Equivalent offset migration in anisotropic media

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Objective

- Use non-hyperbolic moveout to improve imaging
- Estimate anisotropy parameters
- Use the simplicity of time migration

- We'll only get to the first one.

What i'll be talking about

- Hyperbolic vs non-hyperbolic moveout
- Shifted-hyperbola
- Offset varying shifted-hyperbola
- EOM: depth and time
- Combining EOM and anisotropy
- Examples of time migrations

Hyperbolic moveout

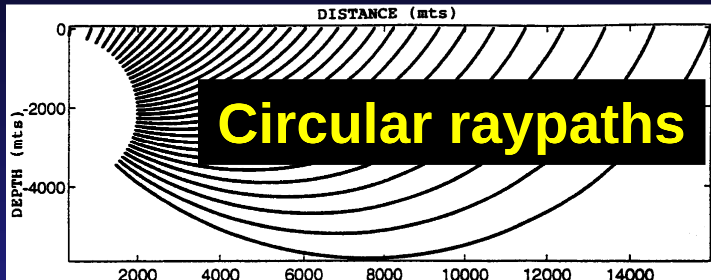
- Hyperbolic: only for constant velocities
- Moveout and migration hyperbolae have asymptotes that intersect at the surface

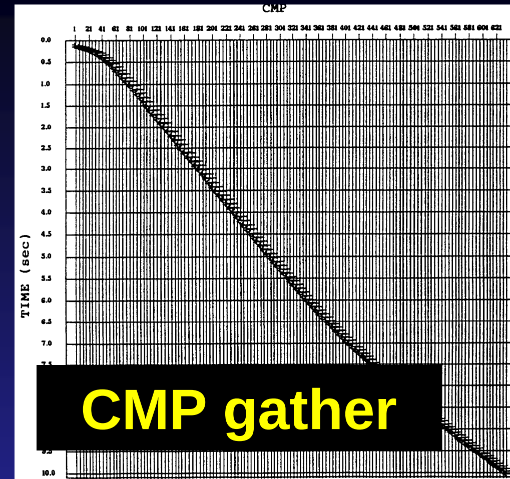
- (Consider a shifted hyperbola to be non-hyperbolic)

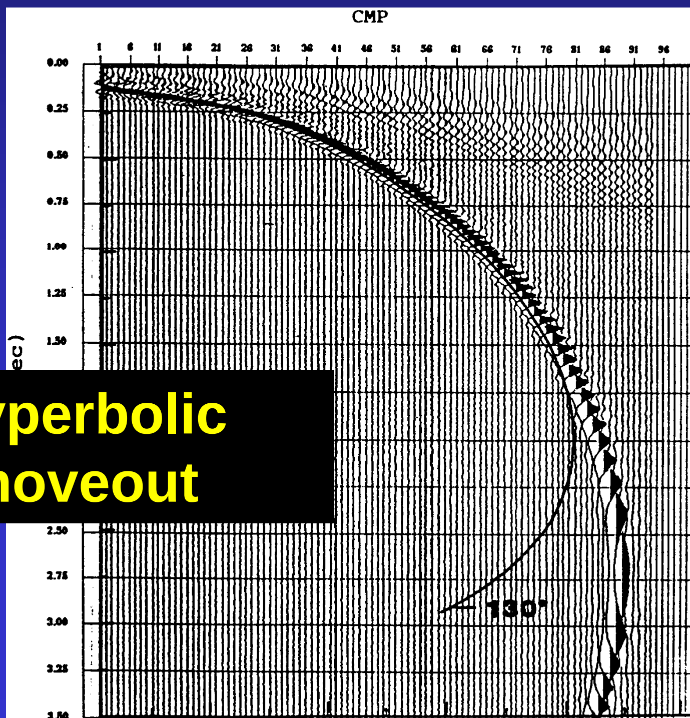
Horizontally layered media

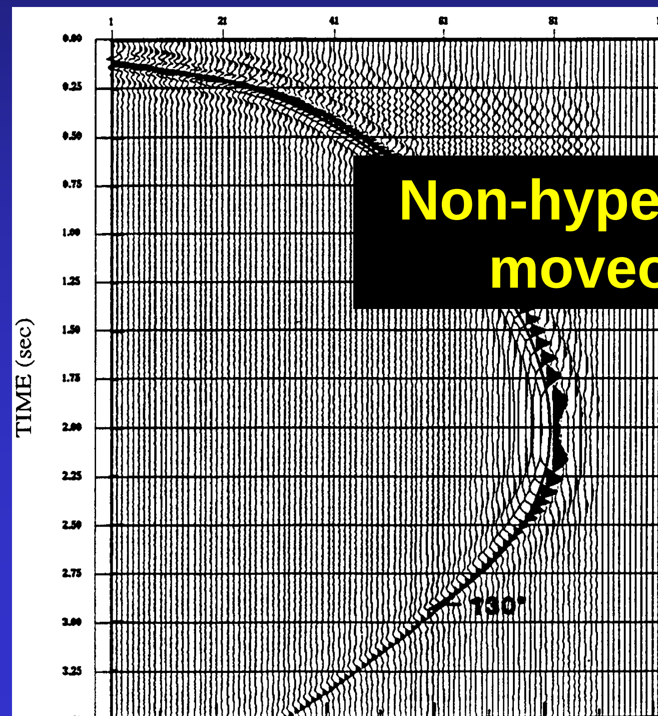
- RMS velocity exact match of curvature at zero offset
- Fudge this RMS velocity to give a better fit at reasonable offsets
- Use a shifted hyperbola to match longer offsets
- Use an offset varying shifted hyperbola for an even better fit at longer offsets
- Could use a polynomial of a given order to match fit.

