Extracting more information from Rig source VSP

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TOTAL

Innovation Energie Environnement

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OUTLINE

I. Additional info from rig source VSP direct arrival

II. Mud filtrate microseismic infiltration noise

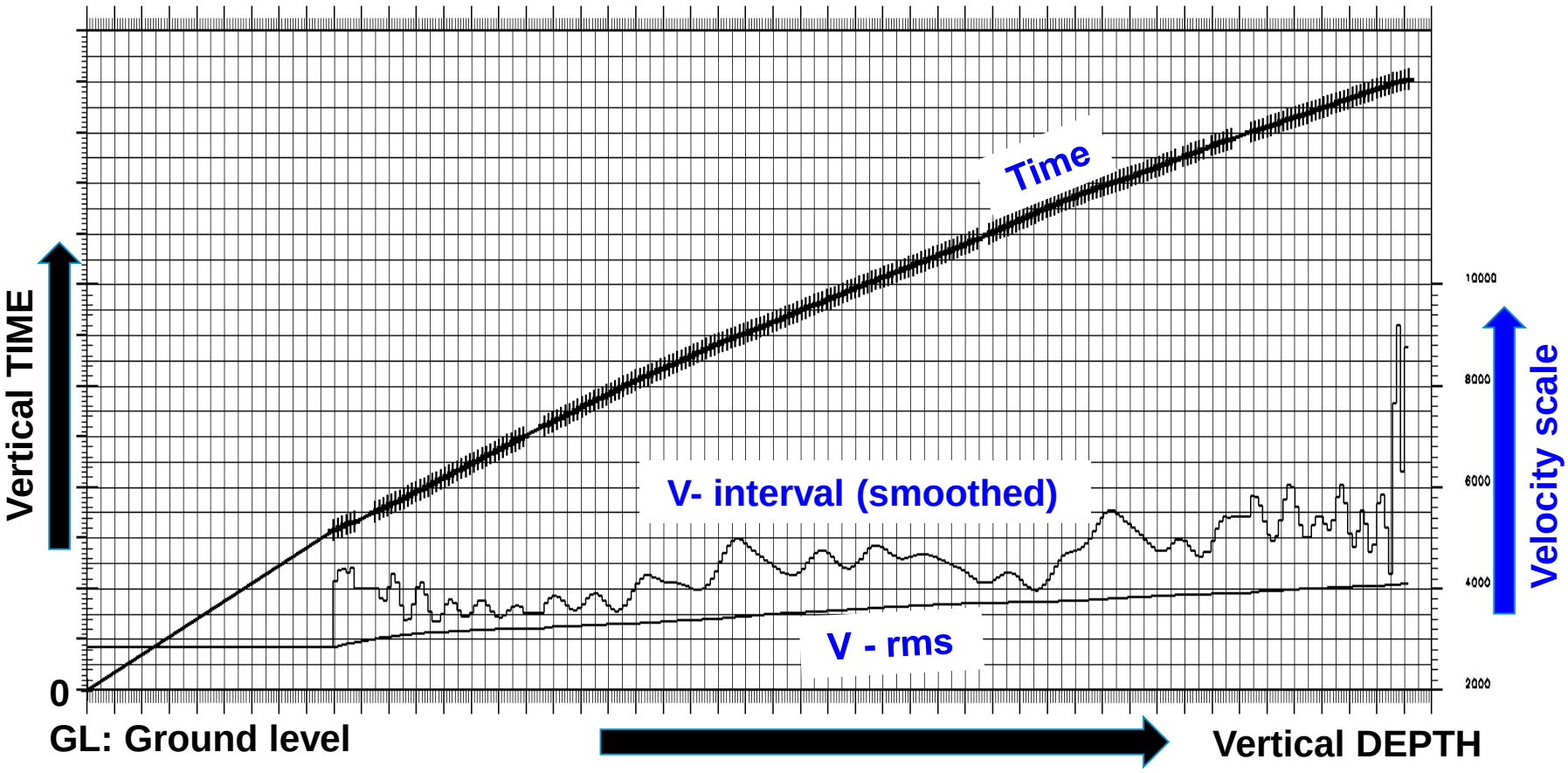
III. Condition for deconvolution of multipath direct wavetrain in borehole seismic.

IV. Conclusion, discussion

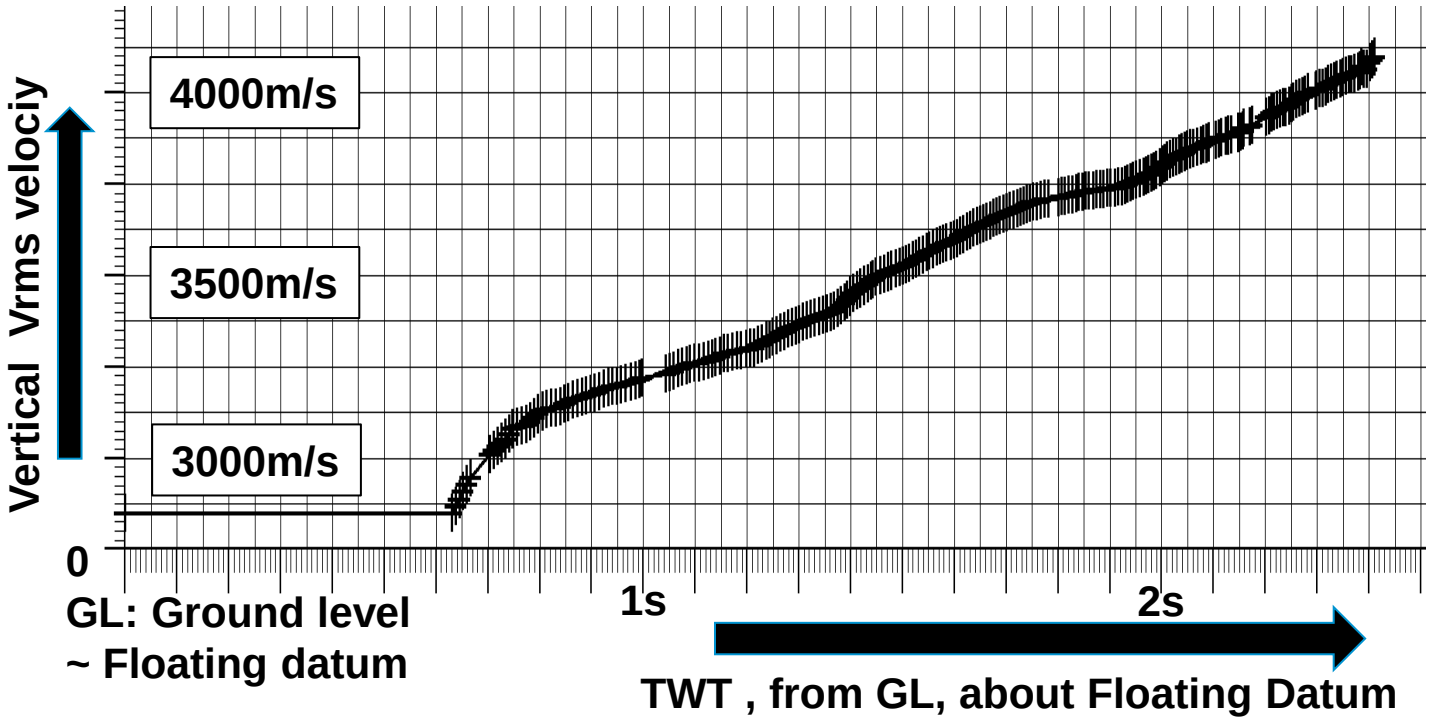
Additional info from rig source VSP direct arrival

- Desired Vrms and Divergence outputs to facilitate surface seismic processing calibration and QC:
  - Vertical Vrms at **Two way time** scale, in addition of time and velocities versus depth.
  - Spherical divergence factor V^2T at **Two way time** scale, Log crossplot to estimate the exponent n of the to T^{**n} divergence relashionship.

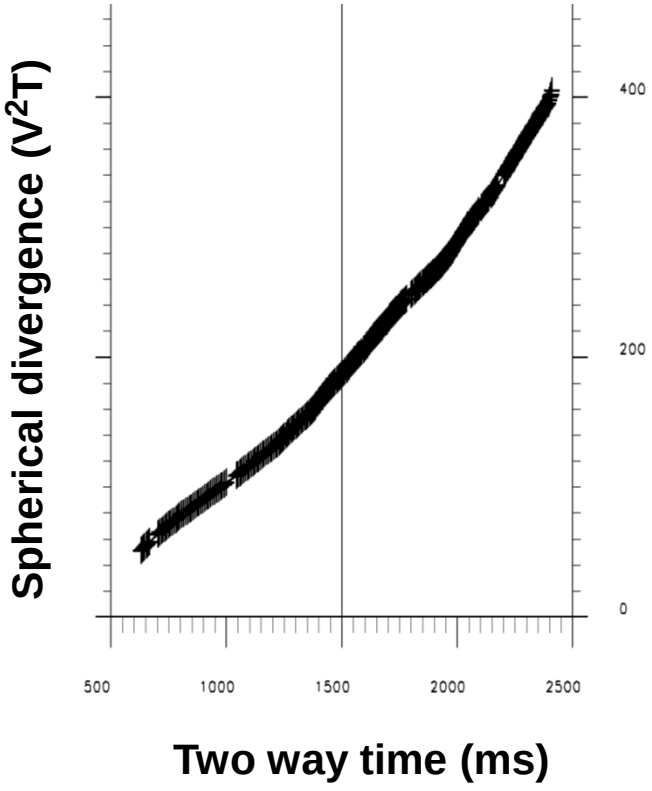
Conventional VSP output, from Ground Level origin: Time vs Depth and Interval velocity, Vrms vs Depth

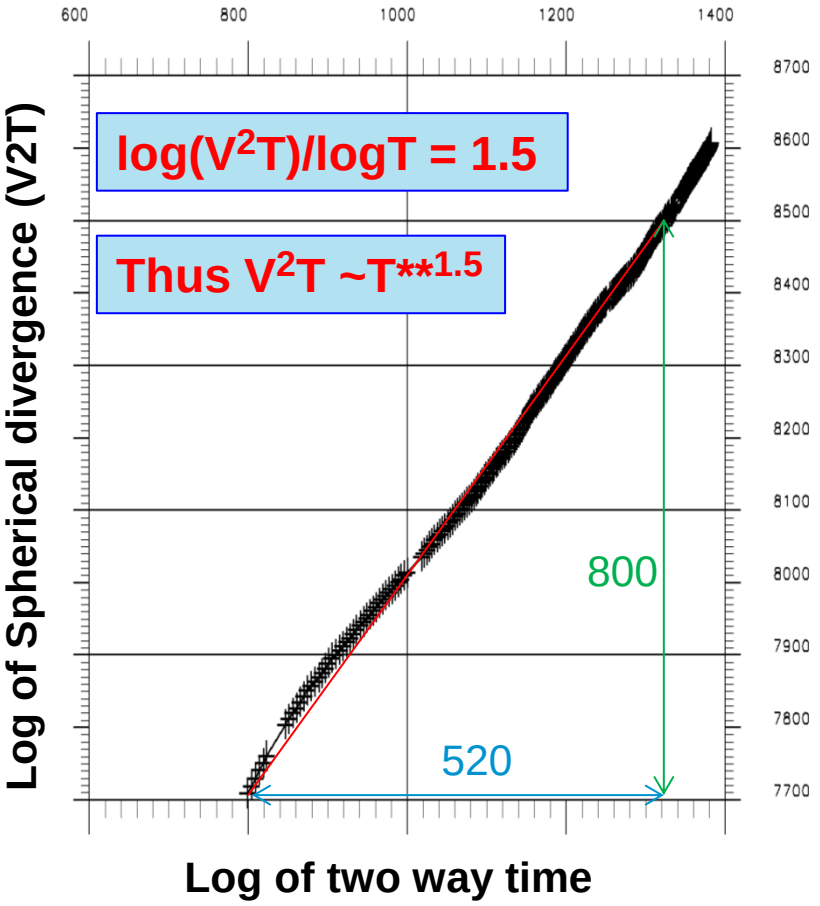


Desired VSP Outpout : Vrms versus TWT



Desired VSP Outpout : Linear & Log-Log crossplots of Spherical Divergence V^2T versus time TWT.





