

# Fracture Orientation from P-Wave Seismic Data Using Volumetric Curvature, Silo Field, Wyoming

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# Conclusion

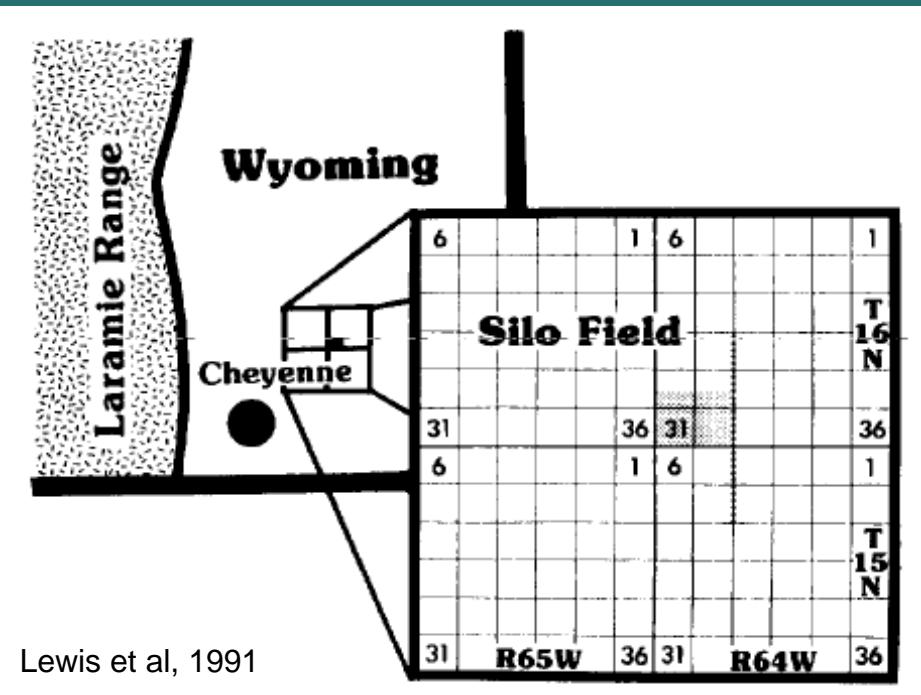
- ◆ P Wave Curvature provides identification of fracture orientation as well as 9-C shear wave data

# Outline

- ◆ Initial Experiment
- ◆ Curvature
- ◆ Comparison

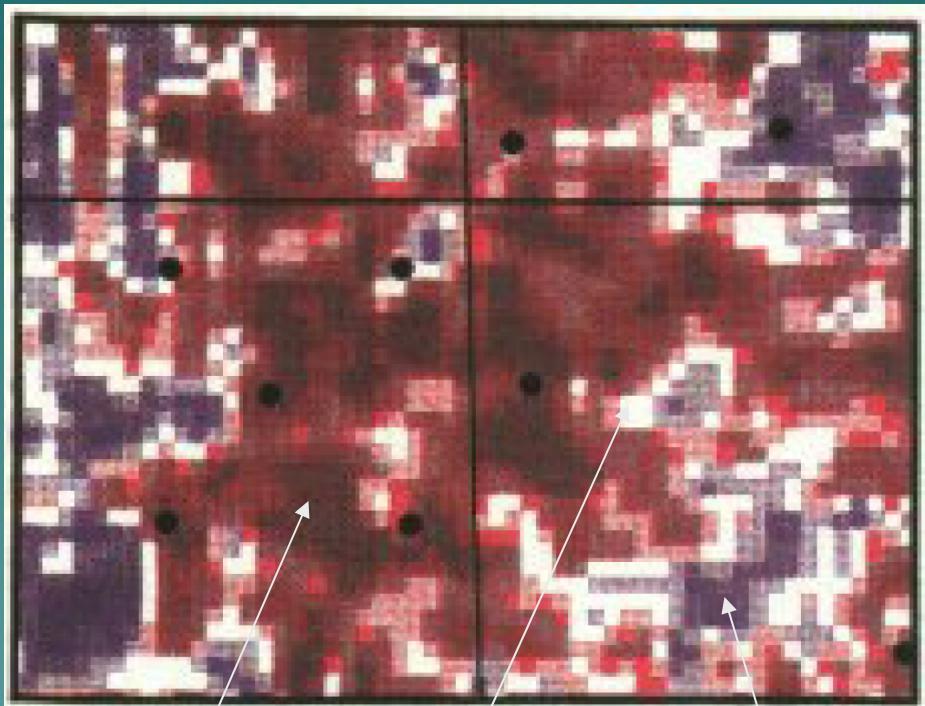
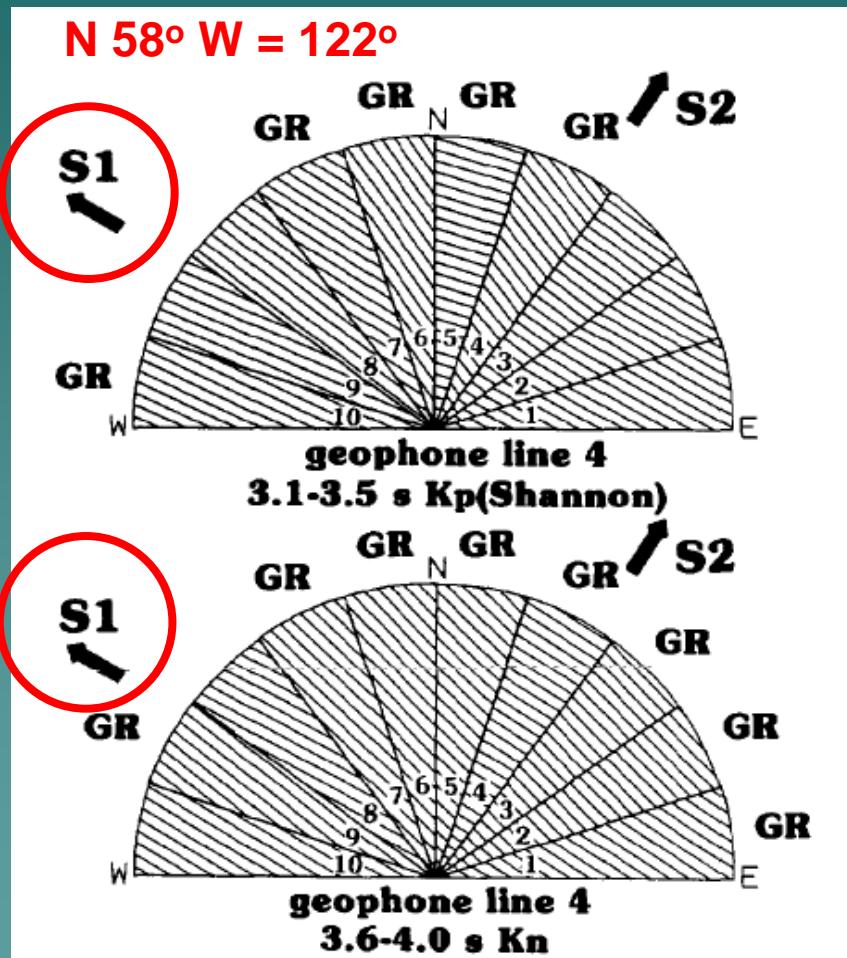
# Original Experiment

- ◆ Colorado School of Mines, 1988
- ◆ Silo Field-fractured chalk
- ◆ Shear wave vibrators/geophones
- ◆ P Wave survey as well
- ◆  $V_{\text{fast}}$  and  $V_{\text{slow}}$  give fracture orientation
- ◆ High anisotropy indicates good production