Linear *v*(*z*) example

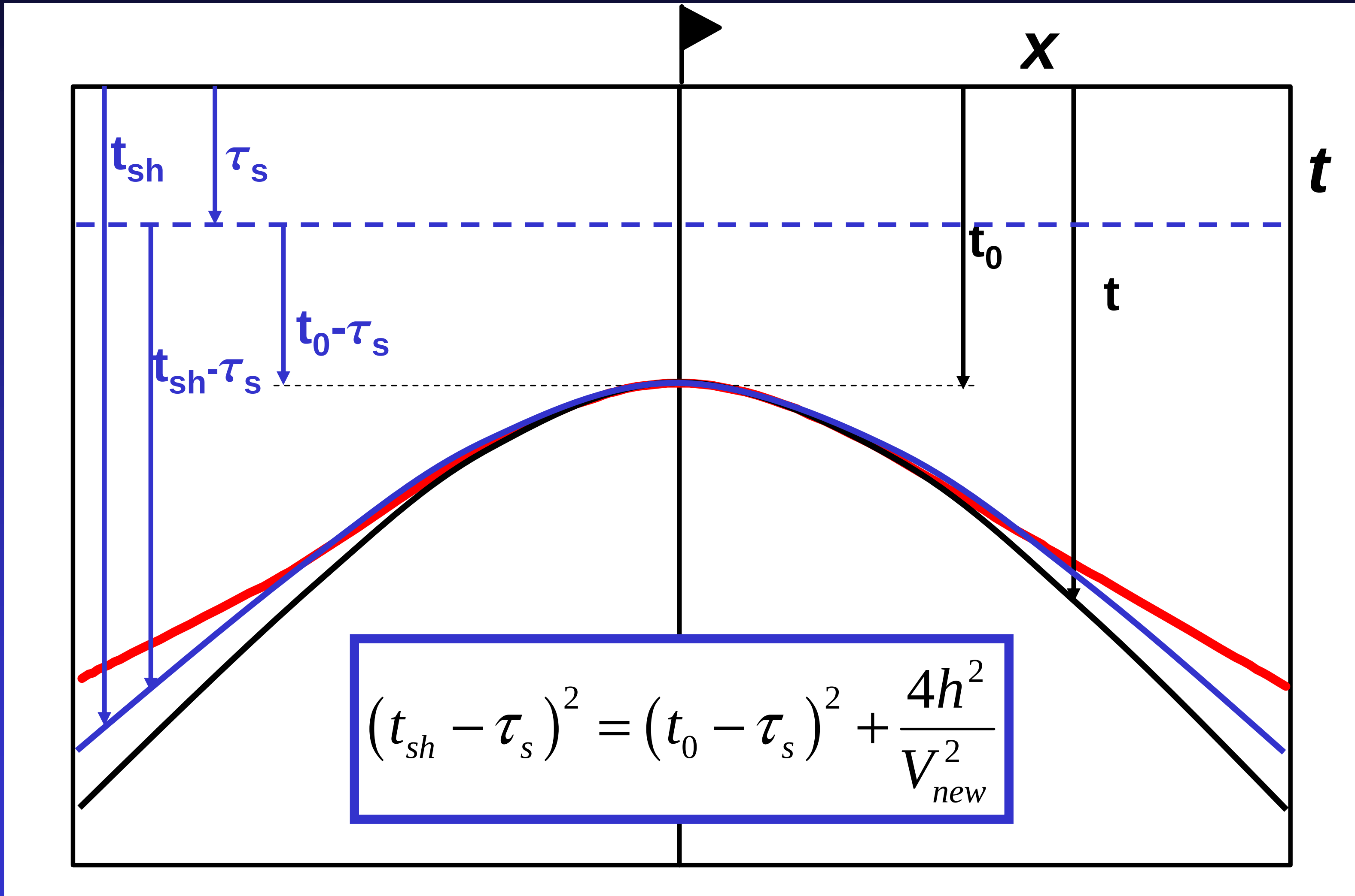








Shifted hyperbola

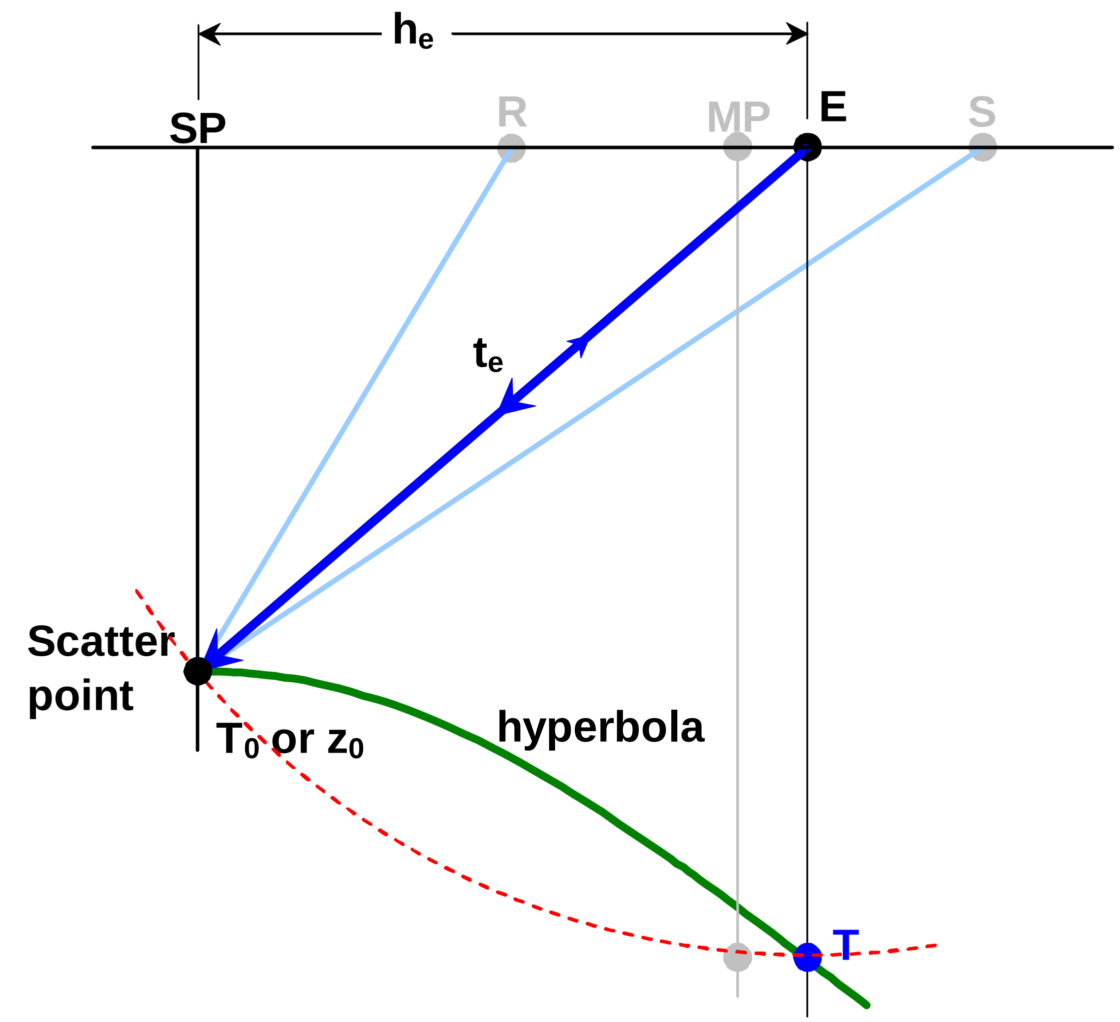


$$\left(t_{sh}-\tau_s\right)^2=\left(t_0-\tau_s\right)^2+\frac{4h^2}{V_{new}^2}$$