OUTLINE

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Mud filtrate microseismic infiltration noise

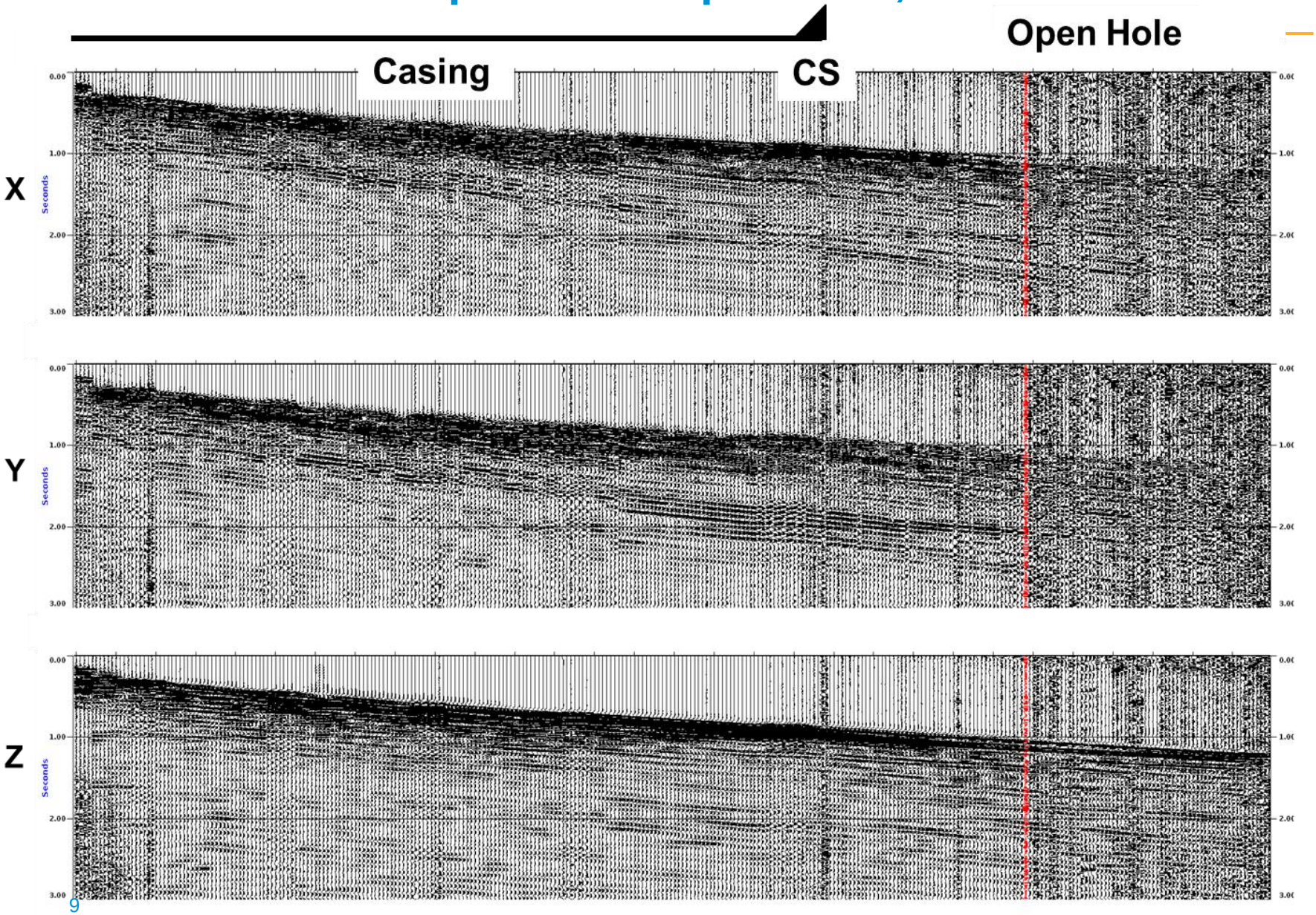
When noise appears at certain VSP depth stations on the standard vertical stack correlated VSP records, with or without edition before stack, investigating the noise origin may be necessary.

- A copy of uncorrelated raw records, SEG-Y format, labelled with all ancillary info in trace headers (RB sensor angles, caliper, anchoring force.. , borehole geometry) , was requested from the VSP field service company for in depth analysis.

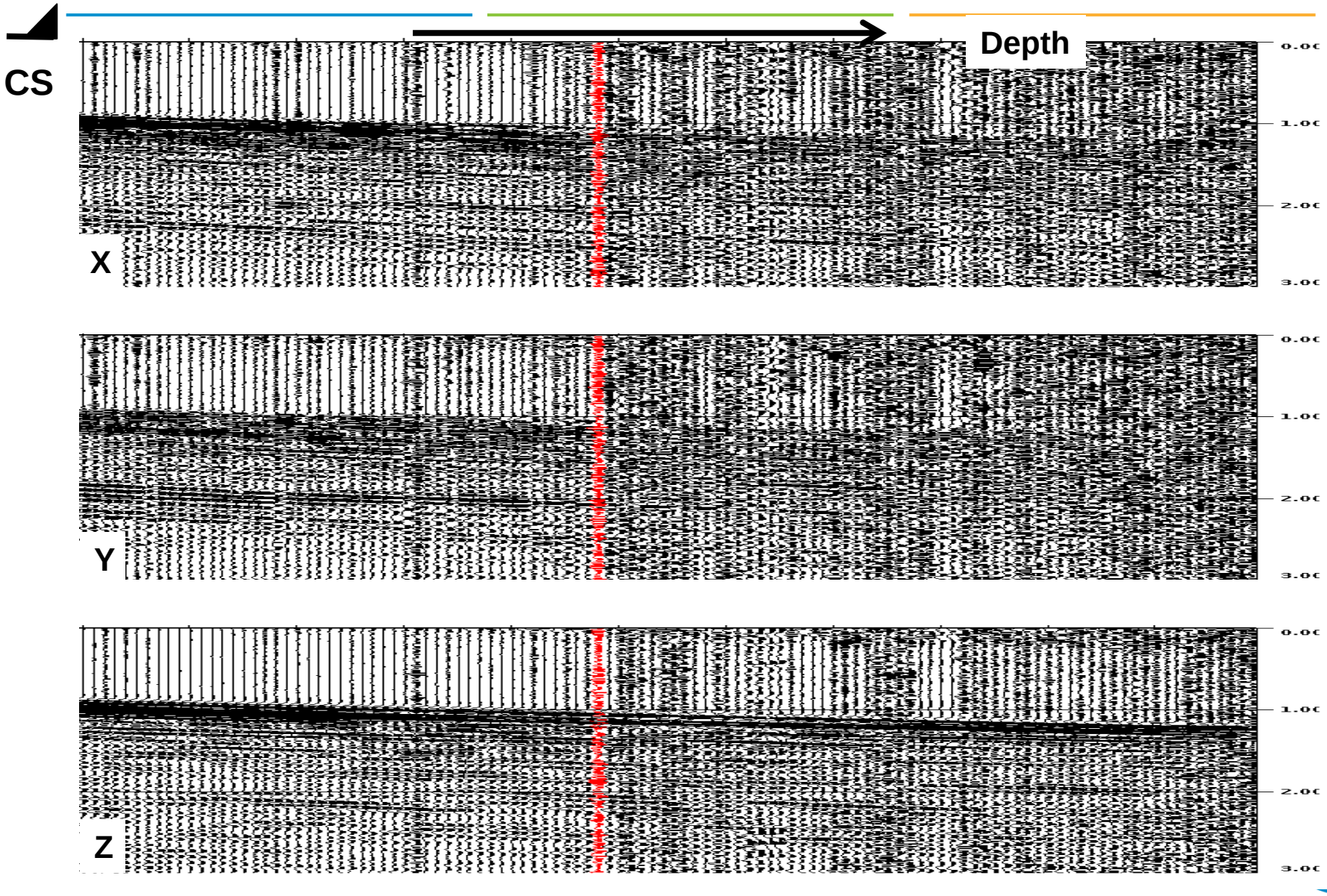
- Noise bursts can be easily eliminated by various stacking procedures BEFORE correlation, but the presence of permanent, continuous noise of variable amplitude remained. Thus the seismic noise polarization was analysed from the raw 3C unit records, before direct arrival and beyond. The continuous noisy levels are all located in the open hole interval.

- The analysis concluded to the presence of linear microseismic noise induced by mud infiltration into the formation. In the present case, during VSP acquisition and wireline logging, mud was continously added into the borehole by the driller in order to maintain the downhole pressure (*detail not reported in the VSP field acquisition report*).

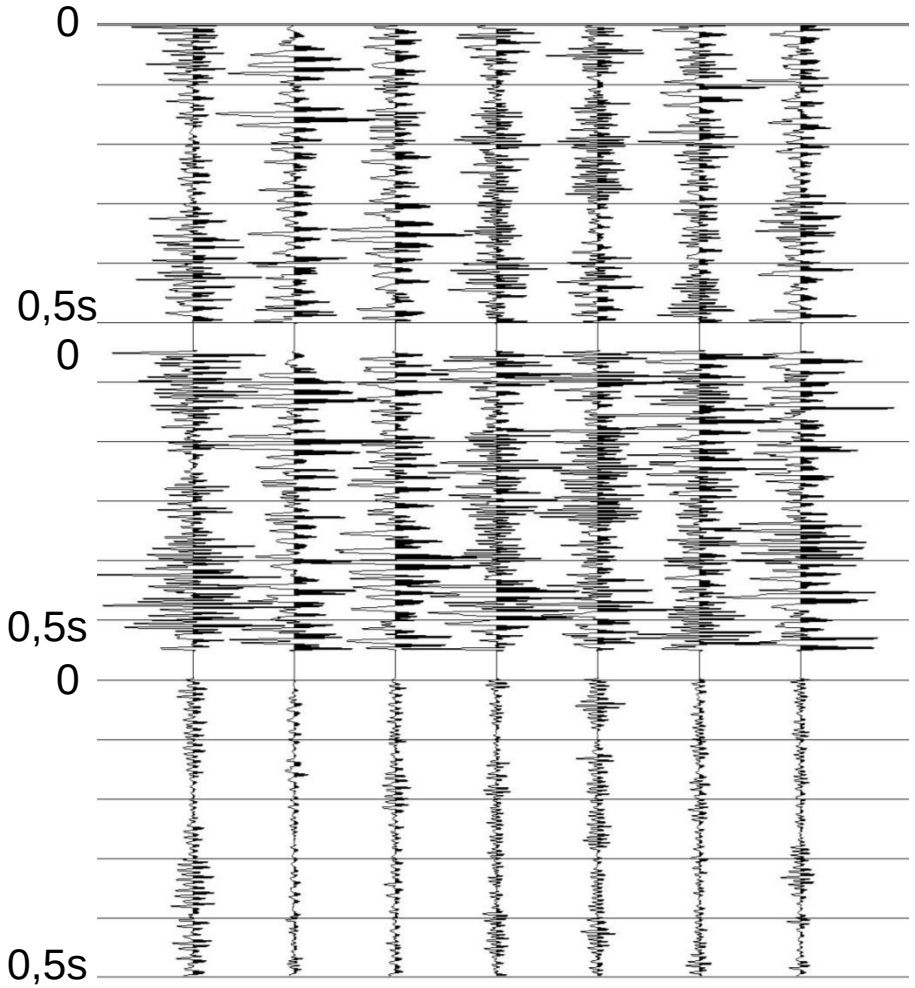
ZVSP raw stacks correlated (no edition): **the noise level increases with depth in the Open Hole; less noise on Z**



ZVSP raw stacks correlated (no edition): 3C display in the **Open Hole section ONLY.** Focus at a noisy level in **red**



