INTERPRETATIVE UNCERTAINTIES
of surface seismic images
investigated with a VSP and basic logs.
APPENDICES from VSP analysis

Case study in Alberta, Canada

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KEYWORDS: Density log corrections,
true amplitudeVSP reflections, VSP derived density,
3C orientation of VSP data, Frequency analysis

APPENDICES from VSP analysis

VSP and surface seismic re-processing in 1996 by IFP using CGG seismic software

- **APPENDIX- A: Wireline logs**

  Caliper, Density, Vp velocity

- ***Large caves are observed in Coalbed, degrading the recorded Density log.***
- ***True amplitude VSP corridor stack allows for a correct estimation of the formation where large borehole washouts are present.***

- **APPENDIX- B: 3-Component orientation**

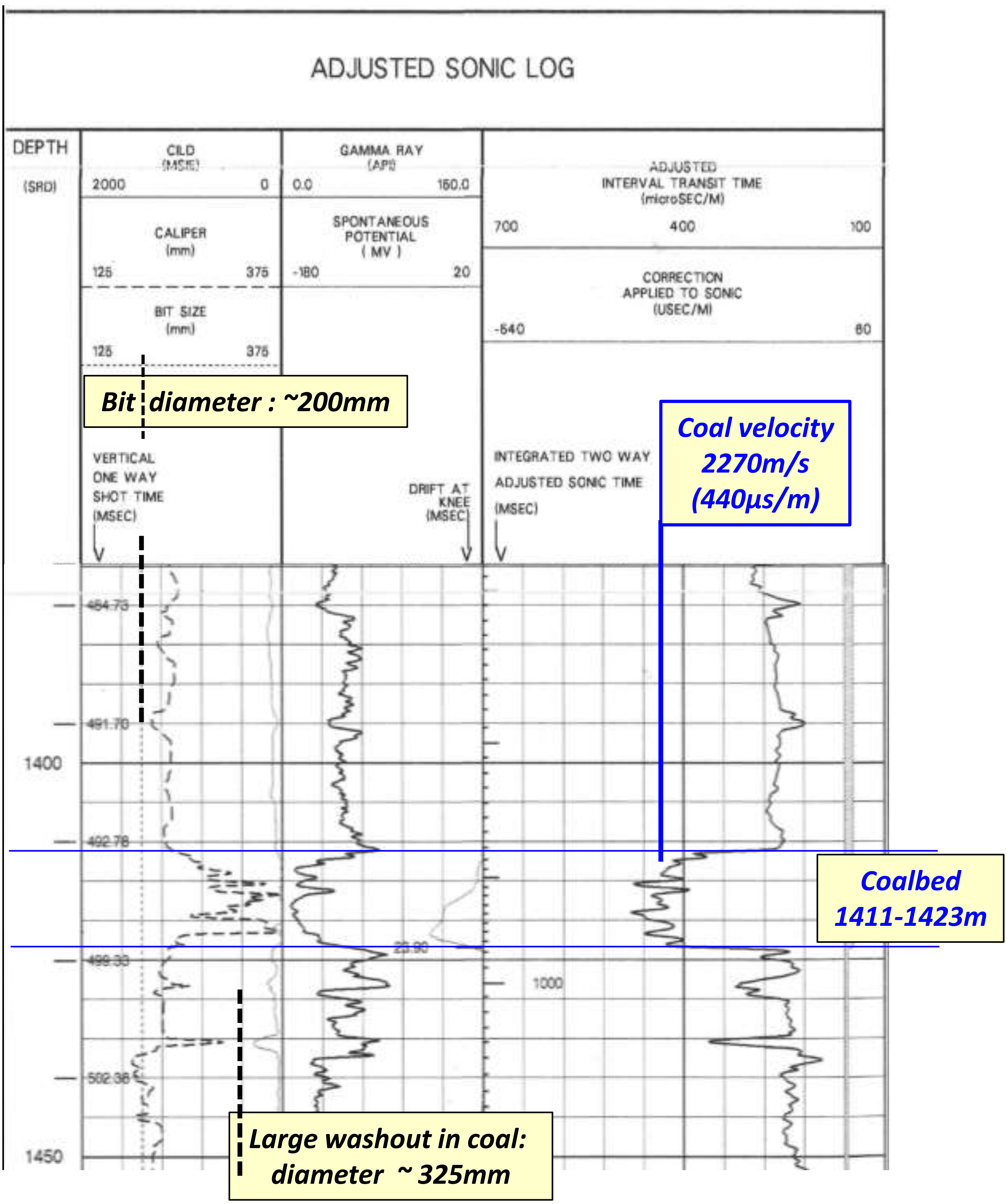
- *Displays and S-wave time, Vs, Vp/Vs.*

- *3C systems.*

- **APPENDIX- C: FREQUENCY analysis on deconvolved VSP upgoing wavefield**

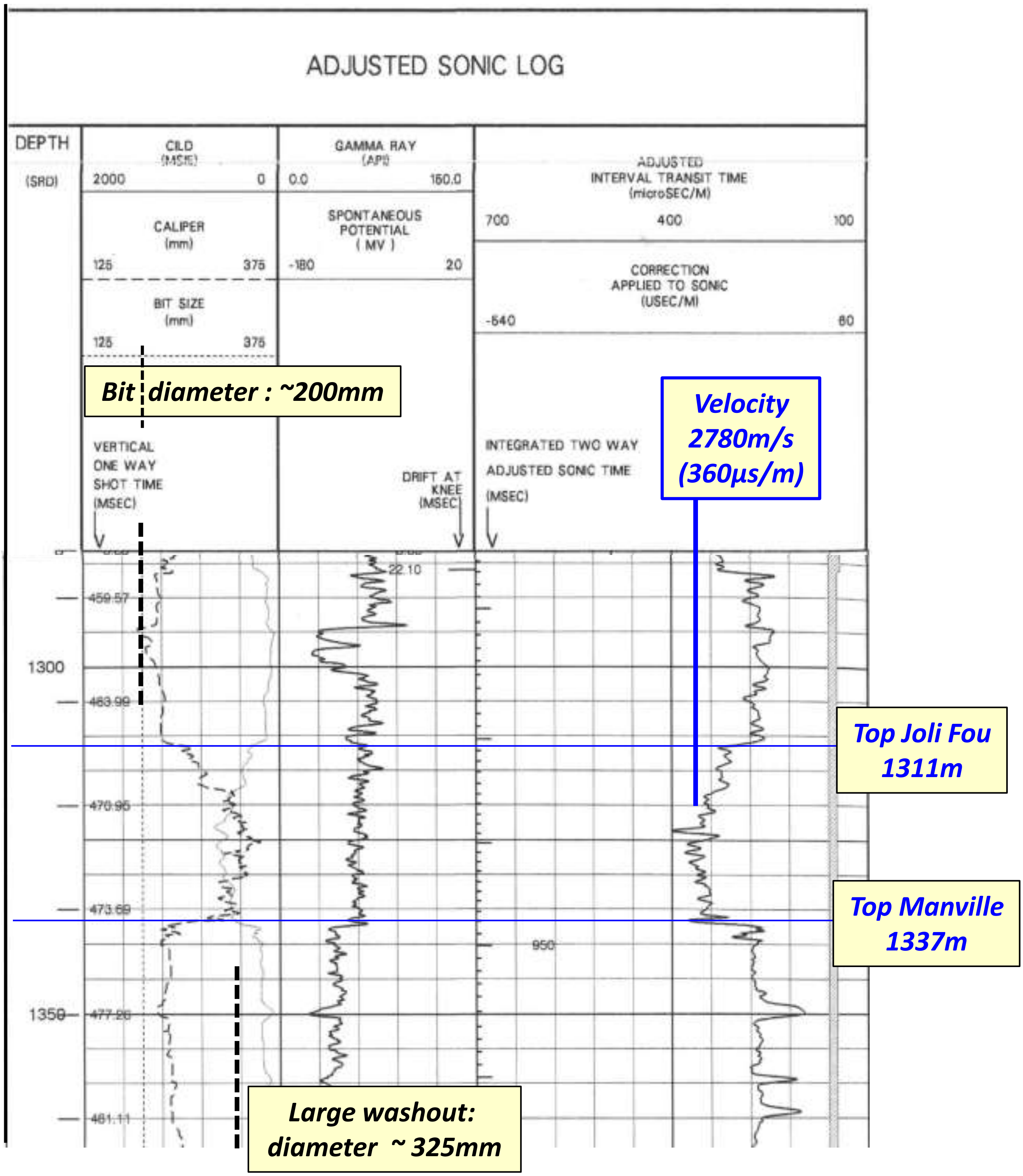
- *Reflection frequencies above 60Hz are irrecoverable on VSP data above coalbed, thus in surface seismic at regional scale.*

APPENDIX- A: Wireline logs Cal, Rho, Vp (A1) *Large caves are observed in Coalbed, degrading the Density log*



