Virtual Shear Source: a new method for shear-wave seismic surveys

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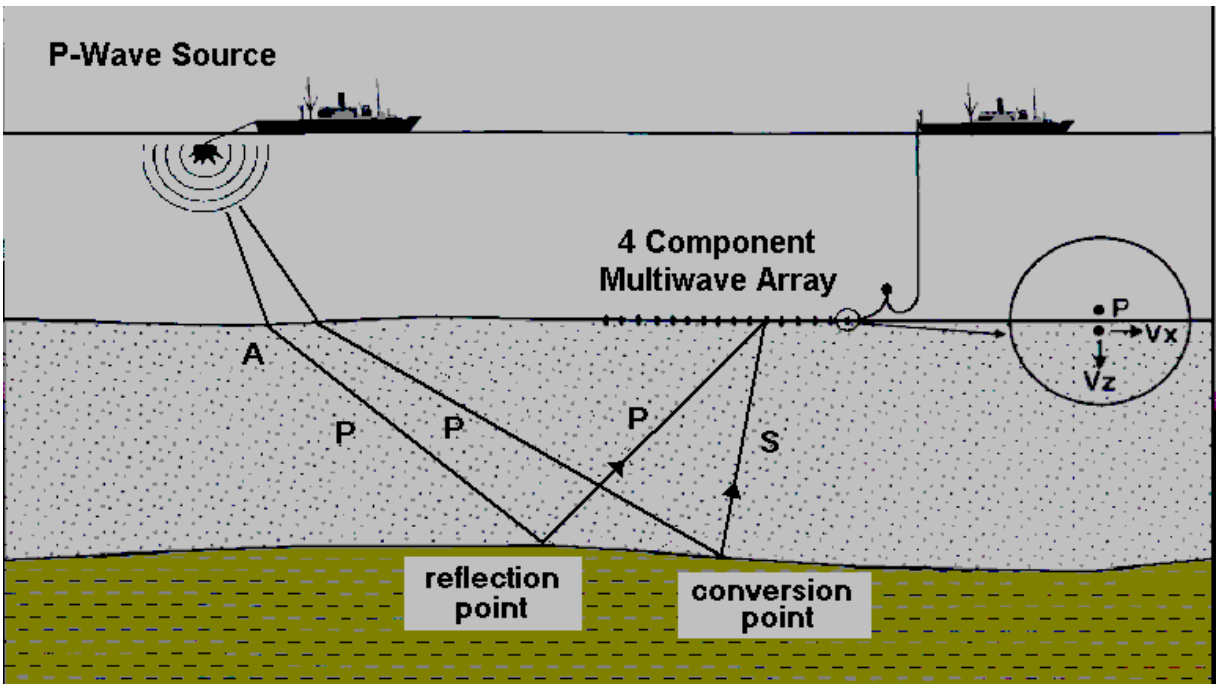
Why shear waves *(SS)* did not fly?

- Excitation of shear waves is costly
- Abundant shear anisotropy even in near surface
- Shear-wave source always excites substantial *P* -wave energy that acts as "noise" on shear records
- Shear velocities are extremely low and vary greatly in the near-surface (both on land and on sea bed). Thus near-surface is a bigger problem in shear-wave seismic.

Converted *(PS)* waves

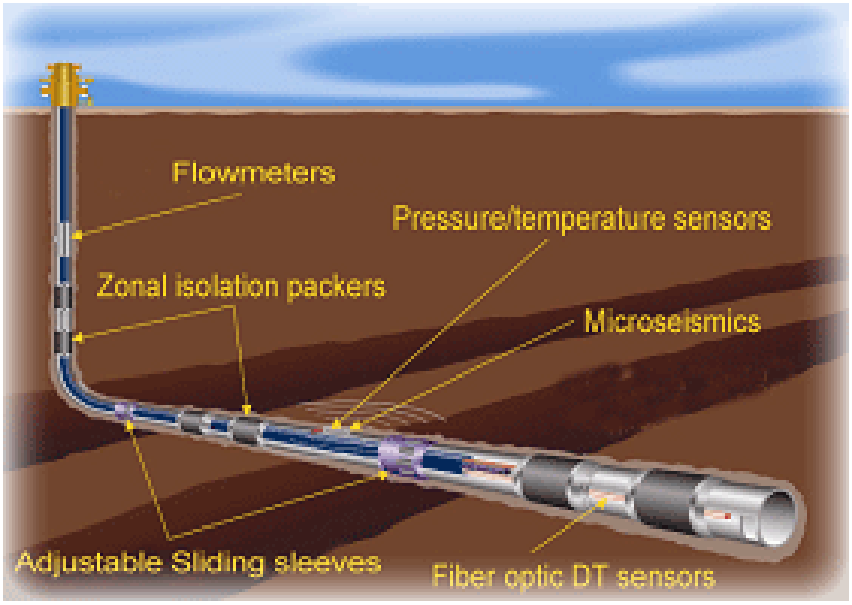
- Polarization of excited shear waves is not controlled
- Joint processing with *PP* data is required to estimate shear-wave properties
- Converted wave processing is much more complicated
- Fully suffers from near-surface problems (P and S)



Cheap slim wells

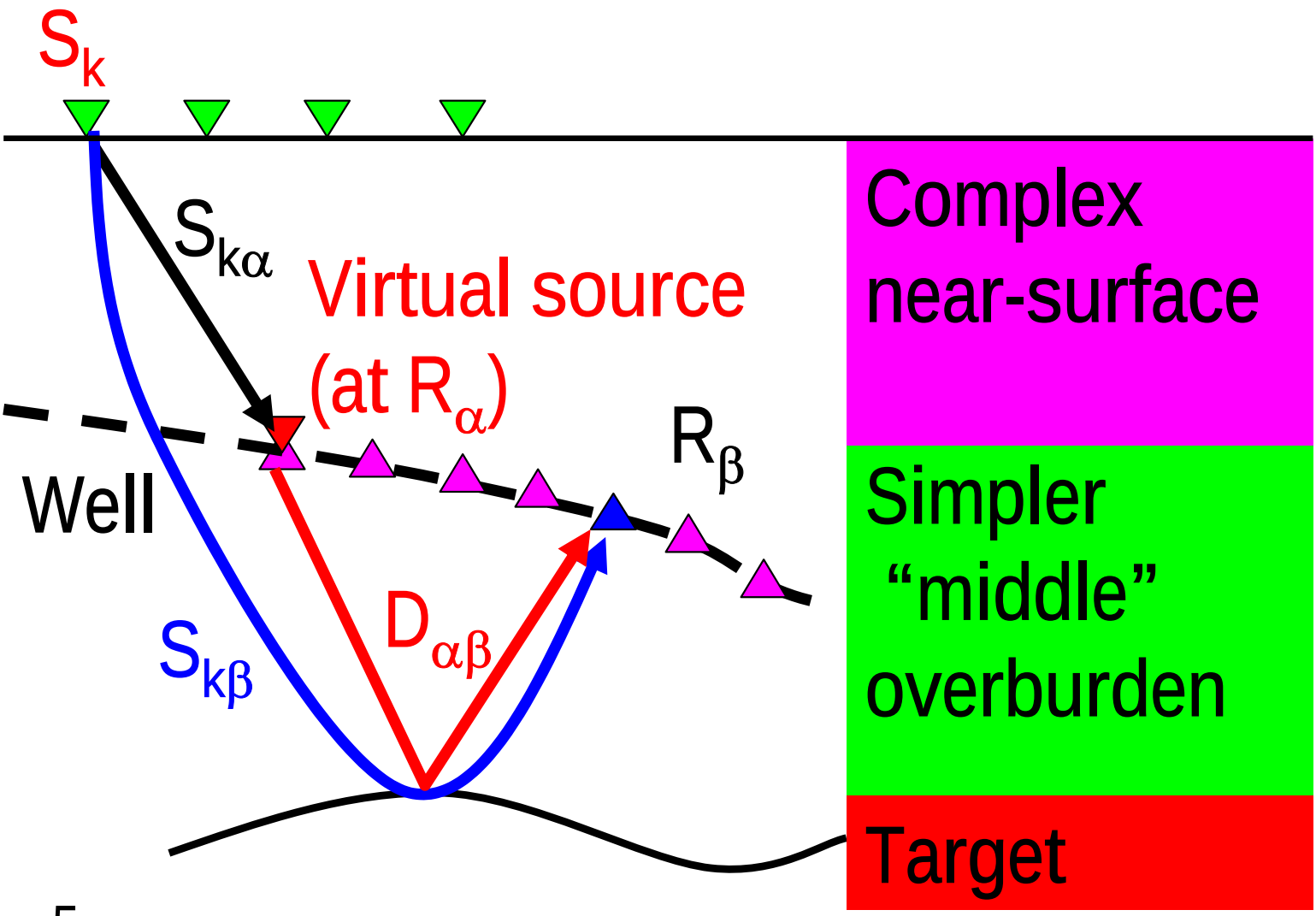
potential for instrumented observation wells in the overburden