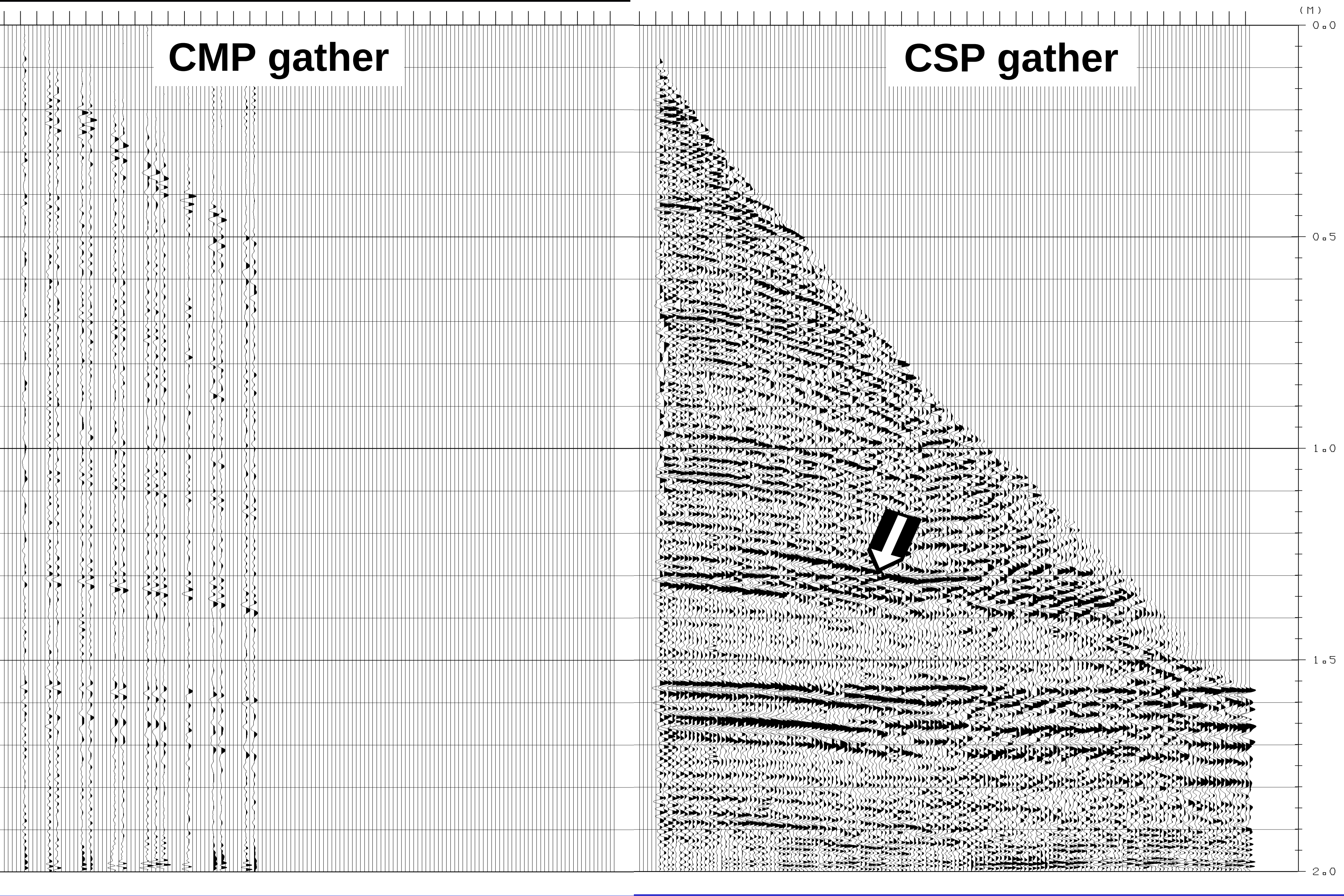
EOM (equivalent offset migration)

- Equate two-way traveltime with a zero offset traveltime
- Double-square-root eqn. = Hyperbolic eqn. $\Rightarrow \mathbf{h_e}$
- Form common scatterpoint gathers
- No time shifting when forming the gather
- Accurate velocity analysis after the gather is formed
- Moveout correction and stack produces prestack migration

EOM



$$t = t_s + t_r = \sqrt{\frac{t_0^2}{4} + \frac{(x+h)^2}{v_{rms}^2}} + \sqrt{\frac{t_0^2}{4} + \frac{(x-h)^2}{v_{rms}^2}} = 2\sqrt{\frac{t_0^2}{4} + \frac{h_e^2}{v_{rms}^2}}$$


CMP gather
CSP gather
(M)
0.0
0.5
1.0
1.5
2.0

EOM depth

- Conventional traveltime computations
- Sort data to offset gather by h_e for velocity correction
- No time saving, but better velocity analysis

EOM time

- Sum data into CSP gathers
- NMO and stack to complete the prestack migration
- Significant time saving

Combine anisotropy into EOM (time)

- Use the shifted hyperbola to define source and receiver traveltimes
- Equate to equivalent offset hyperbola

$$t_0\left(1-\frac{1}{s}\right)+\sqrt{\left(\frac{t_0}{2s}\right)^2+\frac{h_s^2}{sV_{rms}^2}}+\sqrt{\left(\frac{t_0}{2s}\right)^2+\frac{h_r^2}{sV_{rms}^2}}=2\sqrt{\left(\frac{t_0}{2}\right)^2+\frac{h_e^2}{V_{rms}^2}}$$

One more trick

- Pavan used an offset varying ***"s"*** parameter (Castle 1994)

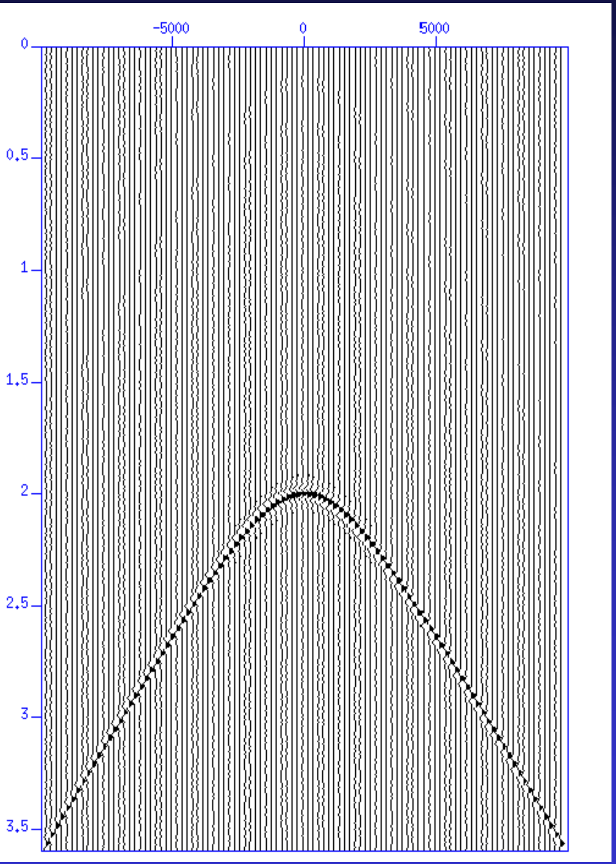
$$s(h) = s + ah + bh^2$$

- Parameters are now ***s***, ***a***, and ***b***.