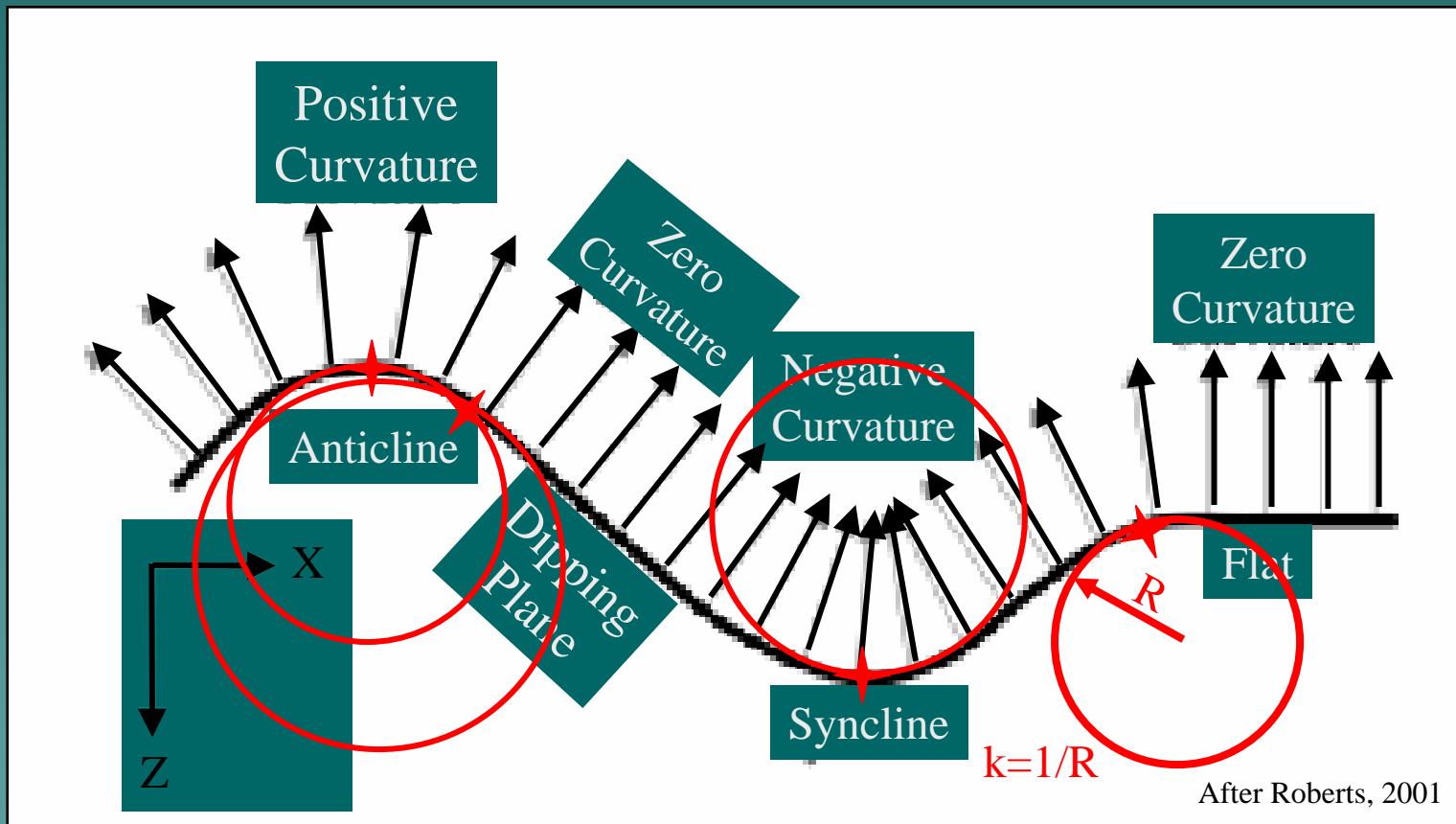
Lewis, C., T. L. Davis, and C. Vuillermoz, 1991, Three-dimensional multicomponent imaging of reservoir heterogeneity, Silo Field, Wyoming, *Geophysics*, V. 56, no. 12, p. 2048-2056