(A2) Log readings on Joli Fou/Manville

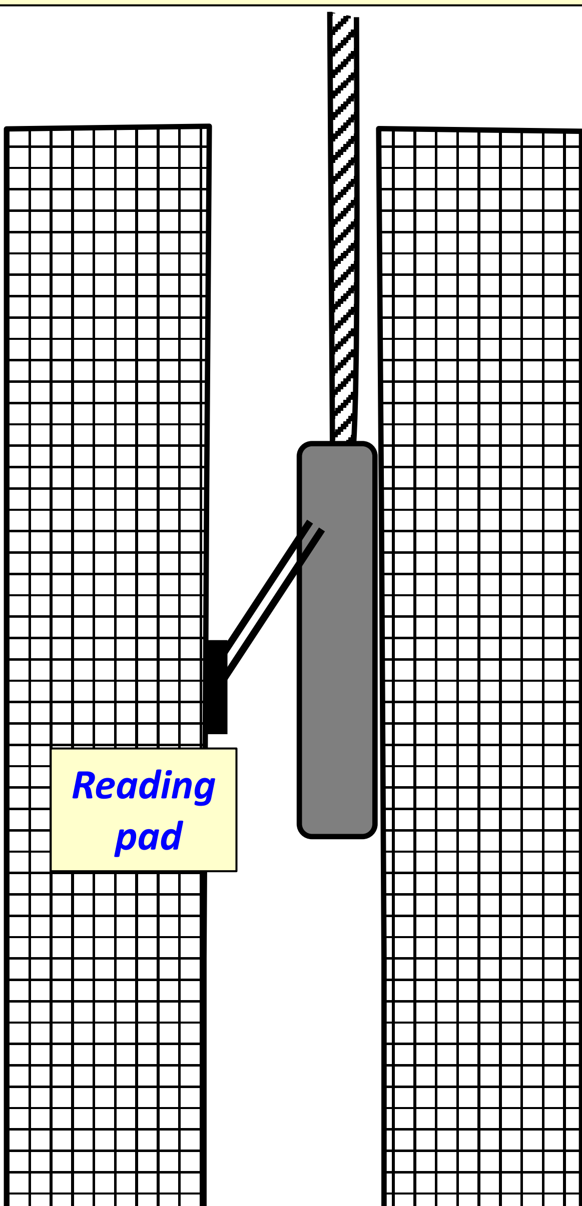
Large caves are observed, altering the Density log



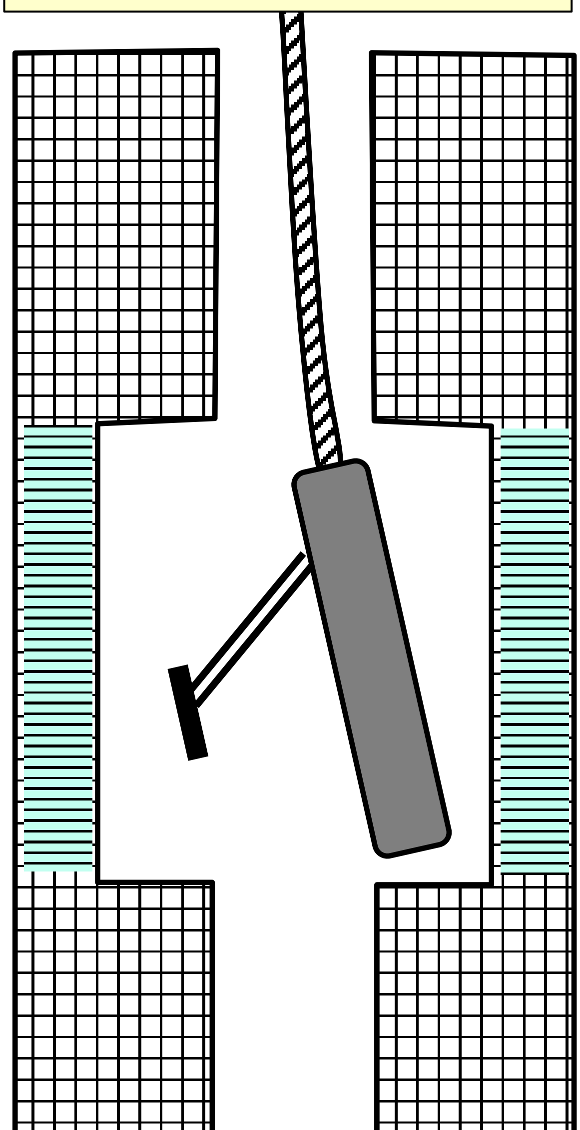
(A3) Wireline Logging Tool for Density

(Compton/Thomson scattering of gamma rays)

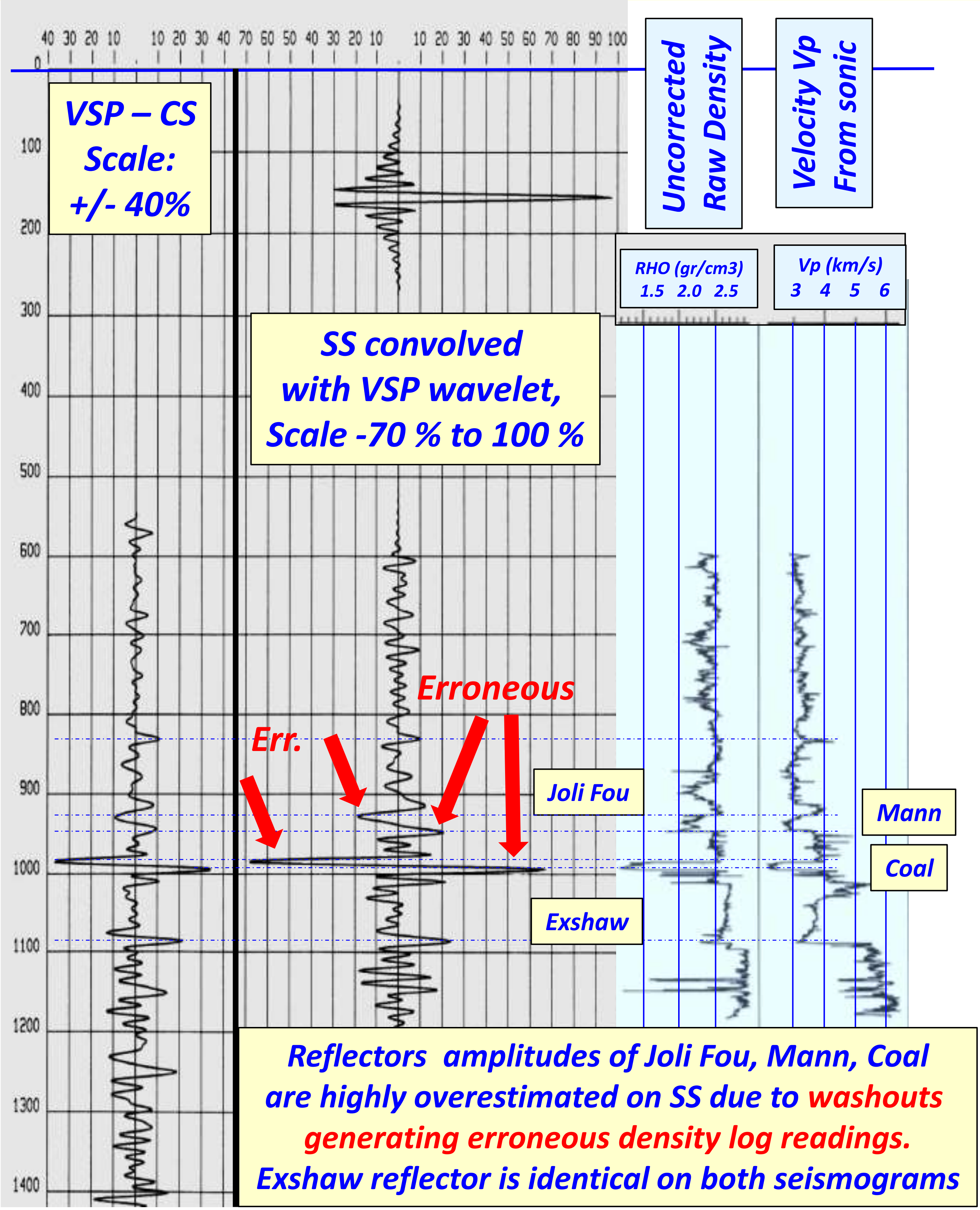
Usual Borehole conditions
The Reading pad of the Density tool is in contact with the borehole wall and the rock formation
Bulk density readings are correct



In a large washout, the Reading pad of the Density tool reaches its maximal diameter extension
The readings values are intermediate between mud density and formation density



(A4) True Amplitude VSP Corridor Stack (VSP-CS), and Synthetic Seismogram (SS) from raw logs.