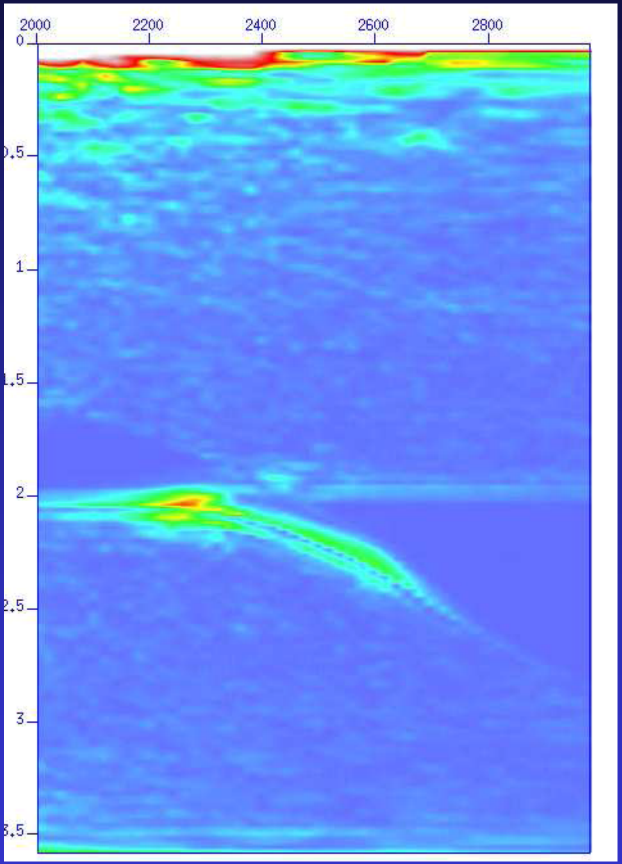
The process:

- Form isotropic CSP gather using conventional EOM
- On this gather pick traveltimes of all events
  - labour intensive
- Use simulated annealing inversion to estimate ***s***, ***a***, and ***b***
- Use estimated parameters to form anisotropic CSP gather
- Pick new velocities on A-CSP gather
- NMO and stack to complete prestack migration.

