Schlumberger

Origin Energy Resources Ltd

Rockhopper-1 / Rockhopper-1 ST1

WELL SEISMIC PROCESSING REPORT

VSP-D / WSC / GEOGRAM

[See also Q-Borehole & QC VSP Reports]

FIELD: Rockhopper (T /18P)

COUNTRY: Australia

COORDINATES: Latitude: 39° 47' 34.18" S
: Longitude: 145° 26' 21.47" E

RIG: Kan Tan IV

DATE OF SURVEY: 04-Jan-2010 & 09-Feb-2010

SURVEY TYPE: Rig VSP, Offshore, Airgun, Deviated Well, 2x

REFERENCE NO: DS 0110-04

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Note:

The Seismic Reference Datum used in this project was LAT.

Origin Energy requested the main digital deliverables to be provided as well using MSL as Seismic Reference Datum. These files are clearly marked with _MSL in the name. The corrections made are done with the following relations: TVD(msl) = TVD(lat) + 1.6 m and TWT(msl) = TWT(lat) + 2 ms.

1 Introduction

Two borehole seismic surveys for VSP processing were recorded in Rockhopper-1 and Rockhopper-1 ST1, both deviated offshore exploration wells (max. 43.5° and 36.7° well deviation) on the 4th of January 2010 and the 9th February 2010 respectively from the rig Kan Tan IV.

The main goals of the surveys, obtaining Time/Depth relations as well as a VSP corridor stacks, have been achieved. Furthermore images underneath the well trajectories were also obtained. Complete field results are reported in the separate “Q-Borehole Survey Reports”. Initial QC VSP processing results are reported in the separate “VSP QC Reports”. It is important to realize that these initial QC results used single component processing and simple geometry correction only and that, due to the significant well deviation in combination with a rig source, further processing was required to obtain more accurate vertical times and images underneath the well trajectories.

This report describes the 3-C processing of both surveys to obtain combined VSP results with sonic calibration, synthetic seismogram generation and surface seismic to establish a three way tie.

It documents the quality of the acquired data and presents the corrected time-depth-velocity listing as well as VSP processing. Additionally it contains the results of sonic calibration and synthetic seismogram generation using compressional depth-time relationship of compressional velocity logs. It describes the processing techniques used, the parameters chosen and presents the results of the data processing. A comparison is made between the surface seismic, VSP and the synthetics seismograms.

The source signature for both surveys is stable producing reliable and consistent downhole signals. Quality of the data is good and the resultant corridor stacks and images match with the synthetic seismograms produced using the available log data and the surface seismic provided by Origin. Tying of the surface seismic data to the Synthetic/VSP data shows that a good overall match is achieved without any time shift of the surface seismic to match the VSP and Synthetic data.

2 Data Acquisition

The data were acquired in single logging runs in both open and cased hole, using a four level three component Versatile Seismic Imager Tool (VSI-4 with 15.12 m spacing) fitted with GAC accelerometers. A G-Gun delta cluster (3×150 cui) was used as the source suspended below a buoy. The geometry of the surveys is shown in Figures 1a/b.

Rockhopper-1

This survey included Rig Source VSP / Checkshot measurements from 2614.6 m MD DF to 294.1 m MD DF. It was not possible to descend to the planned TD of 3489 m MD DF.

The source cluster was deployed from the rig with an azimuth of 048 degrees with reference to North. The offset of gun was fixed 51 m from the wellhead. The guns were submerged from a buoy 5 meters below the tide level and fired at 1910 psi using N2 bottles.

Seismic Reference Datum (SRD) for the vertical Time-Depth information in this report is LAT. The average tide level during the VSP survey was 0.3 m above LAT and a bulk correction has been applied to the data. Survey geometry corrections and a static shift to correct the data to SRD were applied. This correction was done with a surface velocity of 1524 m/s.

Rockhopper-1 ST1
This survey included Rig Source VSP measurements from 3431.7 m MD DF to 1615.2 m MD DF.

The source cluster was deployed from the rig with an azimuth of 029 degrees with reference to North. The offset of gun was fixed 46 m from the wellhead. The guns were submerged from a buoy 4.8 meters below the tide level and fired at 1850 psi using N2 bottles.

Seismic Reference Datum (SRD) for the vertical Time-Depth information in this report is LAT. The average tide level during the VSP survey was 2.1 m above LAT and a bulk correction has been applied to the data. Survey geometry corrections and a static shift to correct the data to SRD were applied. This correction was done with a surface velocity of 1524 m/s.

For both surveys a calibrated Near Field (NF) reference hydrophone was deployed 1.25 meters below the center of the gun cluster. Schlumberger's Trisor Gun controller was used for the tuning and firing of the gun cluster, hence no source to hydrophone time correction is required. This new generation of Schlumberger proprietary borehole seismic system provides automated source control and enhanced QC functionality such as Gun depth and pressure measurements. Recording was made on the Schlumberger Maxis Unit using LDF format. The acquired gun source signatures are shown in Figures 2a/b.

Well	Rockhopper-1	Rockhopper-1 ST1
Elevation of DF	26 m above LAT	
Elevation of GL	74.3 m below LAT	
Elevation of SRD	0 m (LAT)	
Well Deviation	max 43.5°	max 36.7°
Energy Sources	3×150 cu in G-Gun cluster	
Time Reference	FTB Signal from TrisorOFS	
Source Offset / Azimuth	51 m / 048°	46 m / 029°
Source / Sensor Depth	5 m / 6.25 m below tide	4.8 m / 6.05 m below tide
Reference Velocity	1524 m/s	
Downhole Tool	VSIT-C (4 shuttles)	
Sensor Type	3-C GAC	

Table 1: Survey Parameters

3 Well Seismic Edit

The initial preparation of the data is called Well Seismic Edit and consists of:

- Load Data
- Edit bad records & Sort Data
- Median stack
- Geophone Transform
- Pick Break time on Stacked Data

Each shot of the raw GAC data was evaluated and edited to remove bad traces. The hydrophone data were also evaluated for signature changes and timing shifts. The data were stacked at each level using a median stacking technique, to increase the signal to noise ratio of the data. For better comparison with geophone data, a transform to a 10 Hz/70% damped geophone is applied to the GAC data. After stacking the transit time of each trace was re-computed.

The following subsections describe the main aspects of the well seismic edit phase.

3.1 Data Quality

Rockhopper-1

Data quality is considered to be good. This dataset was acquired as a checkshot survey with 3 shots per tool setting and variable level spacing (45.36 m long VSI-4 array moving up 100 m). The top levels of the survey (above 1059.5 m MD DF) are affected by casing ringing noise. The Time-Depth relationship up to 1014.1 m MD DF is estimated using the X, Y and rotated 3C component data, above this no accurate Time-Depth information can be picked. A Gamma Ray log was run for depth correlation and the VSP is within 1 m on depth with the reference GR log. The NF hydrophone sensor and Trisor QC displays indicate that the source signature / Gun pressure were stable.

Even though the checkshot spacing is variable and only 3 shots per level were acquired, the good data quality combined with the fact that a VSI-4 was used allows this data to be processed as a VSP dataset to obtain a Corridor Stack and even a migrated Image. Due to the look-ahead capability of borehole seismic deeper reflectors well below the deepest recorded checkshot level can be distinguished on this data.

Rockhopper-1 ST1

Data quality is considered to be excellent. The VSP levels were acquired with at least 5 good repeatable shots per level. A Gamma Ray log was run for depth correlation and the VSP was shifted down 1.2 m to be on depth with the Run 1 reference log. The NF hydrophone sensor and Trisor QC displays show that the source signature / Gun depth were stable.

Full 3C VSP processing is required for this borehole seismic dataset due to the 2D geometry. Also the time-depth information needed to be further calibrated using a model-based approach and was used to calibrate sonic slowness and other log curves and subsequently to generate time-indexed calibrated logs and synthetic seismogram traces.

3.2 Stacking

After reordering and selecting the best traces, a median stack was performed on the three component source signature deconvolved data. In this method of stacking, at each sample time, the amplitudes of the input traces are read and sorted in ascending order. The output is the median amplitude value from this ordering. The TRISOR-OFS zero time reference is used as the zero time for stacking. The break time of each trace is recomputed after stacking. The X, Y and Z component stacks for both Rockhopper-1 and Rockhopper-1 ST1 surveys are presented in Figures 3a/c and 4a/c respectively. Figures 3d and 4d show the vertical component aligned with a –TT shift, whilst the amplitude spectrum of the downhole data is shown in Figures 5a and 6a,and the Frequency-Wavenumber (F-K) spectrum is shown in Figures 5b and 6b.

3.3 Transit Time Measurement

The measured compressional transit time corresponds to the difference between arrivals recorded by surface and downhole sensors. The reference time (zero time) for the VSP is the Predicted Fire time determined in a closed feedback system of the TRISOR-OFS shooting system and the measured transit time is from the source and not the reference hydrophone. Hence only static corrections from source to datum are required. An inflection point tangent first break picking algorithm was used on the geophone transformed GAC data.