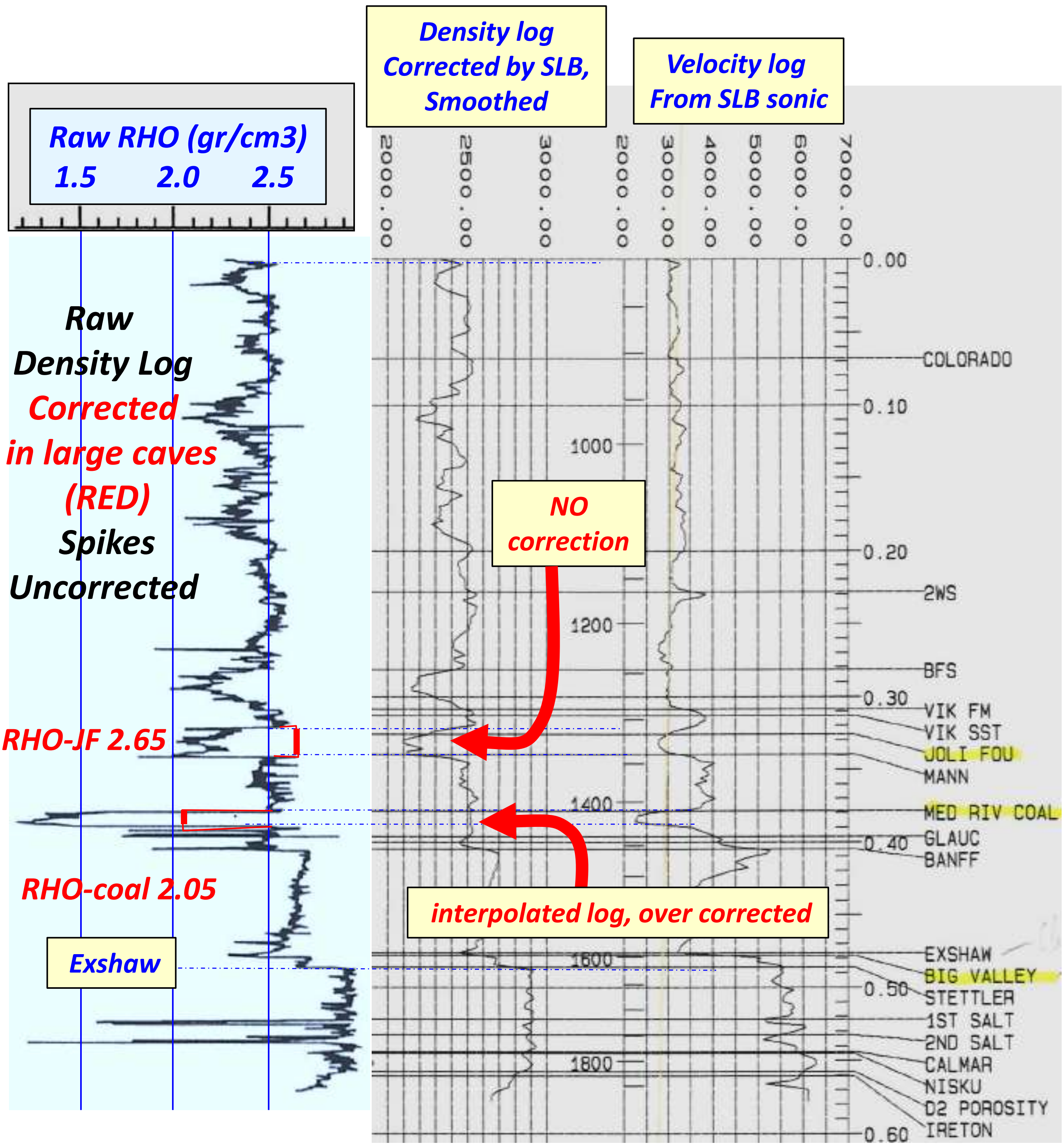
Reflectors amplitudes of Joli Fou, Mann, Coal are highly overestimated on SS due to washouts generating erroneous density log readings.
Exshaw reflector is identical on both seismograms

(A5) Corrections of density log derived from true amplitude VSP Corridor Stack and velocity log

$RC = (\rho_1 V_1 - \rho_2 V_2) / (\rho_1 V_1 + \rho_2 V_2)$; $\rho_2 = \rho_1 V_1 (1+RC)/V_2 (1-RC)$

True RC (top& base JoliFou) = 0.1 : RC (top& base Coal) = 0.35

Corrected RESULTS: Rho (coal) = 2.05; Rho (Joli Fou)=2.65



(A6) Density log correction computation

derived from true amplitude of RC coefficient values read on VSP Corridor Stack and velocity log (sonic)

$RC = (\rho_1 V_1 - \rho_2 V_2) / (\rho_1 V_1 + \rho_2 V_2)$; $\rho_2 = \rho_1 V_1 (1+RC)/V_2 (1-RC)$

True RC (top& base JoliFou) = 0.1 ; RC (top& base Coal) = 0.35

RESULTS: Rho(coal) = 2.05; Rho(Joli Fou)=2.65

RC	Rho1	V1	V2	**RHO2**	Reflector/ incidence
-0,35	2,52	3800	2270	**2,03**	coal-top /down
-0,35	2,51	3900	2270	**2,08**	coal_base /up
-0,1	2,49	3800	2900	**2,67**	Joli-Fou_base /up
-0,1	2,51	3700	2900	**2,62**	Joli-Fou-top /down
Medium 2 is below medium 1 when incident wave goes down					
Medium 2 is above medium 1 when incident wave goes up					

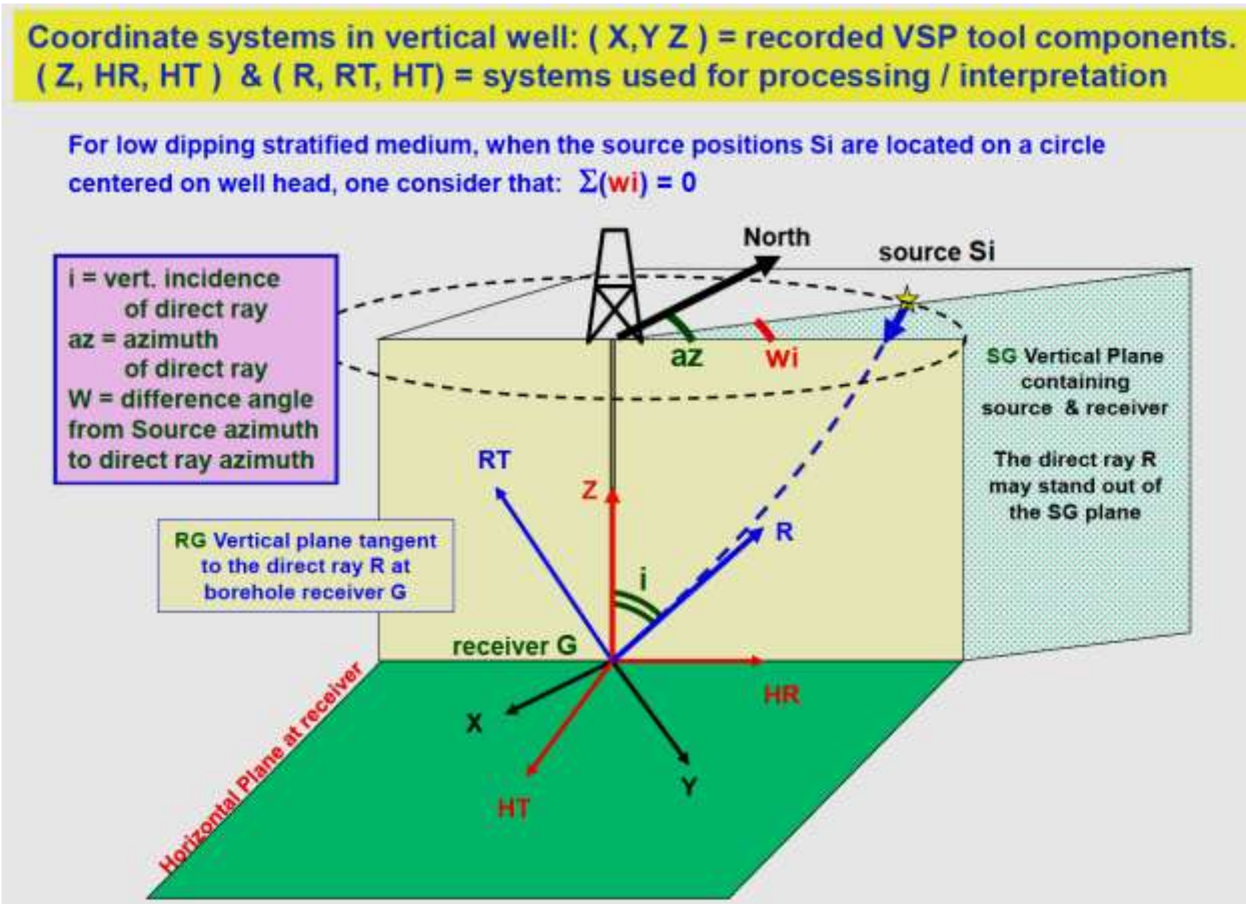
Comments:

True amplitude VSP Corridor Stack can provide :

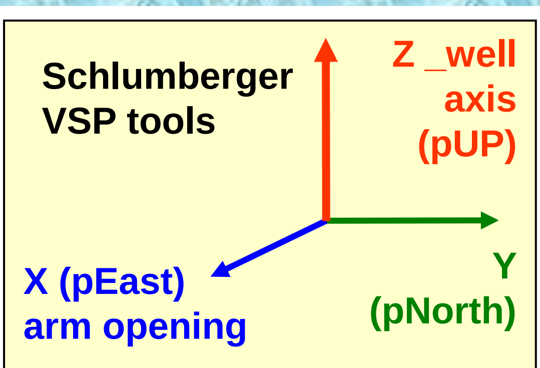
- **Credible corrections of density logs altered by large caves from direct reading of the RC coefficients, using array sonic measurements.**
- **An improved reliability for calibrating the inversion of surface seismic into Acoustic Impedance (AI), and for well tie in general.**
- **A larger time window for AI calibration of seismic inversion and well tie as the VSP corridor stack is often valid down to 400ms below T.D., while wireline logs stop at T.D.**

APPENDIX- B: 3-Component orientation Displays and S-wave time pick.
(B1) 3C systems.