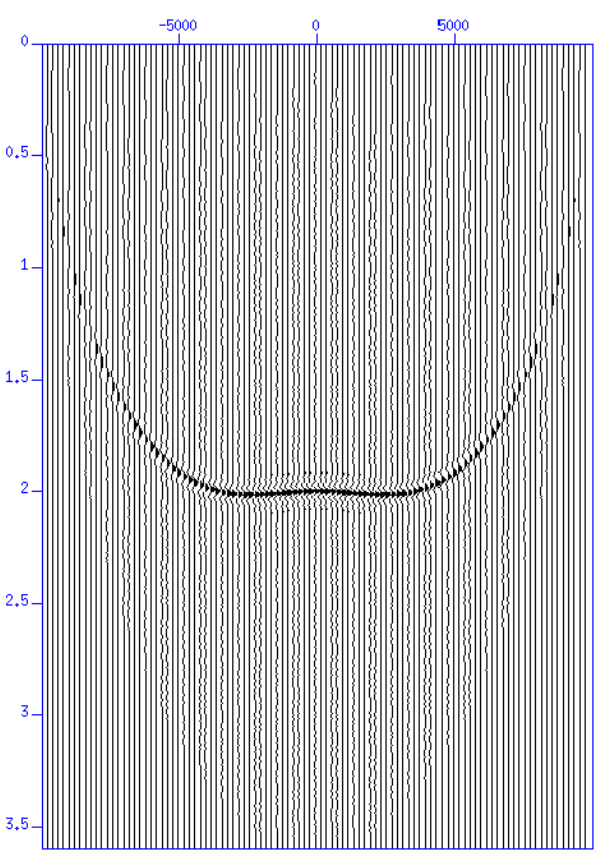
Model v = 3000m/s ϵ = 0.2, δ = -0.2



CMP gather

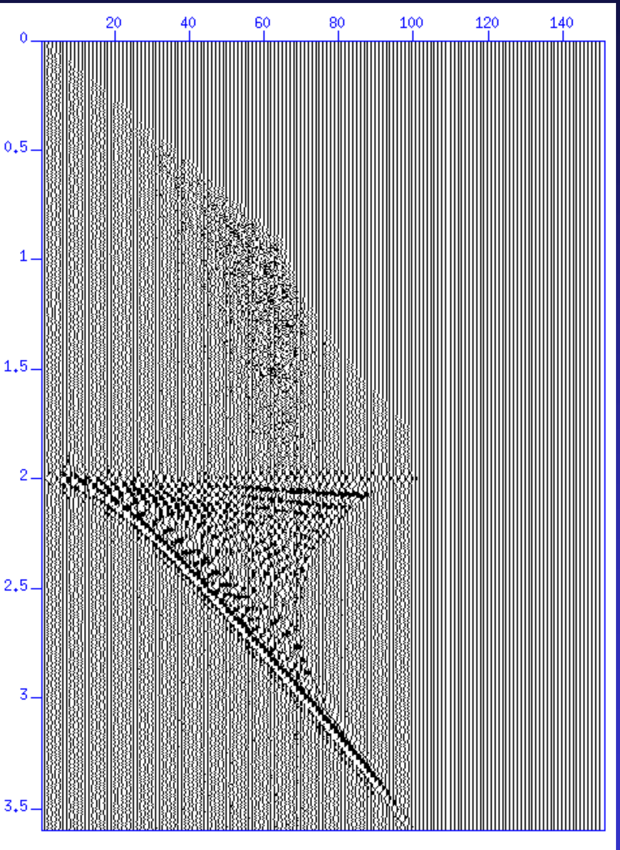


Semblance

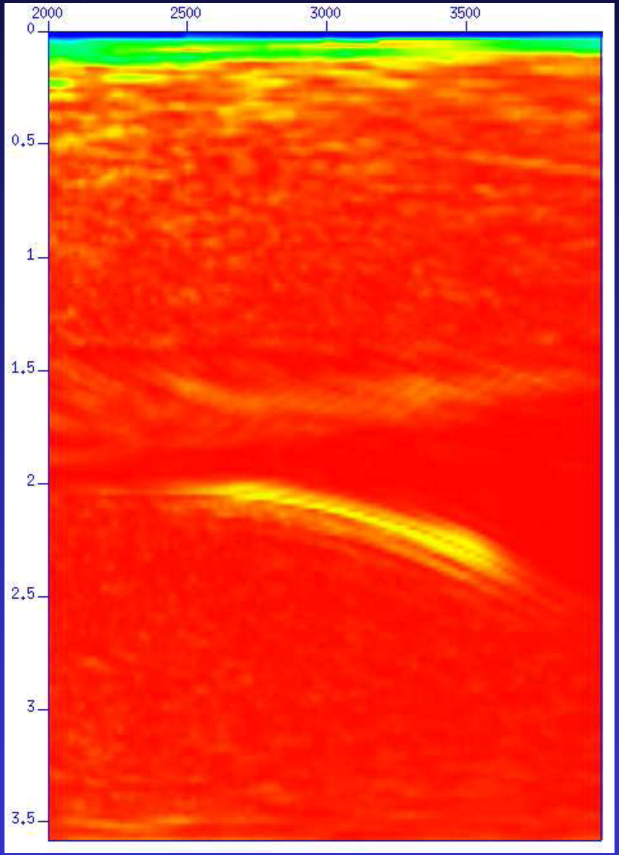


NMO corrected

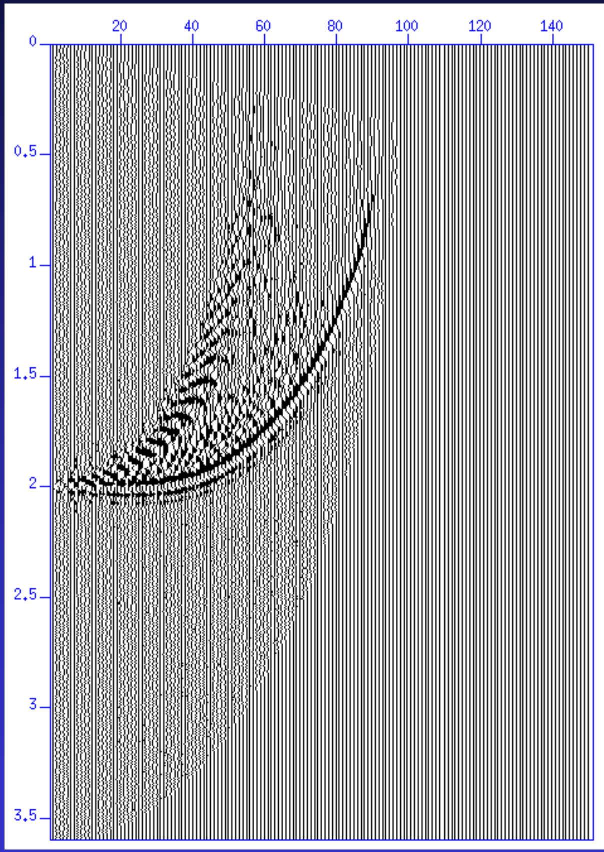
Isotropic EOM



CSP gather