ZVSP uncorrelated data: at red depth station. 7 vibroseis unit records, Time window 0 - 500ms BEFORE direct arrival, true amplitude 3C display

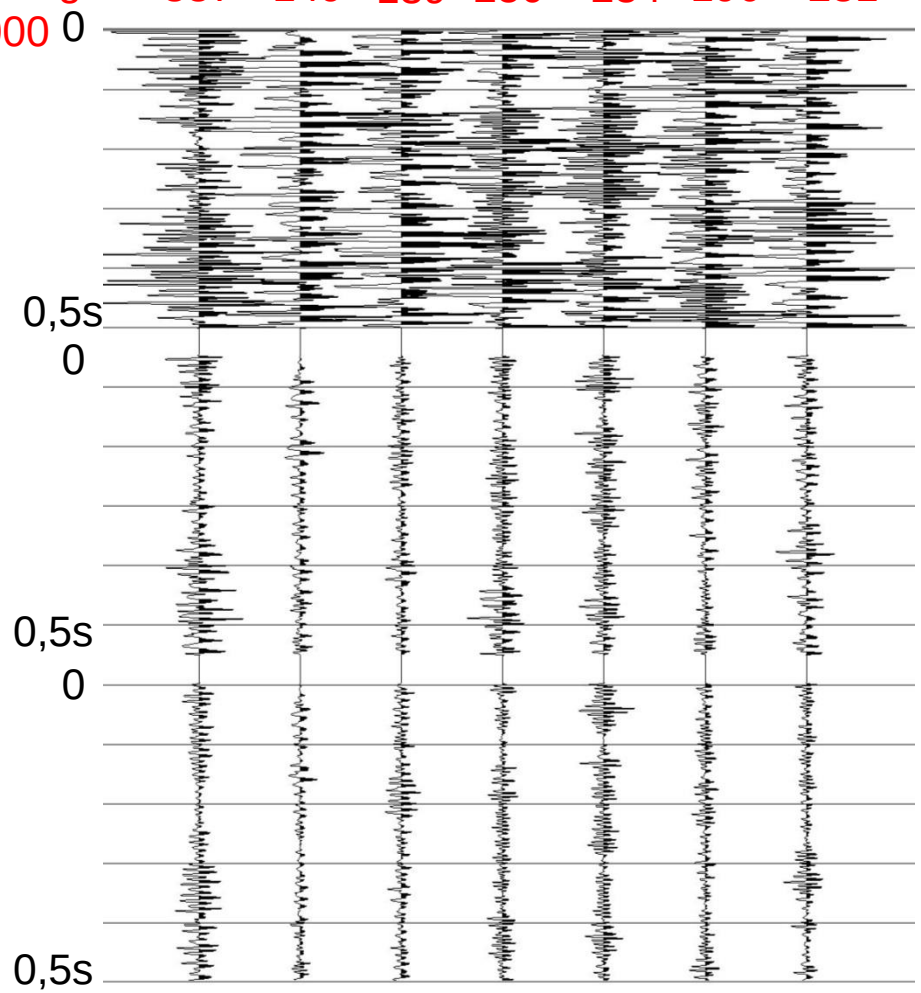


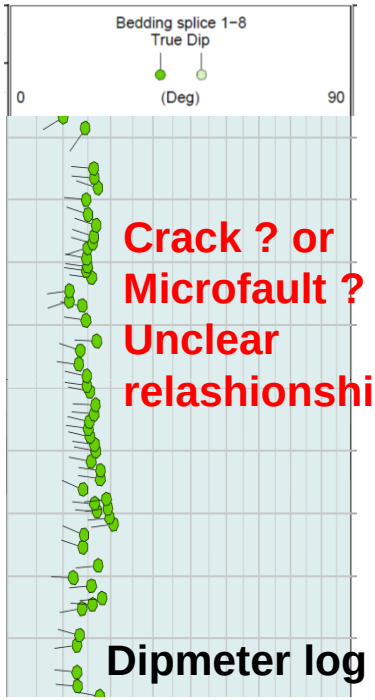
PERMANENT fluid flow microseismic noise is recorded during VSP acquisition. The noise is mostly present on components X,Y radial to the well axis

ZVSP uncorrelated data: time window 0 - 500ms at red depth station after rotation in the maximum polarization direction. True amplitudes

HMX angle (°) 123 123 123 120 120 122 117° (Azimuth of permeability)

Scattering x 1000 337 149 139 250 234 190 231

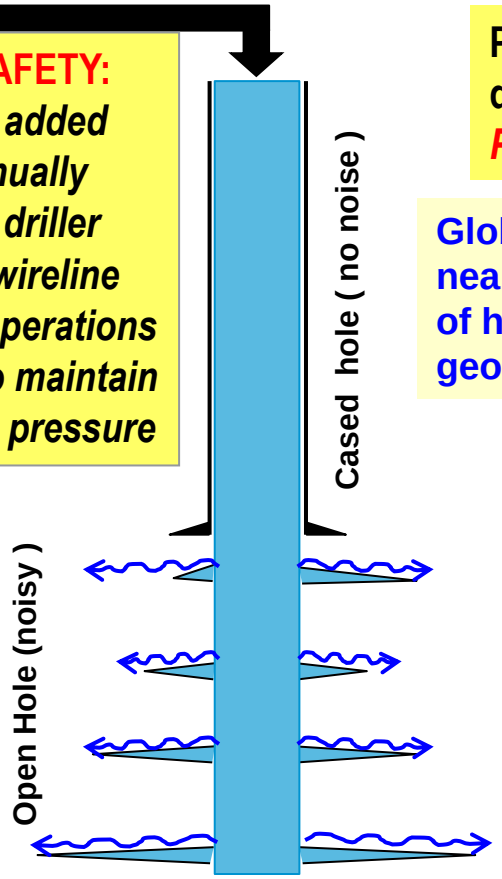




PERMANENT fluid flow microseismic noise appears fairly linearly polarized, and difficult to attenuate

Heavy mud Infiltration NOISE in the Open Hole section, may damage the VSP processing results.

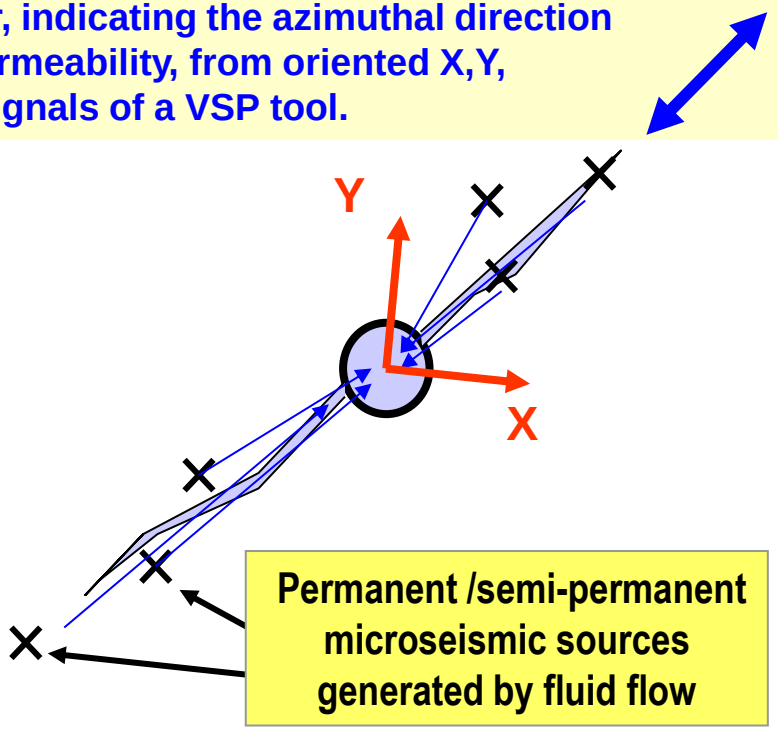
Hole SAFETY:
Mud is added continually by the driller during wireline logging operations in order to maintain downhole pressure



Amplitude of Infiltration Noise in the open hole INCREASES with DEPTH

PERMANENT fluid flow microseismic noise is recorded during VSP acquisition. Sketch of principle.
Proposal: Decrease the depth spacing at VSP acquisition

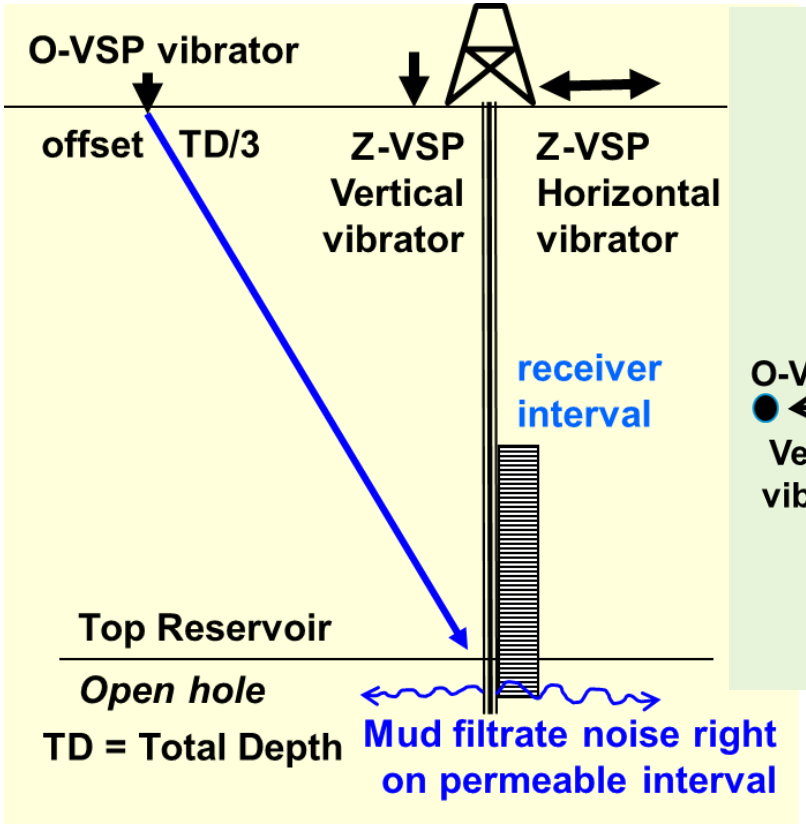
Global particle motion of the microseismic fluid flow noise, nearly linear, indicating the azimuthal direction of higher permeability, from oriented X,Y, geophone signals of a VSP tool.

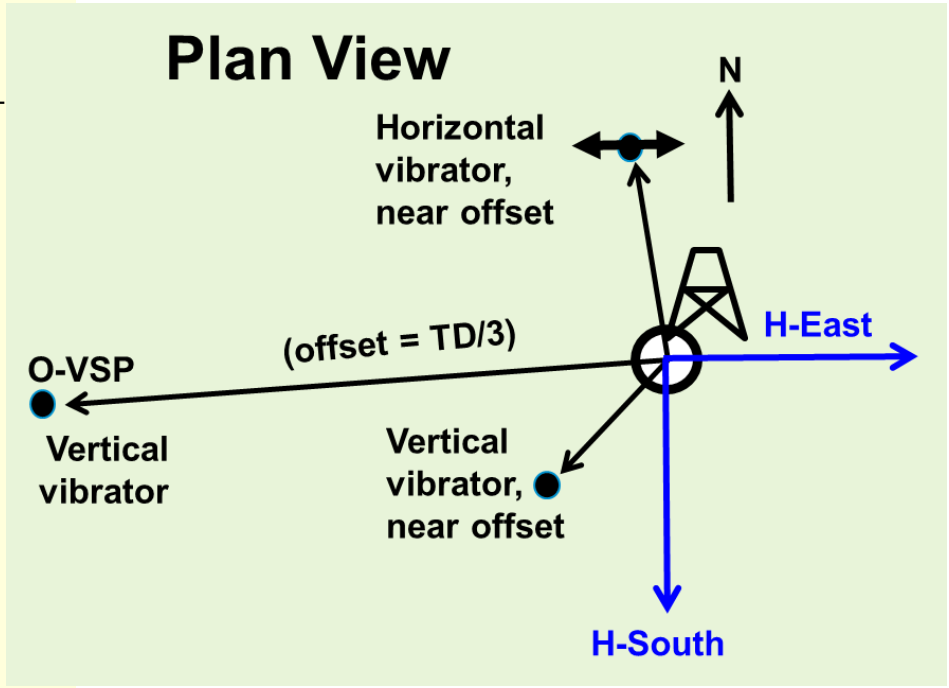


Permanent /semi-permanent microseismic sources generated by fluid flow

Observation of mud Infiltration NOISE in the Open Hole reservoir interval, Dogger formation, Paris Basin VSP, 1986.