Common 3C VSP orientation by maximisation of direct P wave arrival



Right handed 3C arrangement



3C VSP orientation

Horizontal plane:

HR = Hmax(X,Y)

HT = Hmin (X,Y)

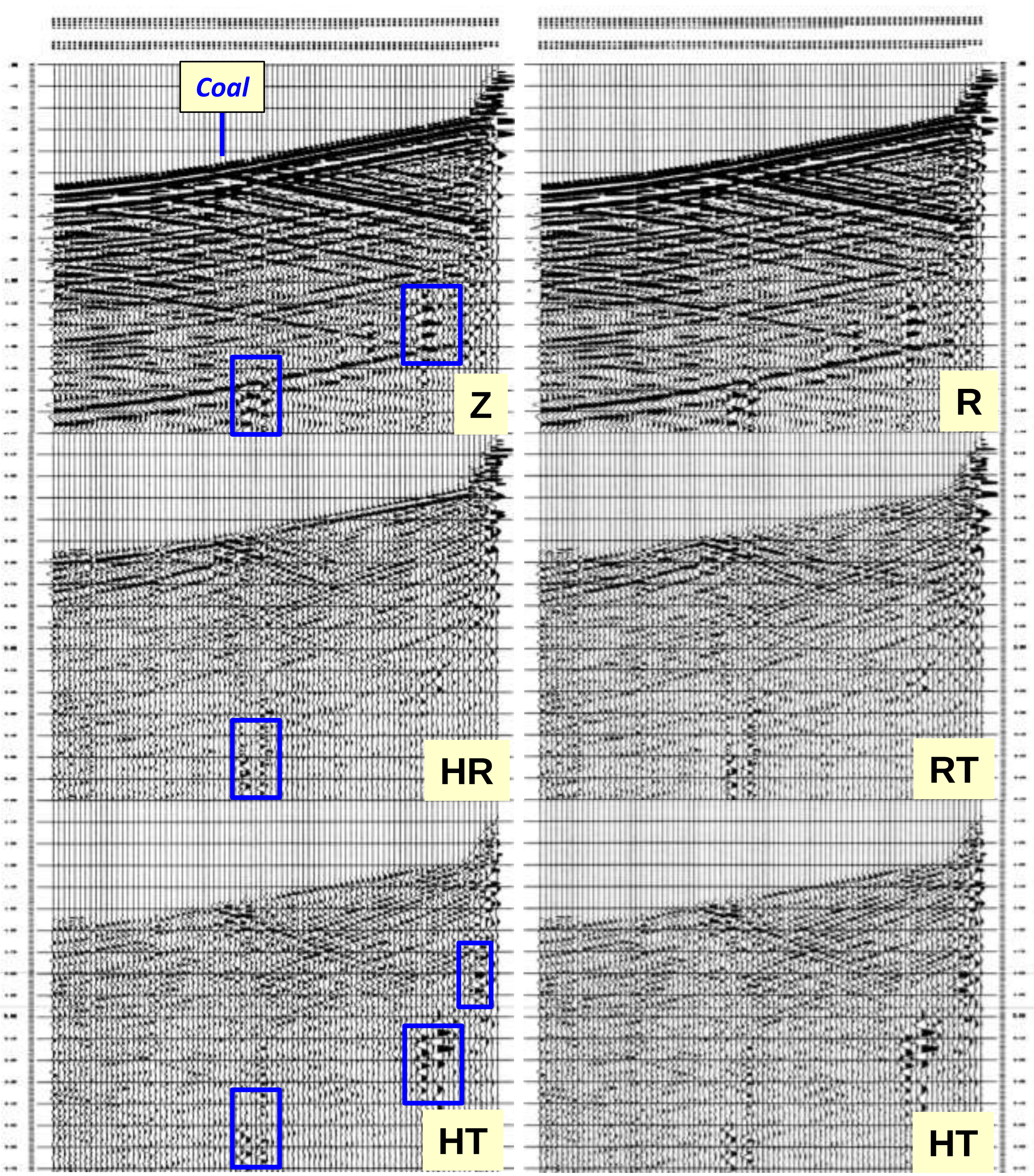
Vertical plane:

R = Max(Z,HR)

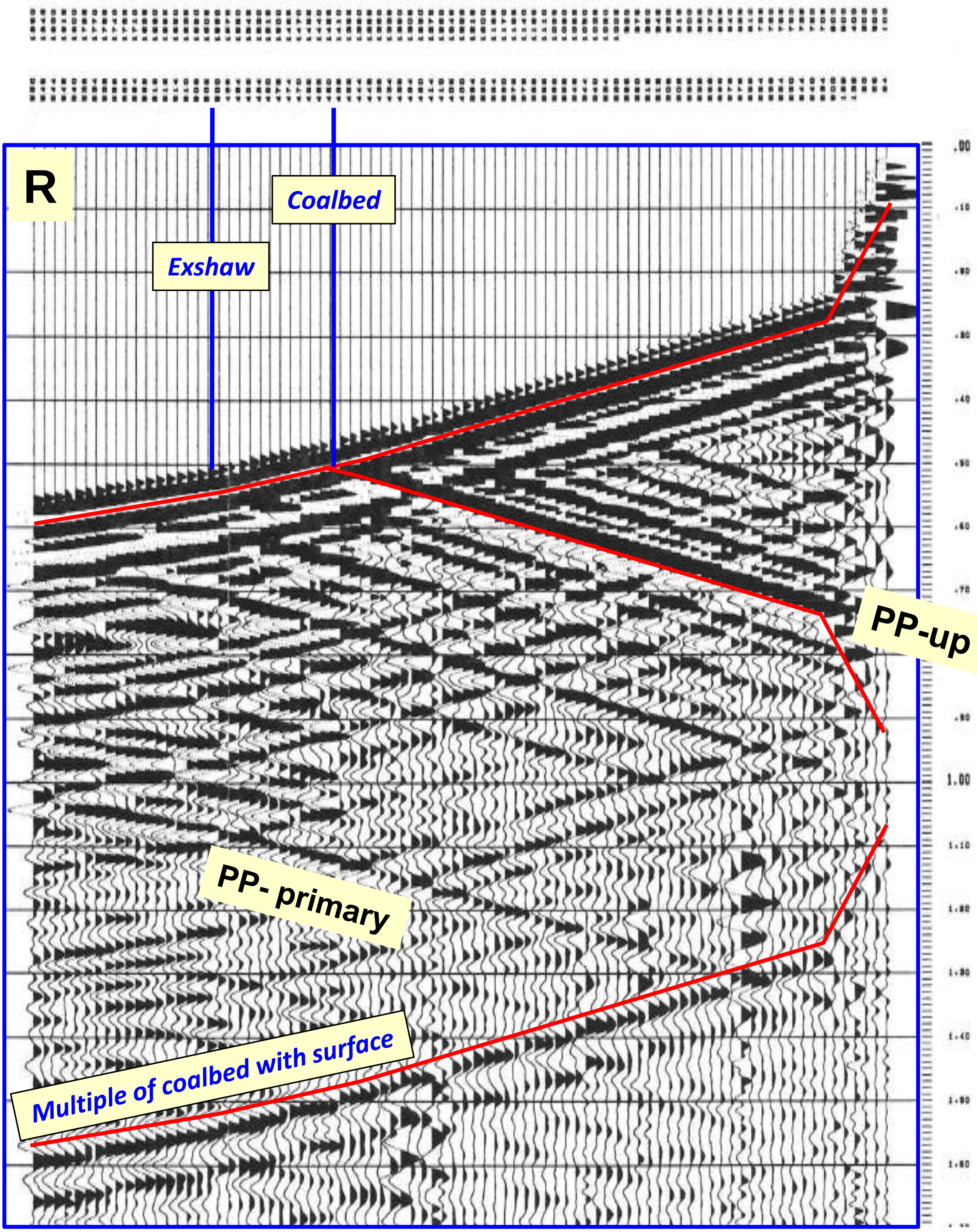
RT = Min(Z,HR)

(B2) Displays of oriented 3C VSP data,

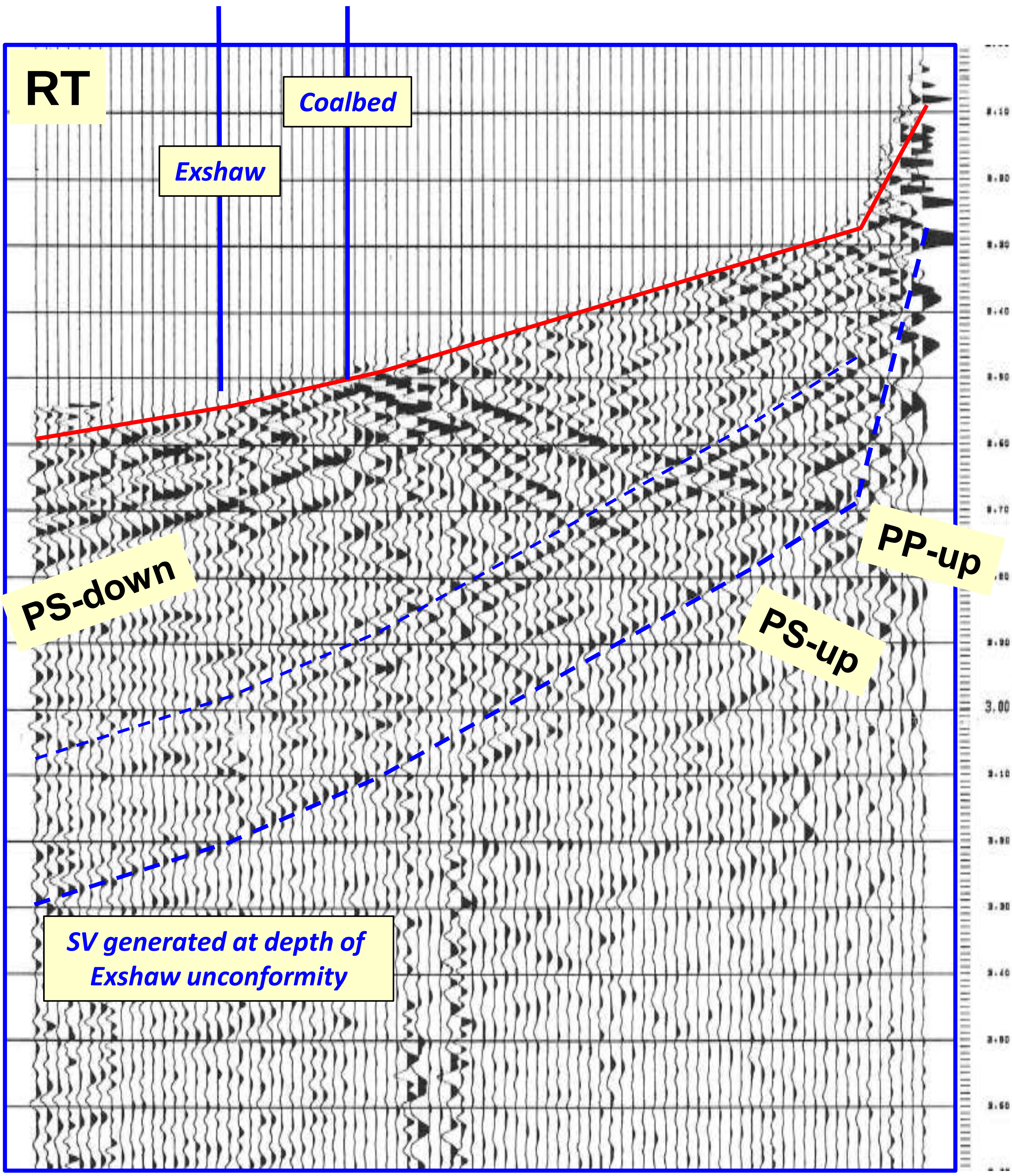
Cross normalized on 3C; high amplitude Tube wave (blue boxes) remain where the VSP tool is in poor contact with the borehole wall (caves).