# Fracture Orientation from Shear Wave Data



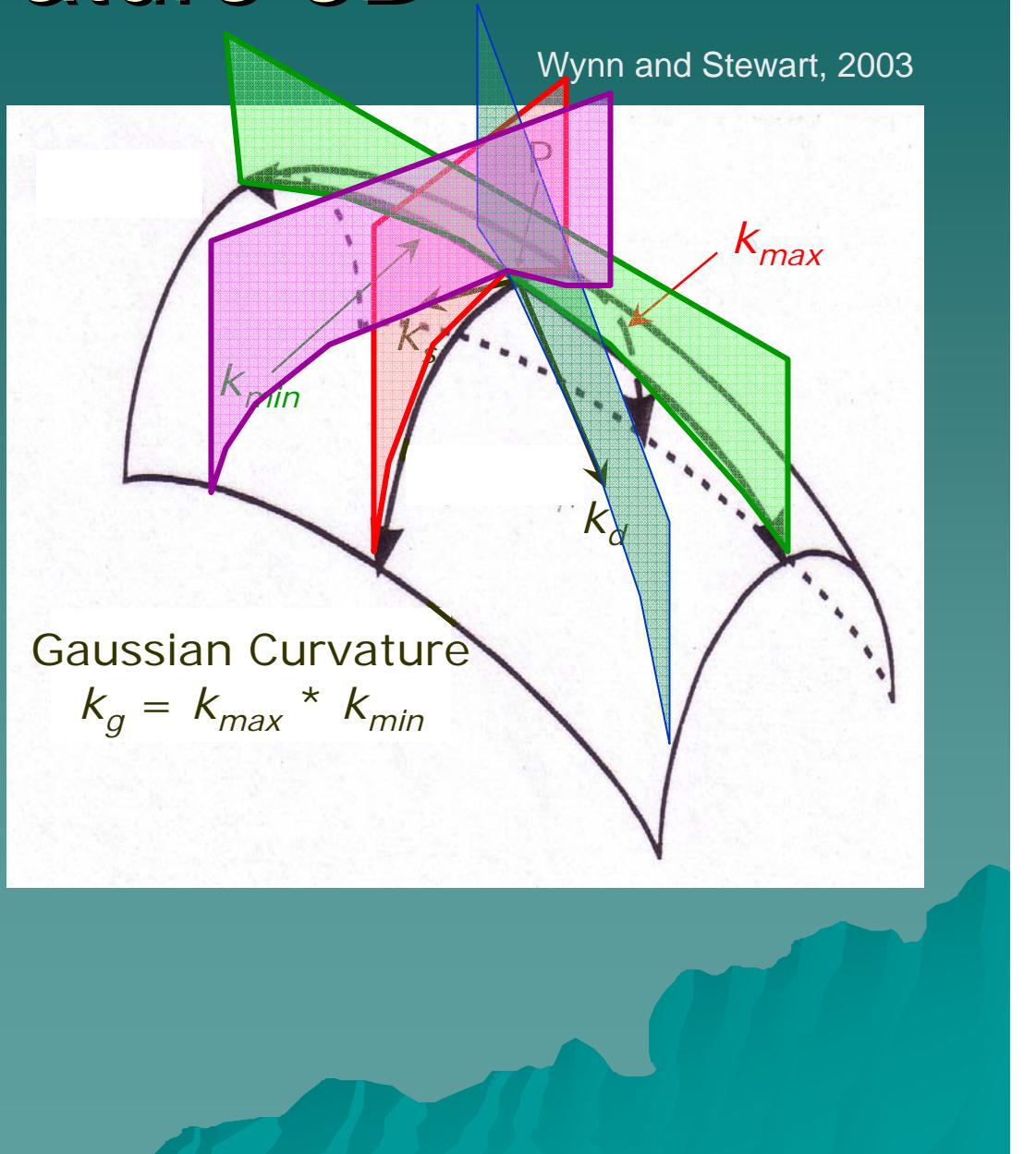
Lewis et al, 1991

# Curvature 2D

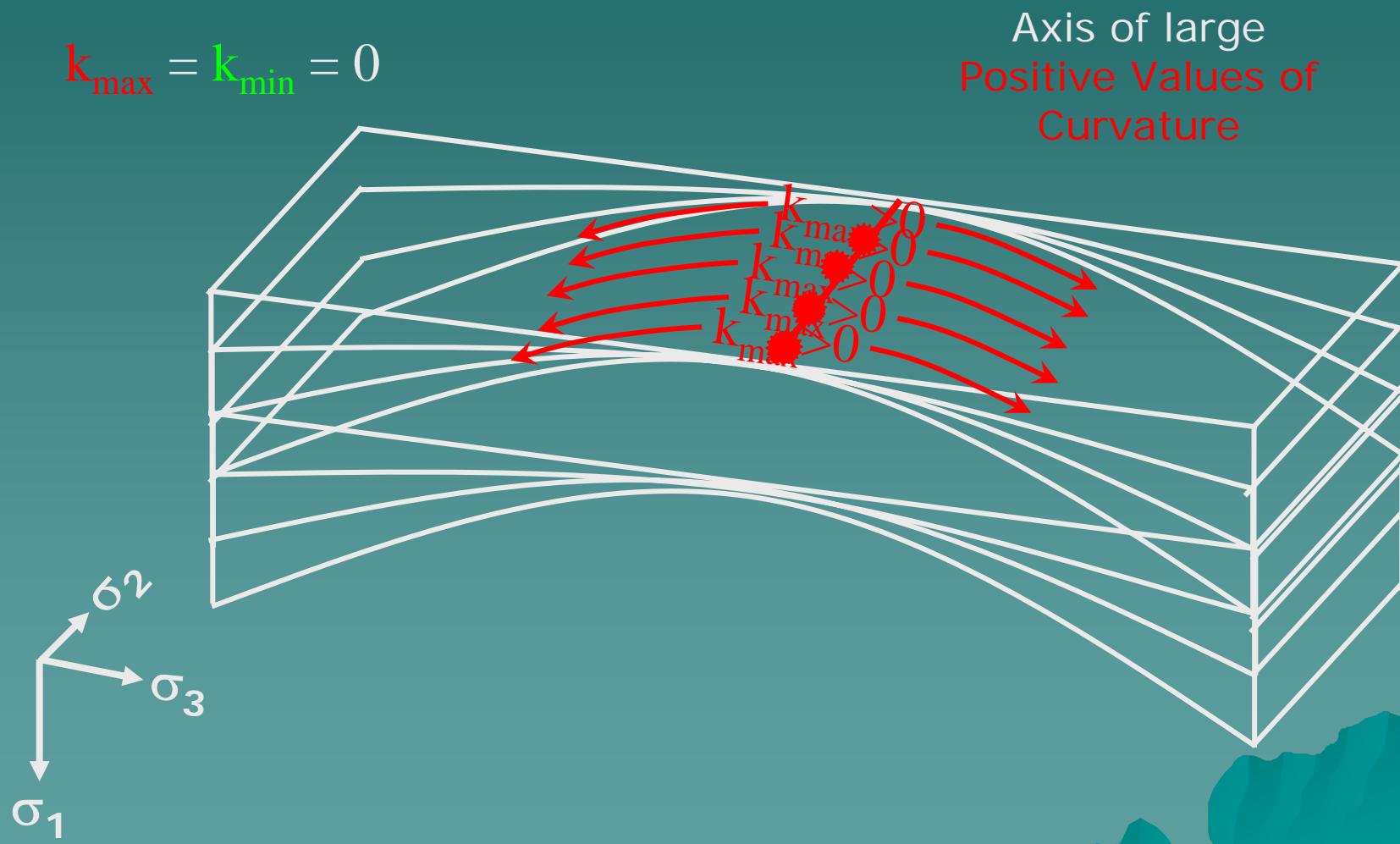


# Curvature 3D

- May be computed at any azimuth about a point P
- Computed normal to tangent plane
- Principal Curvatures are  $k_{max}$  and  $k_{min}$  ( $k_1$  and  $k_2$ )
- Gaussian and Shape Attribute
- Additional curvatures
  - Dip ( $k_d$ )
  - Strike ( $k_s$ )
  - Most Positive ( $k_{pos}$ )
  - Most Negative ( $k_{neg}$ )