Smart wells

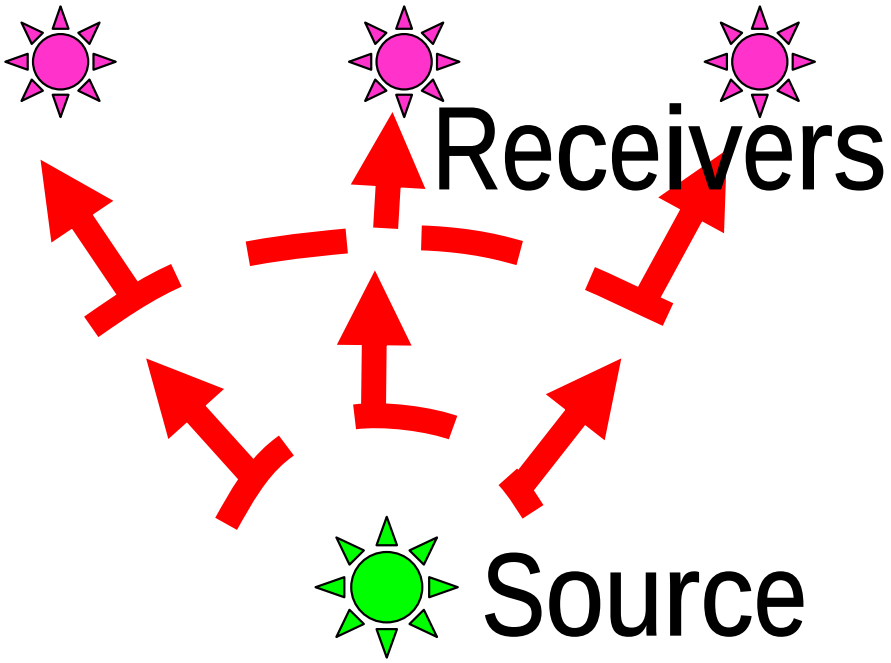


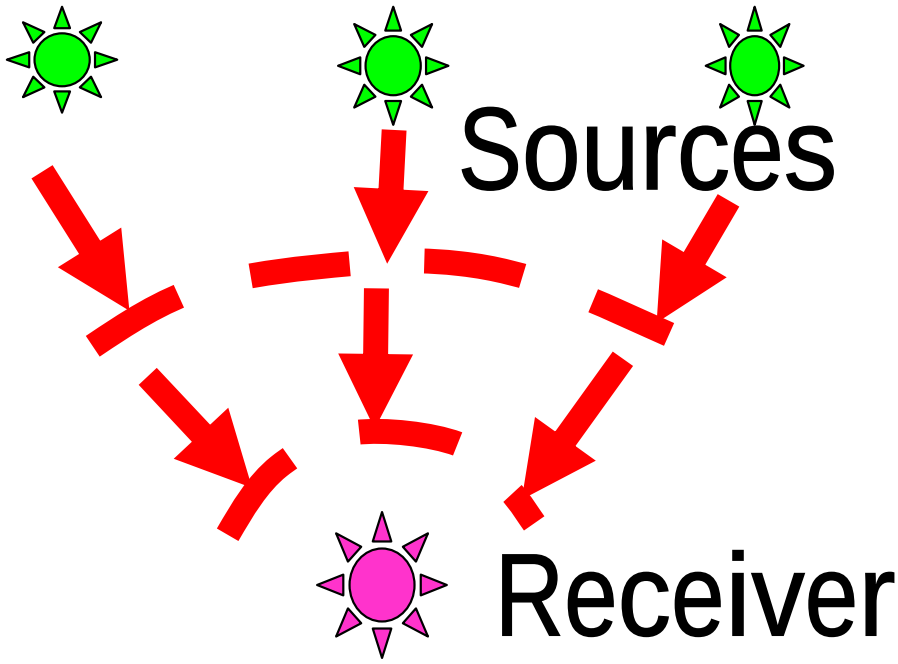
The Virtual Source method

Surface array of sources that simulates virtual source

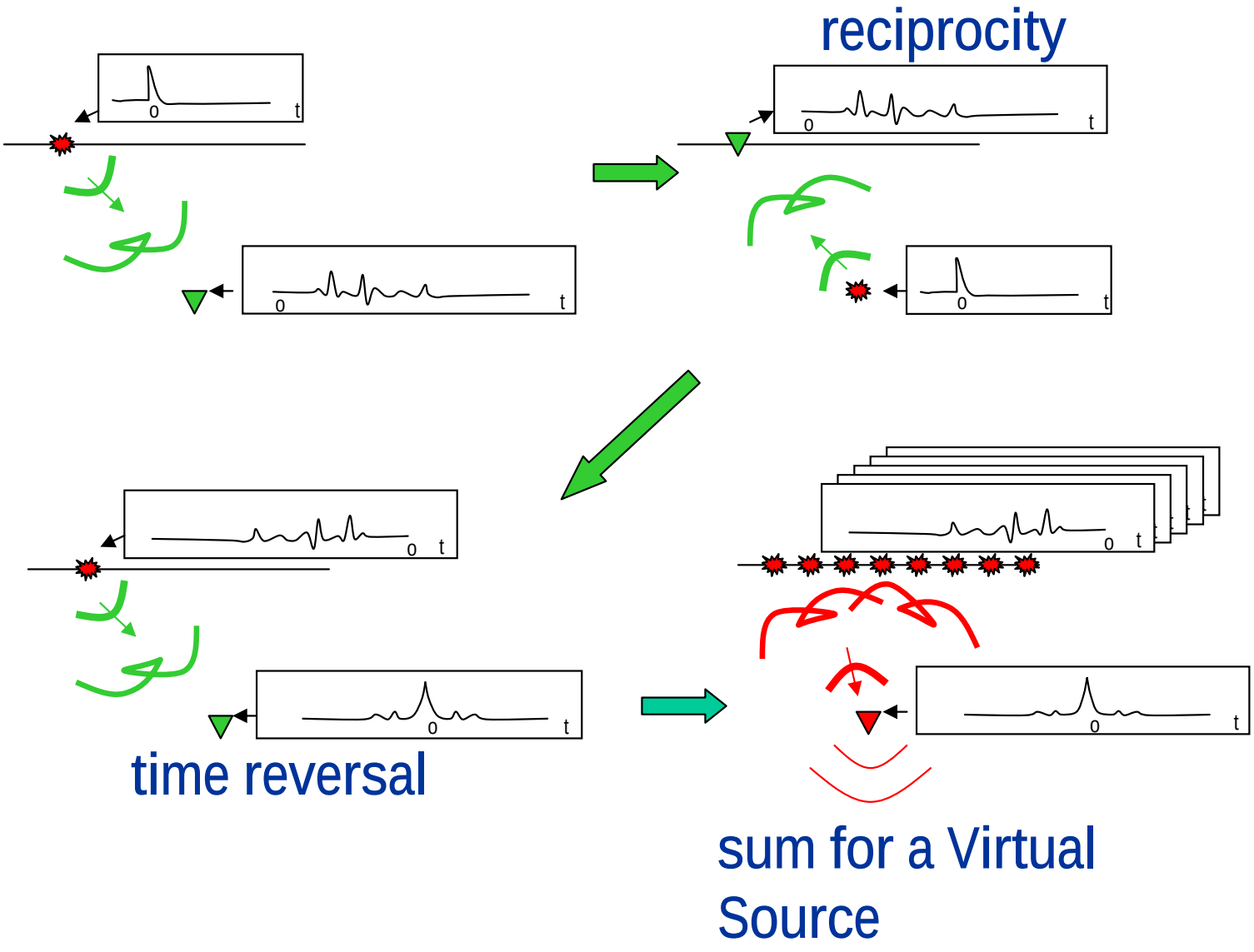


Time reversal

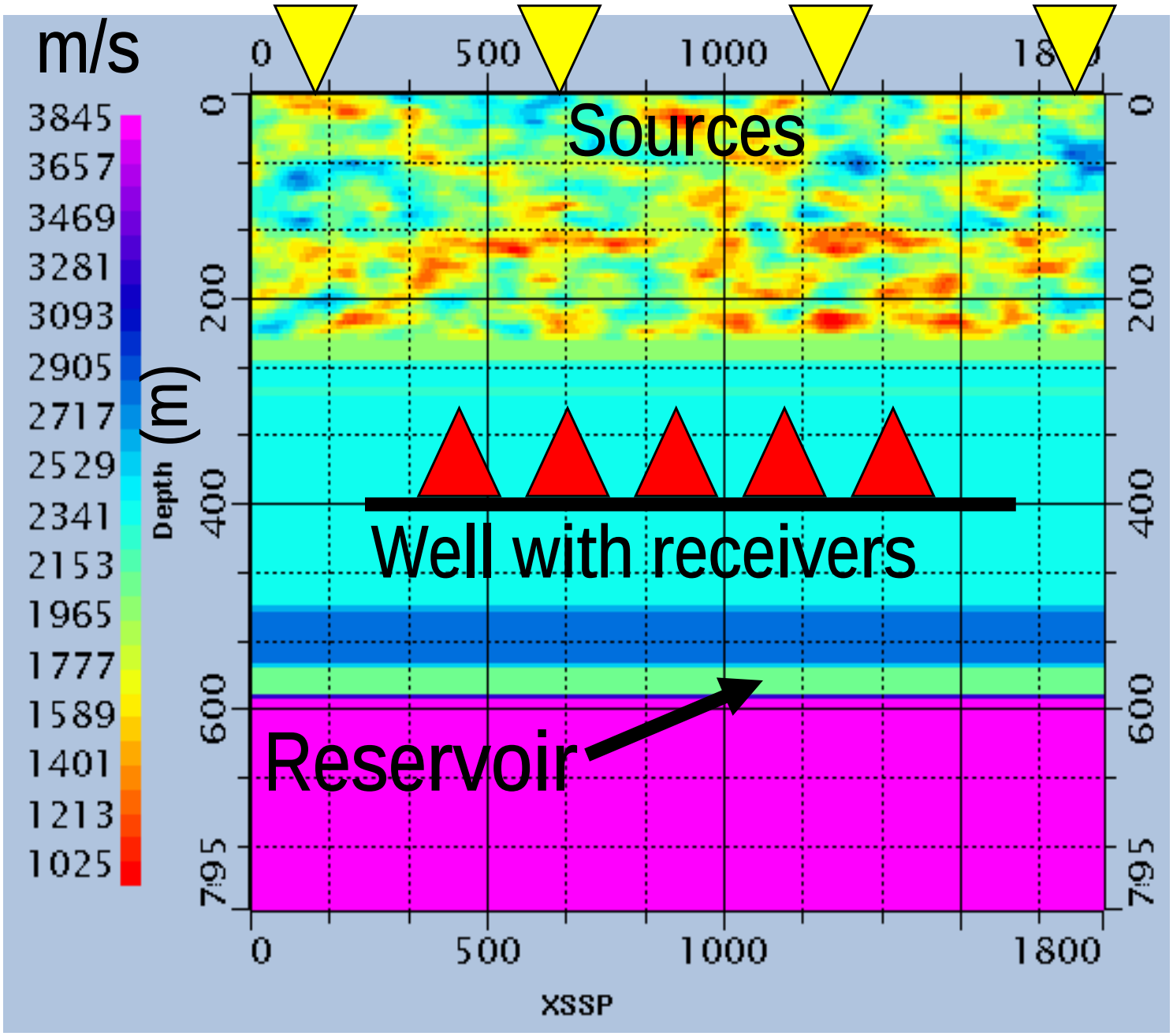




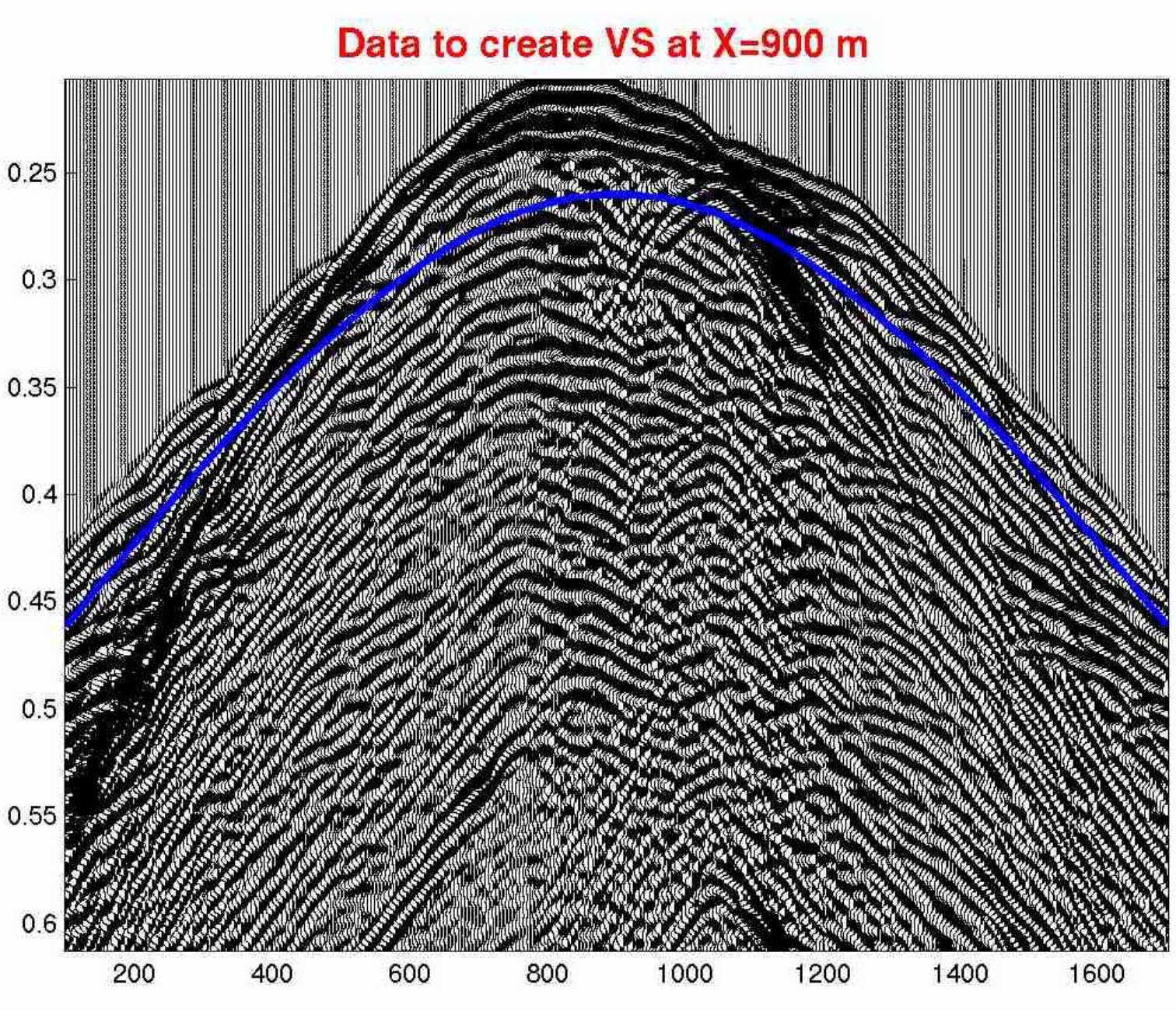
The Physics of Virtual Sources



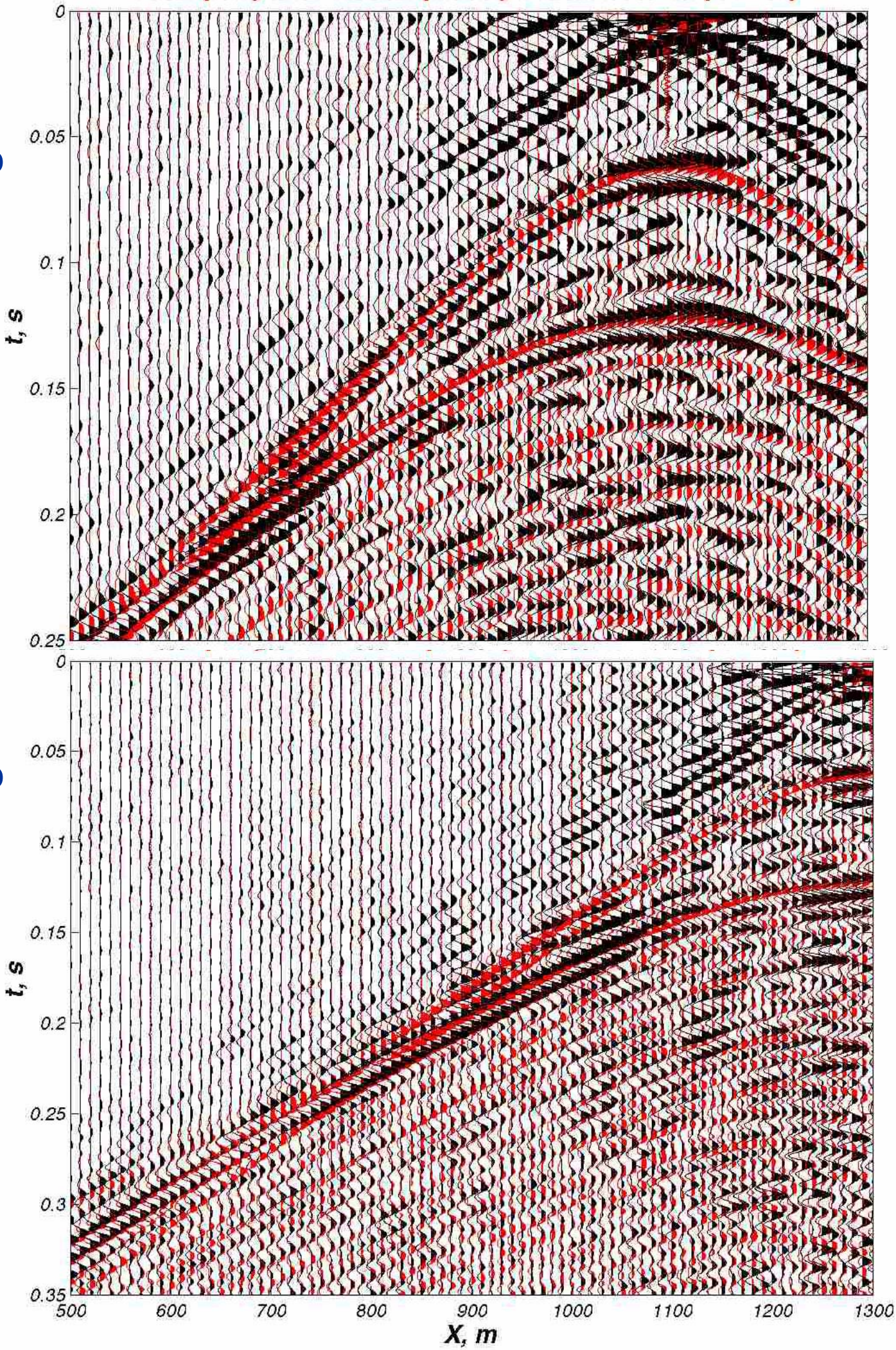