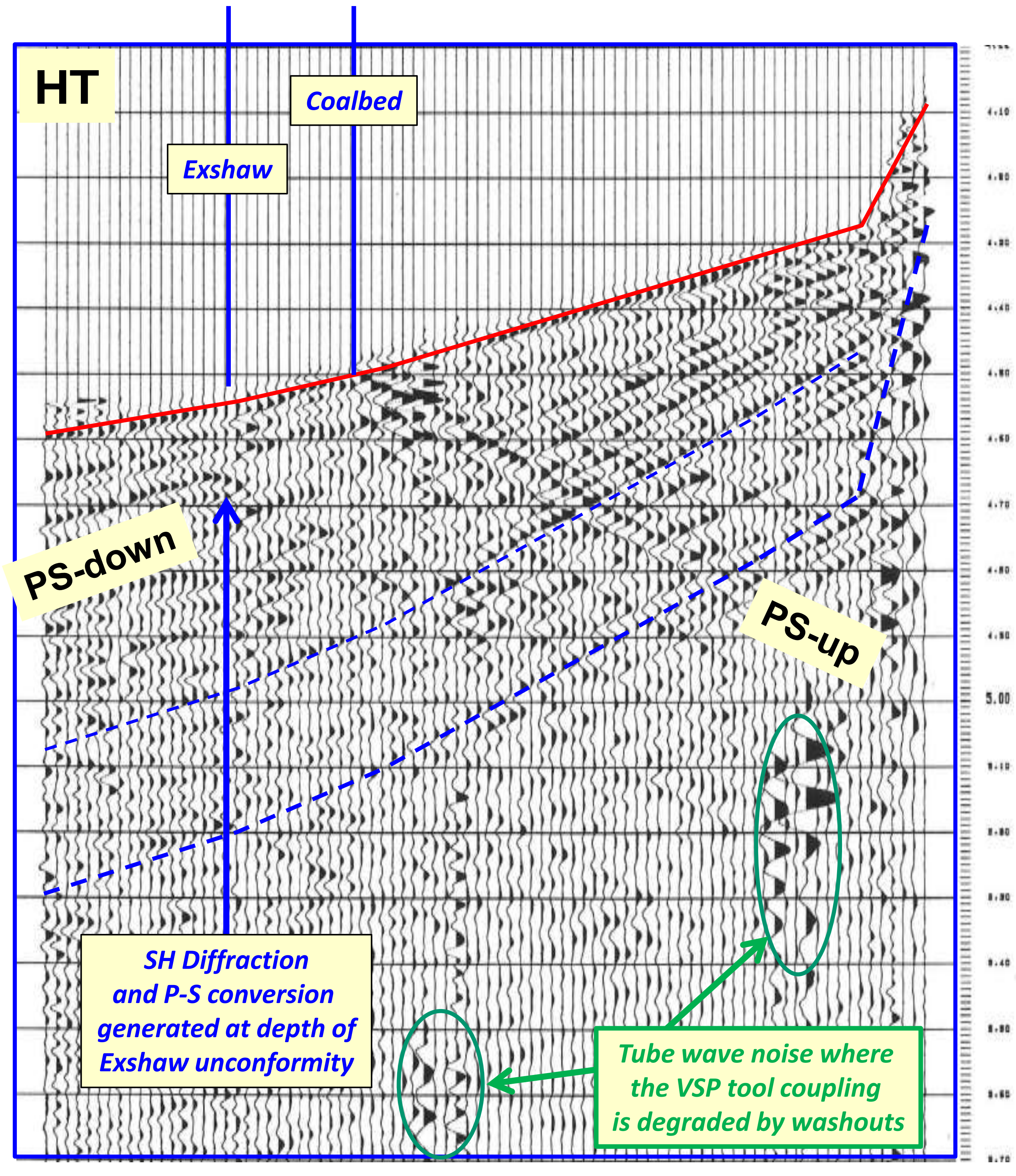
(B3) Display of oriented 3C VSP data,
Incident Resultant R , Cross normalized.



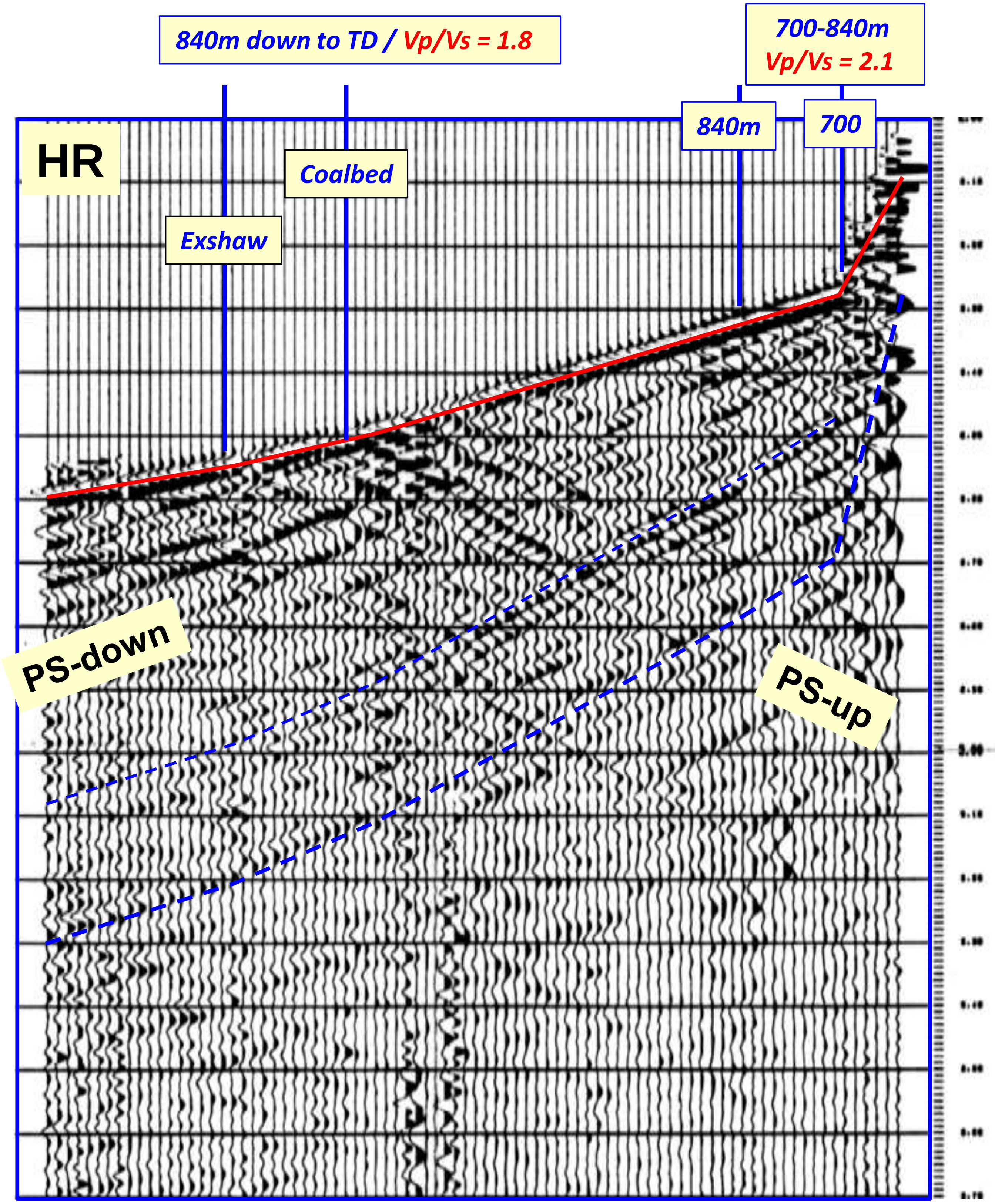
(B4) Display of oriented 3C VSP data, transverse Resultant RT , Cross normalized.