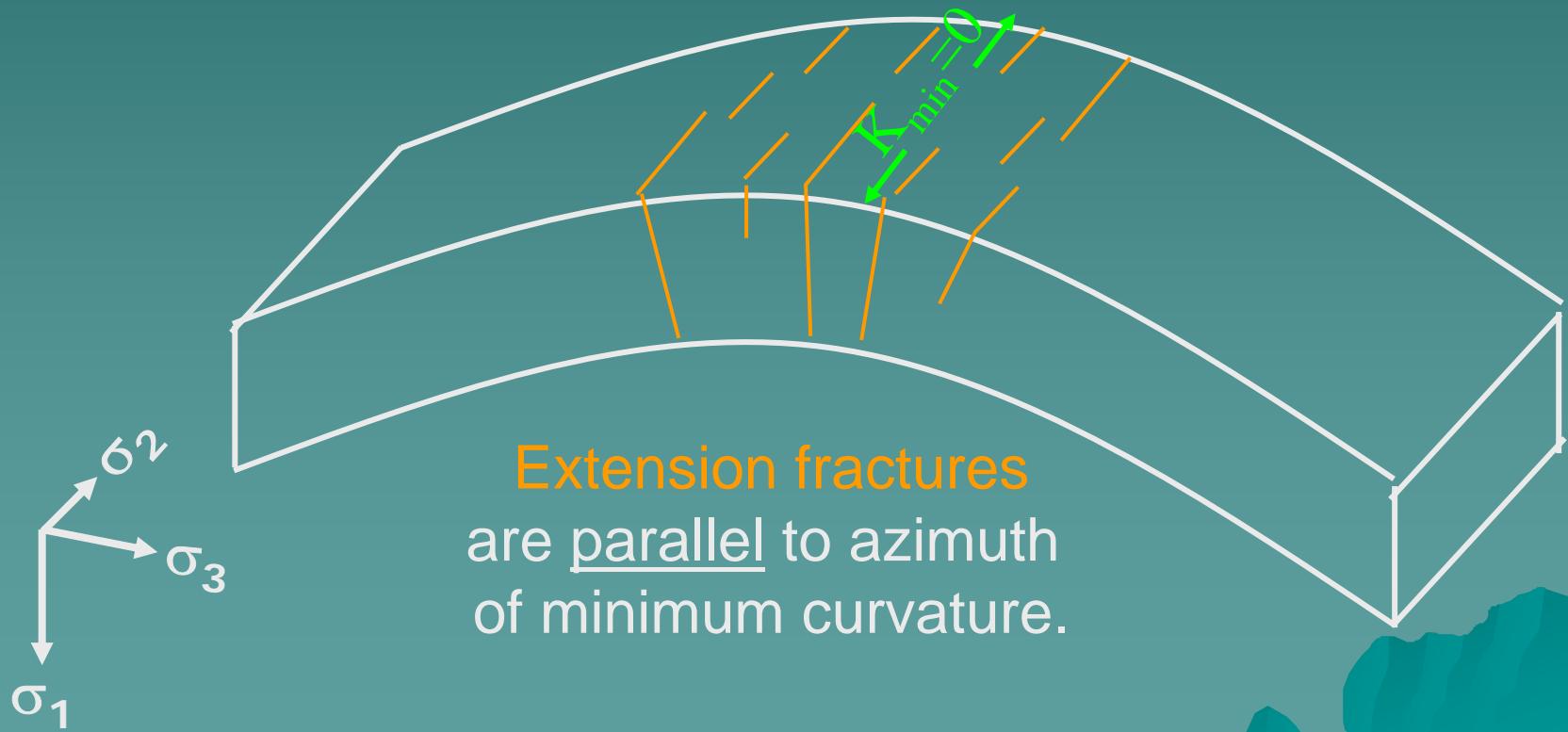


# Maximum Curvature

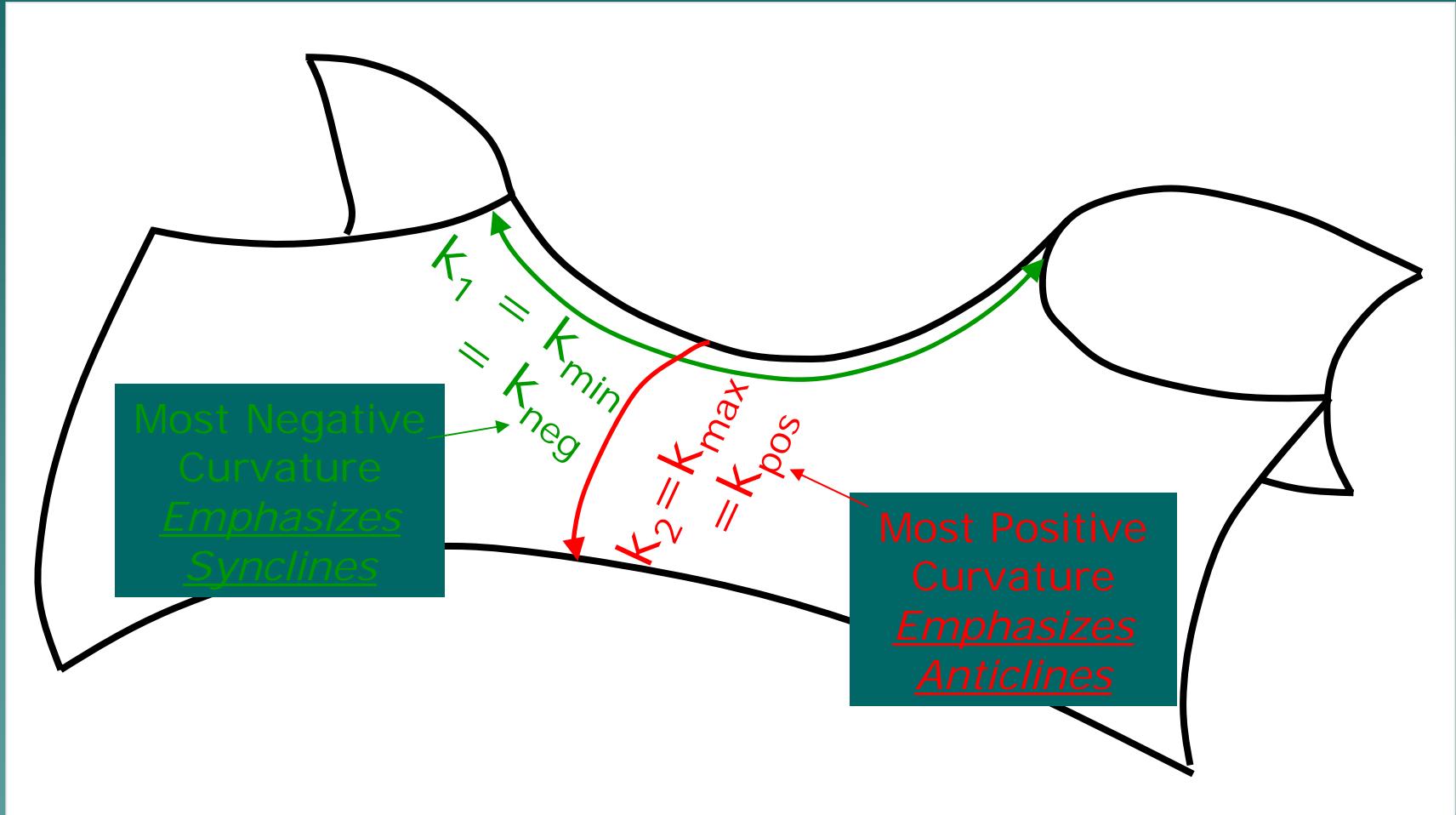


# Azimuth of Minimum Curvature

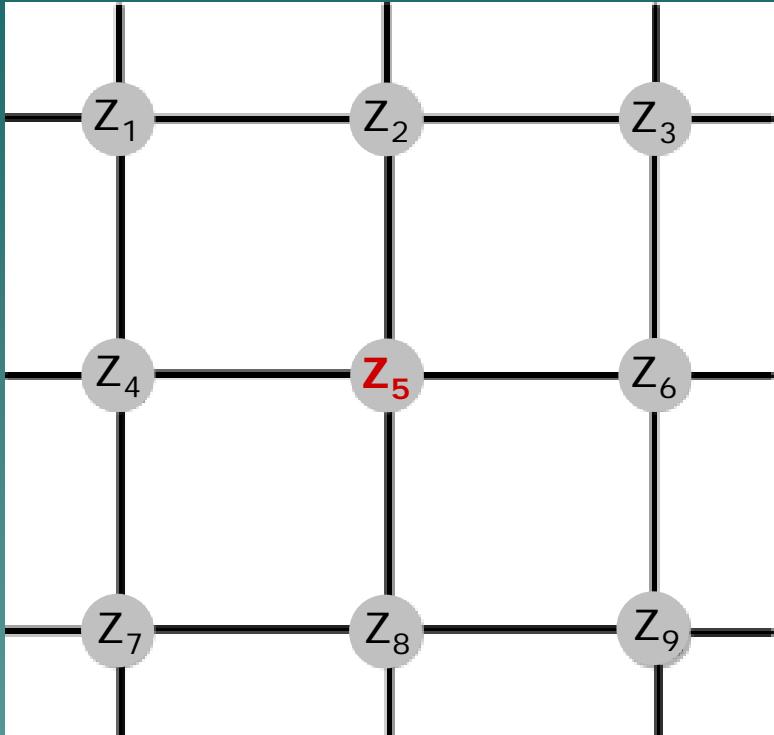
(No Compression, Possible Extension)



# Most Positive/Negative Curvature



# “Surface” Based Curvature



Quadratic Surface  
 $y = ax^2 + by^2 + cxy + dx + ey + f$

At point  $Z_5$ , coefficients are functions of the surrounding  $Z$  values