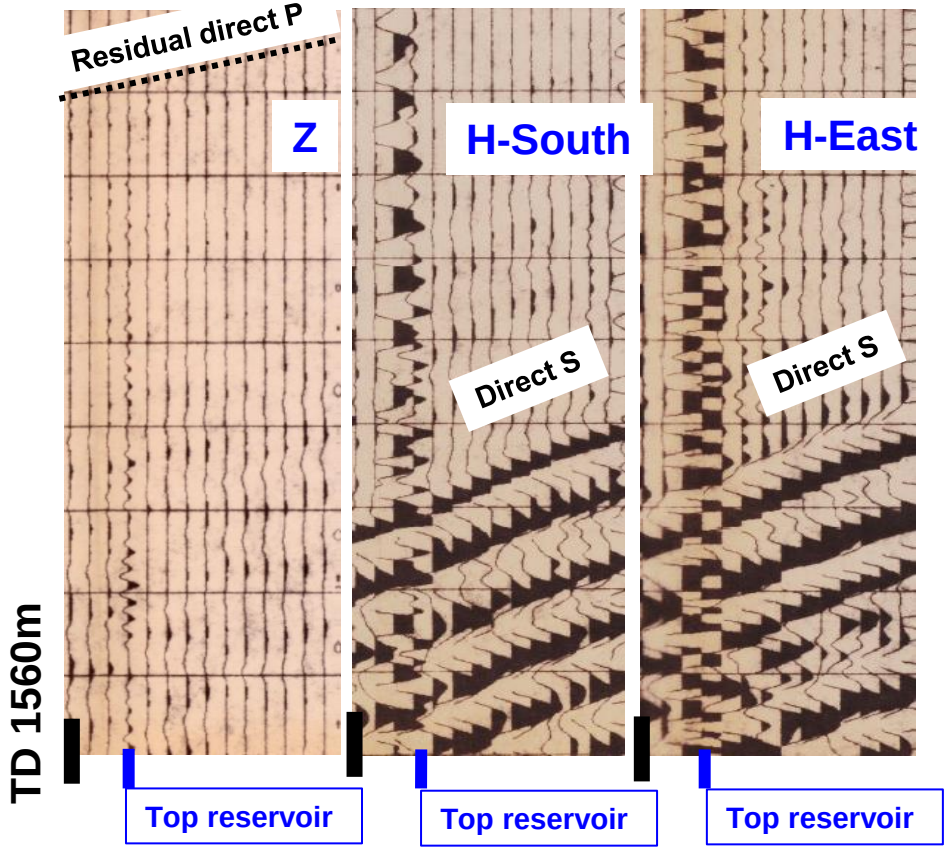
Single run VSP , vertical well , vertical and horizontal vibrators at near zero-offset, + Offset vibrator to derive horizontal component orientation.

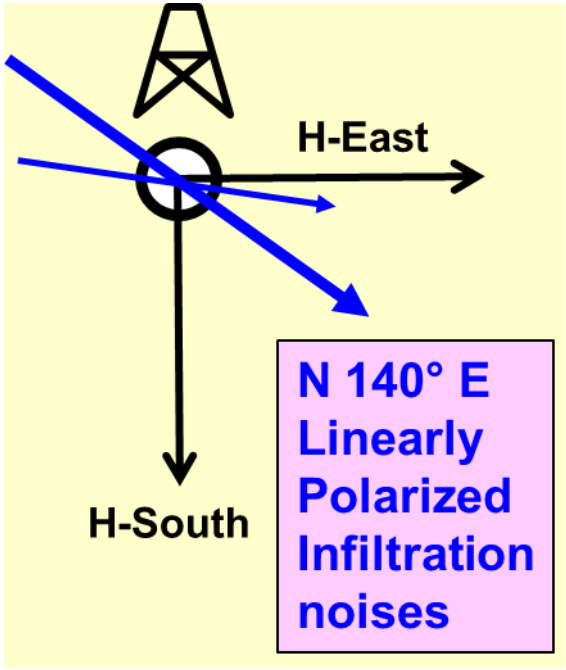




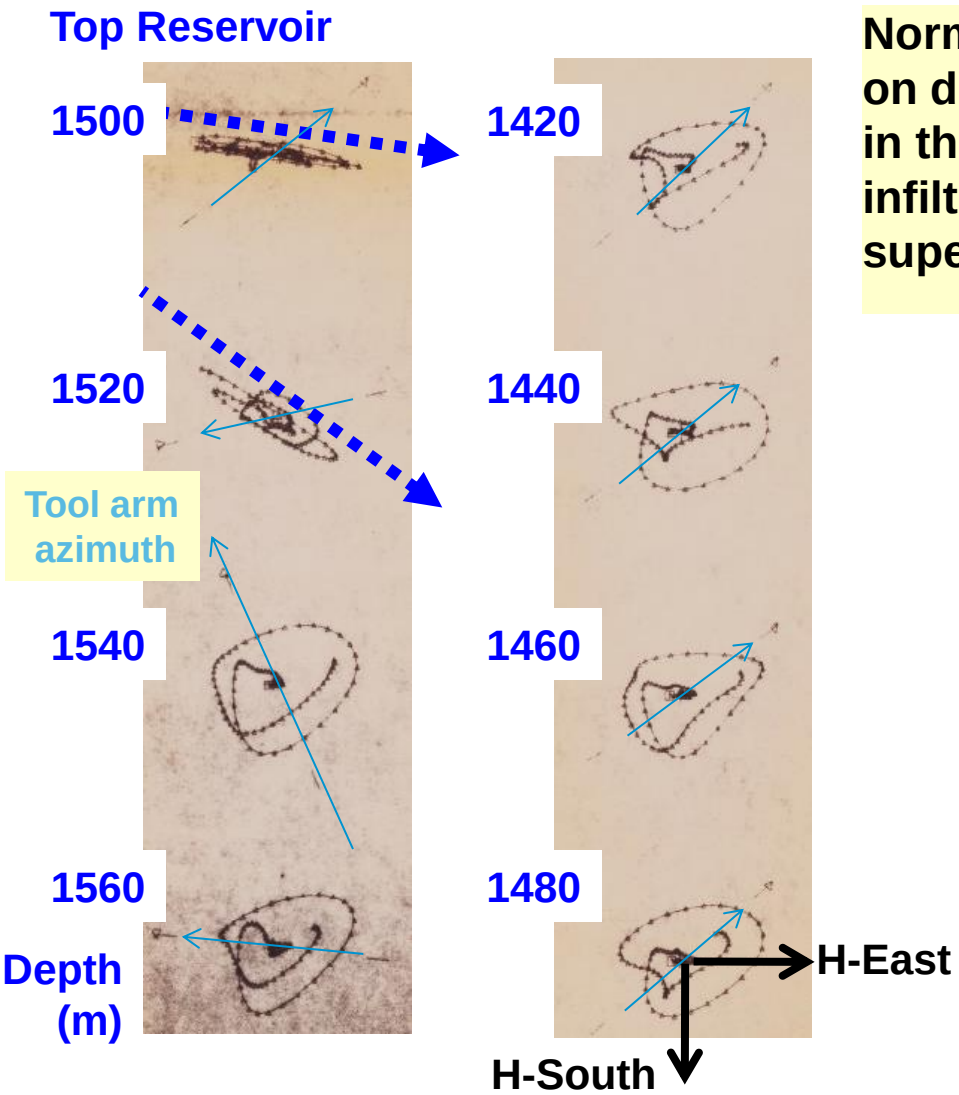
Observation of mud Infiltration NOISE in the Open Hole reservoir interval, Dogger formation, Paris Basin VSP, 1986.

True amplitude Oriented three component (3C) display of zero-offset Shear-wave VSP data in deep interval: a couple of VSP stations appear very noisy on the horizontal components, in the highly permeable reservoir depth interval.

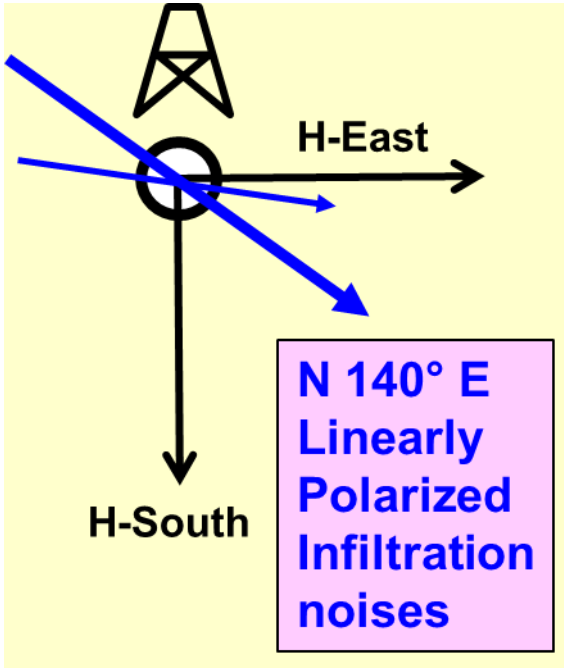




Observation of mud Infiltration NOISE in the Open Hole reservoir interval, Dogger formation, Paris Basin VSP, 1986.

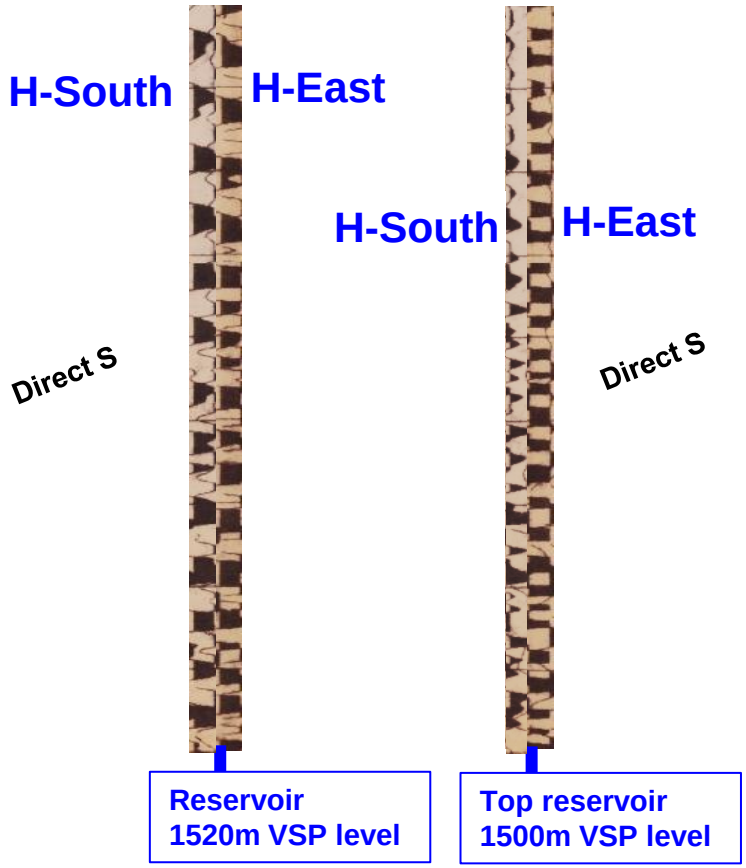


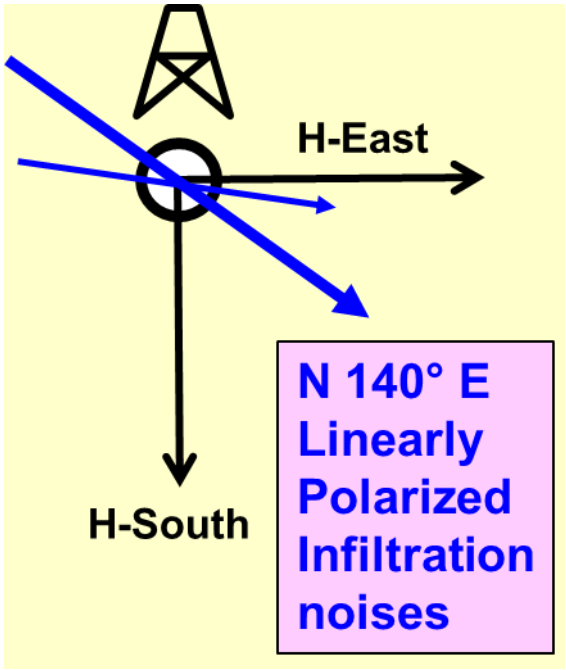
Normalized amplitude particle motions on direct S-wave arrival time window in the reservoir interval : a clear infiltration linear seismic noise is superimposed to the direct S-wave.