4 VSP Processing

This pre-processed VSP data can now be used to derive VSP down going and reflected wavefields, VSP Corridor Stacks and Images for surface seismic matching. The following subsections describe the main aspects of the VSP processing chain:

Rockhopper-1

• Datum and geometry correction	:	Survey Geometry Headers
• 3C Rotations to TRY and V,H	:	Data and Geometry based
• Bandpass Filter	:	Butterworth Zero Phase, 5-200 Hz
• Wavefield Separation Down P (V)	:	Velocity Filter, 7x1 Median, TT
• Wavefield Separation Up P	:	Velocity Filter, 5x1 tri-mean, -TT
• Waveshaping Deconvolution	:	5-100 Hz Zero Phase, Window 2 s
• Spherical Divergence Correction	:	Time Varying Gain, Exponent 1.8
• Wavefield Enhancement Up P	:	Velocity Filter, 7x3 tri-mean, Model Based
• NMO Correction	:	Model Based for Corridor Stack
• Corridor Stack	:	100 ms , 8 deepest traces
• Imaging	:	GRT Migration, TWT

Rockhopper-1 ST1

• Datum and geometry correction	:	Survey Geometry Headers
• 3C Rotations to TRY and V,H	:	Data and Geometry based
• Bandpass Filter	:	Butterworth Zero Phase, 5-200 Hz
• Parametric Wavefield Decomposition	:	WavanaPro, 5-100 Hz, Inverted Model
• Wavefield Separation DP from Up P	:	Velocity Filter, 15x3 Median, TT
• Waveshaping Deconvolution	:	5-80 Hz Zero Phase, Window 2 s
• Spherical Divergence Correction	:	Time Varying Gain, Exponent 1.8
• Wavefield Enhancement Up P	:	Velocity Filter, 7x3 tri-mean, Model Based
• NMO Correction	:	Model Based for Corridor Stack
• Corridor Stack	:	100 ms , 8 deepest traces
• Imaging	:	GRTMigration, TWT

4.1 Correction to Datum

Seismic Reference Datum (SRD) is at LAT (Lowest Astronomical Tide). This is approximately 1.6 m below MSL for this location.

The source was positioned approximately 5 m below local tide levels. Tide corrections were estimated as bulk shifts for each survey and applied to the data. Transit time correction to SRD was initially applied using straight ray geometry to calculate corrected vertical transit time and surface velocity of 1524 m/s. Due to the 2D nature of the survey, a model-based approach was adopted here as described in section 4.4. The time-depth-velocity results of the VSP survey are presented in Attachment 2a (Rockhopper-1) and 2b (Rockhopper-1 ST1).

4.2 Rotation of 3C components

The VSI-4 is equipped with non-gimballed GAC receivers. This means that the Z component is along the tool i.e. wellbore axis. The X and Y components are orthogonal to that with the X component in line with the tool caliper arm. In a vertical well, energy recorded on horizontal components either has traveled along a non vertical path e.g. due to structural dip or faults or has non-vertical particle motion e.g. mode converted shear.

When processing a rig source VSP in a deviated well the 3 component data need to be rotated to the 2D plane containing Source, Receiver and Reflection points. This can be done by first taking the two tool horizontal components X and Y and determining via energy hodograms in a small window around the picked transit time the orientation of the maximum (in-line) component (HMX) and orthogonal to that the minimum (cross-line) component (HMN). Figures 7a/b present examples of the rotated downhole 3C data for both surveys including derived rotation angles and quality control curves.

The Z and HMX components are then rotated to maximize the first arriving energy in the TRY (Tangent to RaY) direction. The borehole deviation was subsequently used to rotate the Z and HMX components to true vertical (V) and true inline horizontal (H) components. Figures 8a/d and 9a/d show the following rotated components: TRY, HMX, V and H.

4.3 Bandpass Filter

The effective bandwidth of the recorded data is evaluated by examining the amplitude spectrum of the stacked vertical component presented in Figures 5 and 6. A wide zero phase Butterworth Band pass filter was applied to the data limiting the bandwidth to 5-200 Hz.

4.4 Velocity Model building

It was necessary to build a model of the subsurface for the following reasons:

- VSP ray tracing modeling to help understand various ray modes in the subsurface
- Advanced processing techniques require a model to guide the algorithms (wavefield separation, amplitude corrections, etc)
- The GRT migration processes require a background velocity model

A mildly dipping layered model was build from the depth converted surface seismic time section along the well trajectory provided by Origin using the VSP time-depth information of both VSP surveys. This initial model was subsequently adjusted to match the borehole seismic data using ray-tracing and travel time inversion. Figure 10a/b show the seismic, the model, the source-receiver geometry as well as the inverted Vp velocities and direct ray paths and reflection points for some reflectors. The model has been inverted for P velocity using Down P arrival times. The overall RMS residual travel time difference between modeled and measured times is less than 1 ms. Figure 10c shows the simulated Vertical Incidence VSP that provides a QC of the NMO corrected vertical time-depth information for listings and sonic calibration processing This analysis is shown in the attached Time Analysis spreadsheet.. Note that no lateral velocity profile information was provided; constant velocity layers were used in the inversion and diverging residuals of both surveys in the deeper layers indicate that these effects may have an influence here.

4.5 Wavefield Separation

Two different flows were used to obtain separated down and up going P wavefields for Rockhopper-1 and Rockhopper-1 ST1. Due to the more vertical angles in the Rockhopper-1 survey, down going P wavefields are estimated and removed from the true Vertical component only as there is not sufficient shear energy present to apply parametric wavefield decomposition techniques. These were used on Rockhopper-1 ST1 Vertical and Horizontal component data.

Flow Rockhopper-1

As the maximum up-going P energy is mostly concentrated on the vertical component, this component was used. Firstly a velocity filter (coherency) method is applied to estimate the down going compressional wavefield. Temporary trace equalization was applied by normalizing the RMS amplitude of the first break to correct for transmission losses of the direct wave. A normalization window of 200 milliseconds was used.

The down going coherent compressional energy is estimated using a 7x1 level Median velocity filter parallel to the direct arrival curve. The filter array is moved down one level after each computation and the process is repeated level by level over the entire dataset. The down going P wavefield is displayed in one-way time in Figure 11a.

The residual wavefield is obtained by subtracting the estimated down going coherent energy from the total wavefield. The resulting up going wavefield is shown in Figure 11b.

Next a 5x1 level Tuckey tri-mean velocity filter enhancement was applied to this residual wavefield and the resulting up going P wavefield is shown in Figure 11c.

Flow Rockhopper-1 ST1

A data-driven parametric wavefield decomposition technique (Wavanapro) was used to separate the up going and down going compressional and shear wavefields. This method decomposes downhole multi-component recordings into scalar wavefields using a parametric least-squares minimization where the data are modeled in a given time window as a superposition of several plane wave events. Each wave is defined by its local velocity, its angle of incidence and its waveform. Initial parameters were obtained from the 2D model and used to guide the processing as well as an initial direction guess based on the survey geometry.

The frequency range used is 5-80 Hz (constrained by special aliasing of shear energy) and processing was done in a single time window. The results of the initial pass were inverted and the final stage of separation is QC of inversion results. Figures 12 a/d show the obtained down and up going compressional (P) and converted shear (PS) wavefields.

To clean up the up going P wavefield from some residual down P this down going coherent compressional energy is estimated using a 15x3 level Median velocity filter parallel to the direct arrival curve. Figure 12e shows the separated up going P wavefield.

4.6 Zero Phase Waveshaping Deconvolution

The waveshaping process shortens the seismic pulse within traces and centers their amplitude peak on the reflector. This improves the resolution of the seismic data and helps to clarify the correlation of the seismic events. It is also applied to collapse the recorded multiples.

The waveshaping deconvolution operator is a double-sided Wiener-Levinson waveshaping filter. The operator is computed for each level of the down going wavefield using a window length of 1 s starting 5 ms before the picked break times in order to include the wavelet precisely. The designed outputs were chosen to be zero-phase with a bandwidth of 5-100 Hz for Rockhopper-1 and 5-80 Hz for Rockhopper-1 ST1. Once the design is made upon the down going wavefield, it is applied to the both down going and up going wavefields at the same level as displayed in Figures 13a/b and 14a/b for both surveys respectively.

4.7 Spherical Divergence Correction

To correct the recorded amplitudes for the loss of energy due to the spherical divergence of the wave front, a time varying gain function of the exponential form:

$$Gain(T) = (T / T_0)^{\alpha}$$

where T_0 is the recorded transit time. The exponent used here is 1.8.

4.8 Upgoing Enhancement

A velocity filter (coherency) technique was used to enhance the zero phase upgoing wavefield.

The up going coherent compressional energy is estimated using a model-based 7x3 level Tuckey tri-mean velocity filter. This enhanced up going wavefield is displayed in one way time (OWT) in Figures 13c and 14c.

4.9 NMO correction and Corridor Stack

A corridor stack in two way time (TWT) was computed on the enhanced zero phase upgoing wavefield after model-based NMO correction by designing a constant 100 ms timing window along the two-way time depth curve and stacking the data onto a single trace. The deepest 8 traces are stacked entirely. The resulting trace provides the seismic representation of the borehole in vertical two-way time.

This corridor stack is displayed in Figures 15a/b along with the NMO corrected up going wavefield in two way time.

4.10 Migration

Final images were produced using the GRT migration technique.