$$a = \frac{(Z_1 + Z_3 + Z_4 + Z_6 + Z_7 + Z_9) - (Z_2 + Z_5 + Z_8)}{12\delta x^2}$$

$$b = \frac{(Z_1 + Z_2 + Z_3 + Z_7 + Z_8 + Z_9) - (Z_4 + Z_5 + Z_6)}{12\delta x^2}$$

$$c = \frac{(Z_3 + Z_7 - Z_1 - Z_9)}{4\delta x^2}$$

$$d = \frac{(Z_3 + Z_6 + Z_9 - Z_1 - Z_4 - Z_7)}{6\delta x}$$

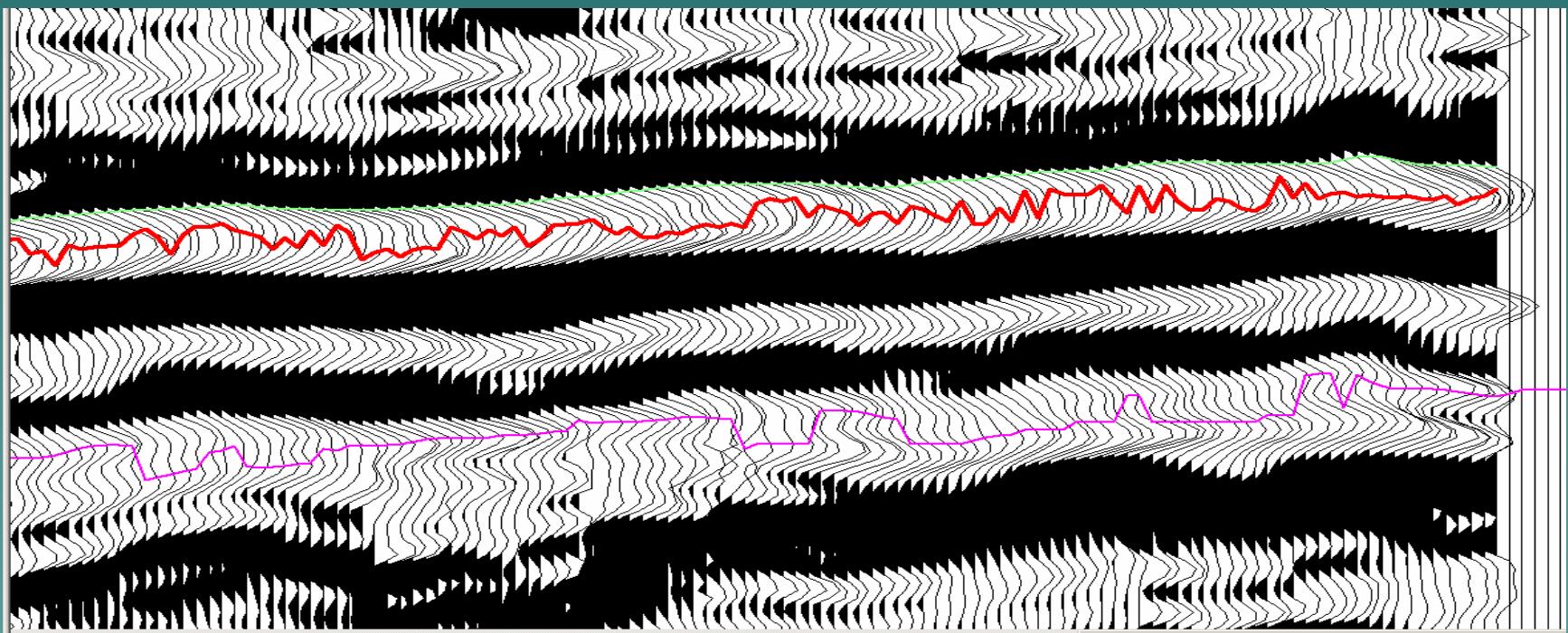
$$e = \frac{(Z_3 + Z_6 + Z_9 - Z_1 - Z_4 - Z_7)}{6\delta x}$$