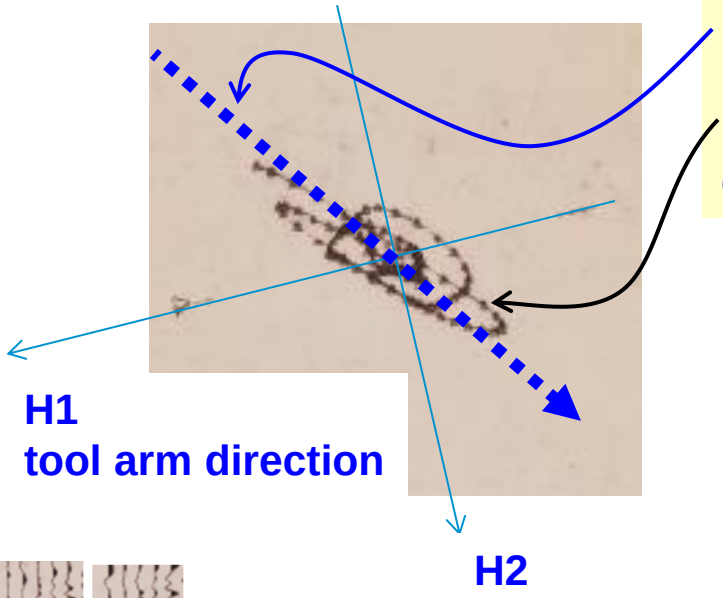
Observation of mud Infiltration NOISE in the Open Hole reservoir interval, Dogger formation, Paris Basin VSP, 1986.

True amplitude noisy levels, Oriented horizontal traces H-South,H-East

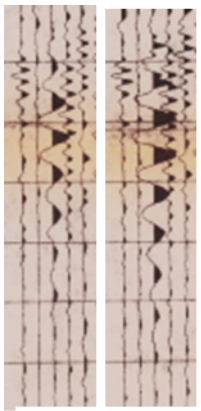




The of linear noise polarisation on Z-VSP horizontal components from VERTICAL vibrator confirms the polarised noise observed on S-wave Z-VSP data, same run



Dotted arrow = Polarisation of observed noise burst on P- source ZVSP @ level 1520m
Hodogram is from S-wave source record at same depth, same VSP tool position in same VSP run



Z-VSP
Raw, non oriented
Components H1,H2;
H1 = arm direction
Linear noise burst @1520m

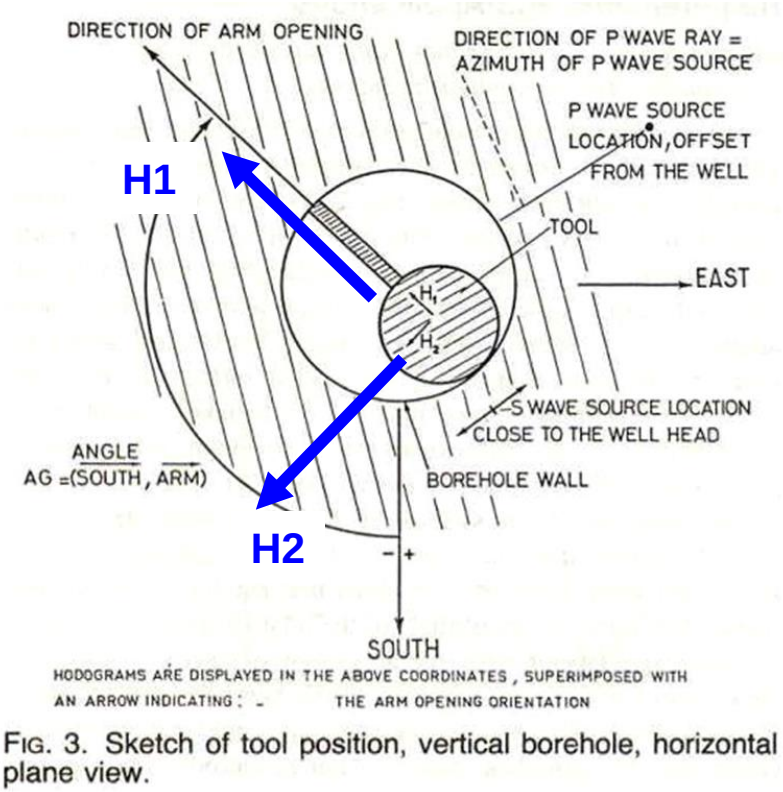


FIG. 3. Sketch of tool position, vertical borehole, horizontal plane view.

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VSP Pre-processing sequence

1. Edition of uncorrelated raw shots
2. QC of source repeatability, shape and amplitude
3. Best stack out of Diversity stack, Median stack, Stack around Median
4. Correlation with sweep
5. Picking of P-direct arrival, flattening along the P-direct arrival
6. Orientation of 3 components using Relative Bearing sensors and hole trajectory
7. **VSP deconvolution tests and deconvolution choice**: ***Following slides***

Condition for deconvolution of multipath direct wavetrain in borehole seismic.

- Deconvolution tests (isotropic 3C) of Z-VSP **PRIOR** to wave separation (instead of post separation decon)

➢ SINGLE OPERATOR decon:

- Multi-comp Wiener Levinson after minimum phasing the raw data
- Signature extraction at different depths to test the decon of whole VSP by a single signature.

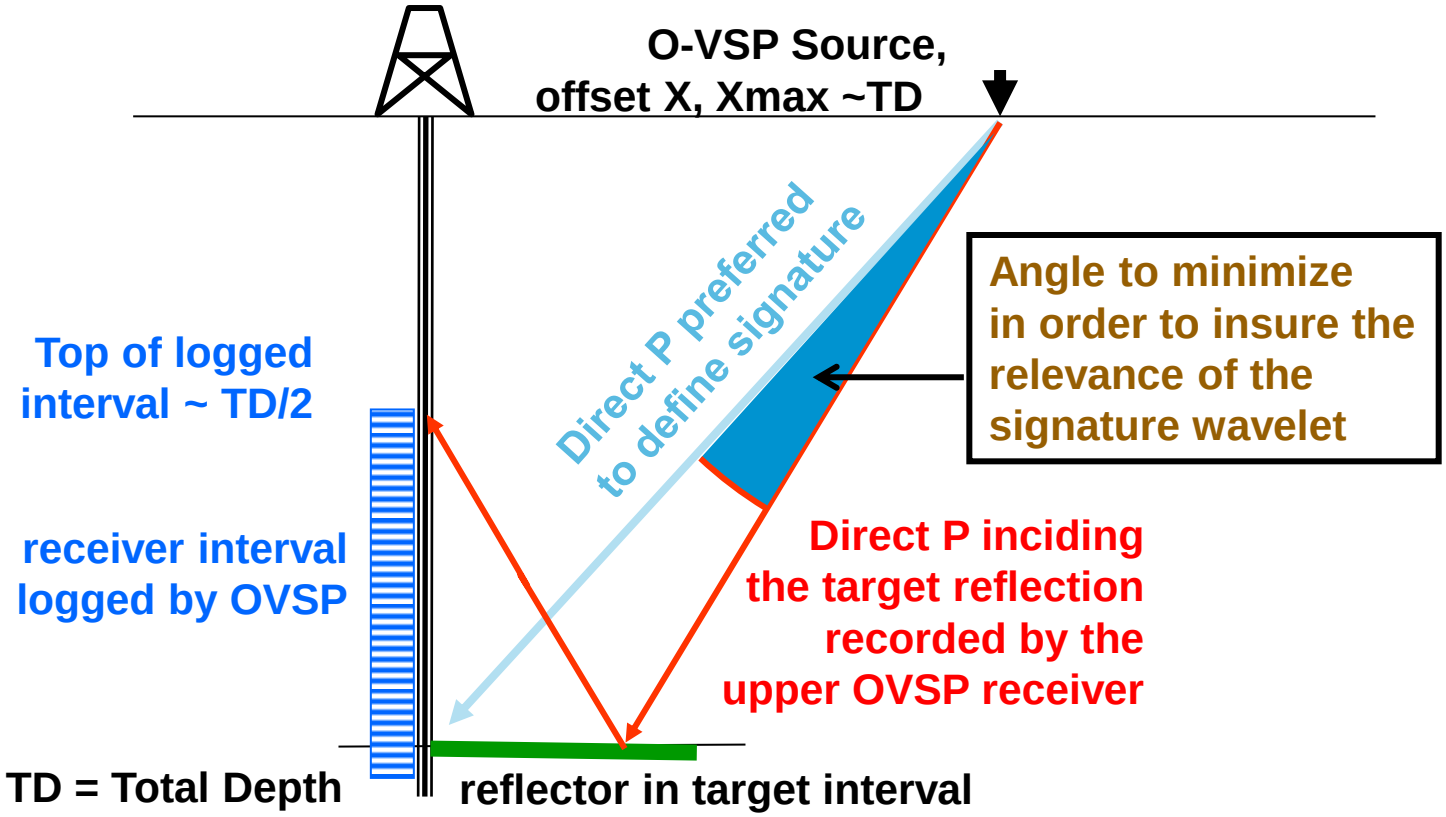
➢ TRACE to TRACE decon of multipath interferred P-wavetrain with complex polarization (not linear).