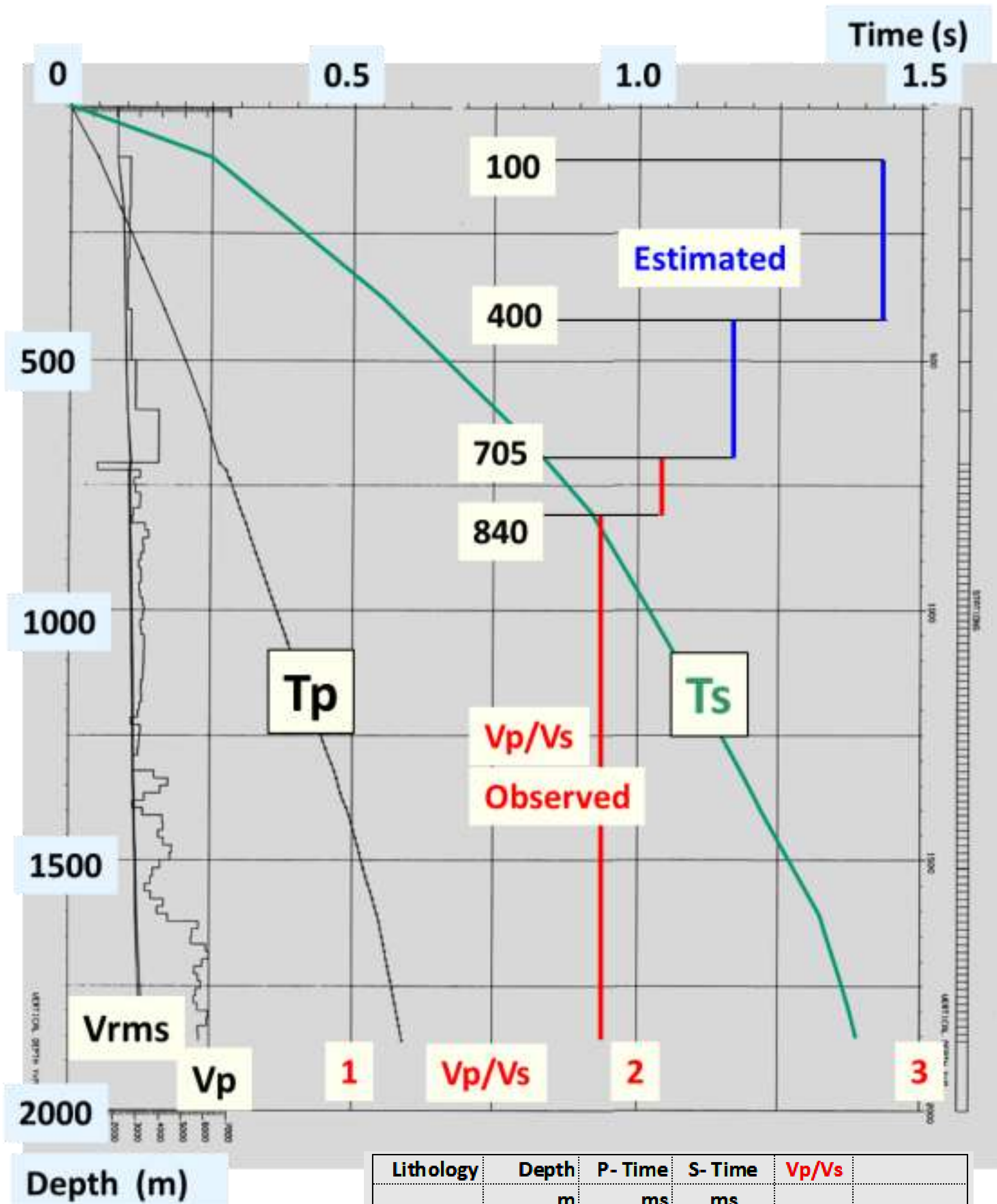
(B5) Display of oriented 3C VSP data, transverse Horizontal HT, Cross normalized.



(B6) Display of oriented 3C VSP data, Radial Horizontal HR, Cross normalized.

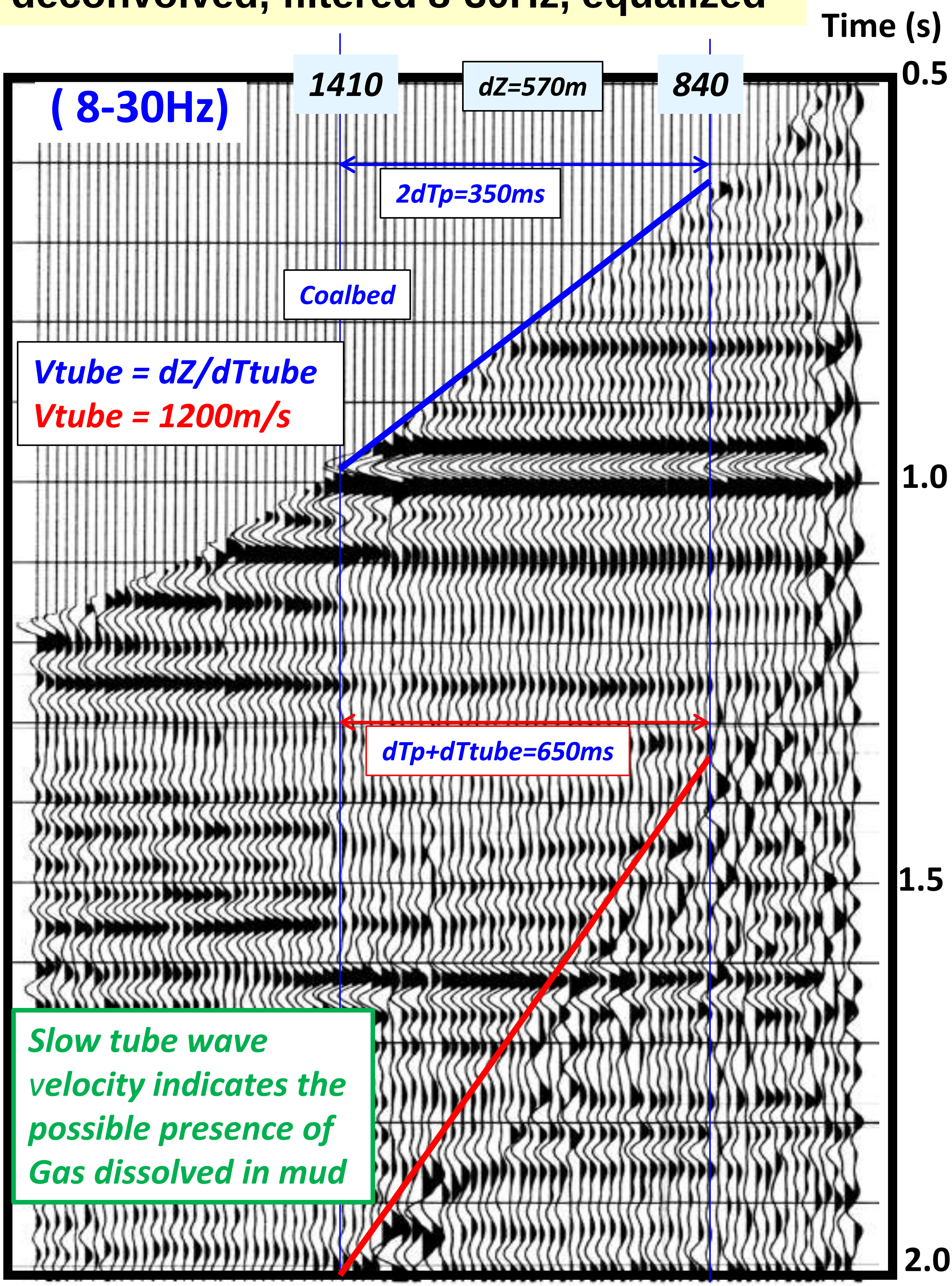


(B7) Time and Velocities versus Depth



Lithology	Depth	P- Time	S- Time	Vp/Vs	
	m	ms	ms		
	0	0	-		
	100	55	255	4,6	est.
	400	165	573	2,9	est.
	705	273	820	2,3	est.
	840	315	910	2,1	observed
Coal	1410	490	1 225	1,8	observed
Exshaw	1597	543	1 319	1,8	observed
T.D.	1860	588	1 400	1,8	observed