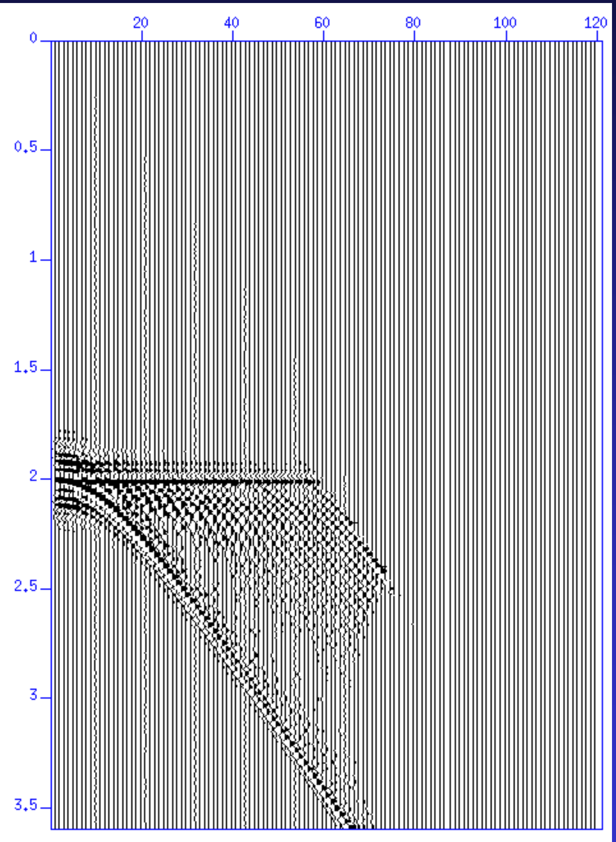


Semblance

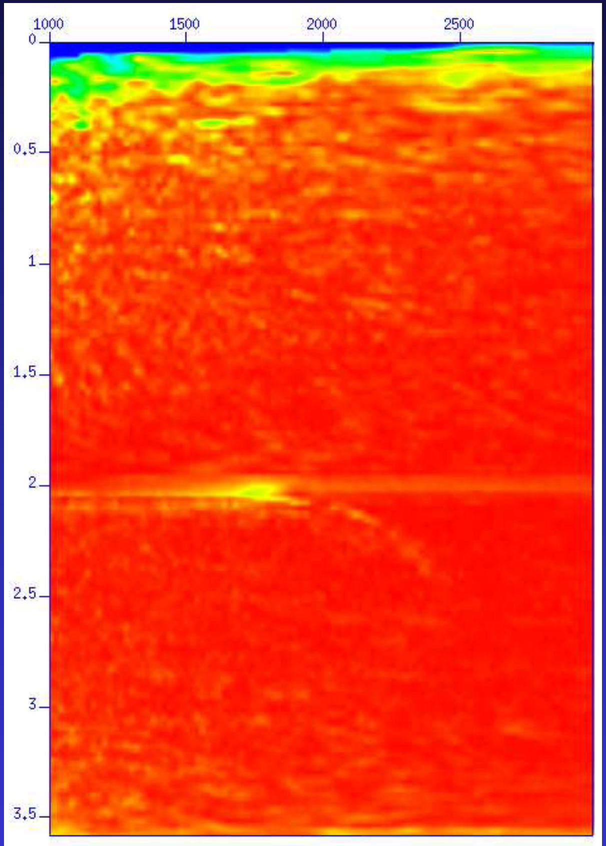


NMO corrected

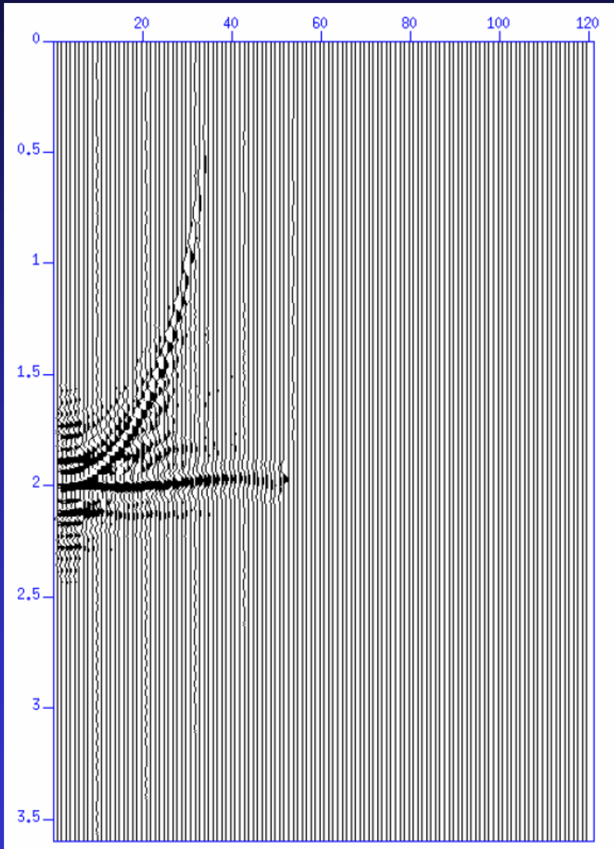
Anisotropic EOM



CSP gather

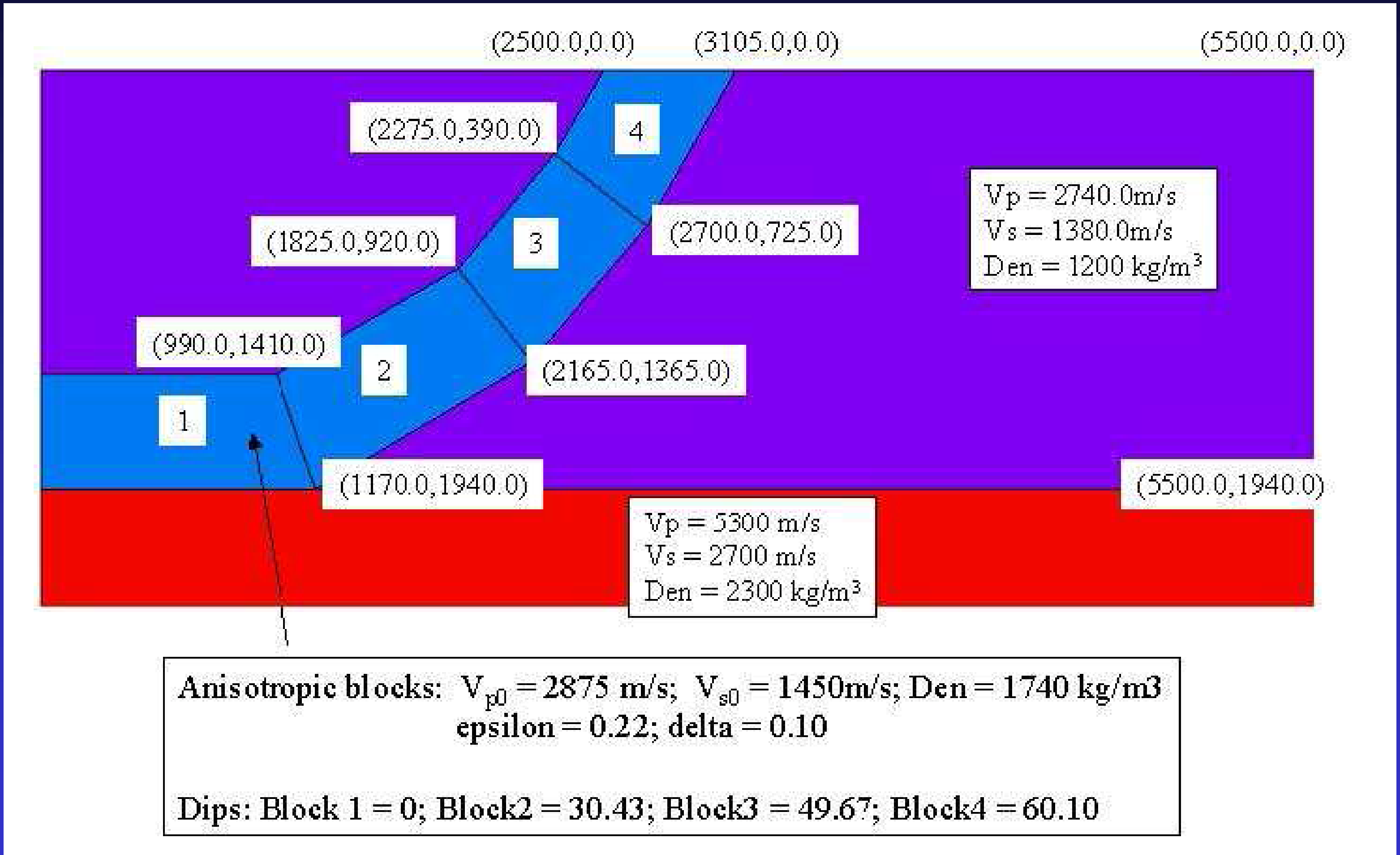


Semblance

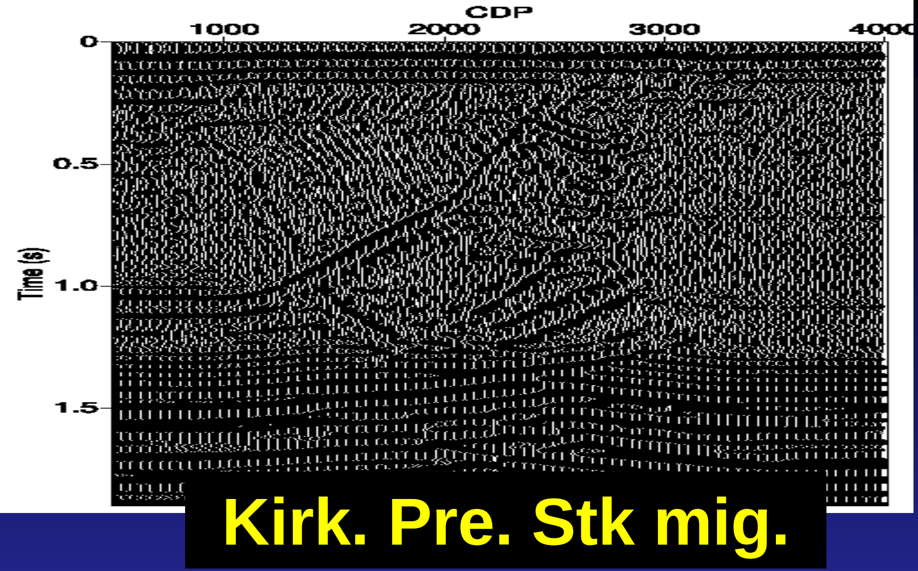