- 3C sliding Multi-comp Wiener Levinson after minimum phasing the global interferred raw data

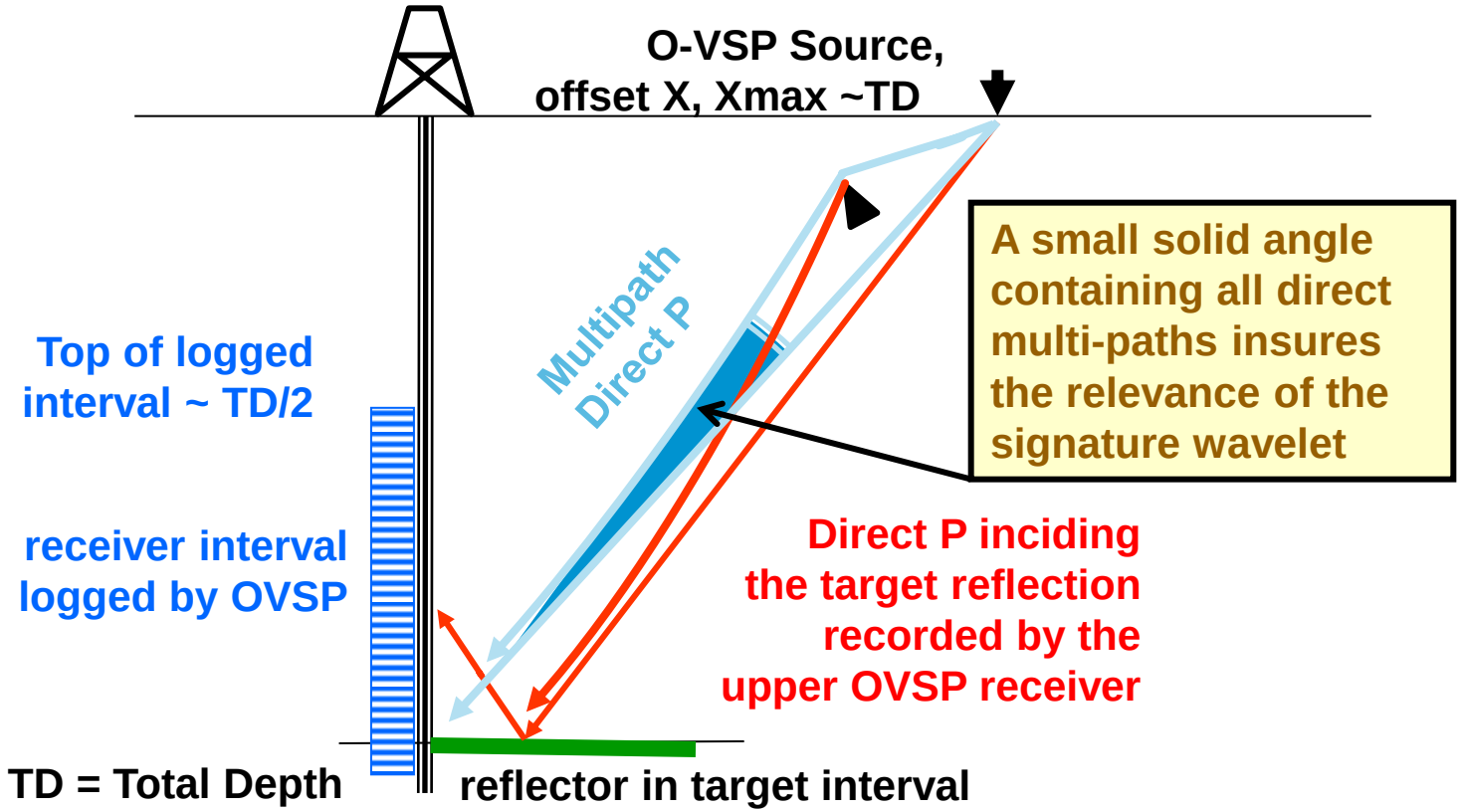
➢ **TRACE to TRACE SIGNATURE decon of near – linearly polarized multipath interferred P-wavetrain:**

- Signature extraction variable with depth to obtain a zero phase result in the corridor stack domain (successful test in following slides)

How to choose deconvolution method ?
Single operator deconvolution

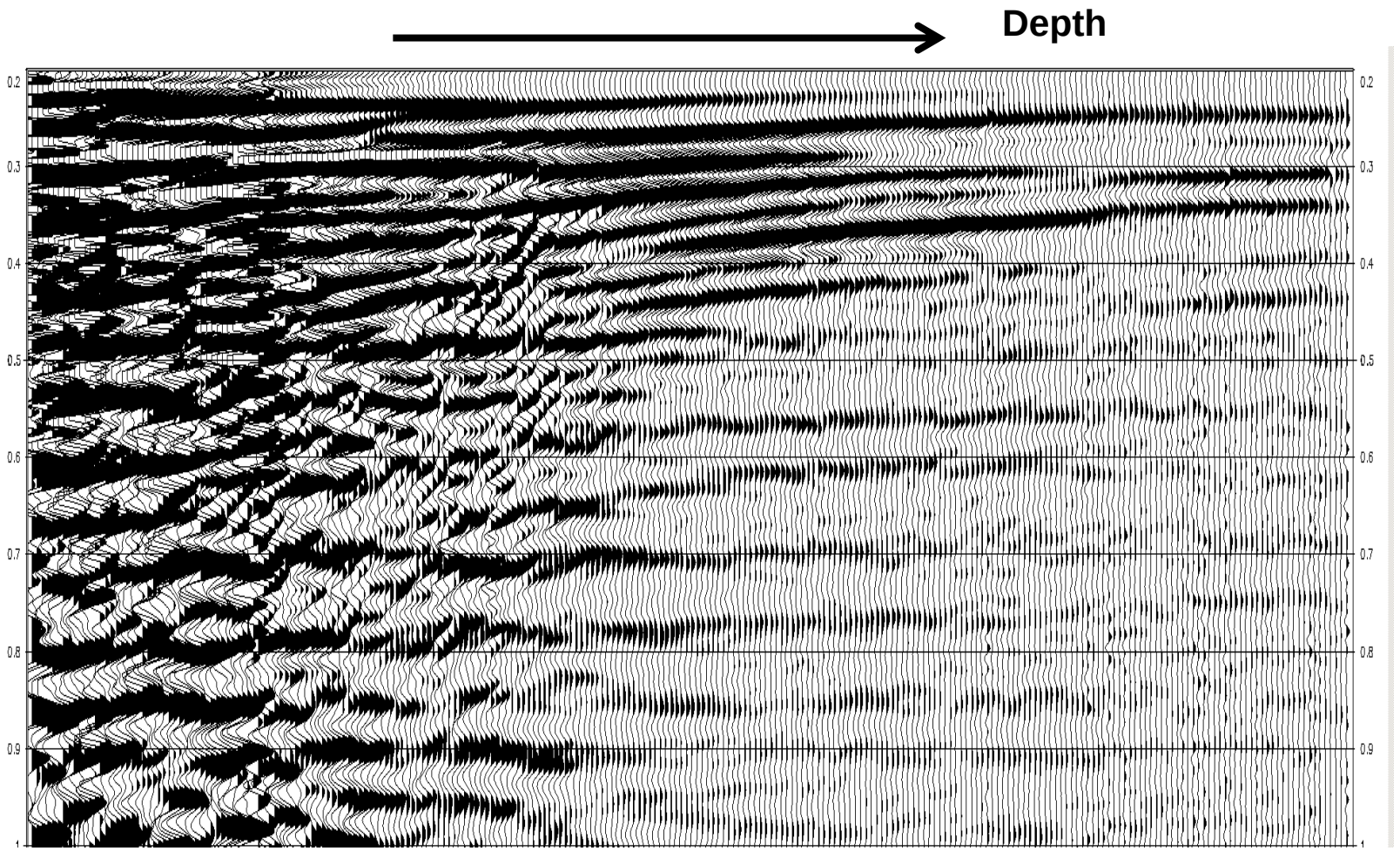


How to choose deconvolution method ?
Trace-to-trace operator deconvolution



METHOD Applicable when multipath interfered downgoing wavetrain REMAINS fairly linearly polarized.

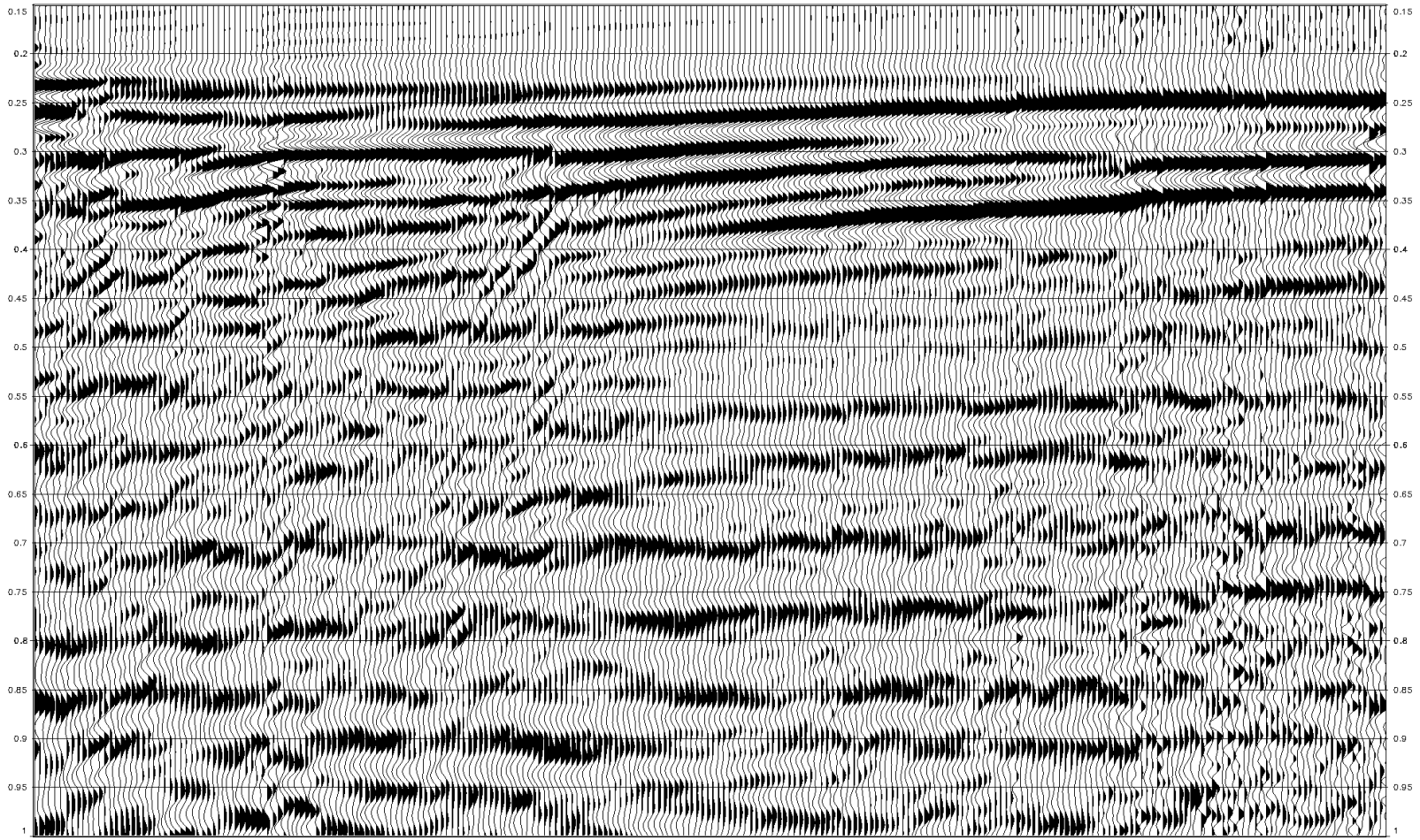
ZV component after reorientation – full depth
Time aligned along P-down, constant gain display



ZV before deconvolution – full depth
Time aligned along P-down,normalized amplitude