(B8) Reflected VSP wavefield display, deconvolved, filtered 8-30Hz, equalized



(B9) the CSI * VSP tool, excerpts from the 1990 commercial brochure

*** Mark of Schlumberger**

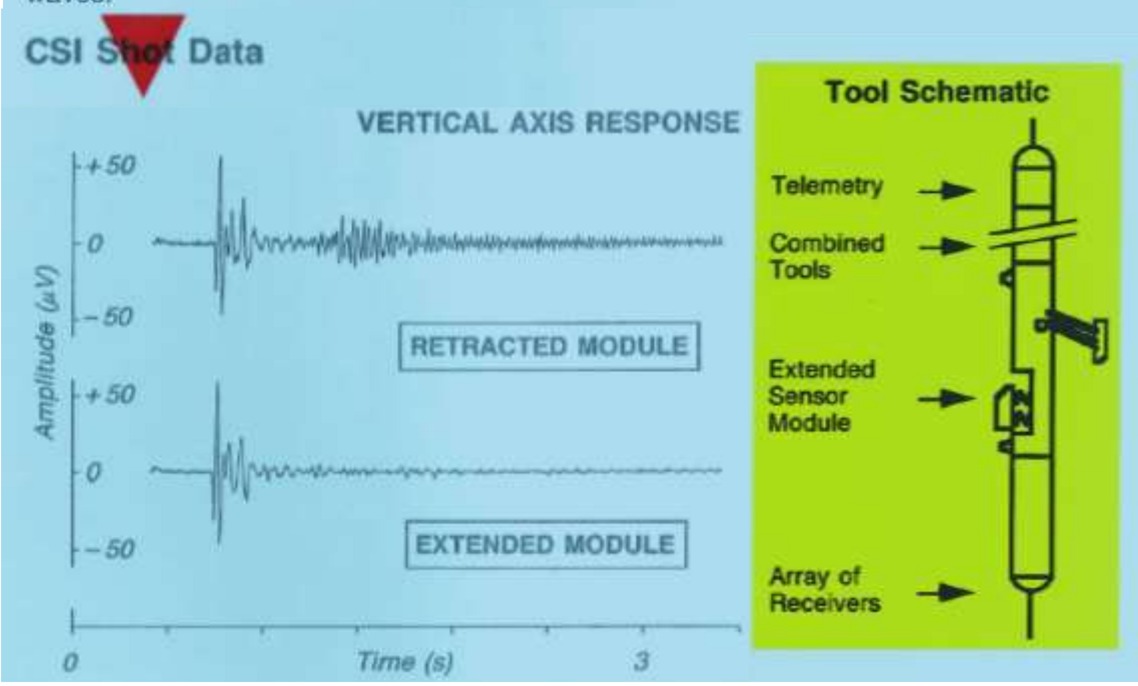
- In large caves, the sensor coupling is loose, thus the recorded tube wave level is higher.

Features

- Sensor module decoupled from sonde body

Decoupling

With its new architecture, in which the **light** sensor module is **decoupled** from the sonde body, ensuring a **flat** frequency response, the CSI tool has a reduced sensitivity to tube waves.



Data Quality

As with any seismic tool, the tube wave excites the tool resonances:

- When the module is retracted, the tool resonances are recorded and subsequent seismic events are masked.
- When the module is extended – and thus coupled to the formation and decoupled from the tool body – the tool resonances disappear and the **formation** elastic **response** is recorded.

APPENDIX-C : FREQUENCY analysis on deconvolved VSP upgoing wavefield

Standard VSP processing applied by IFPEN on Z-component:

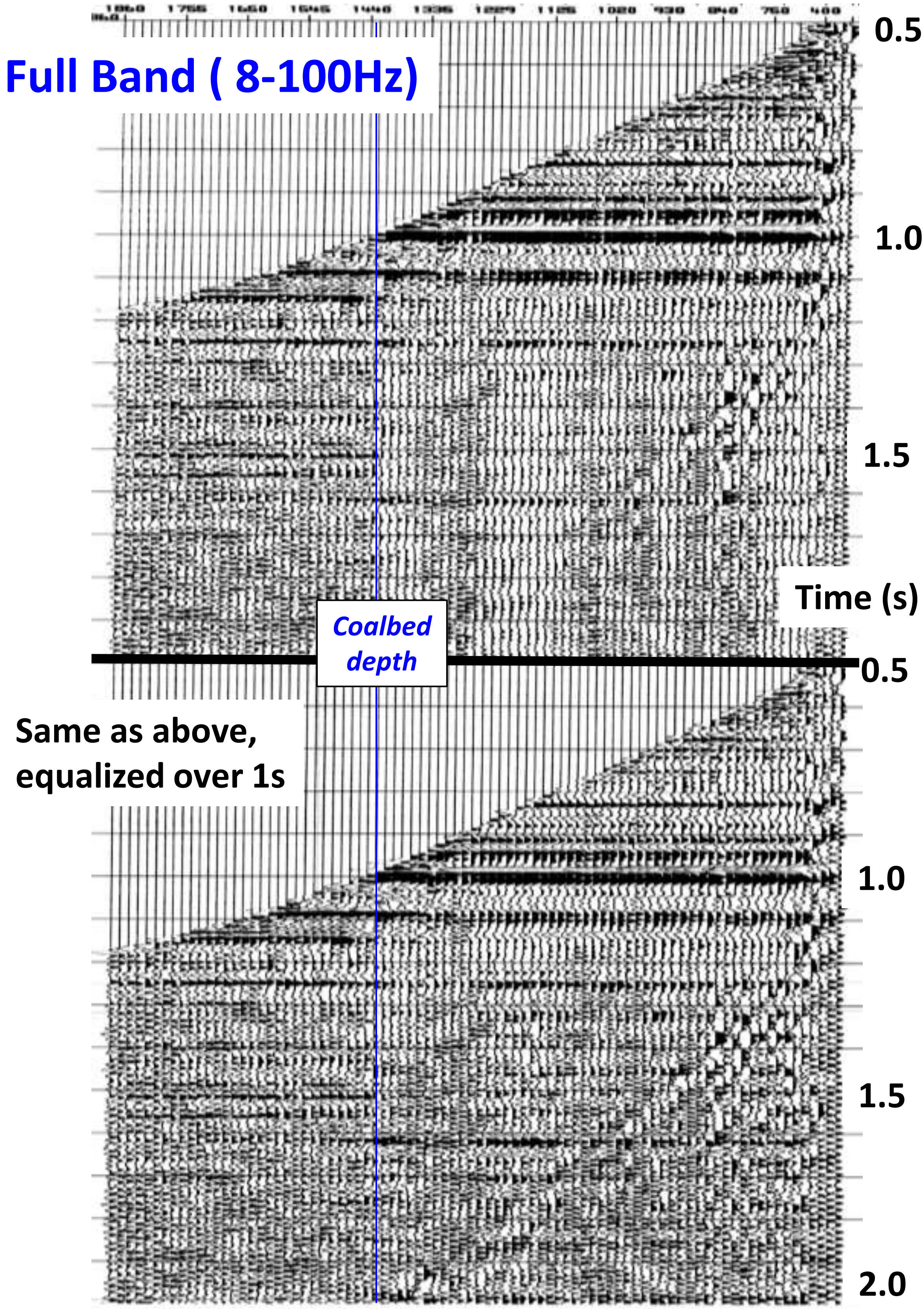
- **INPUT: Edition, median vertical stack at each depth , Bandpass filter 8-100Hz on raw VSP data, by SLB.**
- **Normalization of trough amplitude of first arrival.**
- **Flattening direct arrival,**
- **NO Spherical divergence , NO equalization applied on processed data, except for display**
- **Extraction of downgoing wavefield, design of signature to be used for shaping deconvolution of uupoing wavefield.**
- **Subtraction of P-wave downgoing wavefield and set-up P-P reflections into TWT.**
- **Signature deconvolution of residual wavefield (upgoing P-P + PS if any), by downgoing wavelet, trace to trace**
- **Equalized 800ms on fullband 8-100Hz , next slide C1**
- **4 Bandpass filters applied on equalized fullband reflected wavefield (8-30, 30-60, 60-80, 80-100Hz), slides C2-C5:**
  - **Top display: filter only**
  - **Bottom display: filtered, then equalized 1000ms**

- **Results:**

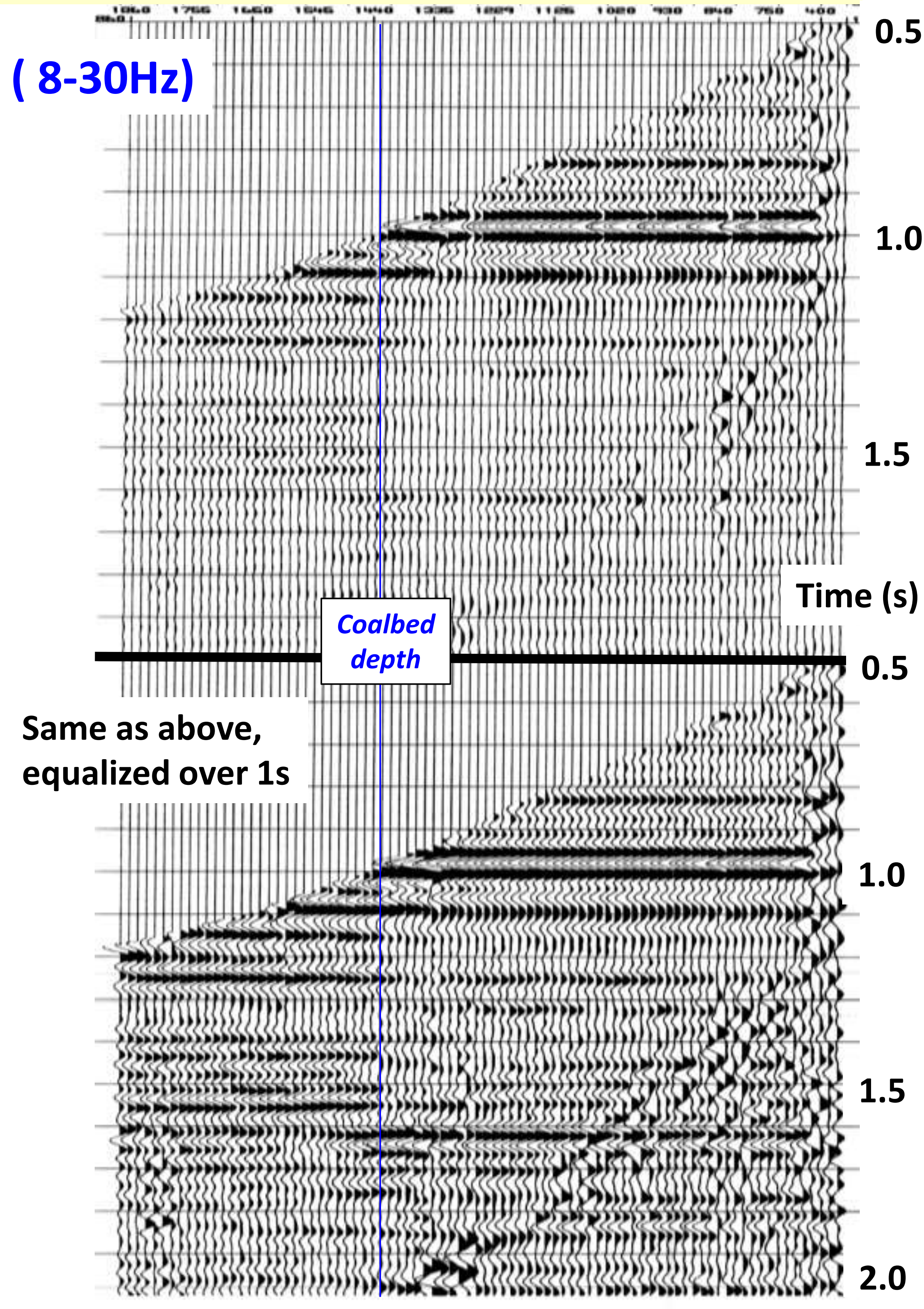
  TOTAL frequency loss above 60Hz for reflections below coalbed observed on VSP sensors located above Coalbed