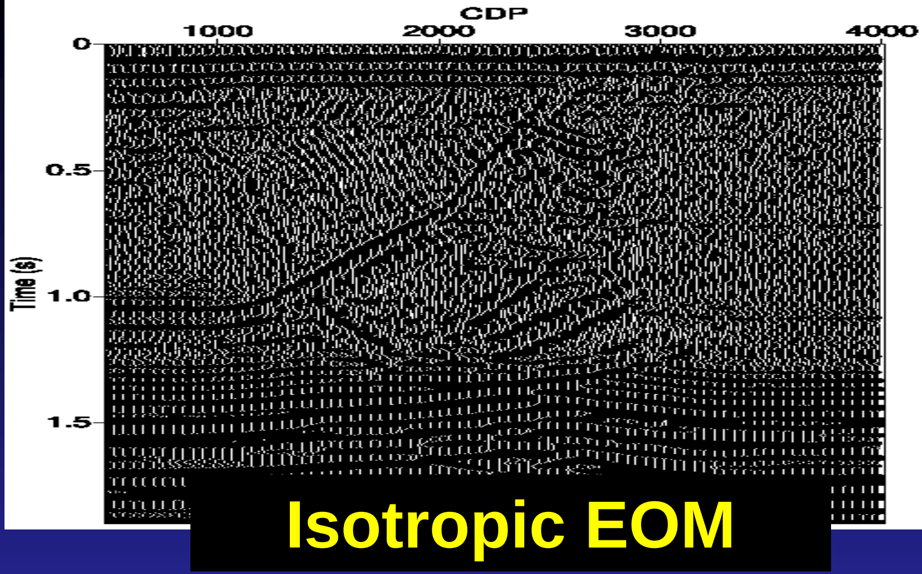
NMO corrected

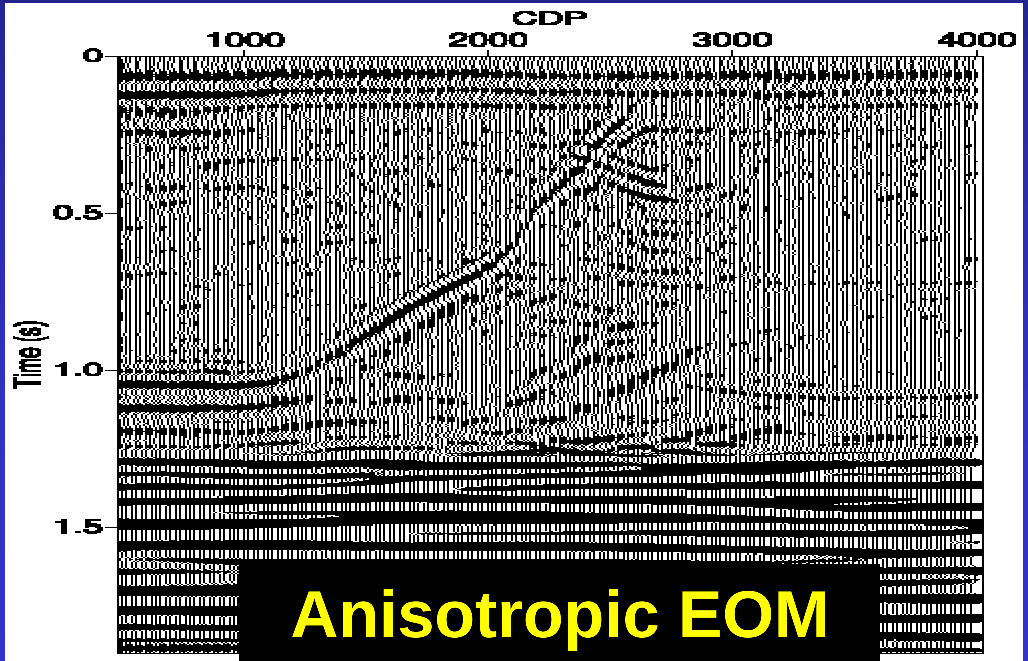
Physically modelled data



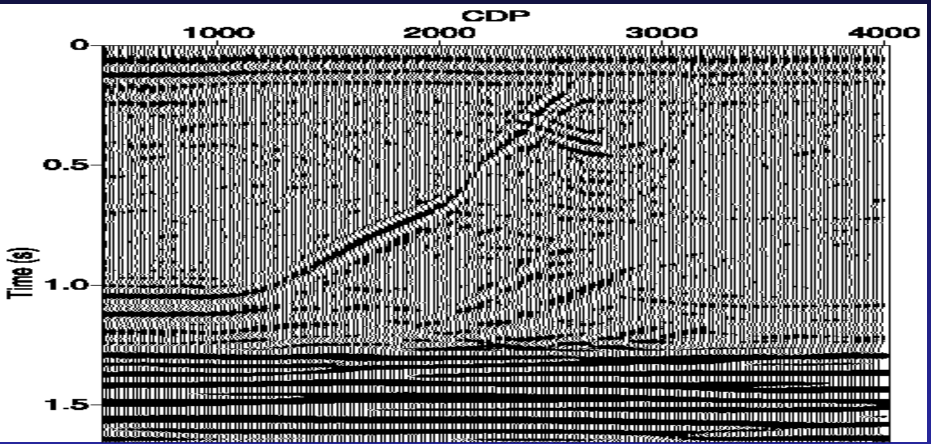
Courtesy Don Lawton


CDP
1000
2000
3000
4000
Time (s)
0
0.5
1.0
1.5
Kirk. Pre. Stk mig.