The Generalized Radon Transform (GRT) migration approach (Miller et al. 1987) based on exact two-point ray-tracing through a 2D medium is used where the theory is similar to that of Kirchhoff migration. In this scheme, each point in the offset-depth (x, z) domain can be regarded as a potential velocity anomaly, capable of scattering seismic energy. Similarly, each point in the data domain (x,t) is based on the contribution of scattered energy from points along an isochron in the (x,z) domain. In a constant velocity medium the isochrones are ellipses with source and receiver points as foci. In a realistic medium with laterally varying parameters, the shapes of the isochrones are distorted. The migration can be carried out either by redistributing the amplitudes of points in the data domain to reproduce points in the (x,z) domain, or by summing along diffraction hyperbolae in the data domain to reproduce points in the (x,z) domain. The former process is known as back projection and the later, used here, is a diffraction stack. The spatial resolution that can be obtained for given source-receiver configurations is directly related to the distribution of isochrones in the (x,z) domain. The best resolution is achieved in a direction perpendicular to the isochrones. A point can be only imaged perfectly when isochrones cross it in all directions, similar to the imaging concept in tomography.

Conceptually the method is based on Huygens principle, where the subsurface can be thought of as a grid of diffraction points. The principle implementation of GRT migration consists of summing along diffraction hyperbola in the data domain (T,Z) defined by the ray-traced time, T1, to propagate from the sources to one particular point (x,z) of the subsurface and the time, T2, to propagate from the point (x,z) to the receiver. Wherever a hyperbola is tangent to a seismic event, the data will be summed constructively, whereas amplitudes along the remaining portions will cancel out. A series of possible isochron surfaces, or dip, can be defined at the image point (x,z) by adjusting the aperture.

The data input are the zero phase deconvolved up going compressional scalar wavefields.
Parameters for this processing step are:

Velocity model	2D, Structure from Surface Seismic, Velocities from VSP TT inversion
Input wavefield:	Scalar, Deconvolved upgoing PP VSP
Aperture:	3 Degrees, Dip interpolated from model
CDP/trace spacing:	10 m
Sampling rate:	1 ms
Corrections:	No geometrical spreading

The resulting migrated sections are displayed in TWT in Figures 16a/b for each survey individually and in Figure 16c after combining both migrated images into a single final Image including an extension using the derived corridor stack. To improve the lateral continuity of this image, a 5x3 tri-mean velocity filter was used.

4.11 Composite Displays of Results

Figures 17a/b show composite displays of the provided surface seismic section along the Rockhopper-1 and Rockhopper-1 ST1 well direction (N-S) and the combined VSP migrated image. The composite displays show a good correlation between the surface seismic and the VSP Image without shifting the surface seismic data.

5 Sonic Calibration Processing

5.1 Sonic Calibration

A 'drift' curve is obtained using the sonic log and the vertical check level times. The term 'drift' is defined as the seismic time (from check shots) minus the sonic time (from integration of edited sonic). Commonly the word 'drift' is used to identify the above difference, or to identify the gradient of drift versus increasing depth, or to identify a difference of drift between two levels.

The gradient of drift, that is the slope of the drift curve, can be negative or positive.

- For a negative drift (Δdrift/Δdepth < 0) the sonic time is greater than the seismic time over a certain section of the log.
- For a positive drift (Δdrift/Δdepth > 0), the sonic time is less than the seismic time over a certain section of the log.

The drift curve, between two levels, is then an indication of the error on the integrated sonic or an indication of the amount of correction required on the sonic to have the TTI of the corrected sonic match the check shot times. Two methods of correction to the sonic log are used.

1. Uniform or block shift. This method applies a uniform correction to all the sonic values over the interval. This uniform correction is applied in the case of positive drift and is the average correction represented by the drift curve gradient expressed in µsec/m .

2. ΔT Minimum. In the case of negative drift a second method is used, called Δ minimum. This applies a differential correction to the sonic log, where it is assumed that the greatest amount of transit time error is caused by the lower velocity sections of the log. Over a given interval the method will correct only Δt values which are higher than a threshold, the Δt_{min} . Values of Δwhich are lower than the threshold are not corrected. The correction is a reduction of the excess of Δt over Δt_{min}, $\Delta t - \Delta t_{min}$.

$\Delta t - \Delta t_{min}$ is reduced through multiplication by a reduction coefficient which remains constant over the interval. This reduction coefficient, named G, can be defined as:

$$G = 1 + \frac{drift}{(\Delta t - \Delta t_{\min})\partial z}$$

Where *drift* is the drift over the interval to be corrected and the value $(\Delta t - \Delta t_{min})\partial z$ is the time difference between the integrals of the two curves Δt and Δt_{min} only over the intervals where $\Delta t > \Delta t_{min}$. Hence the corrected sonic:

$$\Delta t = G\left(\Delta t - \Delta t_{\min}\right) + \Delta t_{\min}$$

The resultant drift curve, knee points and calibrated velocity plot are shown in Figure 18a/b and the attached 36” plots.

5.2 Open Hole Logs

The sonic DTCO curves were used for drift computation. The RHOB, CALI, RT and GR logs were provided by Origin and used as companion curves. The density log was extended to the seabed using Gardner relation.

5.3 Correction to Datum

The sonic calibration processing has been referenced to LAT, which is the seismic reference datum. The calibrated model based NMO results are presented in the listings.

5.4 Sonic Calibration Results

The sonic log was tied to a station (1318.4 m TVDSS) in the seismic log. This station was chosen as the origin for the calibration drift curve as shown in velocity cross plot. The compressional sonic log was extended using the VSP data.

The drift curve is the correction imposed upon the sonic log. The adjusted sonic curve is considered to be the best result using the available data. A mostly positive drift is visible in both VSP section.

One 2D model based synthetic time-depth point was added to the Rockhopper-1 dataset to allow use of logs to TD of this borehole; OWT 1.1436 s at TVDSS 3149 m.

The VSP section residual drift is less than +/-1ms and the calibration process introduced no significant artificial slowness jumps. A list of shifts used on the sonic data is given in A2 Listing (supplied in digital form on Final Results CD-ROM). The Velocity Cross plot is presented in Figures 18a/b and as a separate plot.

6 Synthetic Seismogram Processing

GEOGRAM processing produces synthetic seismic traces based on reflection coefficients generated form sonic and density measurements in the wellbore. The steps in the processing chain are the following:

- Depth to time conversion
- Reflection coefficient generation
- Attenuation coefficient calculation
- Convolution
- Output

6.1 Depth to Time Conversion

Open hole logs are recorded from the bottom to top with a depth index. This data are converted to two-way time index. Rockhopper-1 ST1 formation tops were provided by Origin Energy Resources Ltd. in MD DF and have been converted to calibrated VSP/Geo two-way time (Table 2):

Marker	Measured Depth (m)	TVDSS (m)	Two-Way Time (s)
EVCM	2068.1	2041.5	1.696
Top 2809	2844.0	2711.0	2.078
P3 (2952)	3058.0	2886.9	2.173
Base Low AI	3238.0	3033.0	2.247
TL60	3350.0	3124.0	2.292
Cret Volcanics	3435.0	3193.4	2.327

Table 2: TWT Formation Markers Rockhopper-1 ST1

6.2 Primary Reflection Coefficients

Sonic and density data are averaged over chosen time intervals (normally 1 ms). Reflection coefficients are then computed using:

$$R = \frac{r_2 v_2 - r_1 v_1}{r_2 v_2 + r_1 v_1}$$

where:

r_1 = density of the layer above the reflection interface
r_2 = density of the layer below the reflection interface
v_1 = compressional wave velocity of the layer above the reflection interface
v_2 = compressional wave velocity of the layer below the reflection interface

This computation is done for each time interval to generate a set of primary reflection coefficients without transmission losses.

6.3 Primaries with Transmission Losses

Transmission loss on two-way attenuation coefficients is computed using:

$$A_n = (1 - R_1^2)(1 - R_2^2)\ldots(1 - R_n^2)$$

A set of primary reflection coefficients with transmission loss is generated using:

$$Primary_n = R_n A_{n-1}$$

6.4 Primaries plus Multiples

Multiples are computed from these input reflection coefficients using the transform technique from the top of the well to obtain the impulse response of the earth. The transform outputs primaries plus multiples.

6.5 Multiples Only

By subtracting previously calculated primaries form the above result we obtain multiples only.

6.6 Wavelet

A theoretical wavelet is chosen to use for convolution with the reflection coefficients previously generated. Choices available include: Klauder wavelet, Ricker zero phase wavelet, Ricker minimum phase wavelet, Butterworth wavelet, or User defined wavelet. Here 25, 35 and 45 Hz Ricker zero phase wavelets have been selected for computation of the synthetics.

6.7 Polarity Convention

An increase in acoustic impedance gives a positive reflection coefficient, is written to tape as a negative number and is displayed as a white trough under normal polarity. Polarity conventions are displayed in Figure 19.

6.8 Convolution

The standard procedure of convolving the wavelet with reflection coefficients; the output is the synthetic seismogram.

6.9 Results of Synthetic Seismogram Processing

A snapshot of the 40 cm/s composite displays (PLOT-1A/B and PLOT-2A/B) of VSP calibrated logs, VSP and Synthetic and Surface Seismic data is shown in Figures 20a/b and 21a/b respectively.