- **Remark: In spite of the High Energy VSP source (two M25 vibrators , 5 sweeps 8-100Hz, 12 sec long), and an excellent VSP tool (Schlumberger CSAT), deep HF seismic reflection from underneath coalbed are lost for surface seismic.**

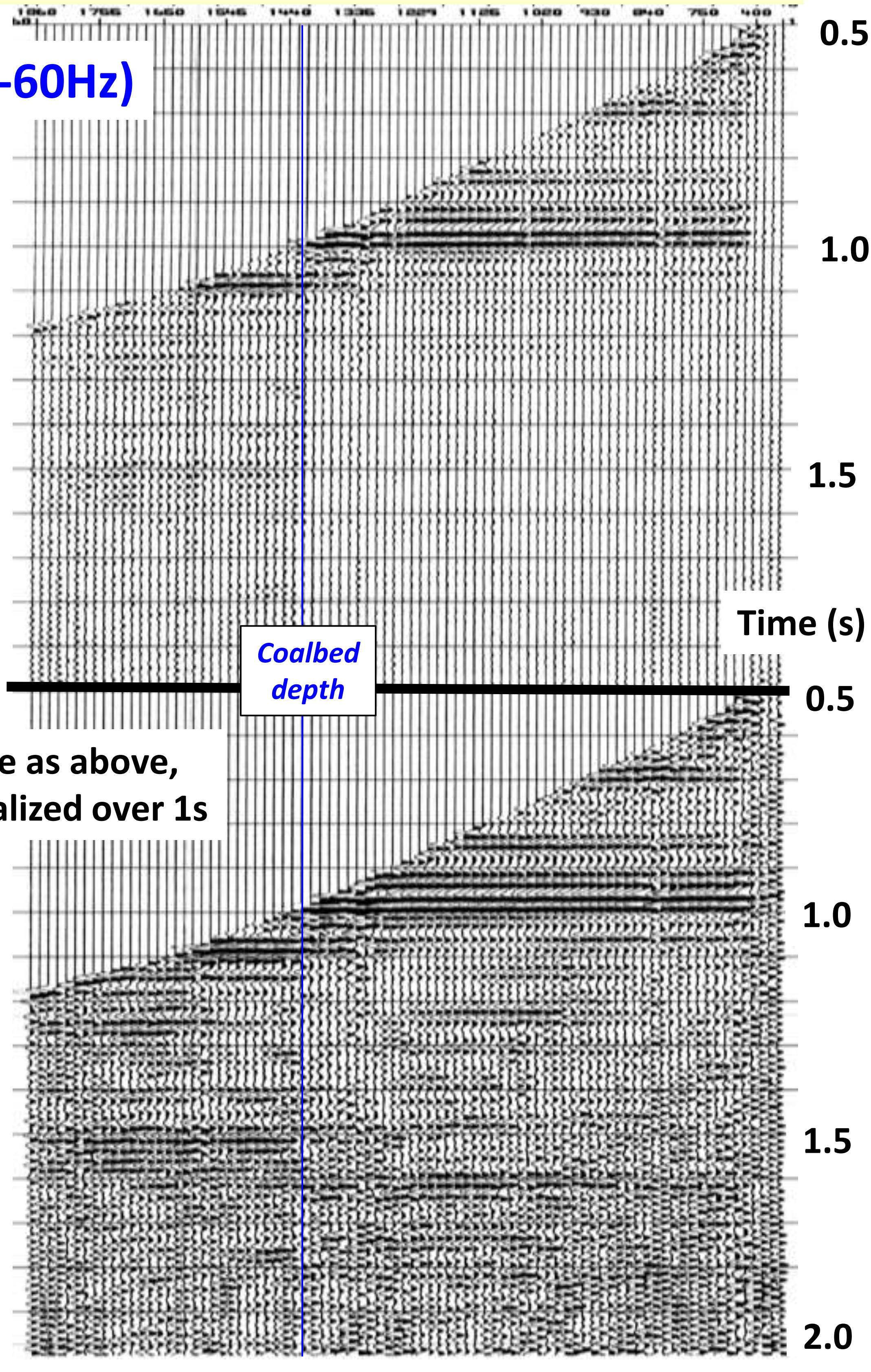
(C1) Reflected VSP wavefield, Deconvolved , 8-100Hz



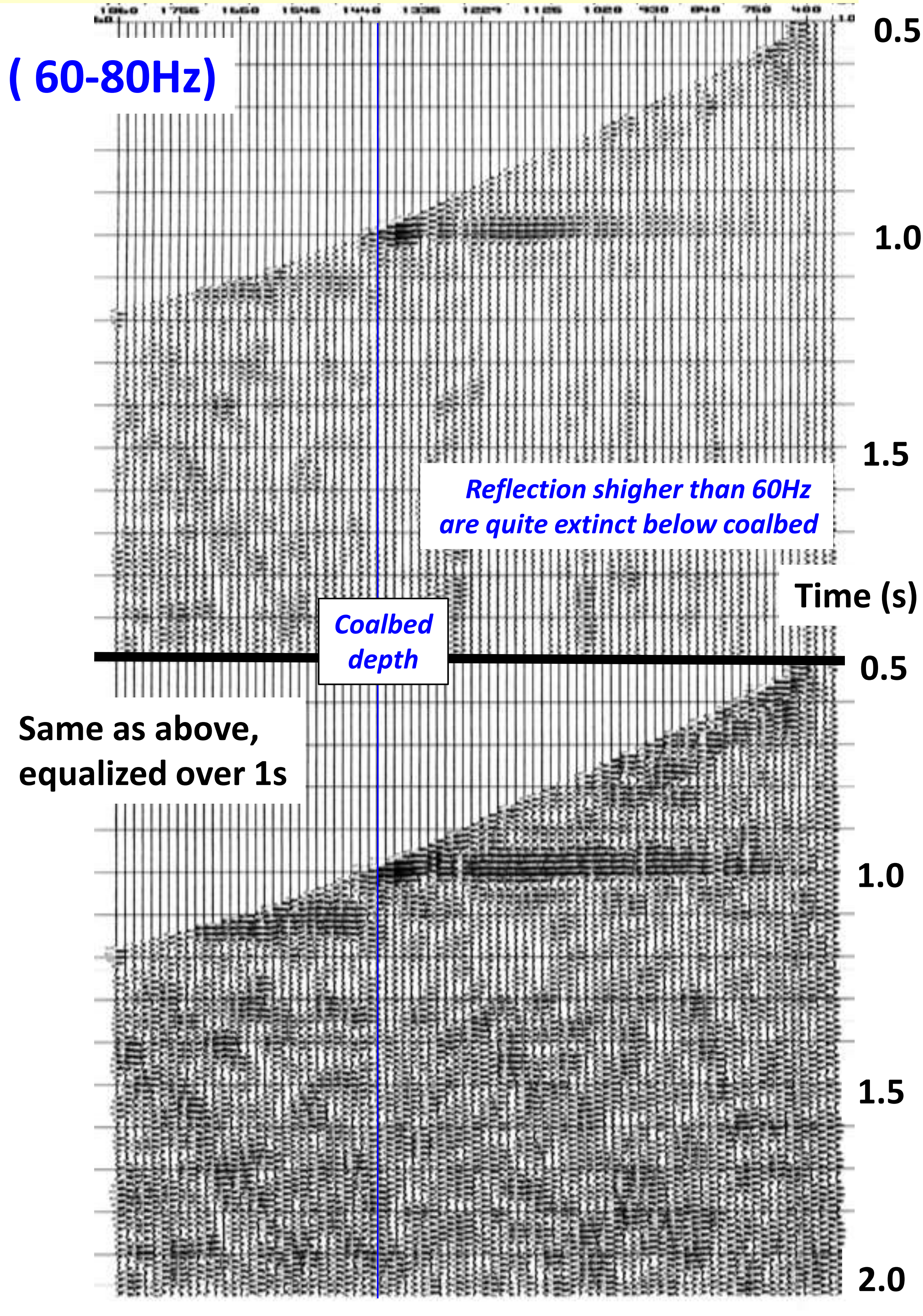
(C2) Reflected VSP wavefield, deconvolved, then filtered 8-30Hz



(C3) Reflected VSP wavefield, deconvolved, then filtered 30-60Hz



(C4) Reflected VSP wavefield, deconvolved, then filtered 60-80Hz



(C5) Reflected VSP wavefield, deconvolved, then filtered 80-100Hz