Synthetic model with horrible overburden (full elastic finite-difference modeling)



Receiver gather
(receiver X=900m, Z=430m, shot line at Z=15m)
Explosion source to vertical component



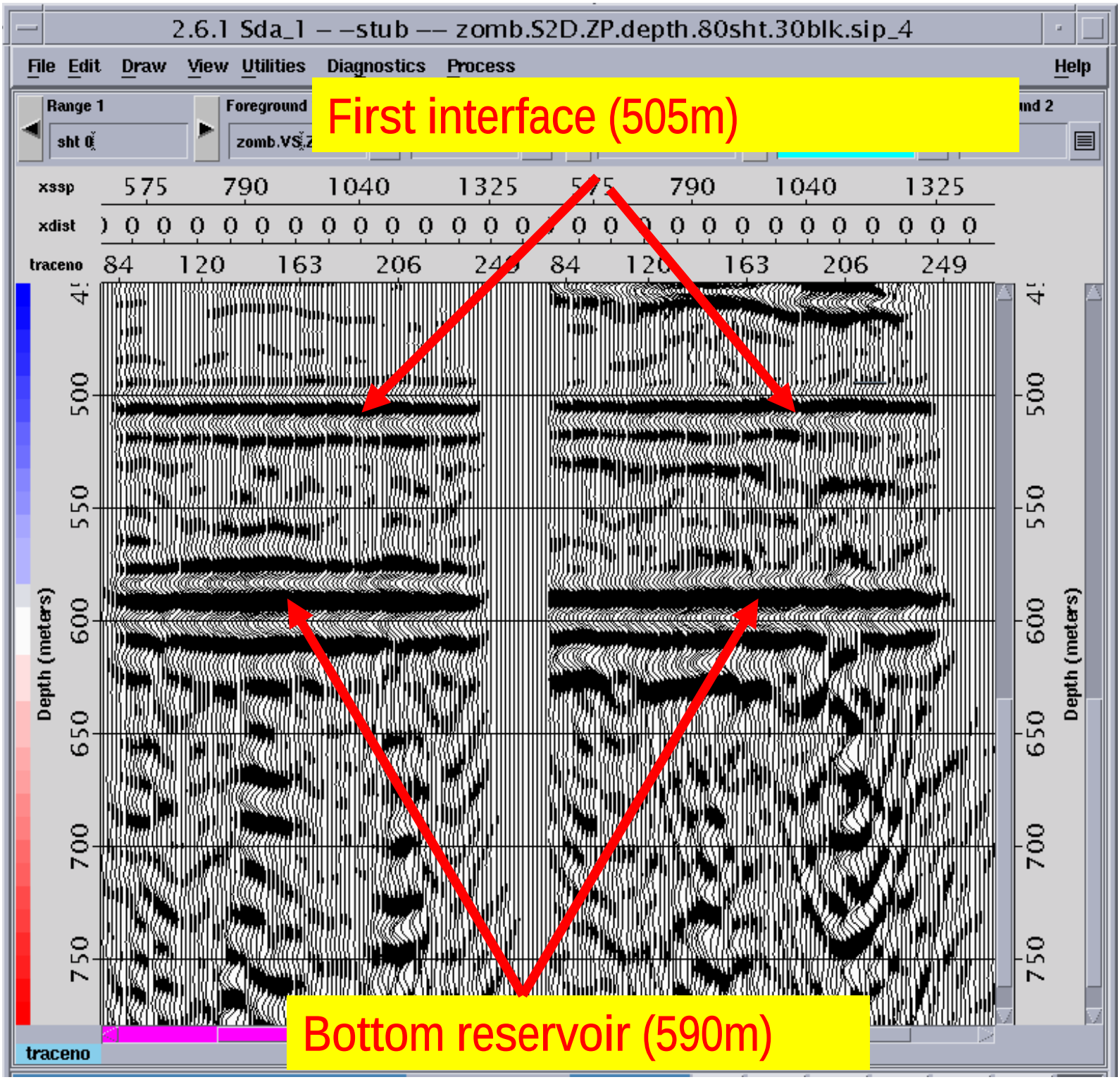
Black – virtual receiver gather, red – real downhole gather



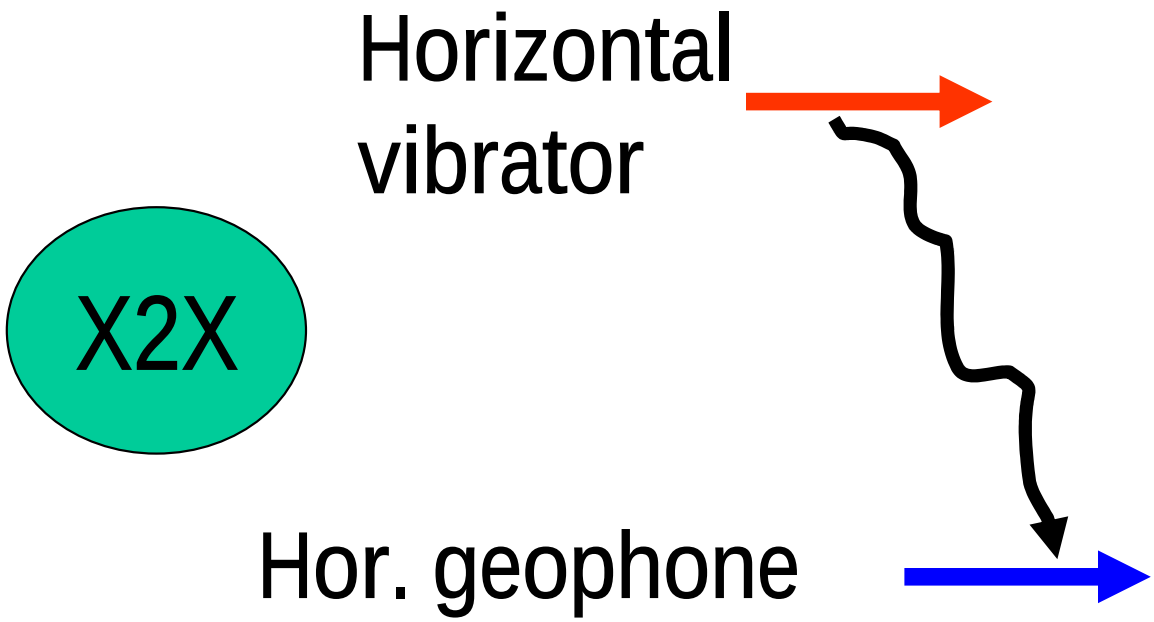
PSDM comparisons

VS data
(aperture 300m)