The 25 Hz, 35 Hz and 45 Hz Ricker wavelets were used to compute the synthetics shown in Figures 22a/b and 23a/b. The computed synthetics were compared to the corridor stack generated from the VSP data and the surface seismic well trace extracted along the well path in time. Overall, there is a good match between the VSP, synthetics and the surface seismic data.

7 Conclusion

A VSP survey was carried out in the deviated Rockhopper-1 and Rockhopper-1 ST1 wells. The main objectives of the survey were acquisition of a vertical checkshot velocity profile (Time/Depth relation) and a VSP dataset for generation of a corridor stack and a VSP Image. These objectives were achieved.

7.1 VSP and Surface Seismic

Acquisition was carried out using a four shuttle VSI tool by Schlumberger Oilfield Australia Ltd. The quality of the acquired data is excellent. Both Rockhopper-1 and Rockhopper-1 ST1 datasets were processed as VSP data sets. The processed data are used to generate corridor stack and migrated VSP Images. Comparing the VSP results and the PSTM surface seismic along the well trajectory it was found that an overall match is achieved without shifting the surface seismic.

7.2 Synthetics

The synthetics were generated using the compressional velocity log, and density logs. The final calibrated log curves are presented in the attached data CD. The synthetics were generated using 25 Hz, 35 Hz, 45 Hz zero-phase Ricker wavelets. The character match between the 45 Hz synthetic and the VSP generated corridor stack and the surface seismic is good, as seen on Plot-1 and Plot-2. Formation tops provided by Origin in MD DF have been converted to calibrated VSP NMO two-way time (Table 2) and are presented in section 6.1.

7.3 Recommendations

Finally it should be noted that for true vertical time-depth information a Vertical Incidence (or Walk-above) VSP would have been the best survey type. This report describes calibrated model-based results. The model-based approach certainly is a step in the right direction, but it cannot guarantee the correct vertical time-depth answer.

8 Figures

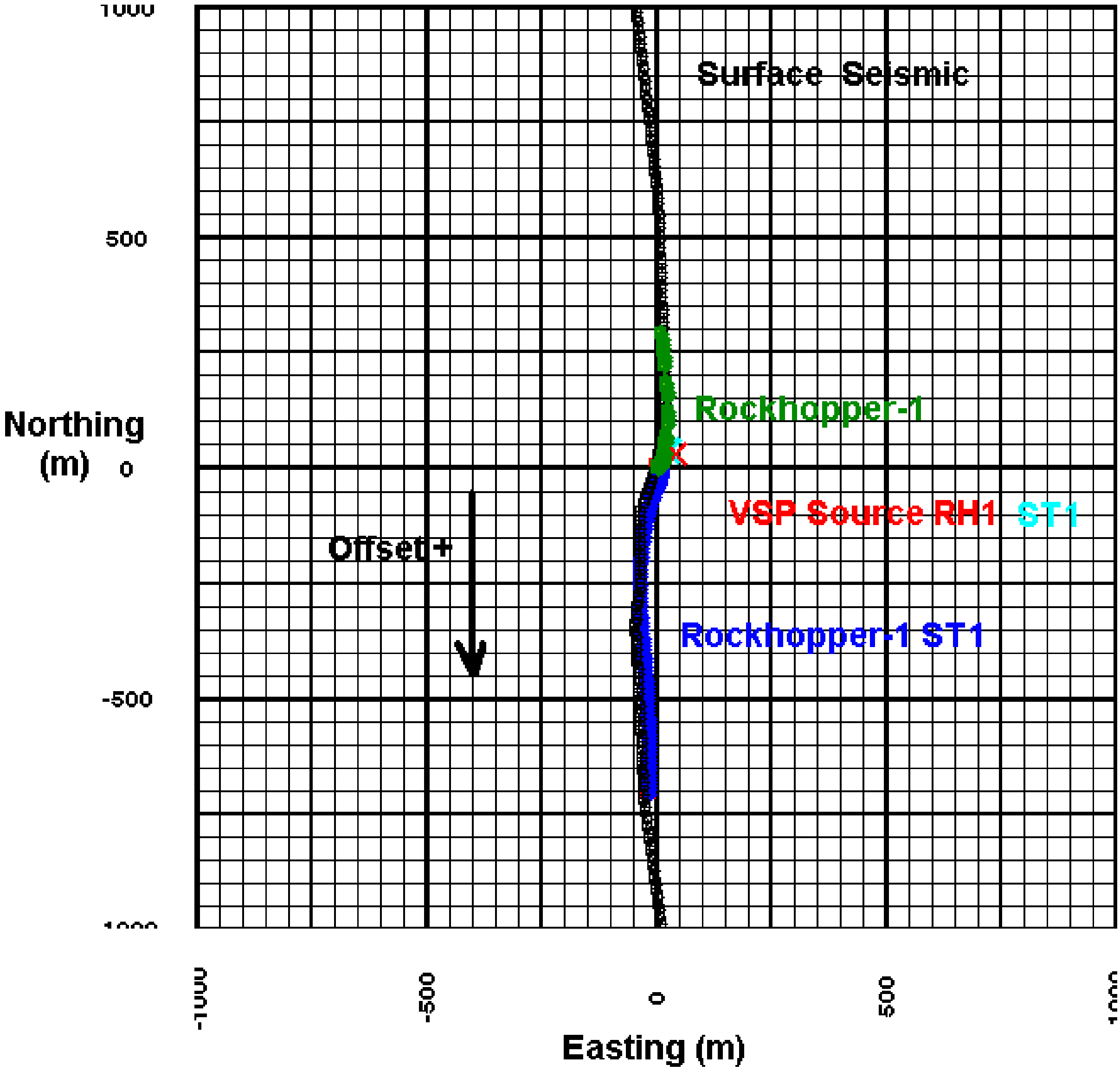
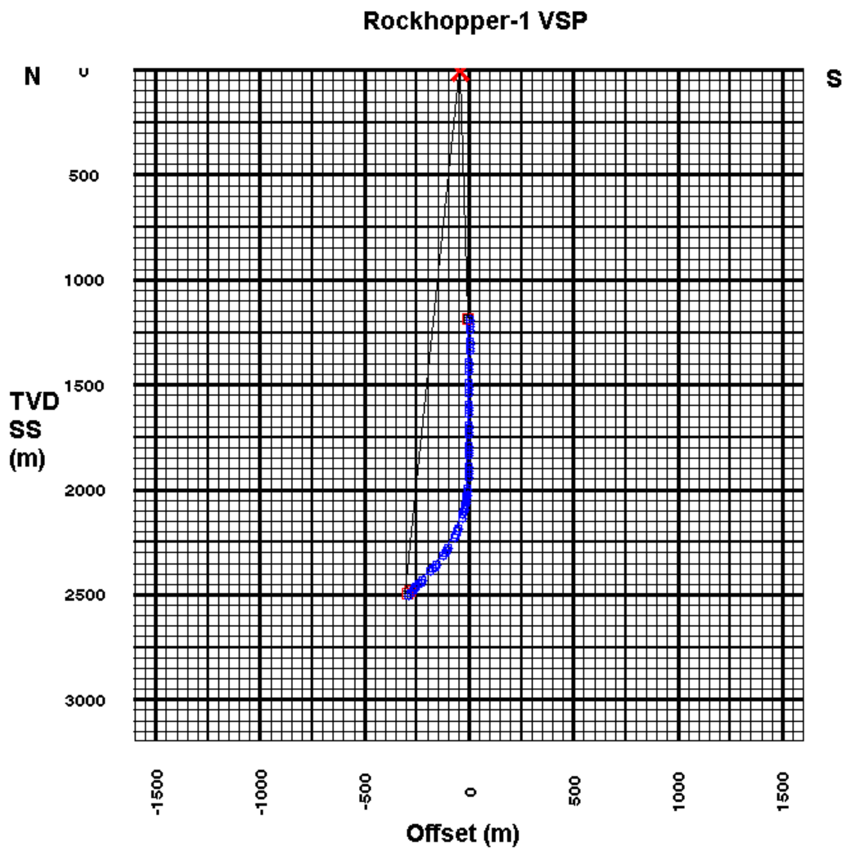