Curvatures, e.g. Gaussian  $K_g$ , are functions of the coefficients

$$K_g = \frac{4ab - c^2}{(1 + d^2 + e^2)^2}$$

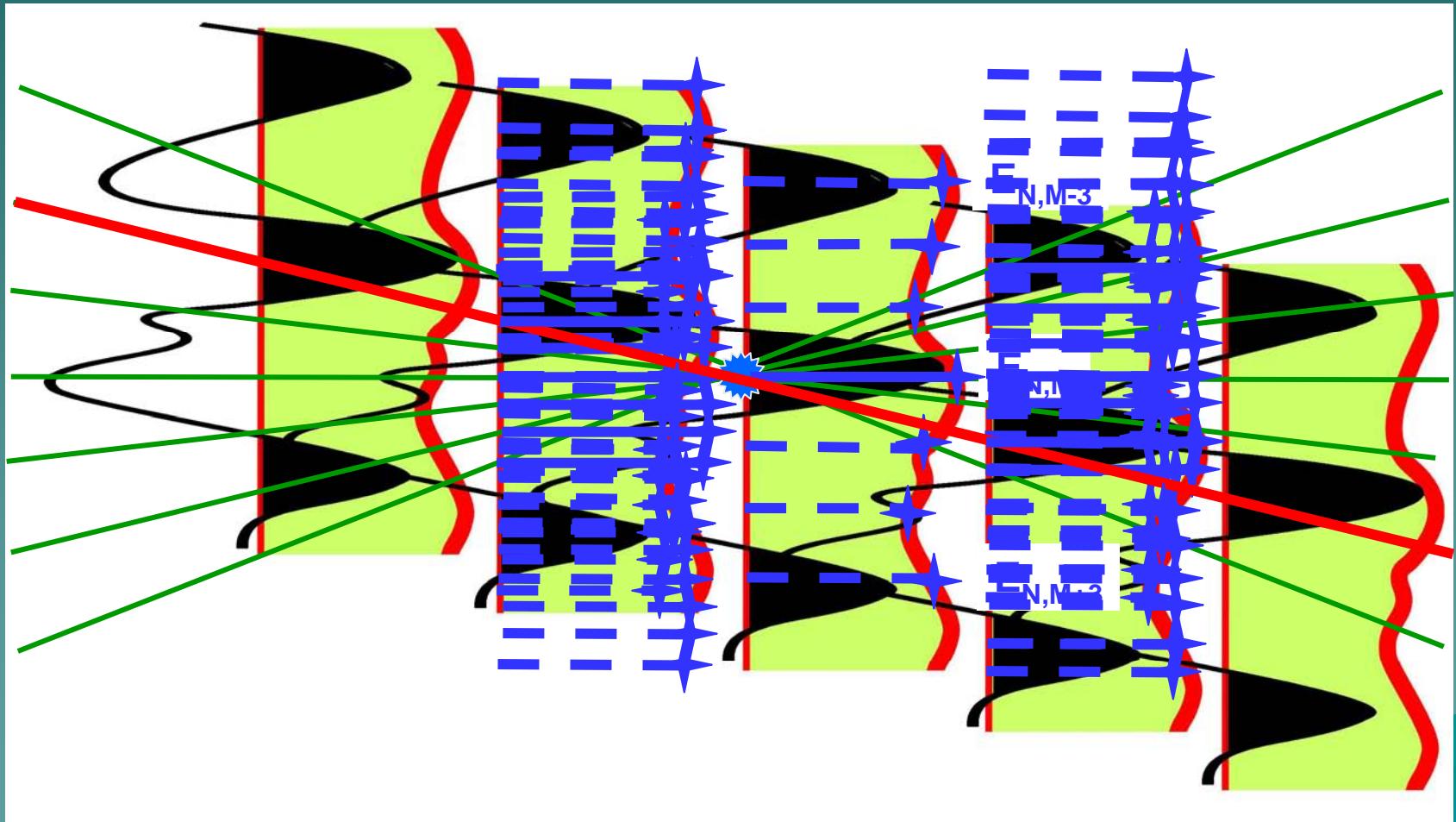
*After Roberts, 2001*

# Auto-Picking Problems

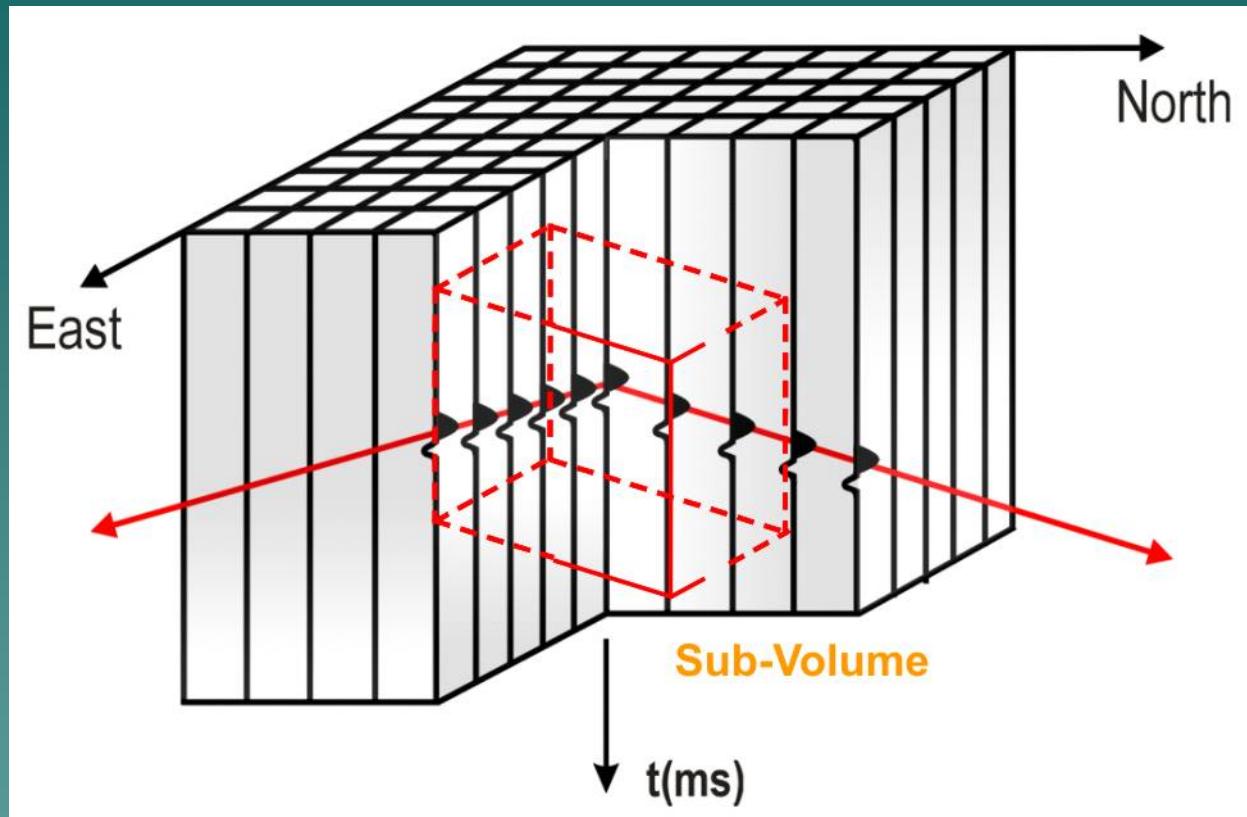


# Volume Method Dip Scan

$T_{N-2}$     $T_{N-1}$     $T_N$     $T_{N+1}$     $T_{N+2}$



# 3-D Surface Definition

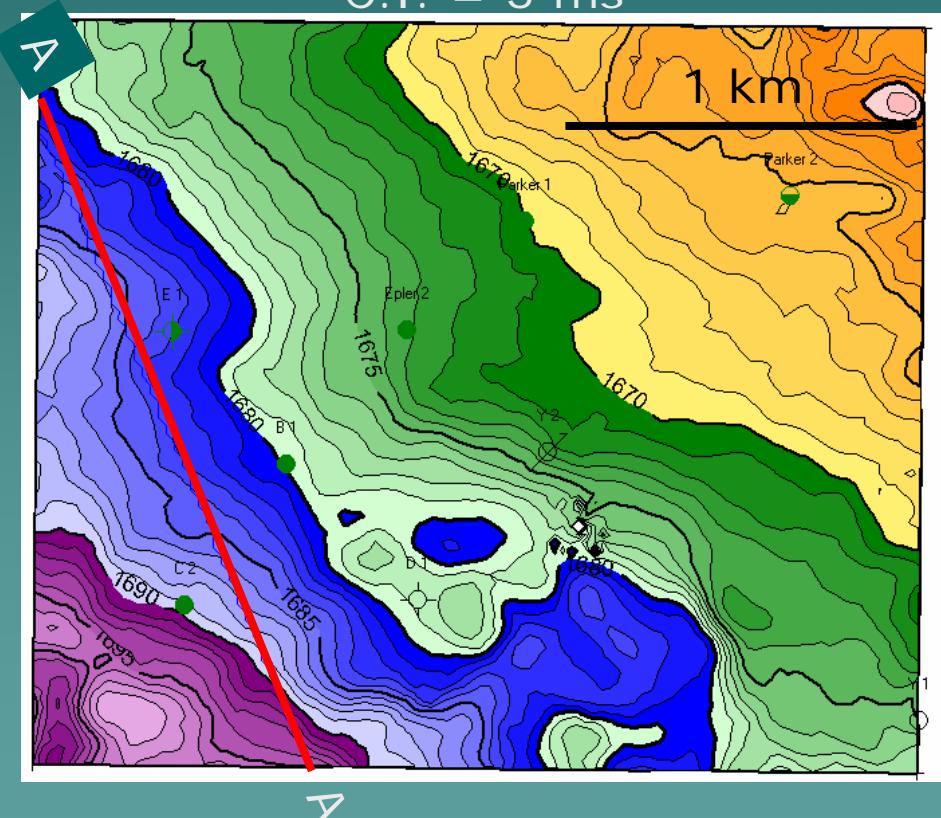


Best fit in 3x3 traces by n samples sub-volume  
gives Dip and Dip Azimuth

# Silo Field

Niobrara

Time Structure Map  
C.I. = 5 ms



A A'

