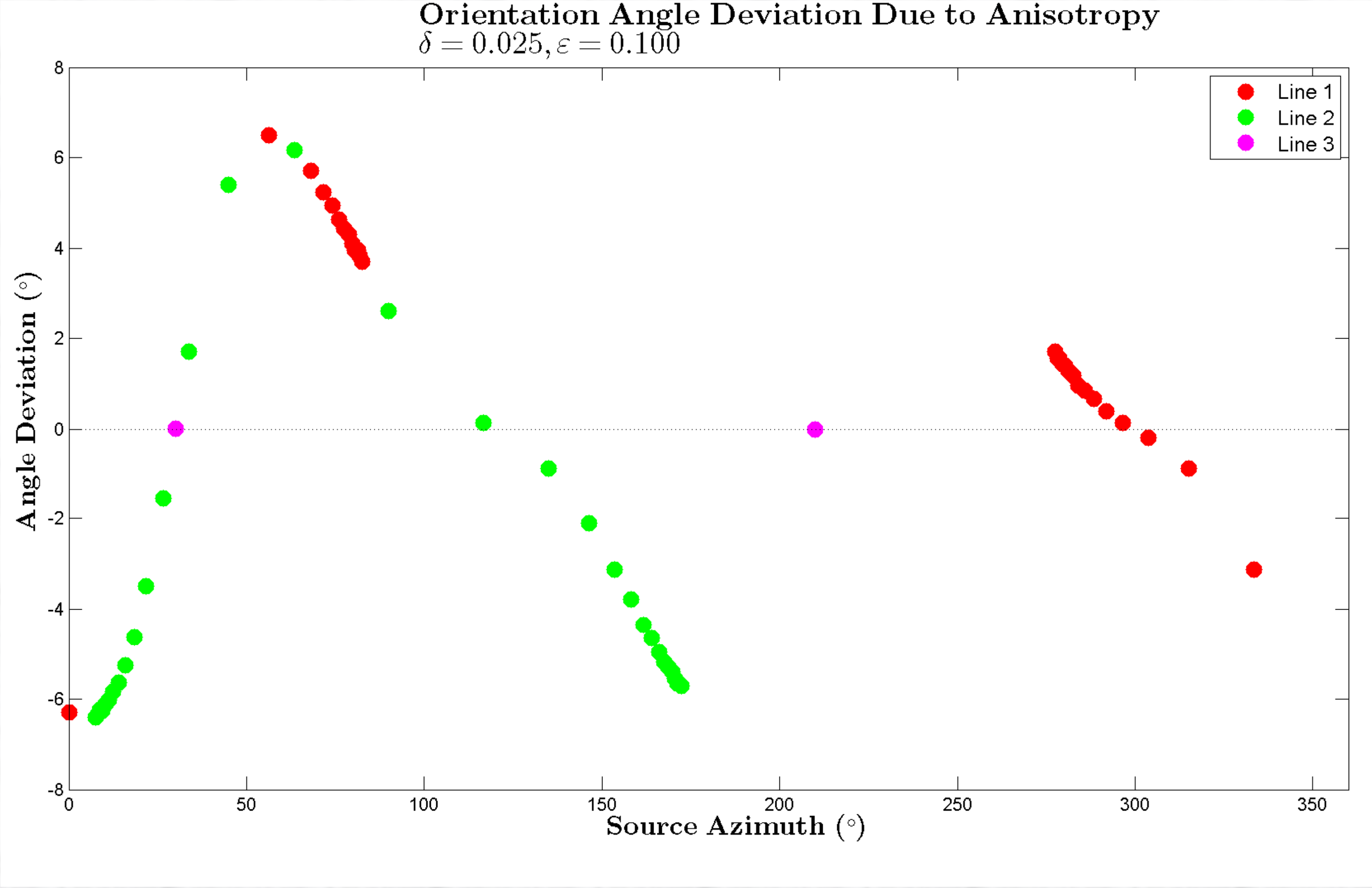

See Gagliardi and Lawton (2011, this report)

Conclusions

- A method was successfully developed for examining orientation azimuths in a deviated well
- Average standard deviation of all 3 Lines was **4.39°**
- Consistency poorest for mid-levels (6.70°), and best for shallow-levels (2.74°)
- Orientation azimuths calculated using **Line 1** were **3.7°** higher than **Line 2** and **3.0°** higher than **Line 6**

Future work

- Modeling should be used to examine effects of anisotropy and structured geology
- Further investigation into effects of noise, offset and depth
- Similar analysis of a VSP in an area known to have anisotropy

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