Surface data migrated with exact velocity model of the overburden

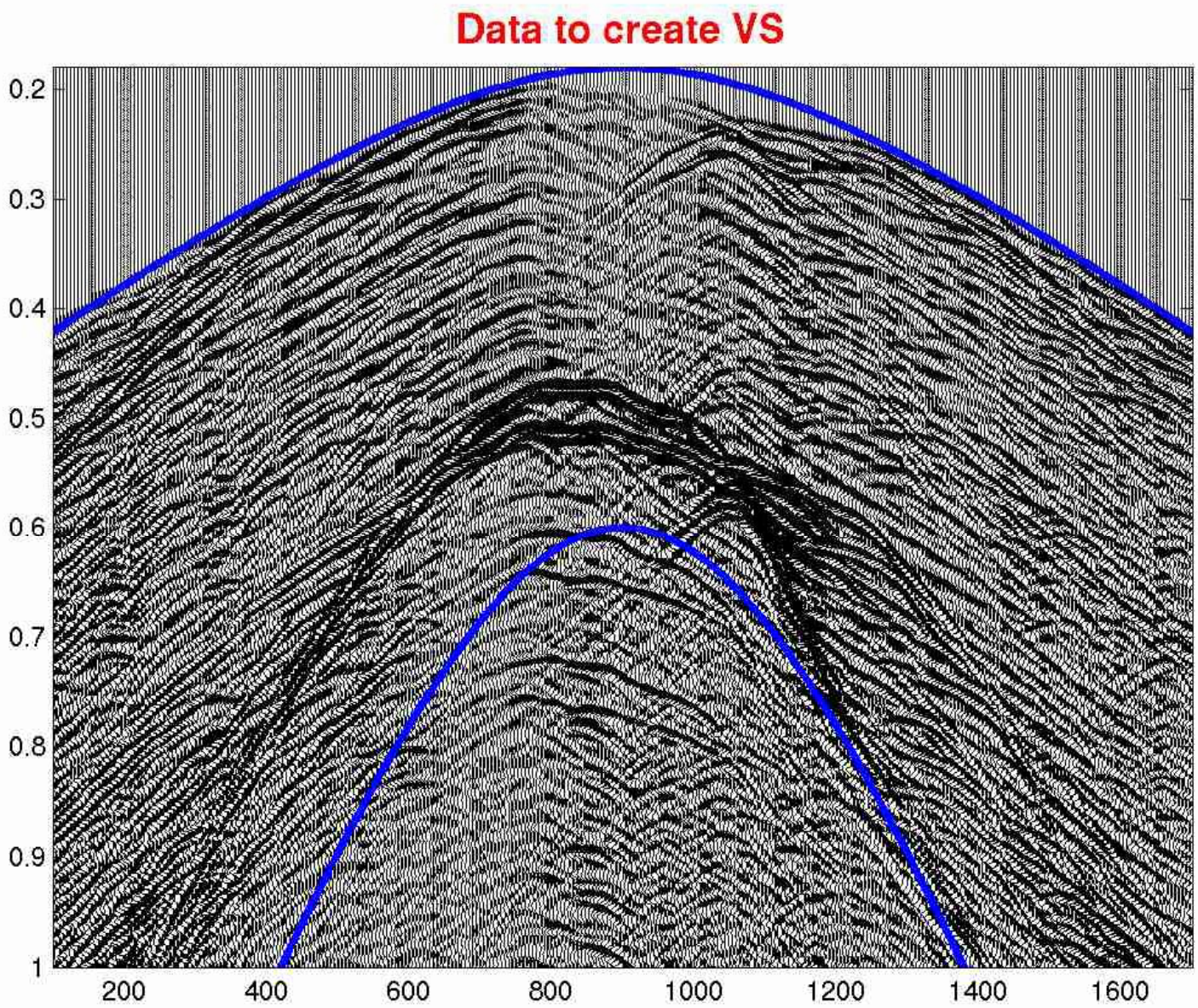


Shear-wave (*SS*) Virtual Source

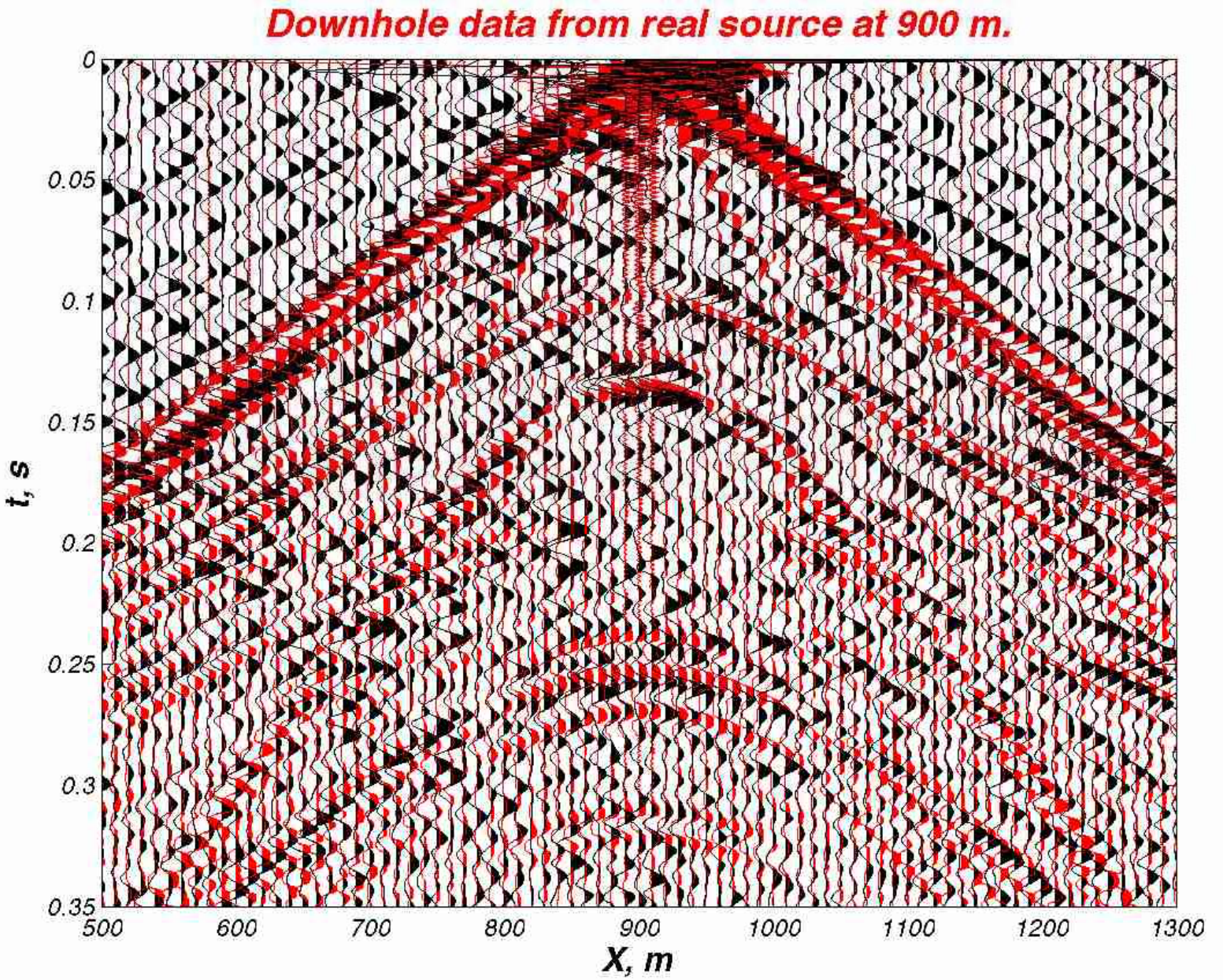


- Test selection of window for time-reversal
- Quality against surface (*SS*) data
- Quality against Virtual Source *P* -wave image