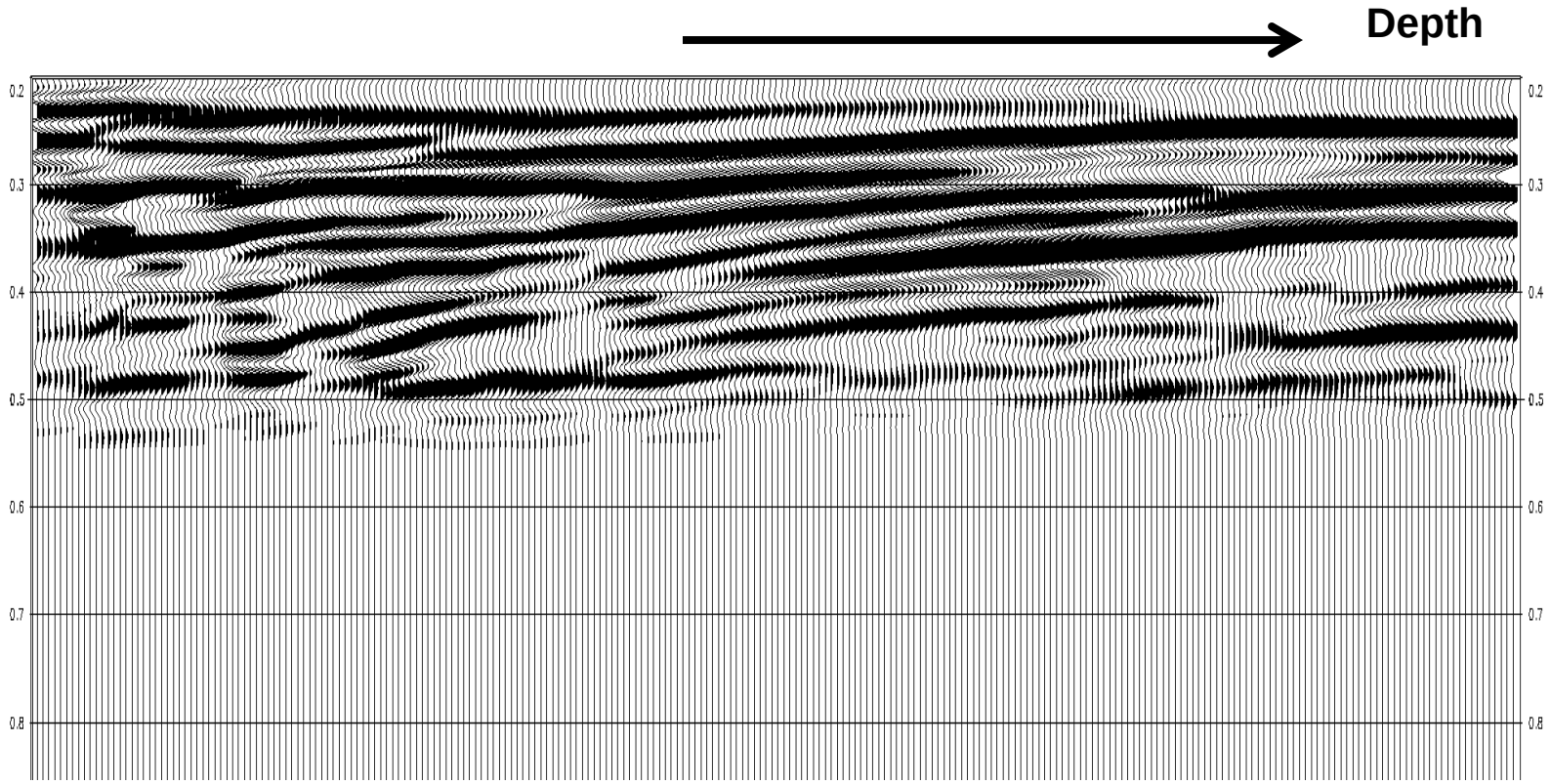
No Divergence amplitude compensation applied before decon

Depth



Signature definition: median filter 9 traces, normalized amplitude, tapered down at 500ms

No Divergence amplitude compensation applied

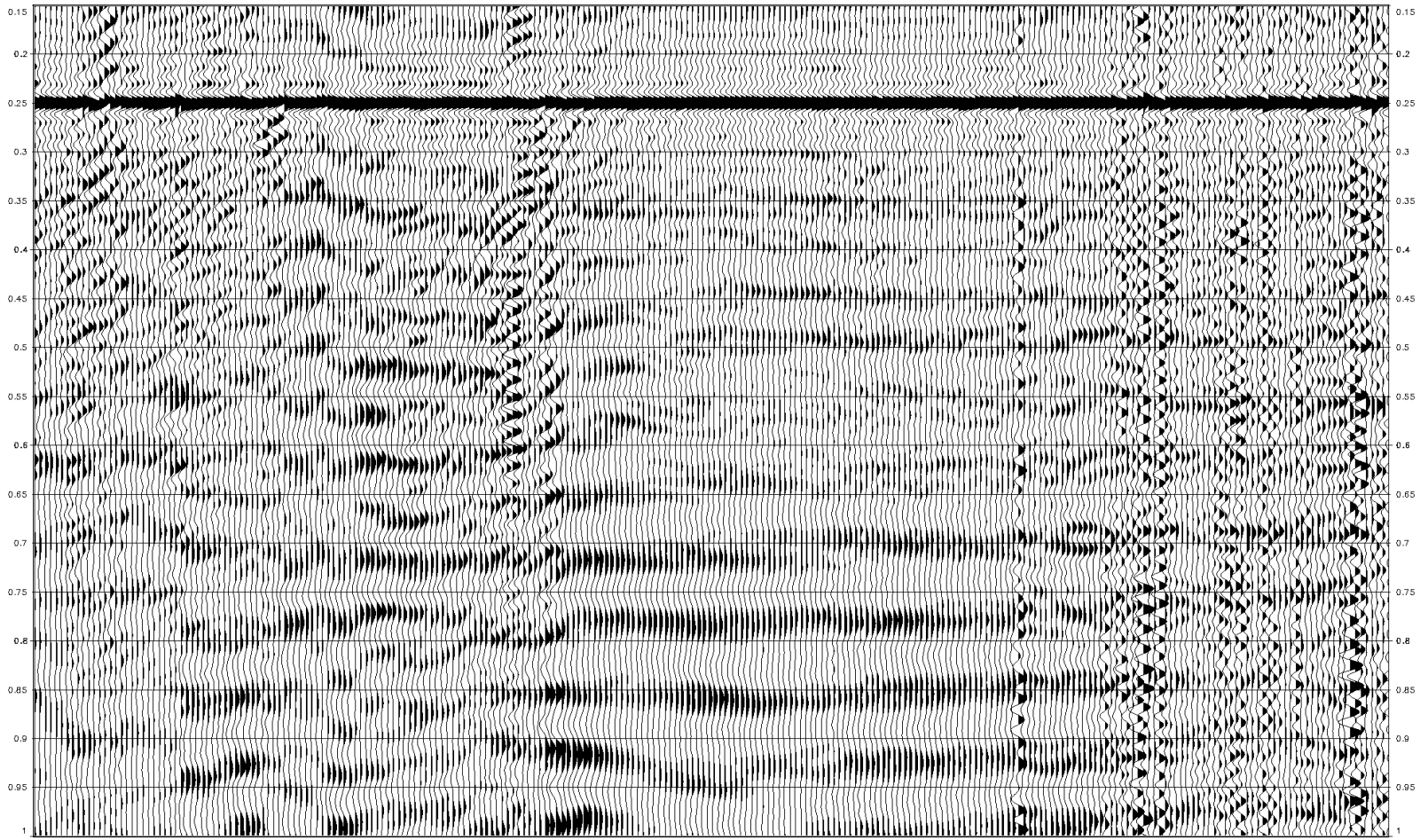


Signature for the trace-to-trace deconvolution of the orientated 3C VSP

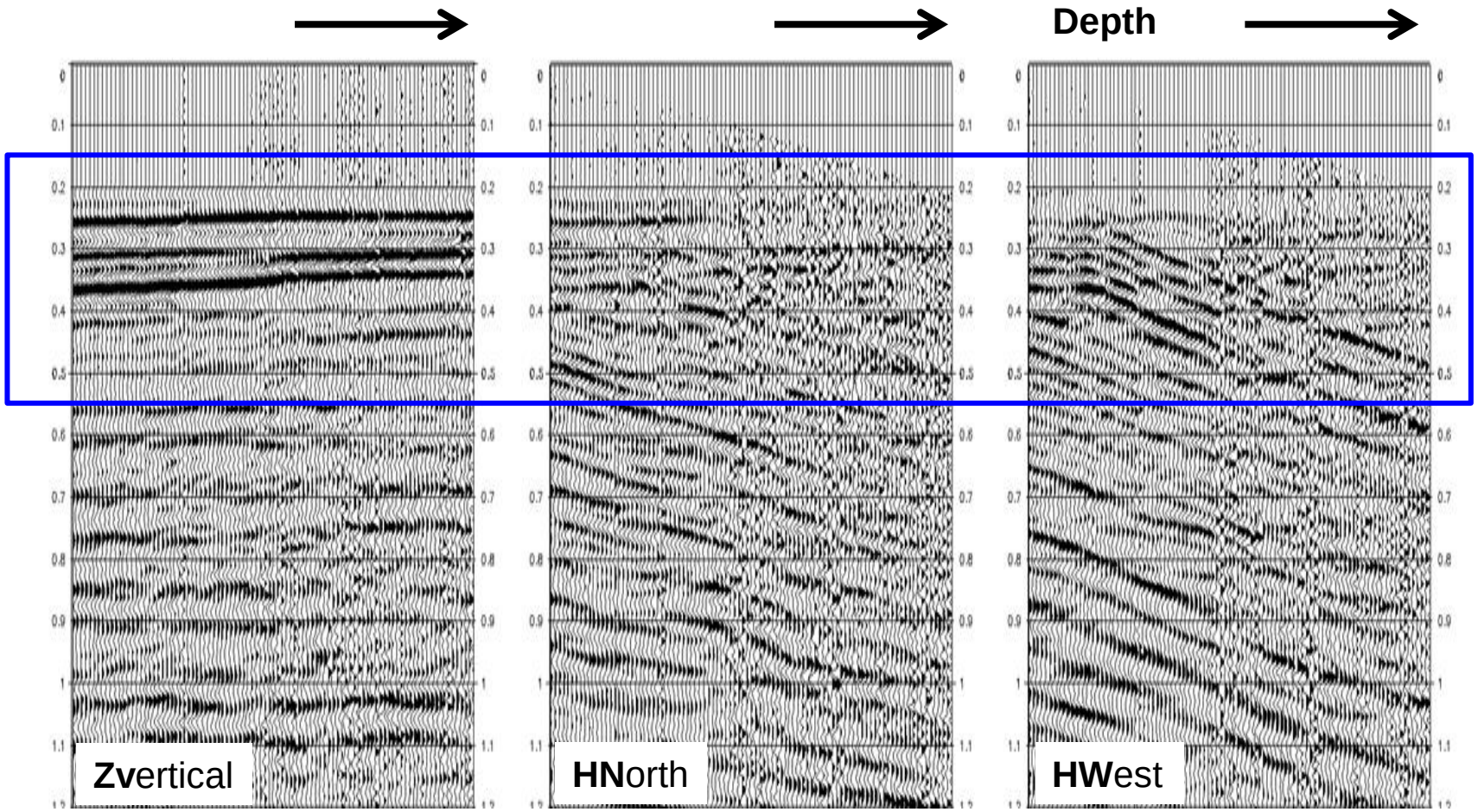
ZV after deconvolution – full depth, normalized peak