1.5

Jm

TR

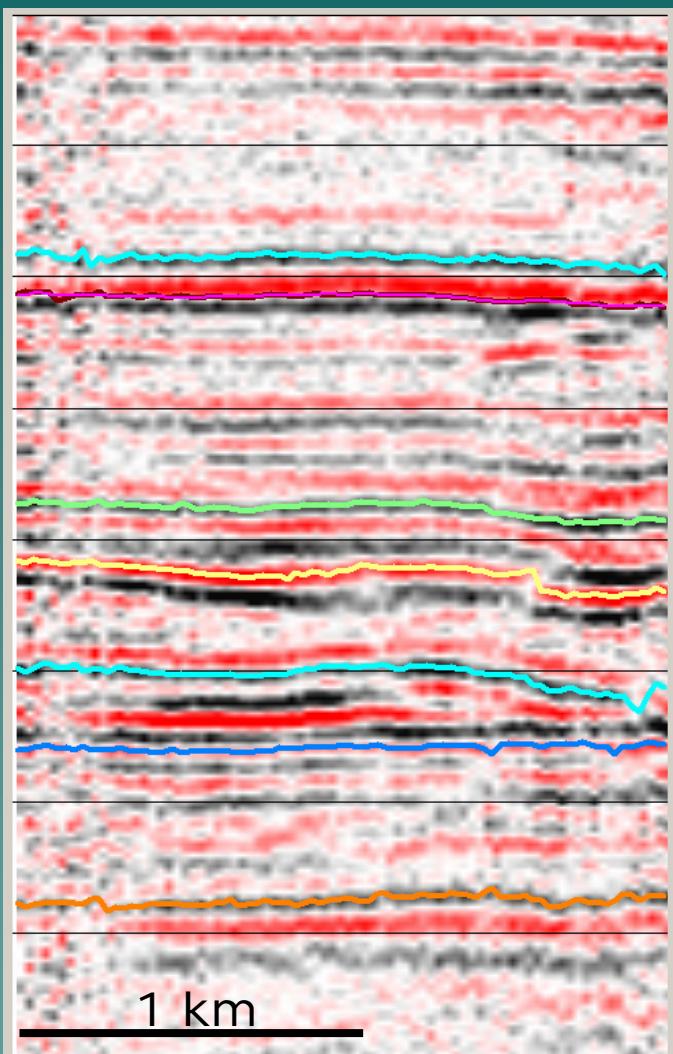
Pw

IM

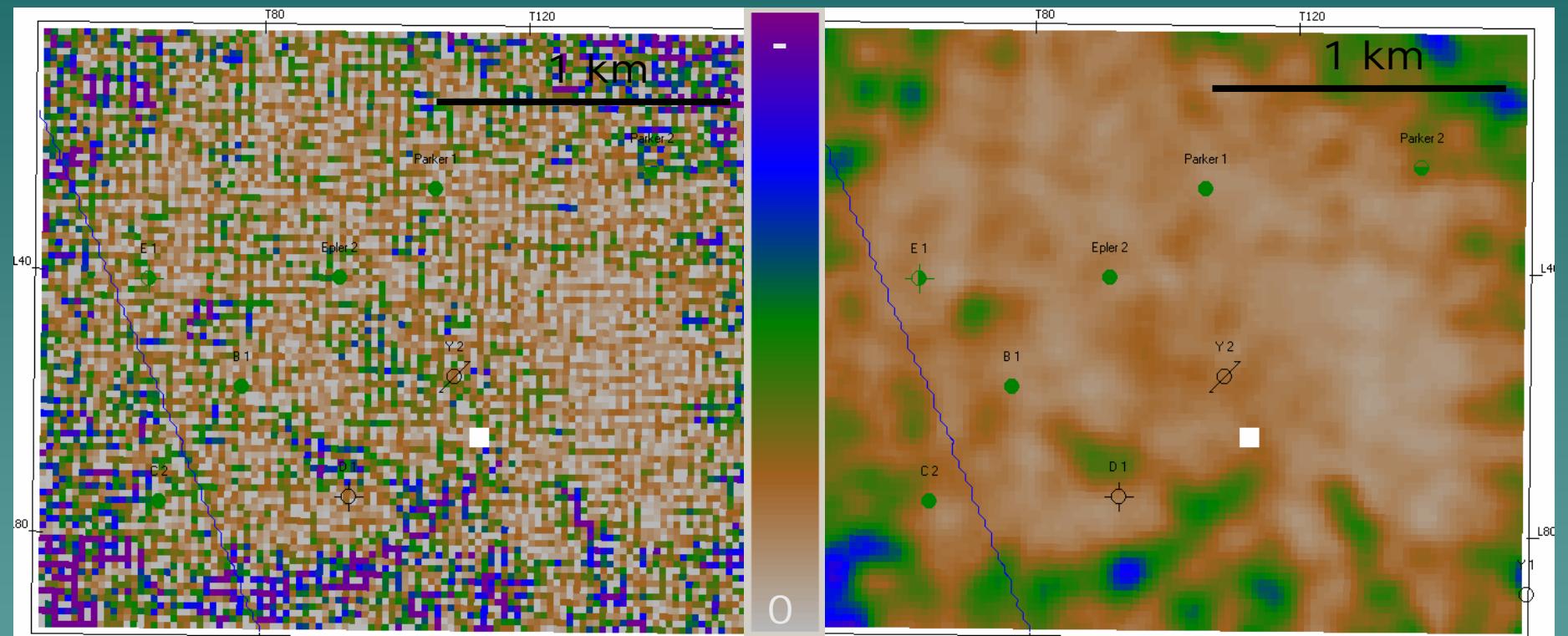
M

2.0

1 km



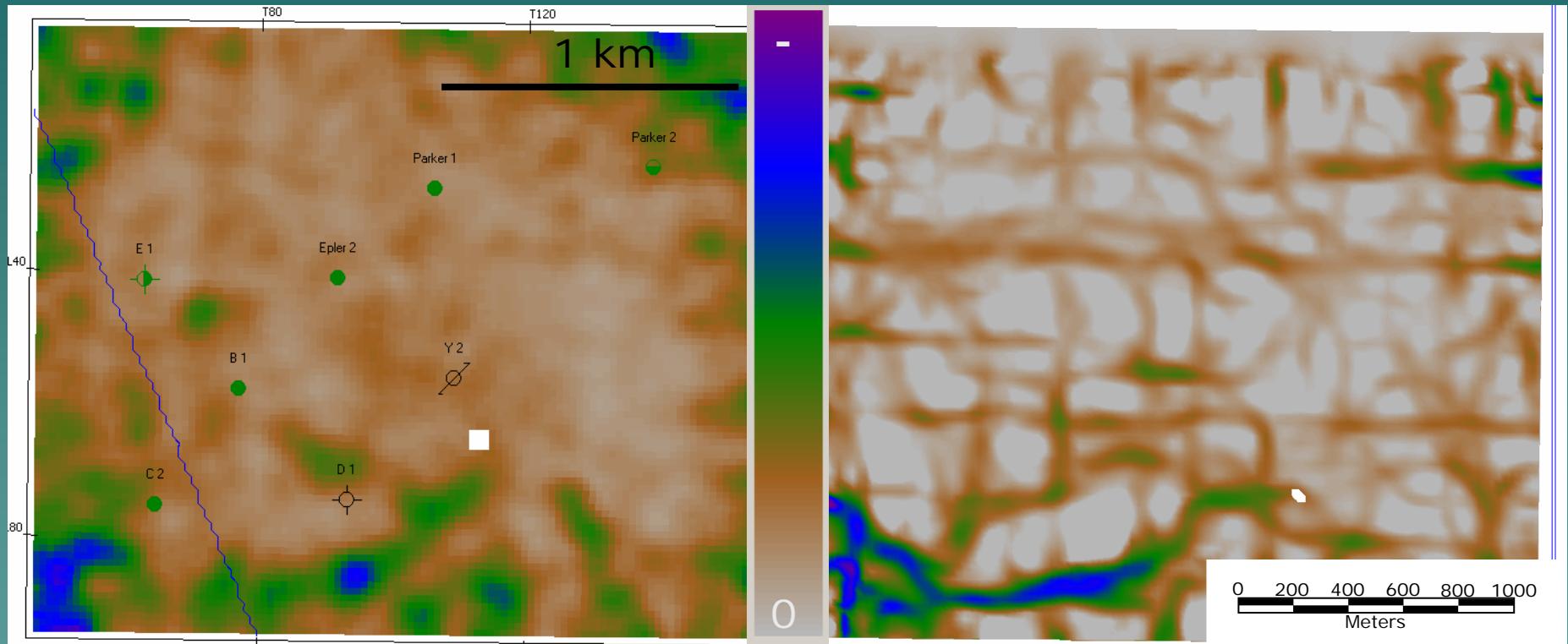
# Most Negative Curvature (Surface Method)