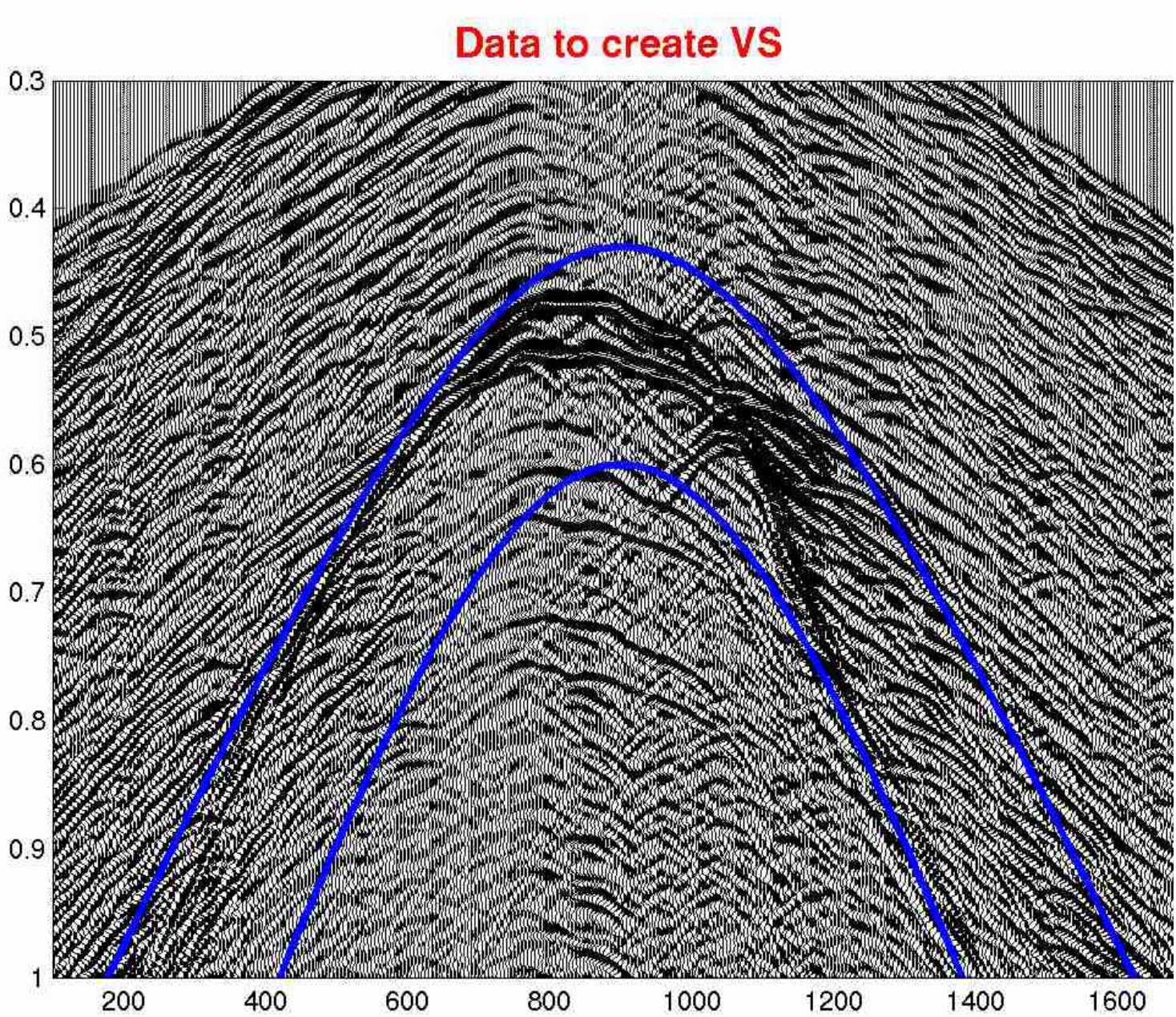
Large window with first arrivals



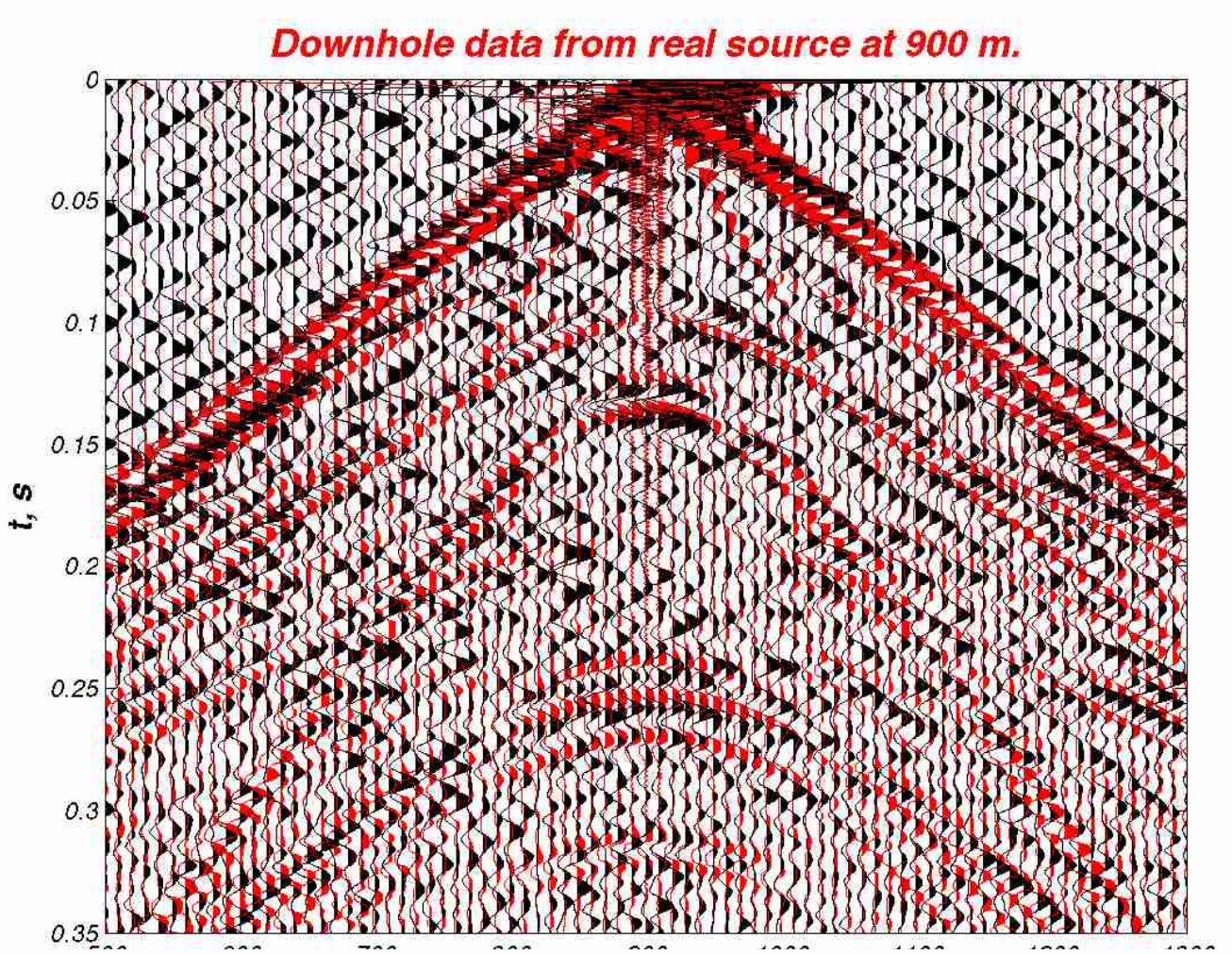
Large window with first arrivals (X2X)



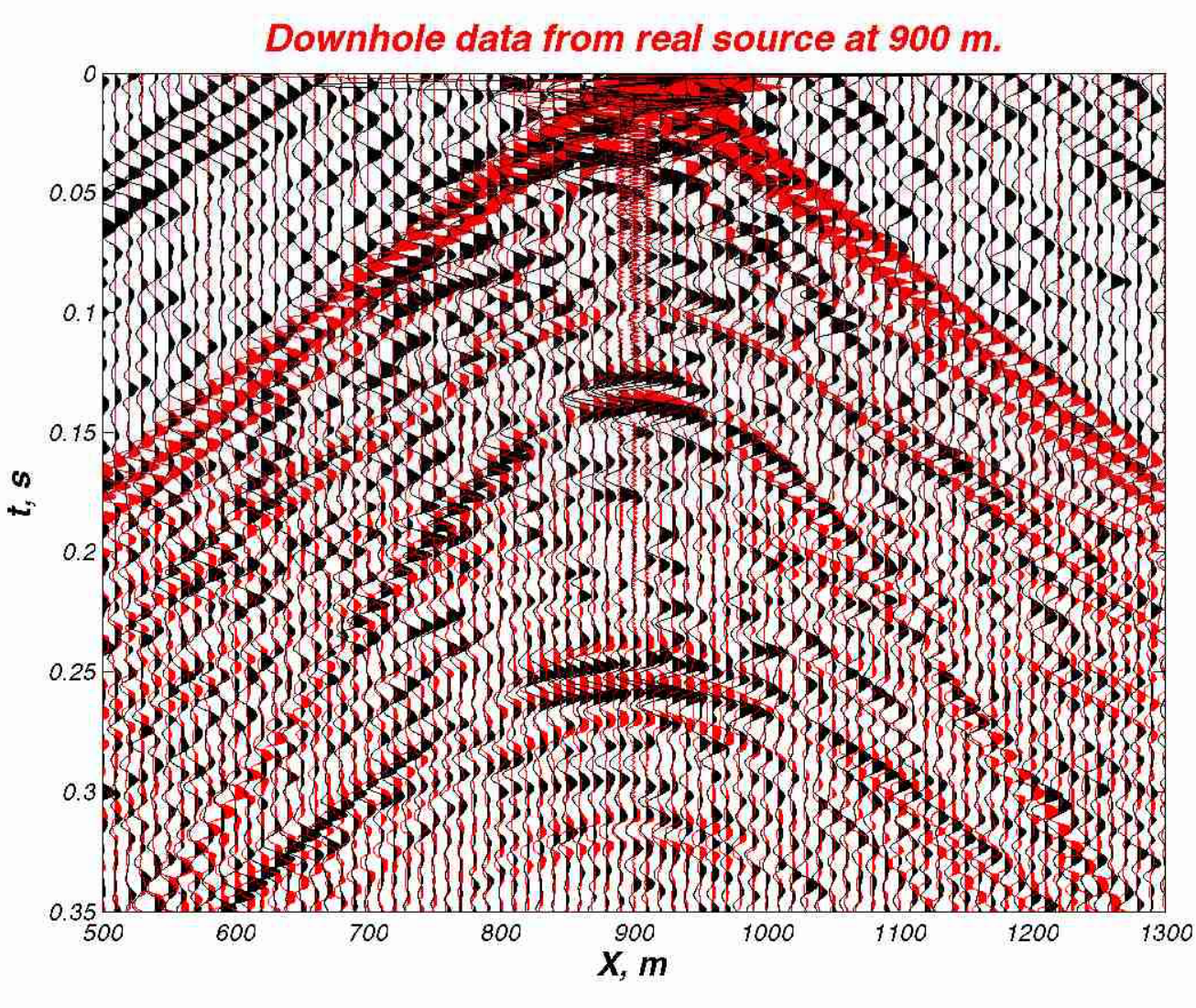
Small window around strongest shear-wave arrival (X2X)



Window with first arrivals



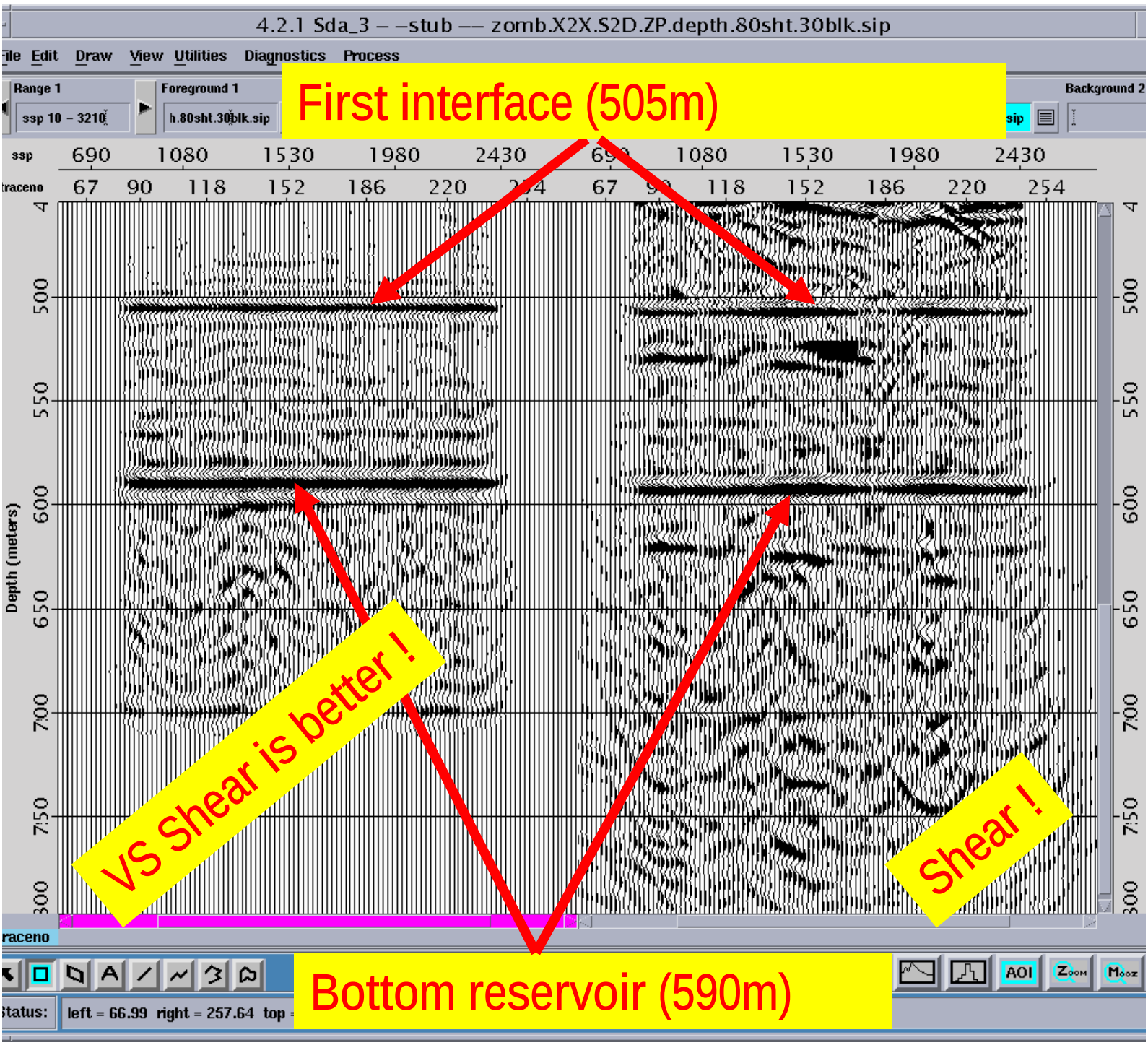
Short window w/o first arrivals



PSDM

VS data
(full aperture)