Divergence amplitude compensation can be applied post decon

Depth

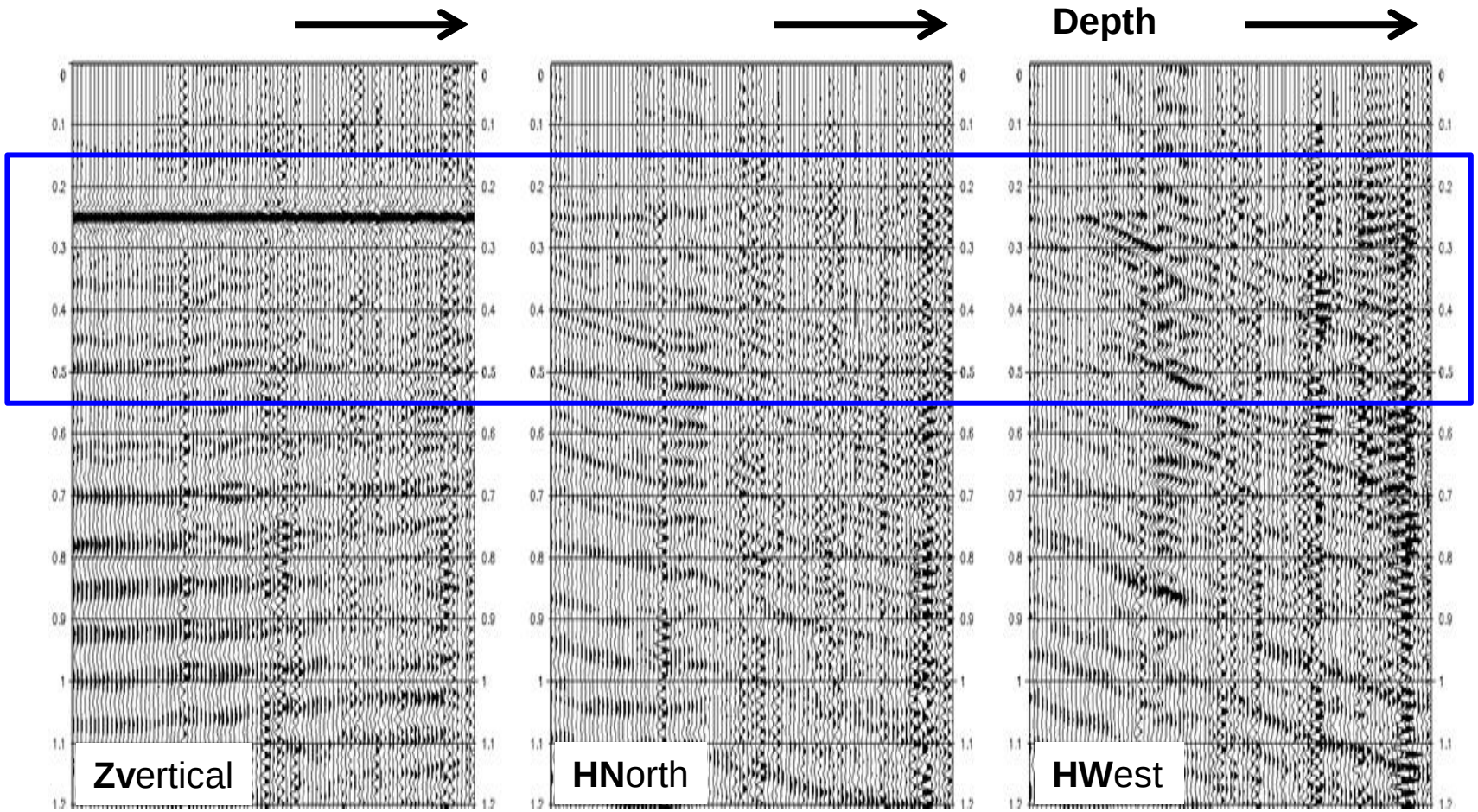


Input: Oriented 3Component ZVSP data – deep part isotropic display, 3C Cross-normalized at each depth



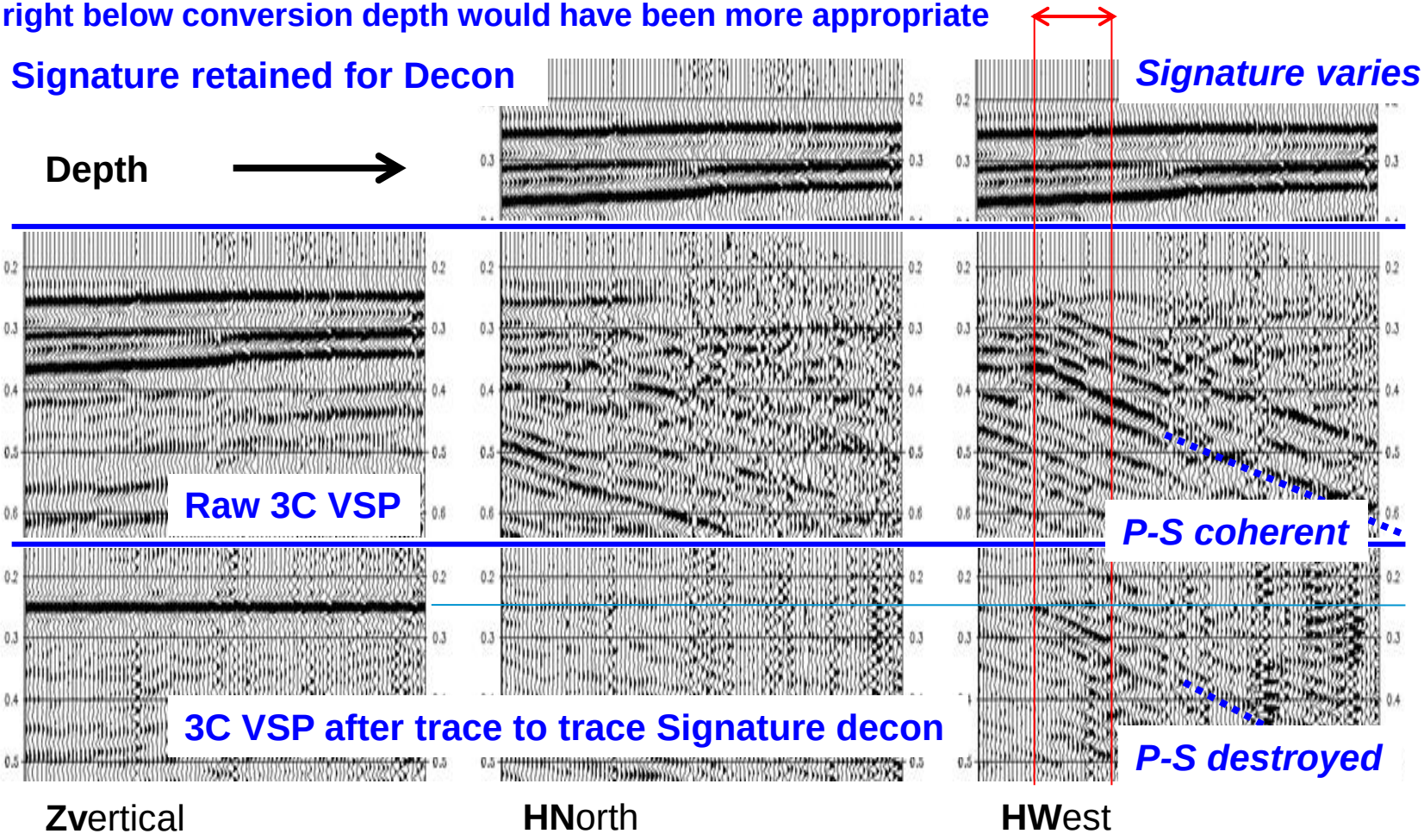
Output of trace to trace Signature decon – deep part isotropic display, 3C Cross-normalized at each depth

Variable trace-to-trace deconvolution with a linearly polarized interfered signature clearifies the VSP corridor stack domain only (blue box)

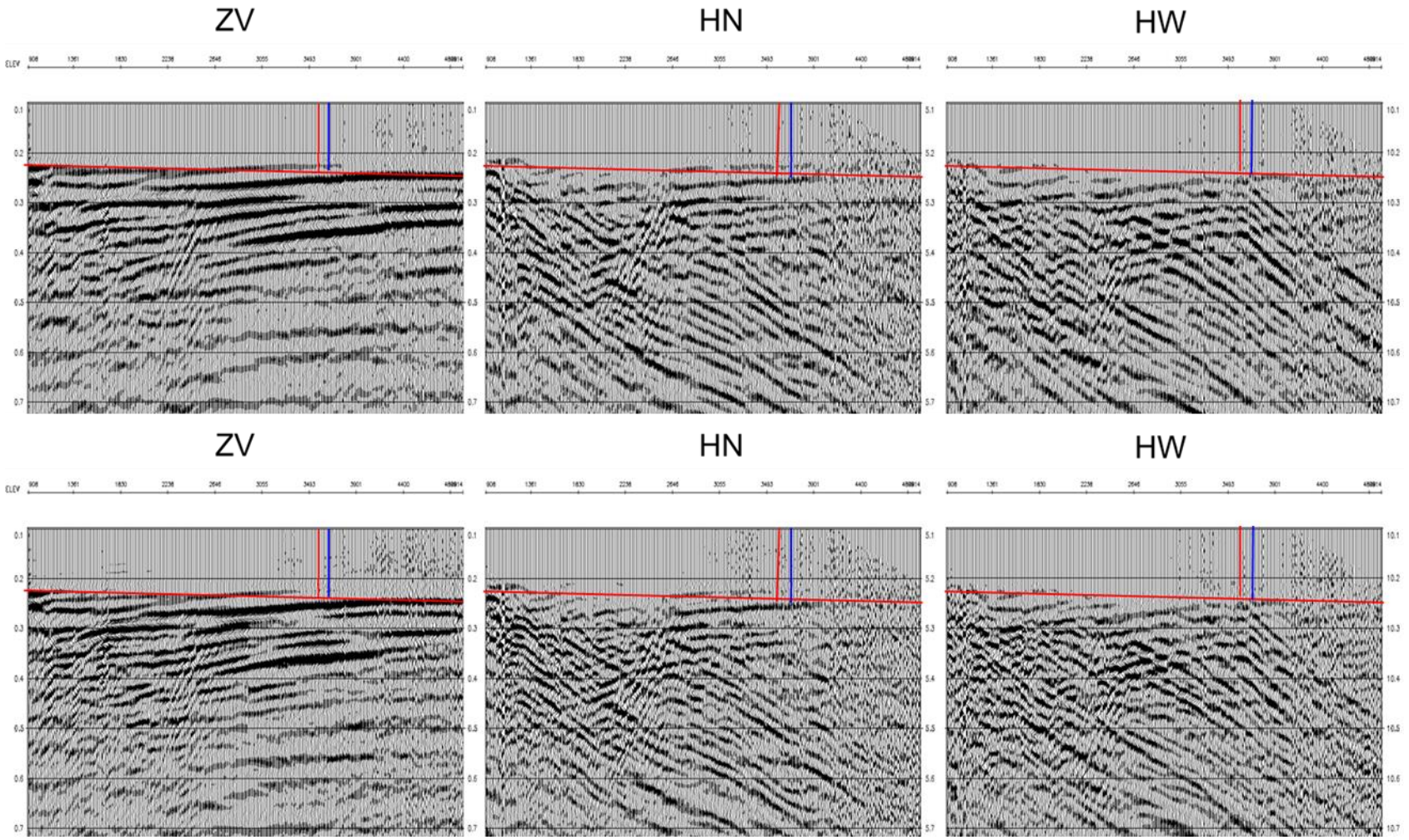


Effect of trace to trace signature decon, oriented 3Component ZVSP data – deep part, isotropic 3C display.

Right below P-S down conversion depth, between the two red depth lines, signature and P-S events are both coherent, so that the trace to trace decon is efficient; deeper, the signature has changed, but the P-S signal remained stable, a single shaping decon operator defined right below conversion depth would have been more appropriate



3C stacks orientated, aligned along P-direct arrival
Top = Raw 3c data; **Bottom** = After predictive Deconvolution



Conclusion, Discussion

- Improved VSP processing practice for various purposes:

- To help the surface seismic geophysicist constraining certain parameters
- To help the structural geologist where complex structures are encountered. ORIENTED 3C VSP data yield more information, and more reliable information; it constitutes an incentive for orienting the 3C VSP data more systematically , on a turnkey basis.
- To help geoscientists understand the seismic propagation, its capabilities and limitations (for both surface seismic and borehole seismic); geometrical spreading , Vrms from VSP are useful; true amplitude reflector extracted from corridor stack (1C or 3C) can guide surface seismic processing, and adjusting parameters for future surface seismic acquisition…

References

I. Paul Newman (1973). ”**DIVERGENCE** effects in alayered earth.” *Geophysics*, vol. 38(3), 481-488.

II. **Microseismic signals from liquid infiltration** : Lengliné, O., L. Lamourette, L. Vivin, N. Cuenot, and J. Schmittbuhl (2014), Fluid-induced earthquakes with variable stress drop, *J. Geophys. Res. Solid Earth*, *119*, 8900–8913, doi:10.1002/2014JB011282.

III. **VSP deconvolution**: patent GB1569581: Seismic delineation of oil and gas reservoirs using borehole geophones by Nigel Allister Anstey , 1976

IV. **Multipath/duplicated seismic refraction arrivals:**

- Manuel de sismique réfraction, Ch. Layat, 1957, CGG internal training book on refraction method .
- Quelques exemples de diffractions en sismique réfraction et leur application à la détermination des vitesses verticales, par Y. Ledoux, CGG, 12th EAEG annual Meeting, Brussels, 1957

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