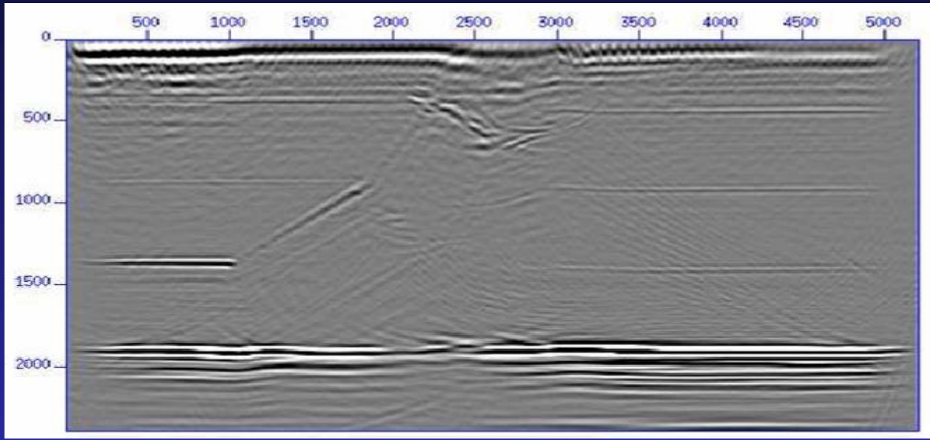

CDP
1000
2000
3000
4000
Time (s)
0
0.5
1.0
1.5
Isotropic EOM


CDP
1000
2000
3000
4000
Time (s)
0
0.5
1.0
1.5
Anisotropic EOM

Comparison of prestack migrations



Anisotropic EOM



Prestack reverse time migration

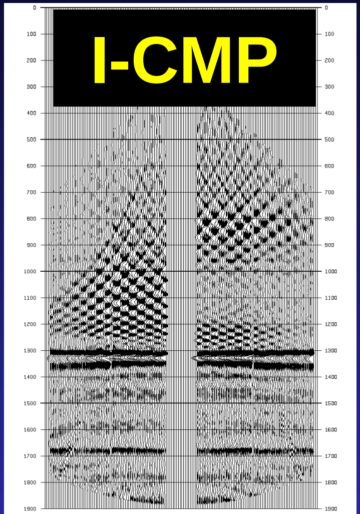
by Xiang Du

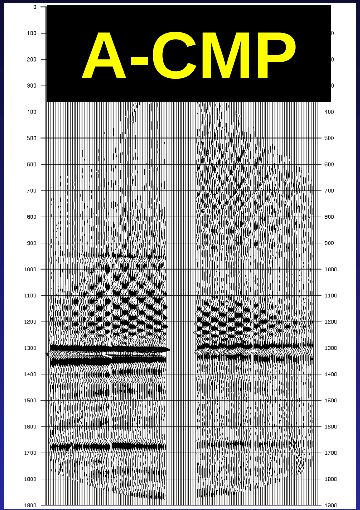
Conclusions

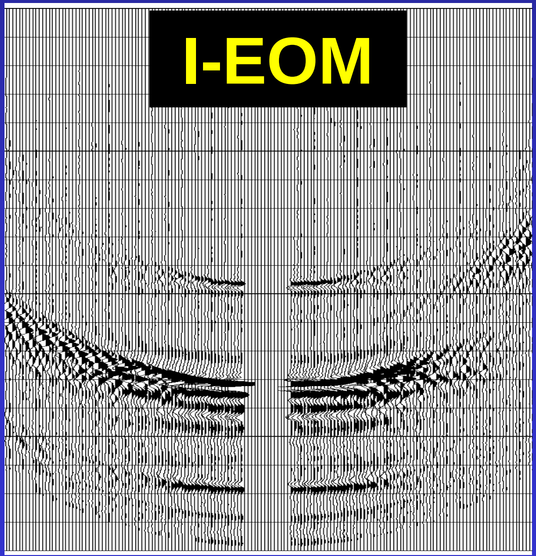
- Non-hyperbolic equation may be approximated by an offset varying shifted hyperbola (OSH).
- OSH mates well with DSR eqn. in EOM
- Result very encouraging

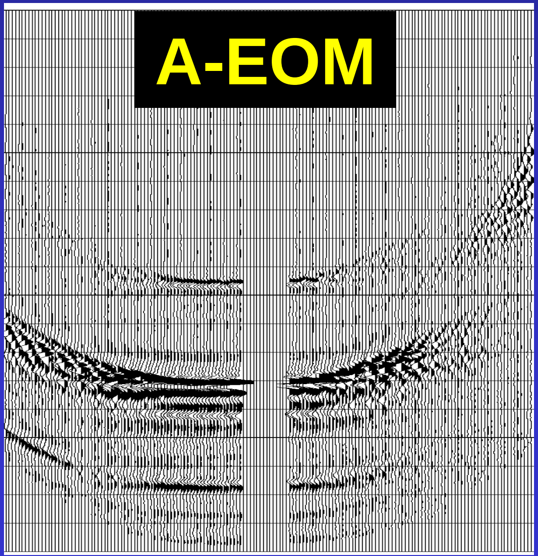

The End

Depth migration results

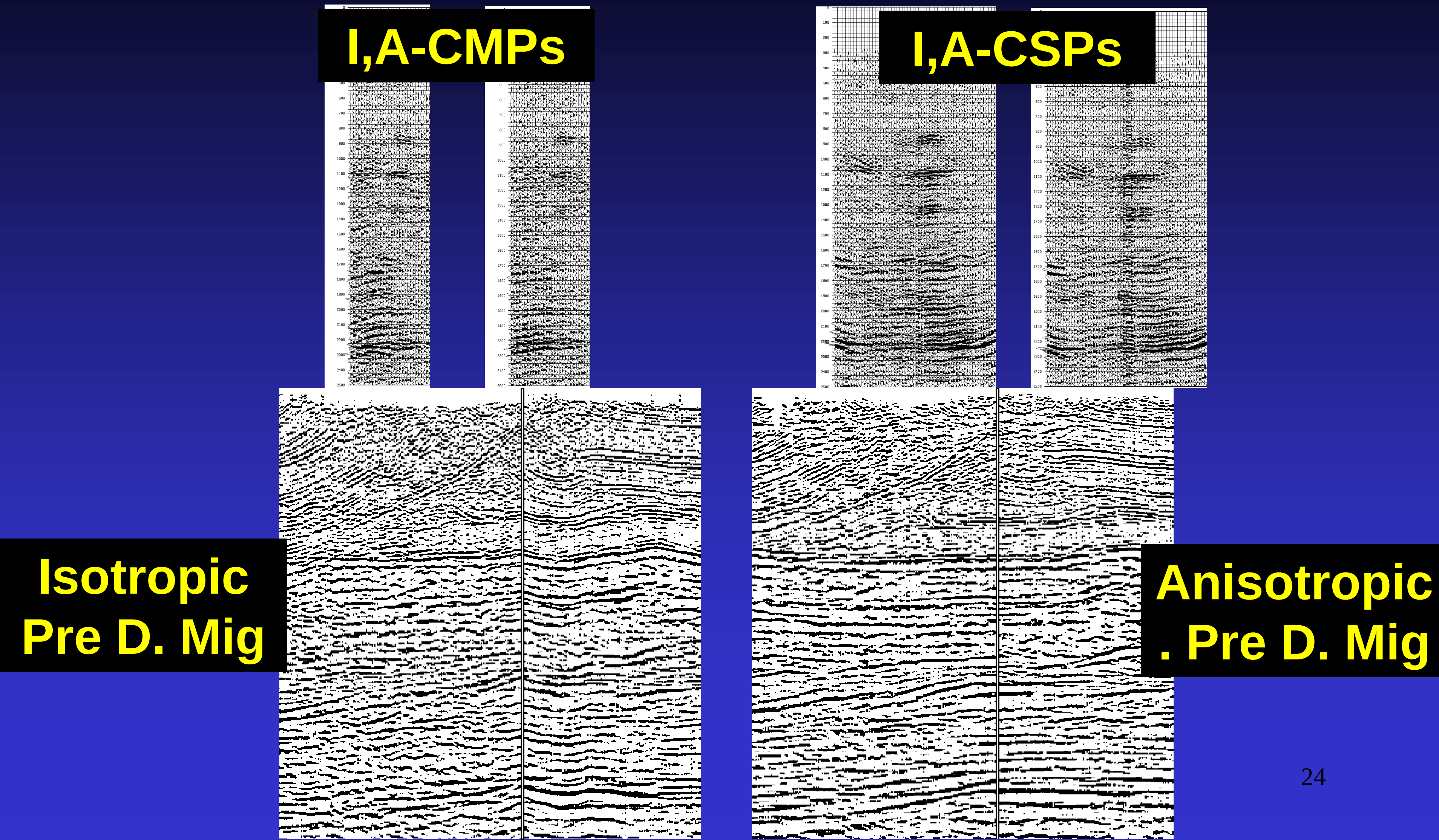








Depth migration results



$$t_0\left(1-\frac{1}{s}\right)+\sqrt{\left(\frac{t_0}{2s}\right)^2+\frac{h_s^2}{sV_{rms}^2}}+\sqrt{\left(\frac{t_0}{2s}\right)^2+\frac{h_r^2}{sV_{rms}^2}}=t=2\sqrt{\left(\frac{t_0}{2}\right)^2+\frac{h_e^2}{V_{rms}^2}}$$

$$h_e=\frac{v_{rms}}{2}\sqrt{\left(t^2-t_0^2\right)}$$

$$h_e^2\approx x^2+h^2$$