Surface data migrated with exact velocity model of the overburden

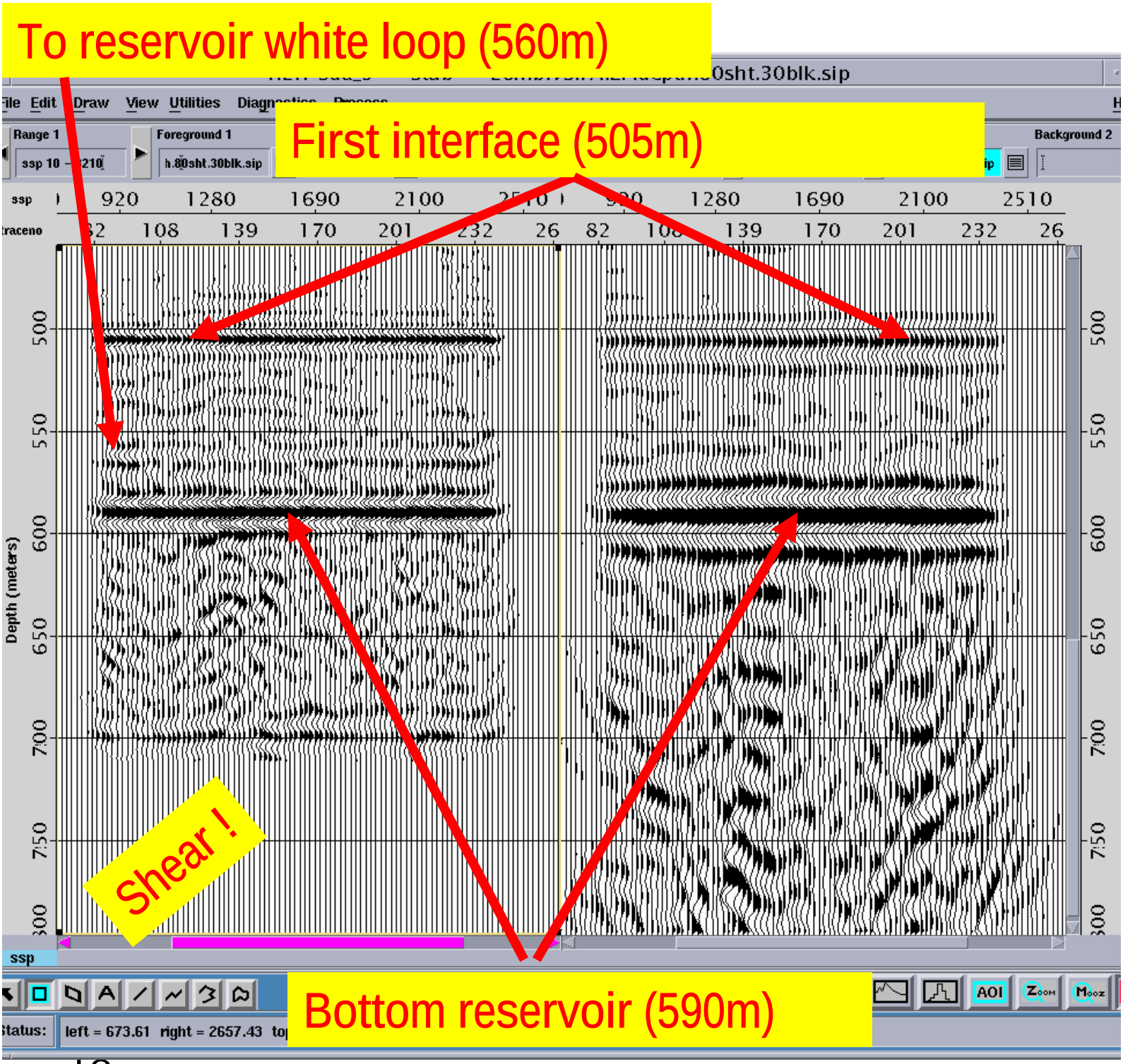


PSDM migration

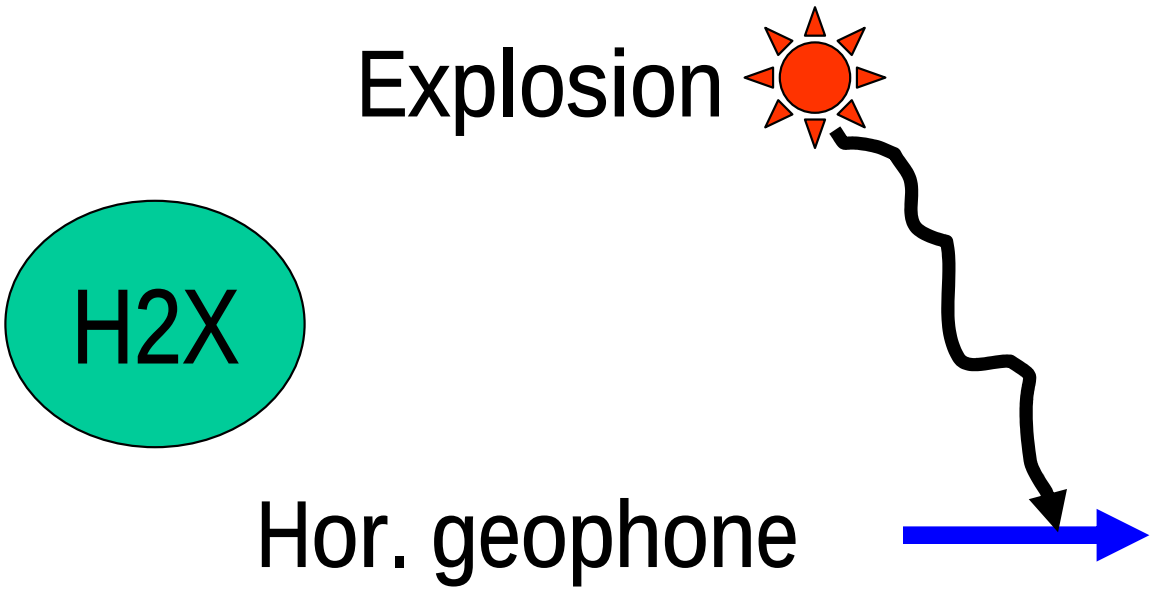
X2X: horiz. force (vibrator) to horiz. component

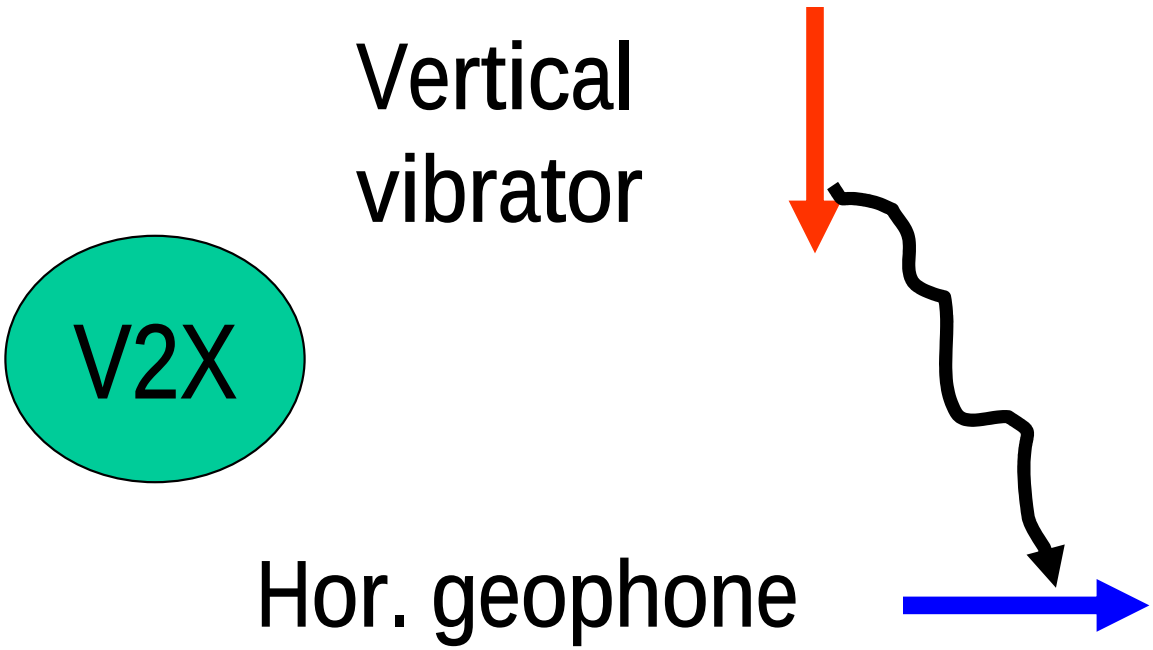
VS *S*-wave image
(full aperture)

VS *P*-wave image
(full aperture)

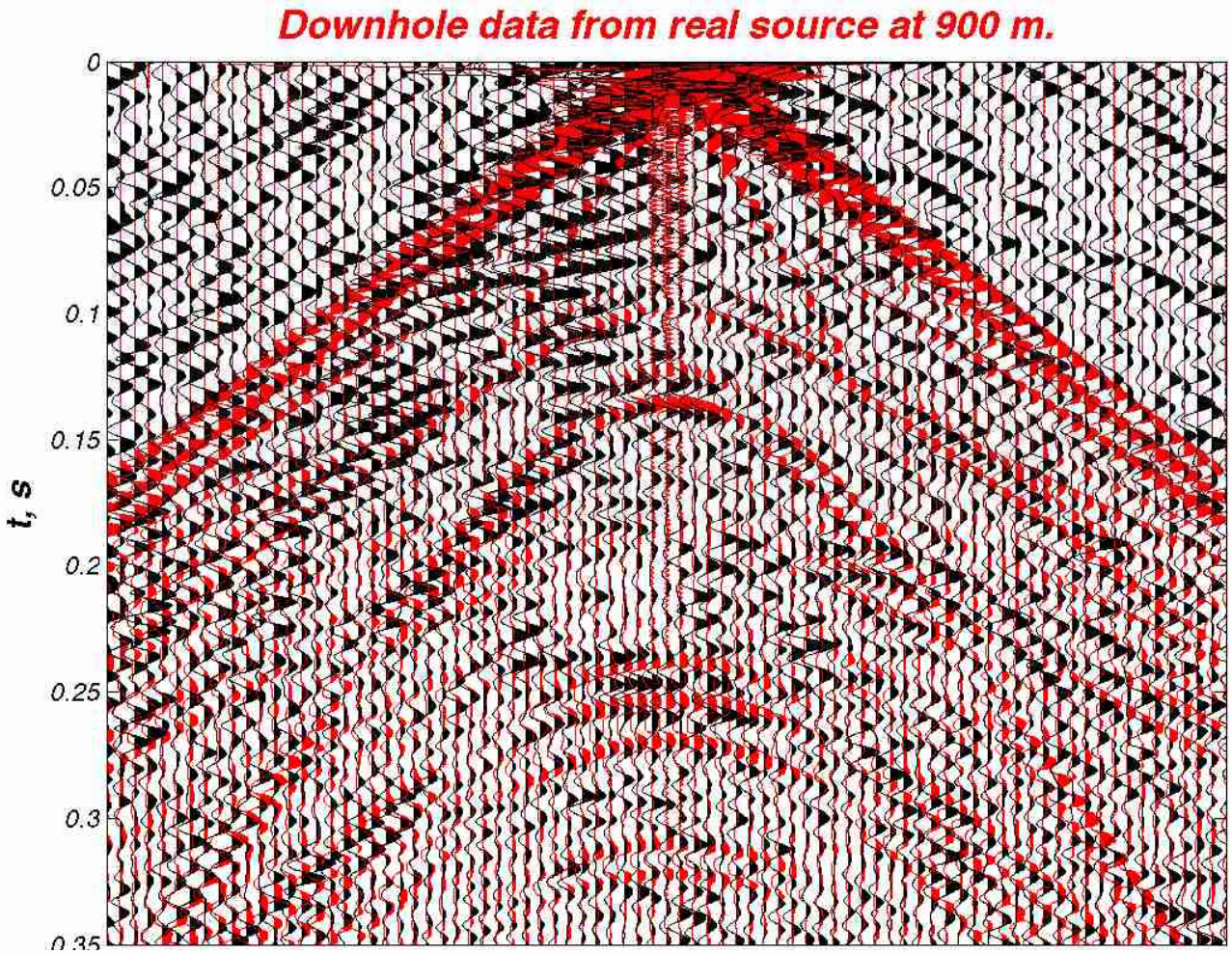


Buy one get one free?