Figure 1a. Top view of both VSP Surveys



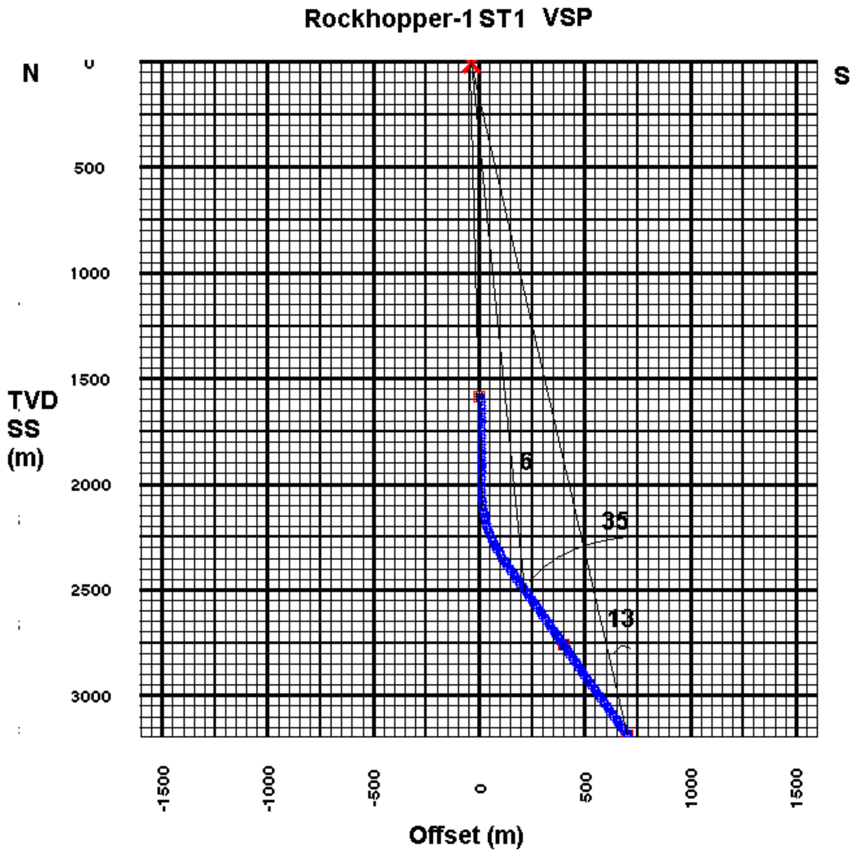


Figure 1b. Side view of both VSP Surveys

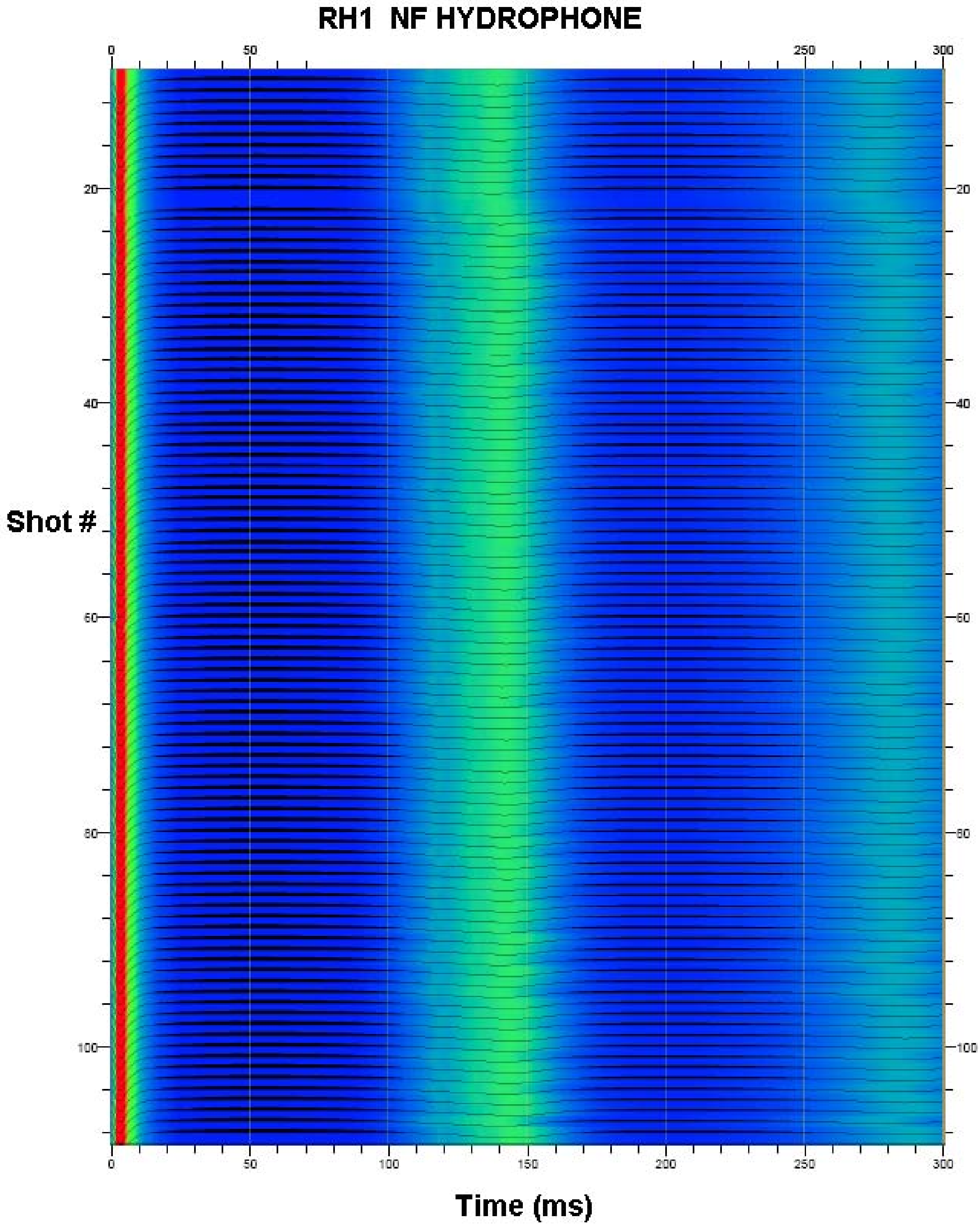


Figure 2a. Near Field Hydrophone QC display of Rockhopper-1 VSP

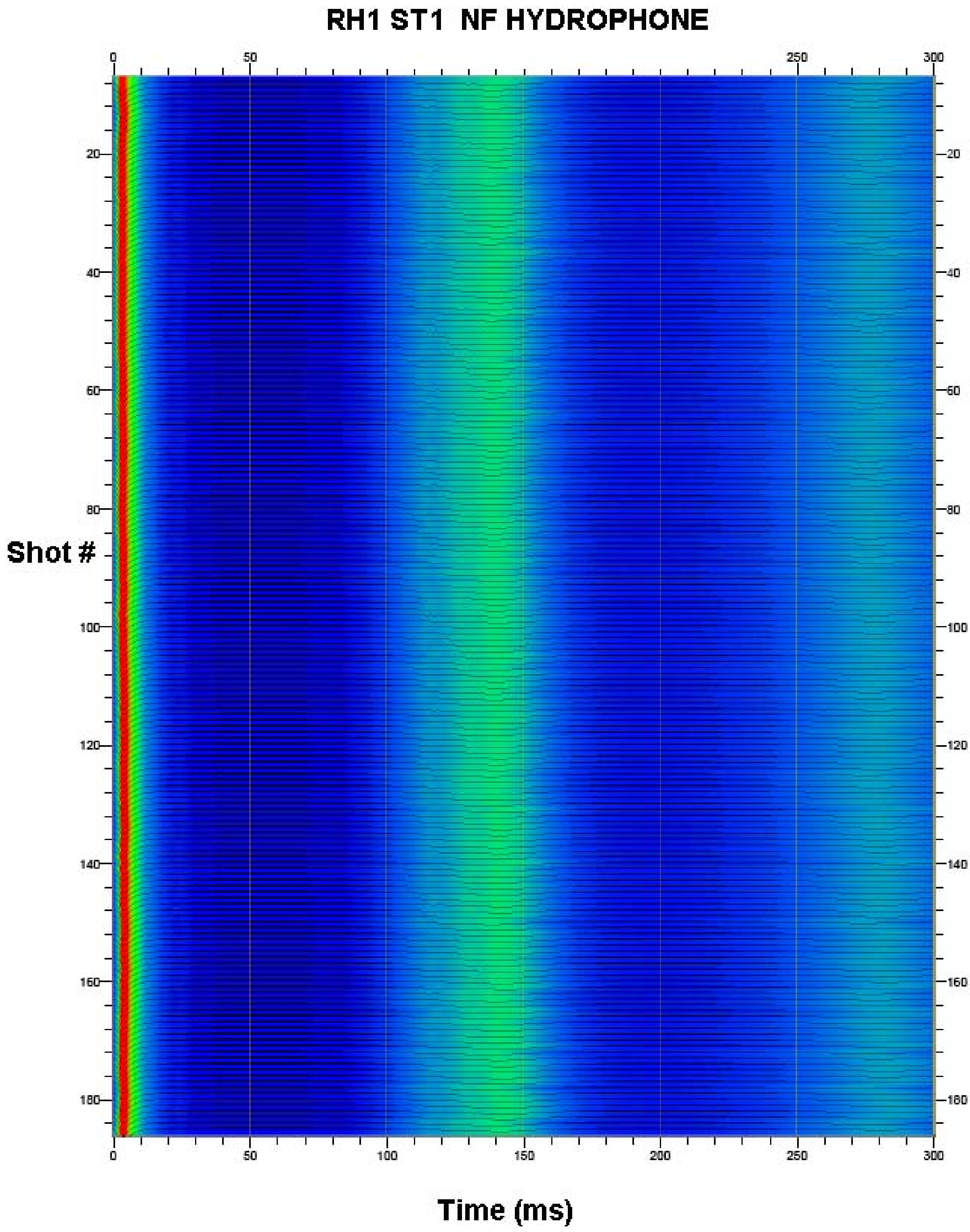