Initial

Smoothed

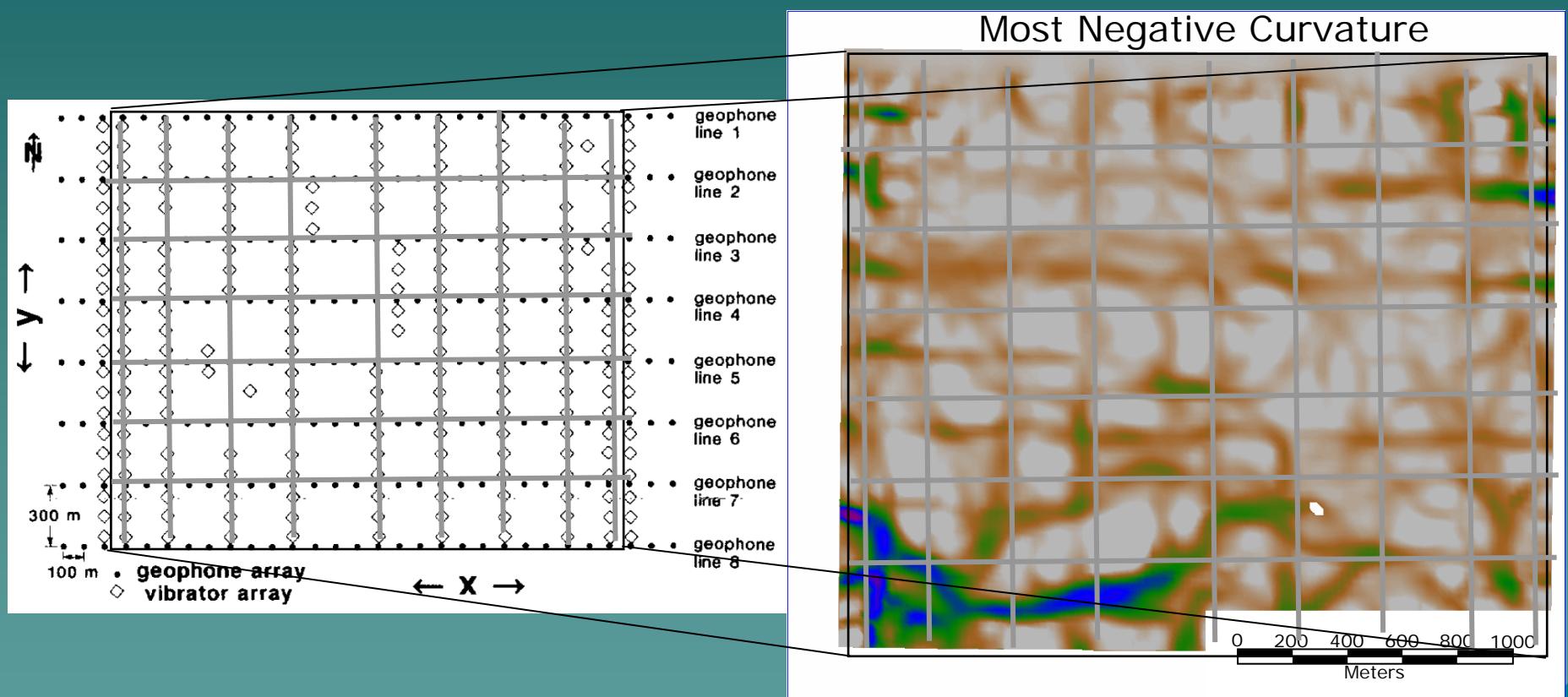
# Most Negative Curvature



Surface Method

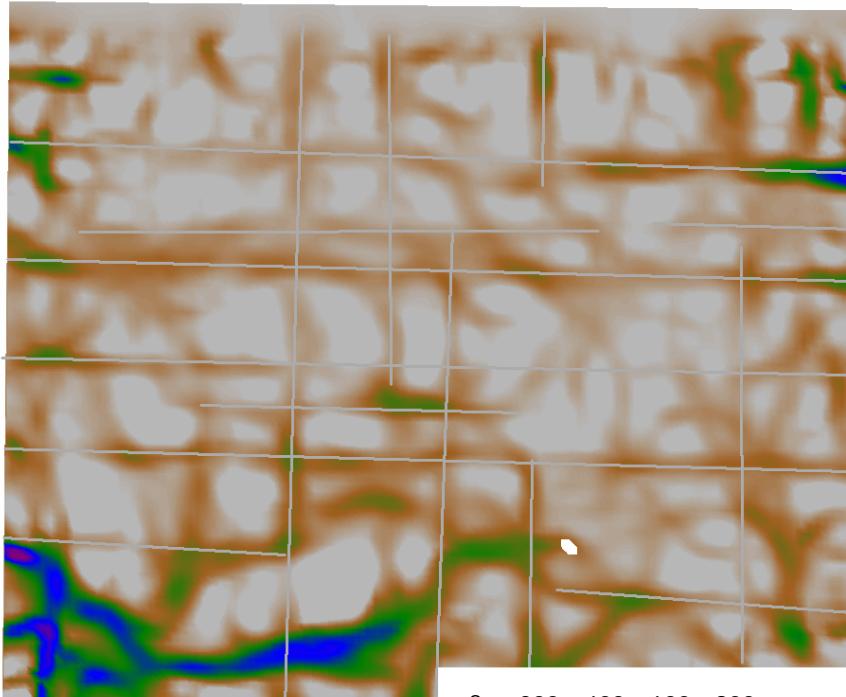
Volume Method

# Acquisition Footprint (Niobrara Horizon Slice)

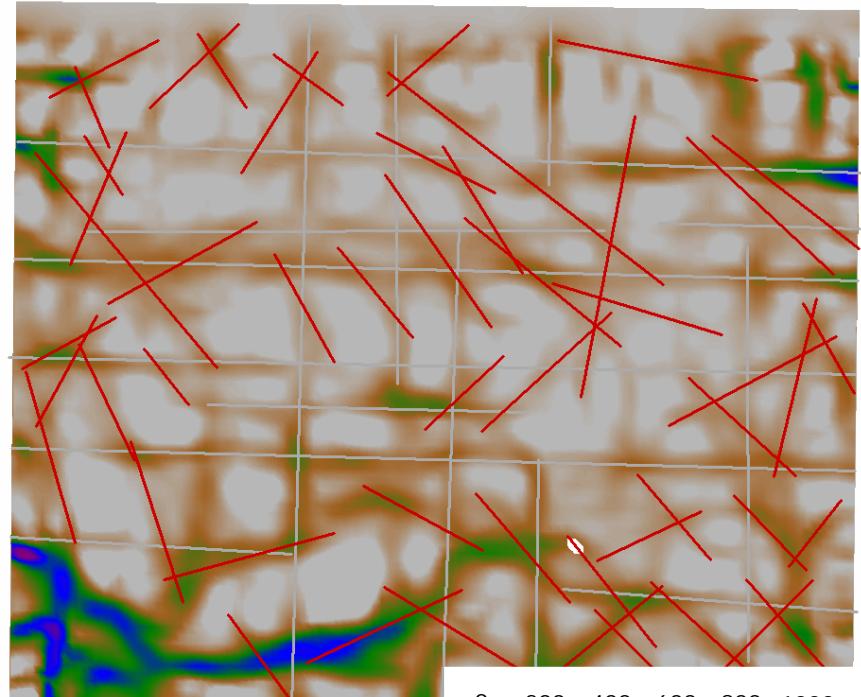


# Interpretation

## (Niobrara Horizon Slice)

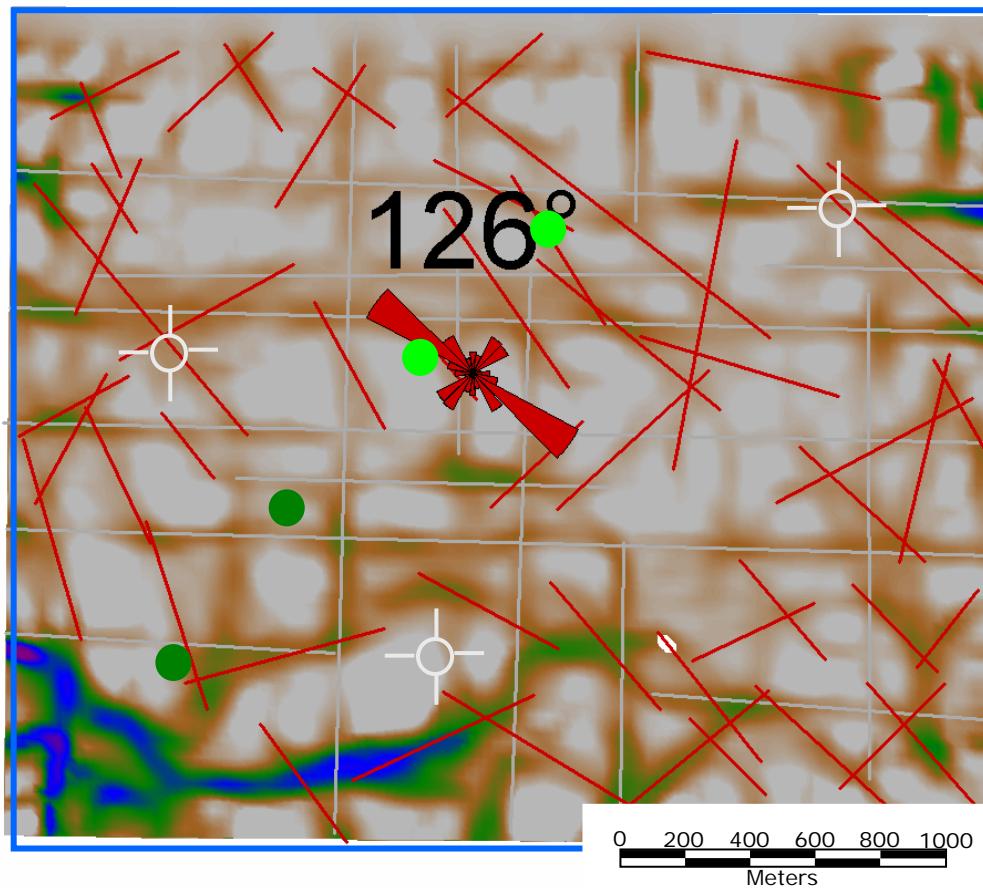


Most Negative Curvature

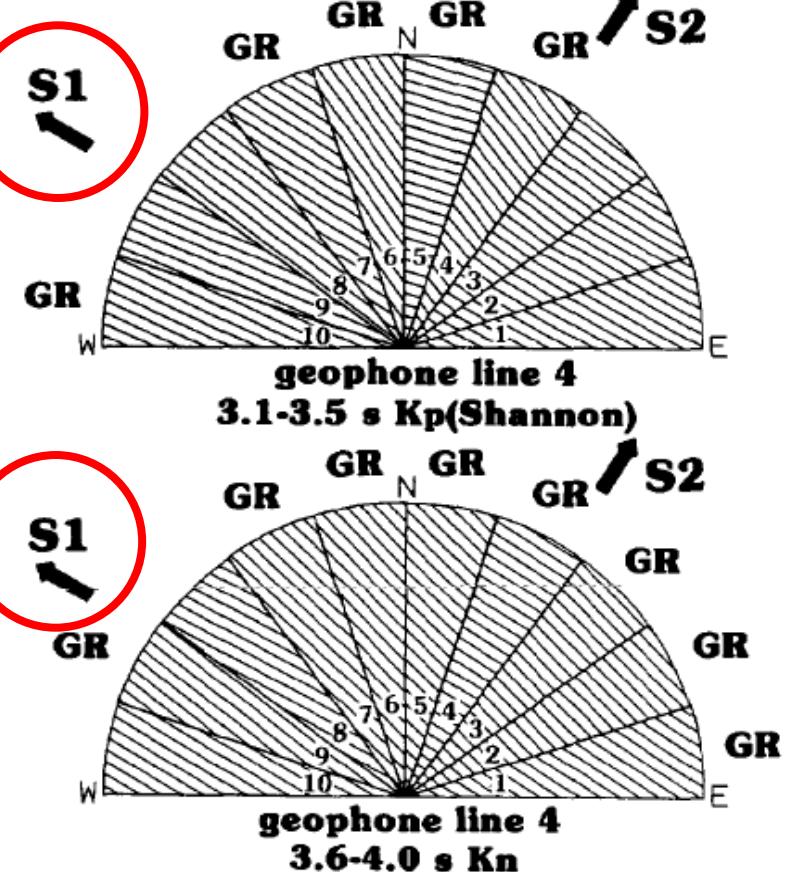


Most Positive Curvature

# Rose Diagram



N 58° W = 122°



# Conclusion

- ◆ P Wave Curvature provides identification of fracture orientation as well as 9-C shear wave data

*Shear Waves? Shear Waves? We  
don't need no stinkin' Shear Waves!*