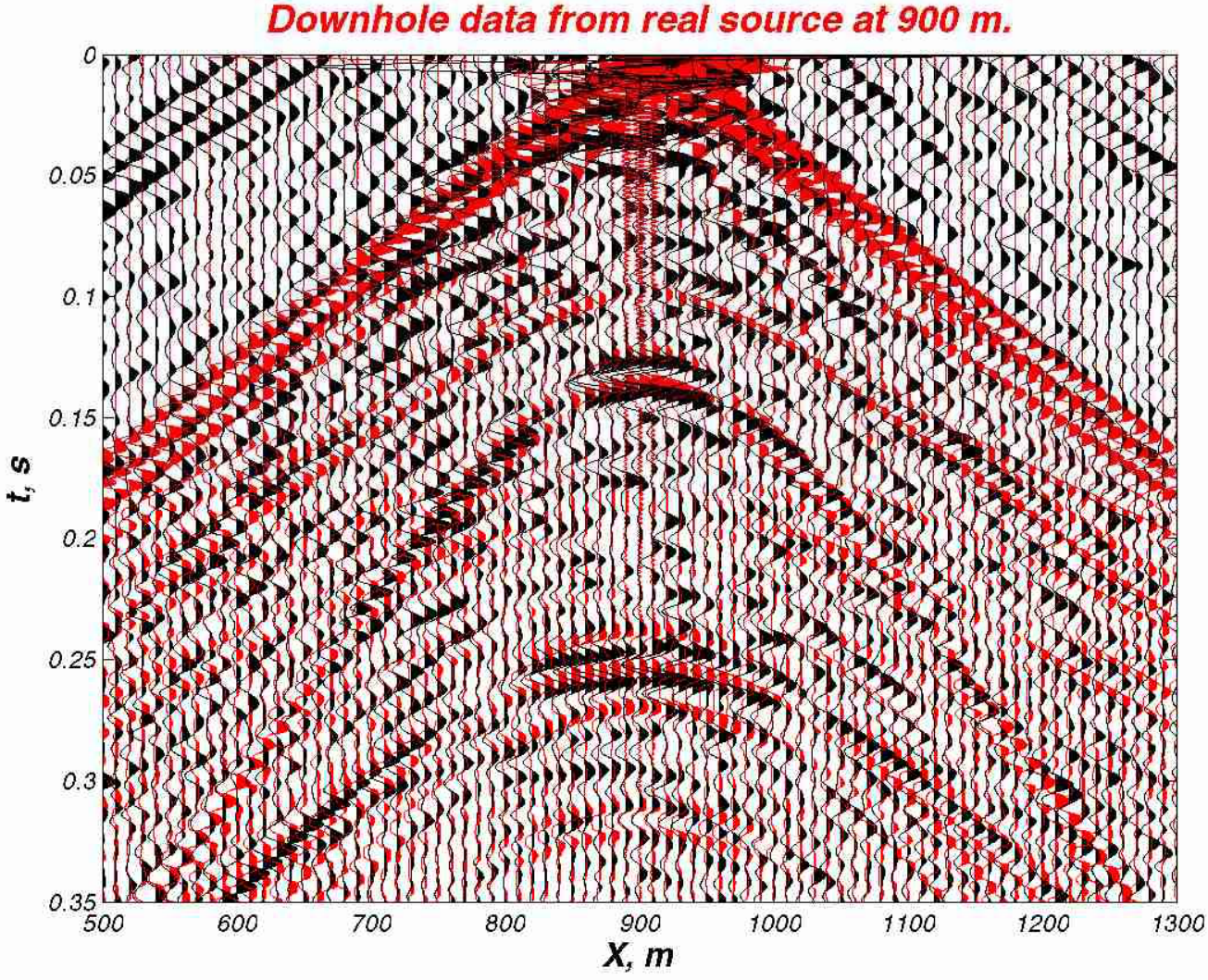




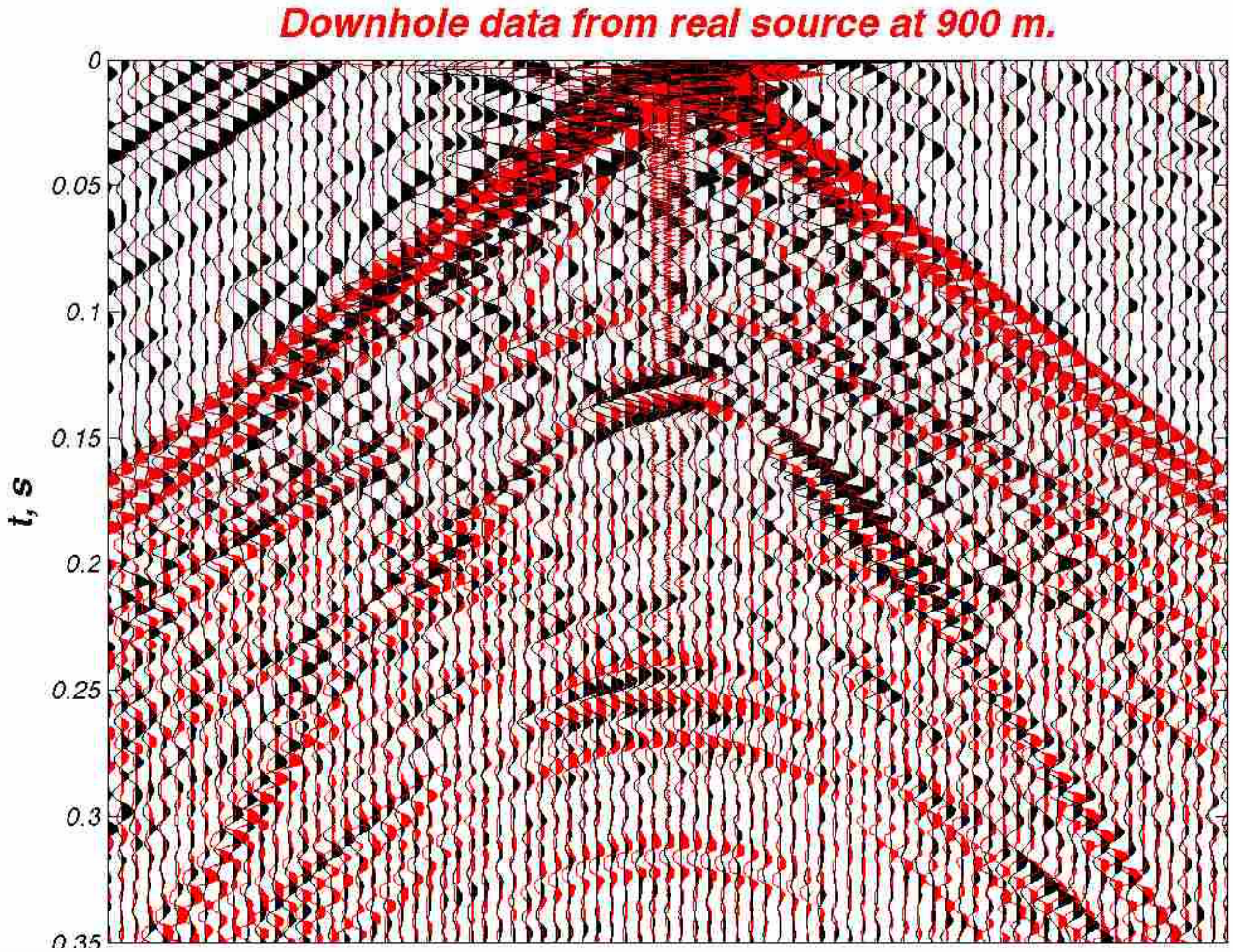
H2X (no first arrivals)



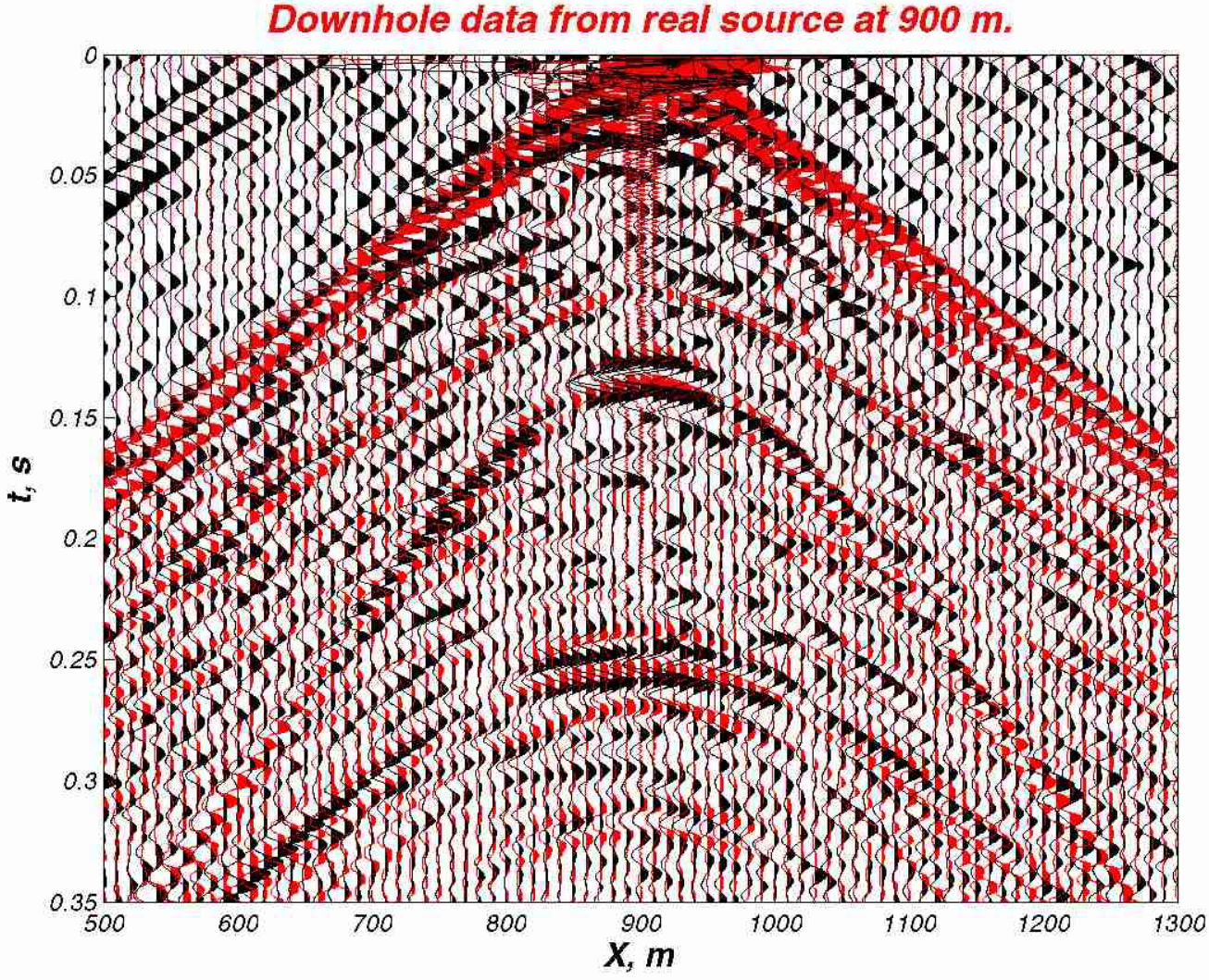
X2X (no first arrivals)



V2X (no first arrivals)



X2X (no first arrivals)



Summary of VS data quality with multicomponent data

Source/Receiver	Explosion	Vert. force	Horizontal force
Hydrophone	Good	Good	Poor
Vertical component	Good	Good	Poor
Horizontal component (inline)	Poor	Poor	Poor

Table 1. Quality of P-wave VS data generated by different sources recorded at various components.