Figure 2b. Near Field Hydrophone QC display of Rockhopper-1 ST1 VSP

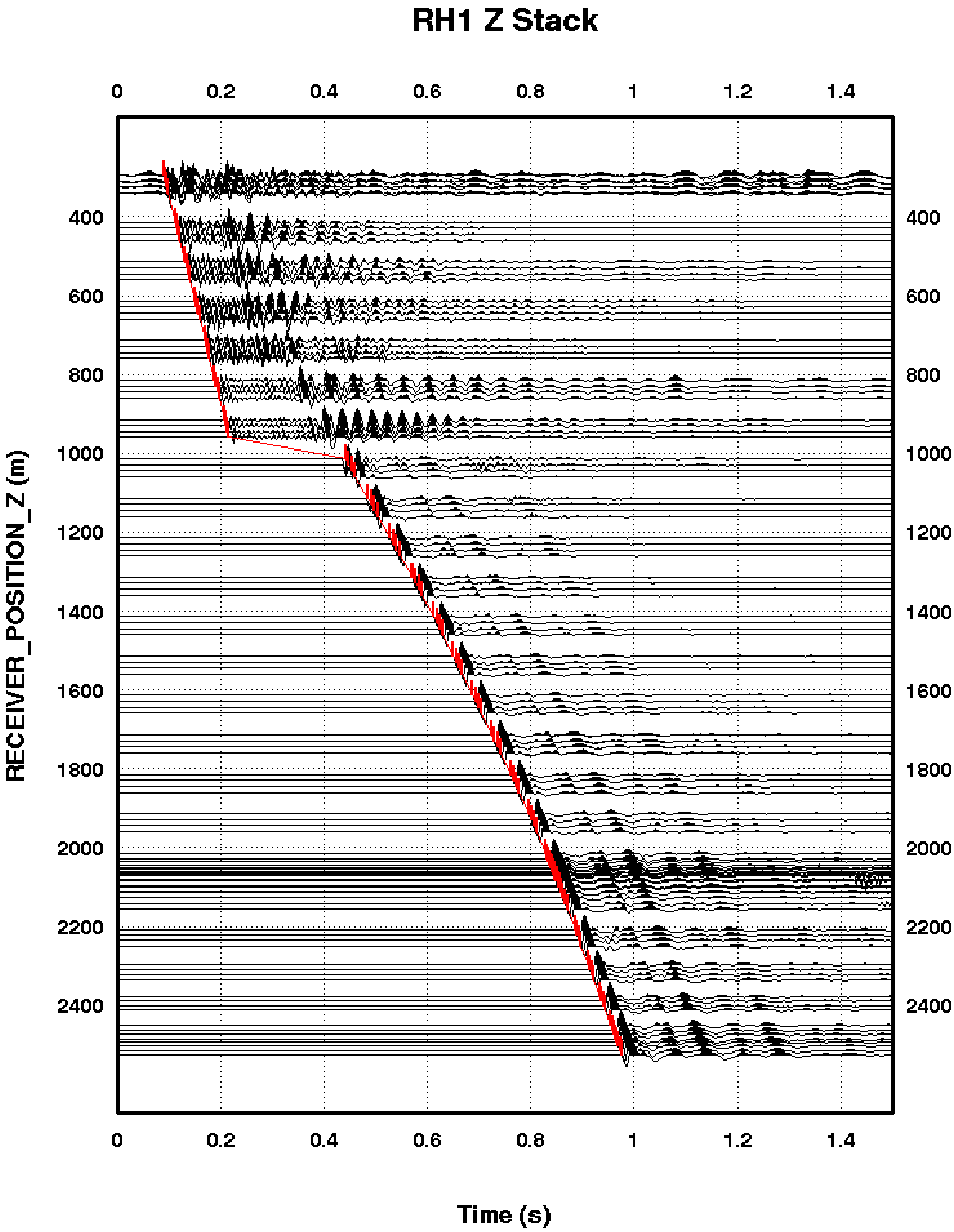


Figure 3a. Rockhopper-1 VSP: Z Component Stack

(Trace Normalised)

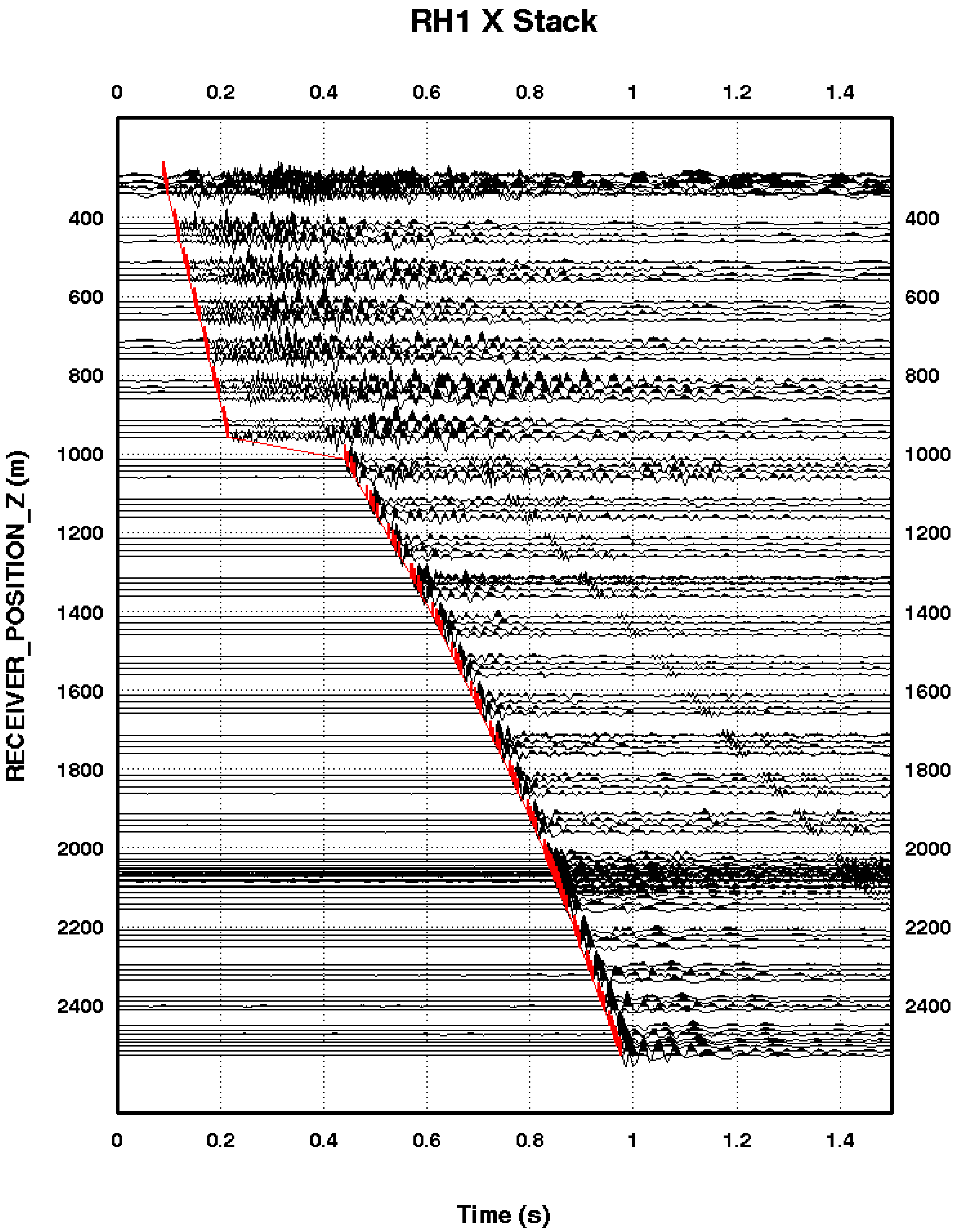


Figure 3b. Rockhopper-1 VSP: X Component Stack

(Trace Normalised)

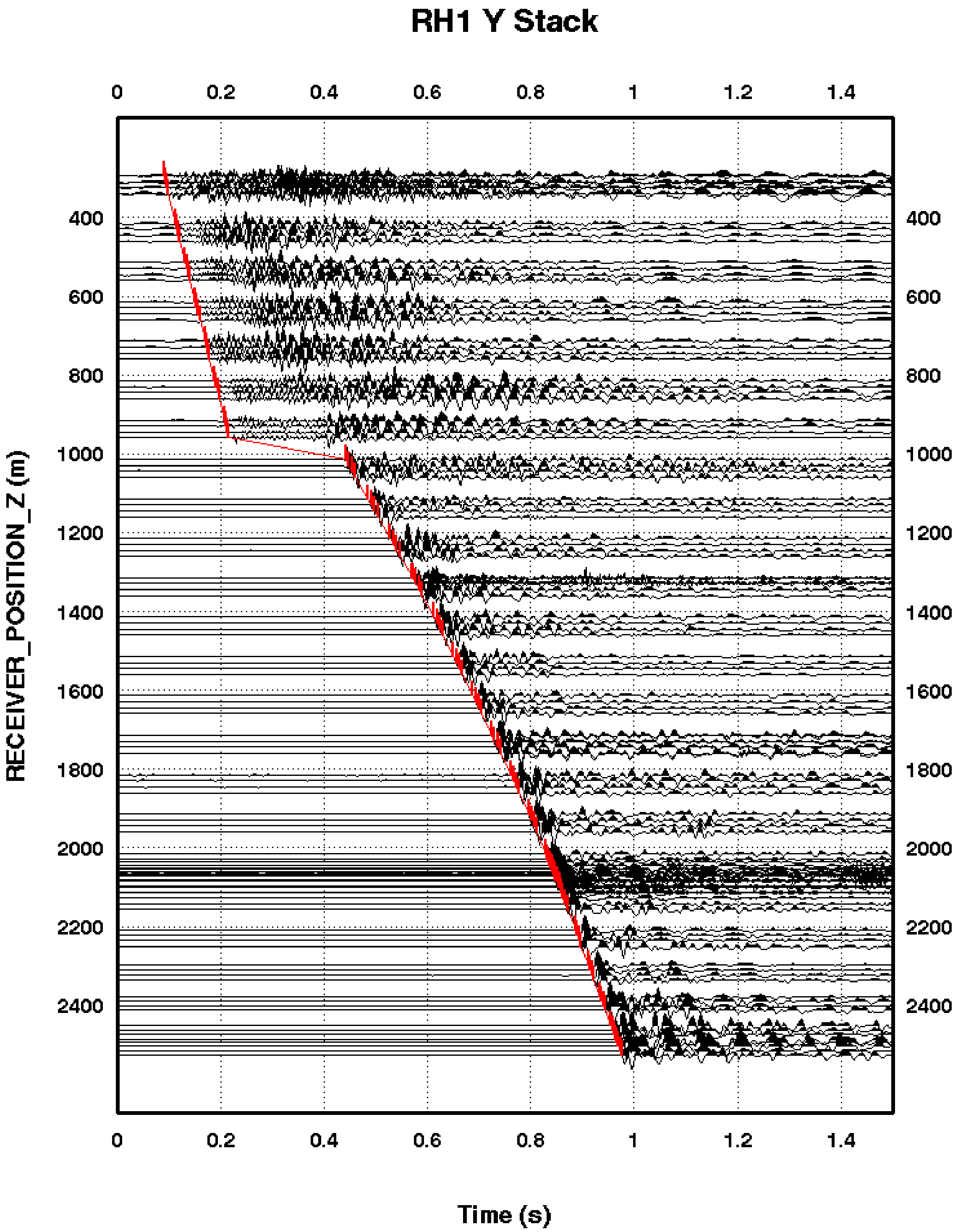


Figure 3c. Rockhopper-1 VSP: Y Component Stack

(Trace Normalised)

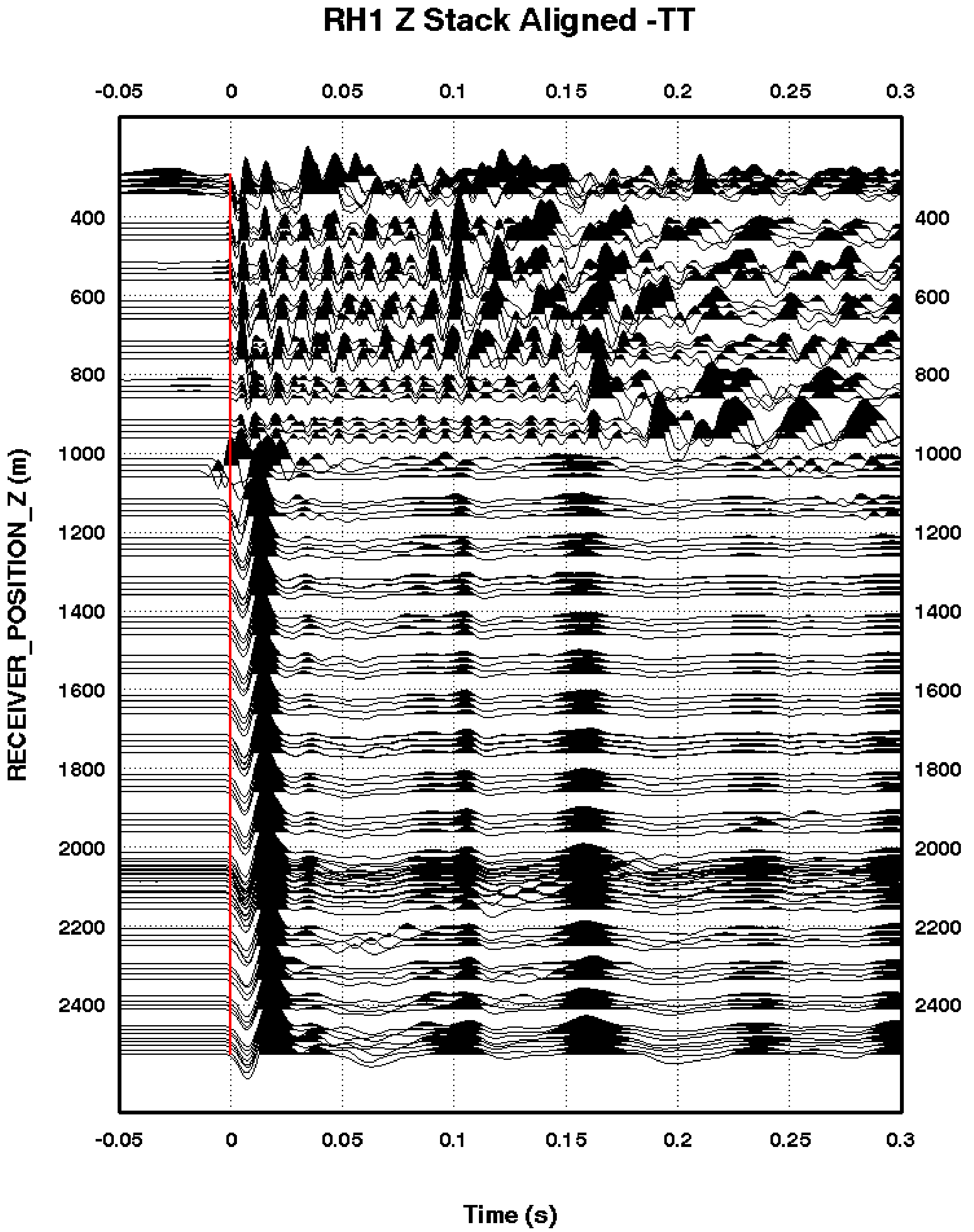


Figure 3d. Rockhopper-1 VSP: Z Component Stack Aligned -TT

(Trace Normalised)

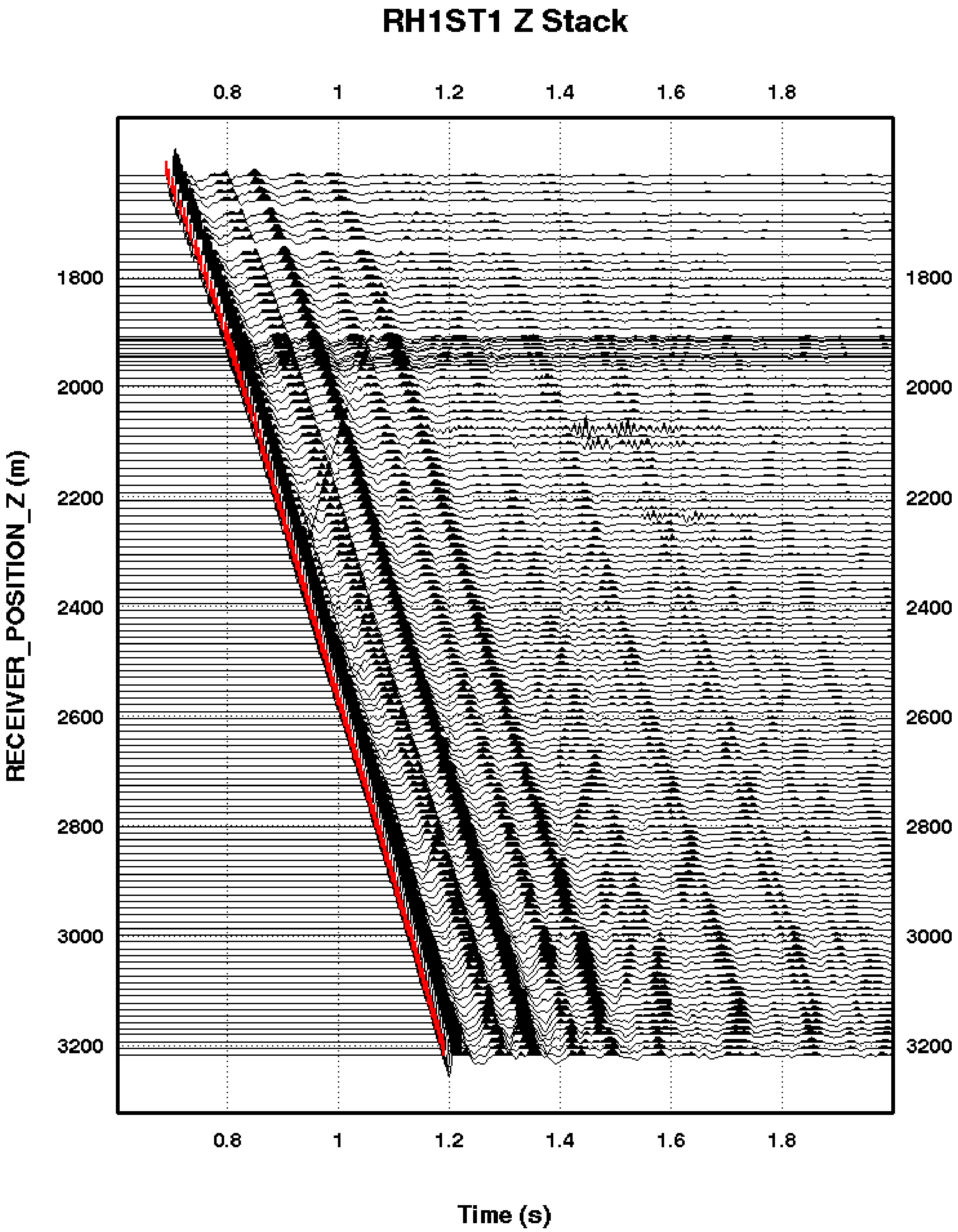


Figure 4a. Rockhopper-1 ST1 VSP: Z Component Stack

(Trace Normalised)