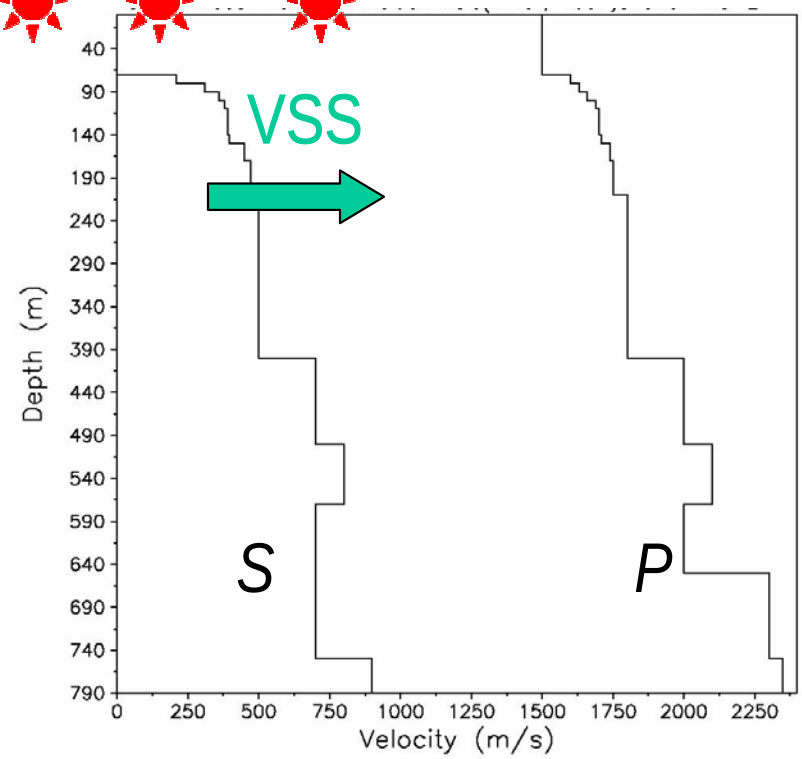
Source/Receiver	Explosion	Vert. force	Horizontal force
Hydrophone	Poor	Poor	Poor
Vertical component	Poor	Poor	Poor-to-medium
Horizontal component (inline)	Poor	Poor-to-medium	Good

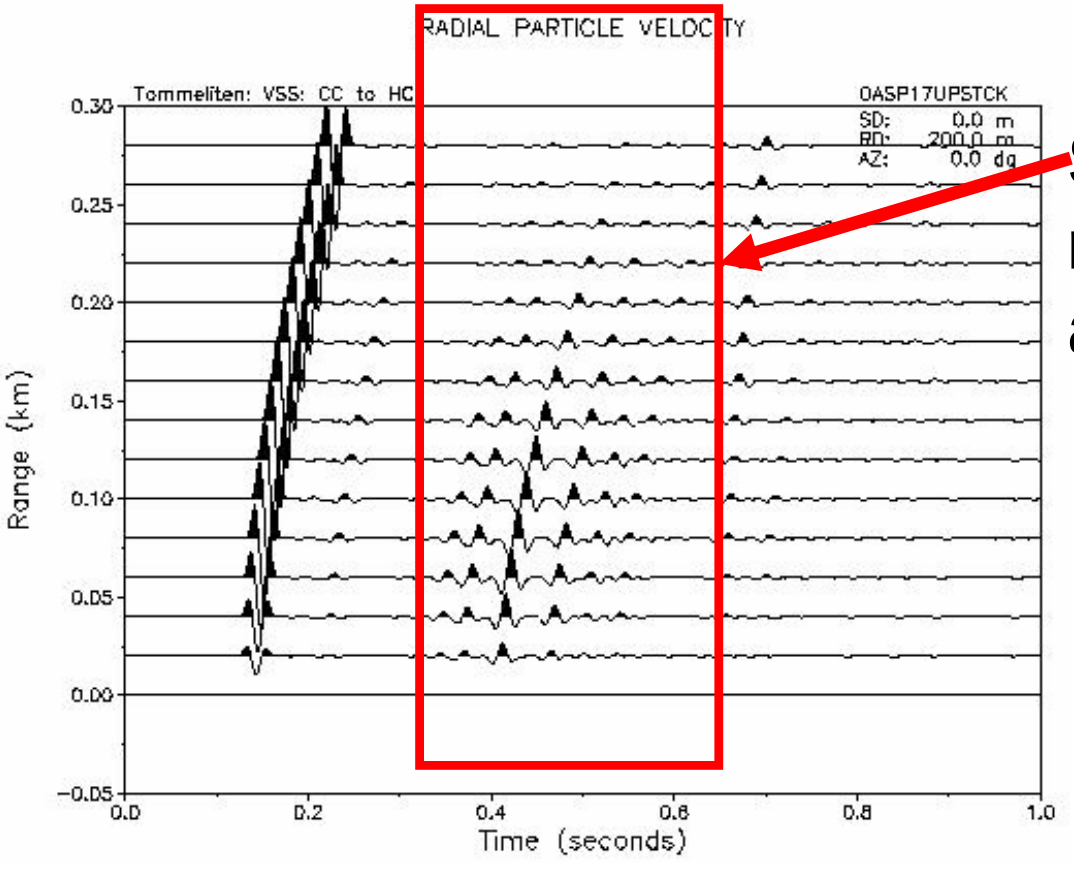
Table 2. Quality of S-wave (SV-wave) VS data generated by different sources recorded at various components.

Shear-wave checkshot with airguns

Airgun array

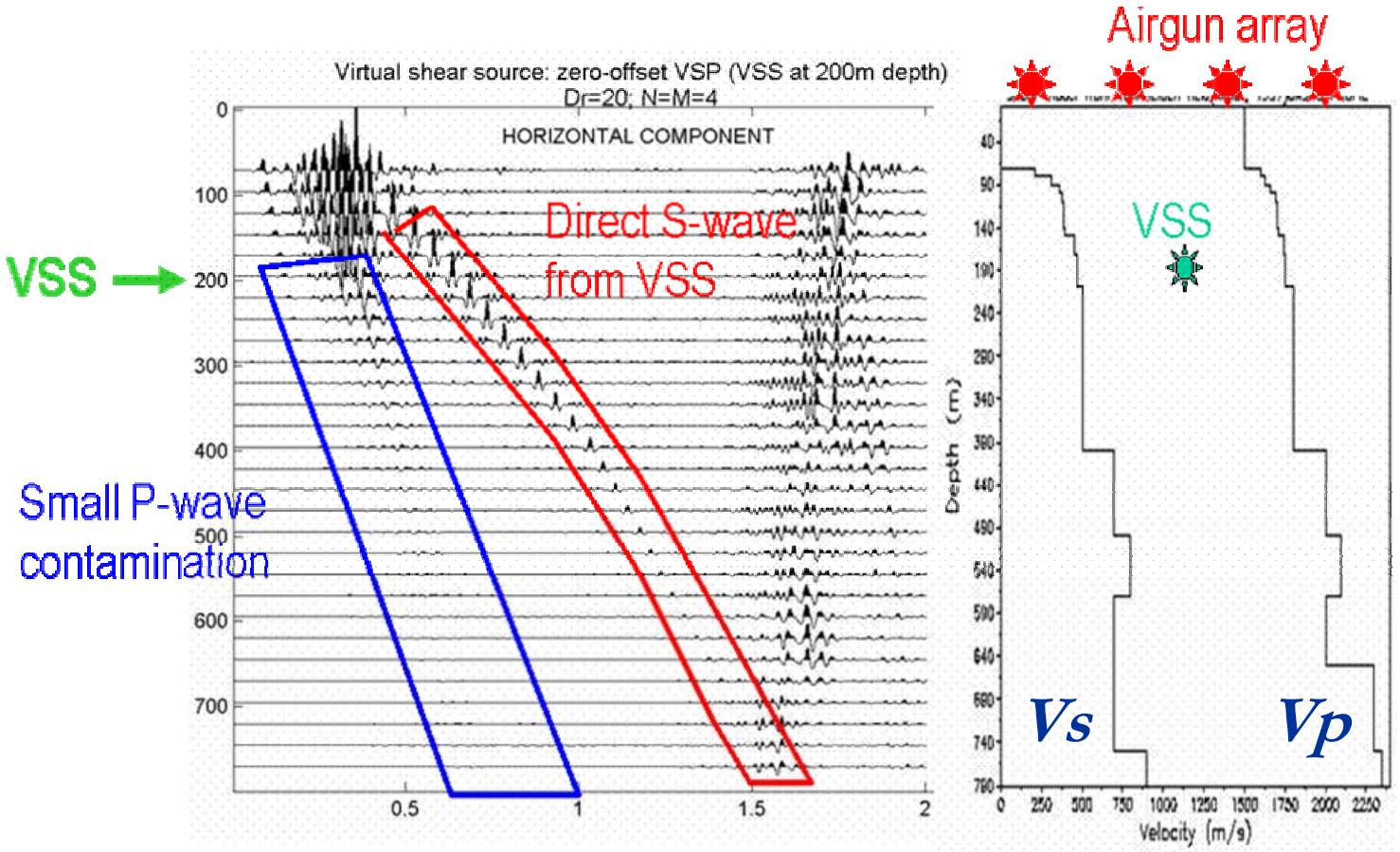
Detailed S-wave velocity model from surface wave inversion on Tommeliten field (North Sea) by Alnor et al. (1997)



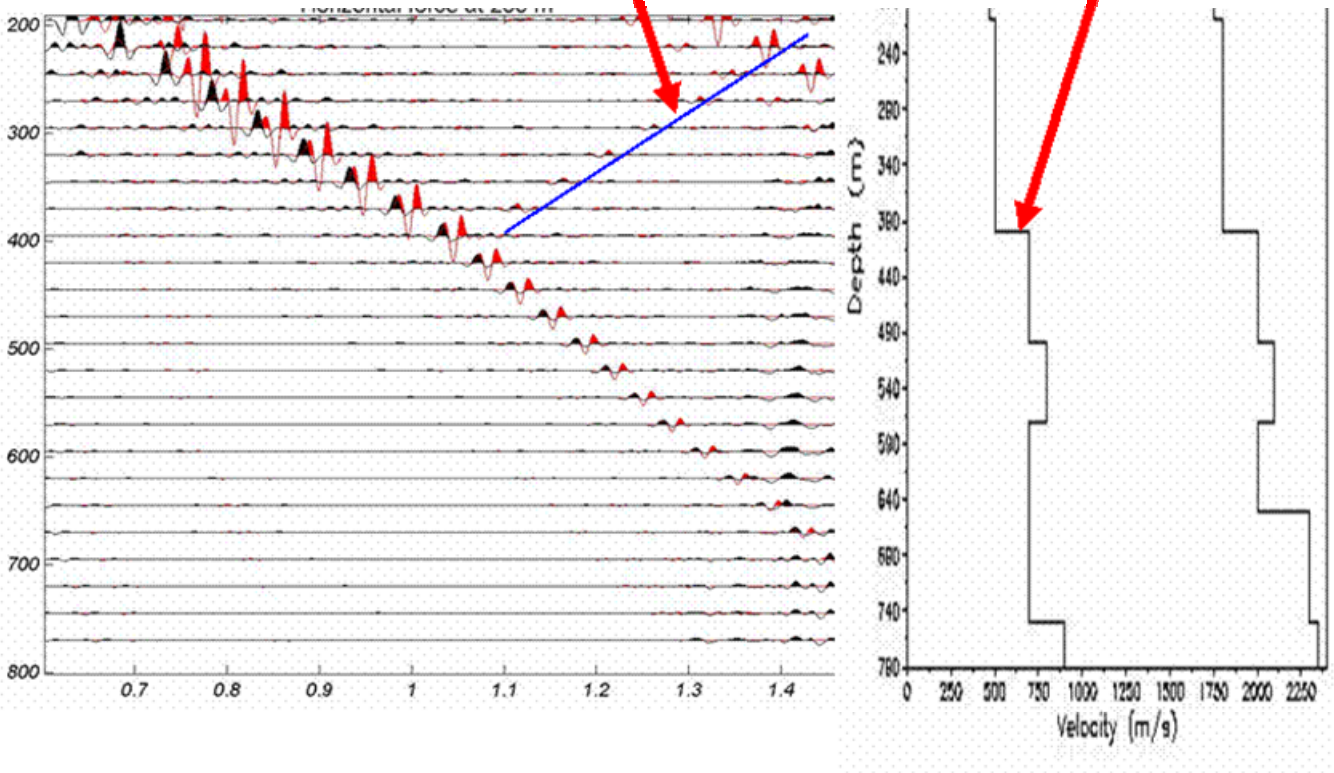


Signal to time-reverse and send back

Shear-wave checkshot with airguns



Upgoing reflection from 400 m interface



Want to know more?

Virtual Shear Source

- New method for imaging/monitoring below very complex near surface using downhole geophones
- Can handle any complexity of near surface (no velocity model required)
- Automatically takes care of regular and 4D statics and changes in the near surface
- Better image than surface *SS* seismic (even with known velocity model!)
- Comparable image with Virtual Source *P* –waves
- Shear-wave checkshot is possible with *P* -wave sources
- May relax requirements for exact repeat of surface shots positions for 4D

Conclusion regarding generation of pure shear-wave data

- VS shear data (*SS*) can be obtained using recorded horizontal component and ALMOST any type of source:
  - Horizontal force (horizontal vibrator) – best quality data similar to P-wave results
  - Vertical force (vertical vibrator) – reasonably good quality – need to handle polarity reversals
  - Explosion source – poor data but still possible
- Key learnings:
  - need to include window where *SS* energy arrives
  - need to exclude window around first *PP* arrivals