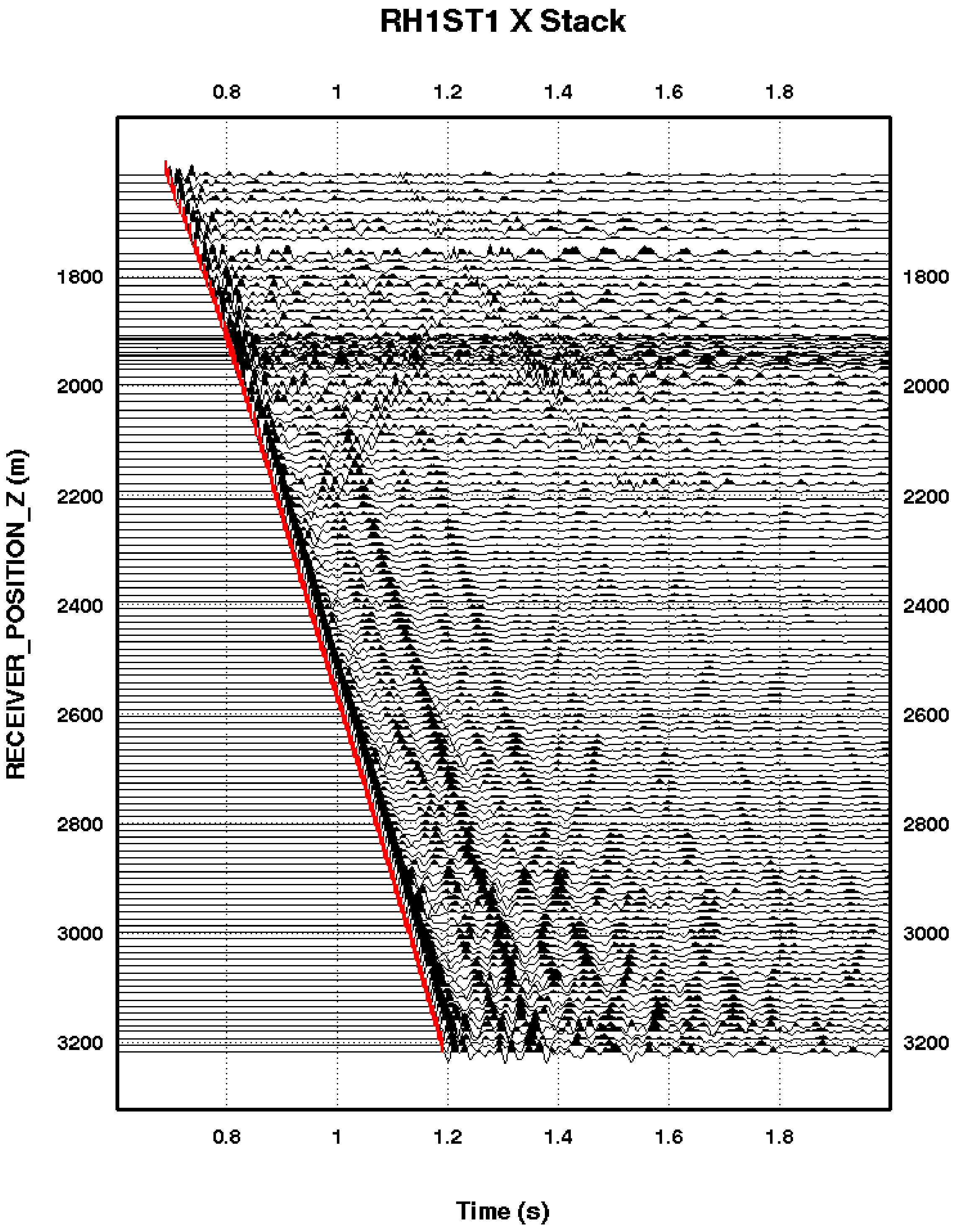


Figure 4b. Rockhopper-1 ST1 VSP: X Component Stack

(Trace Normalised)

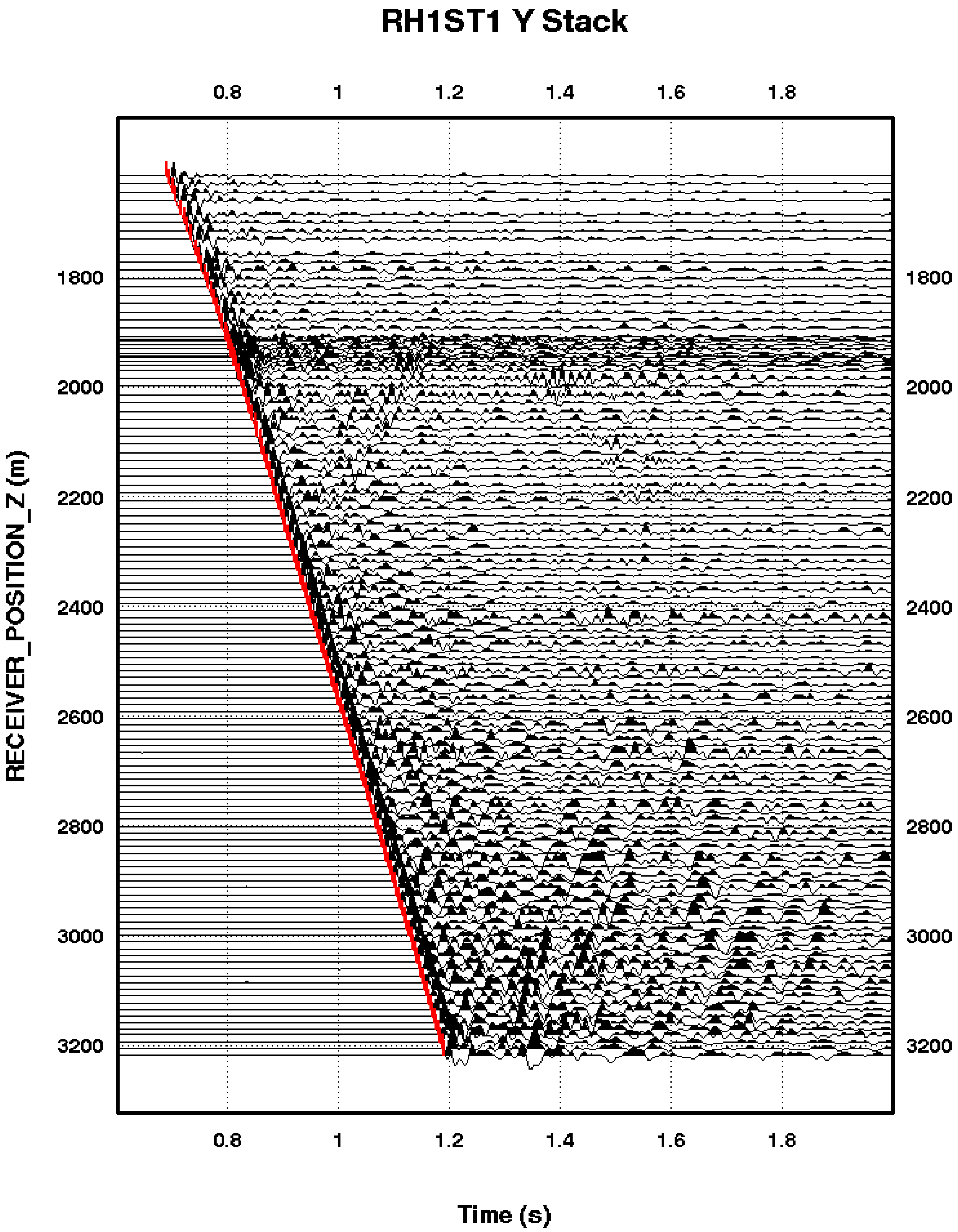


Figure 4c. Rockhopper-1 ST1 VSP: Y Component Stack

(Trace Normalised)

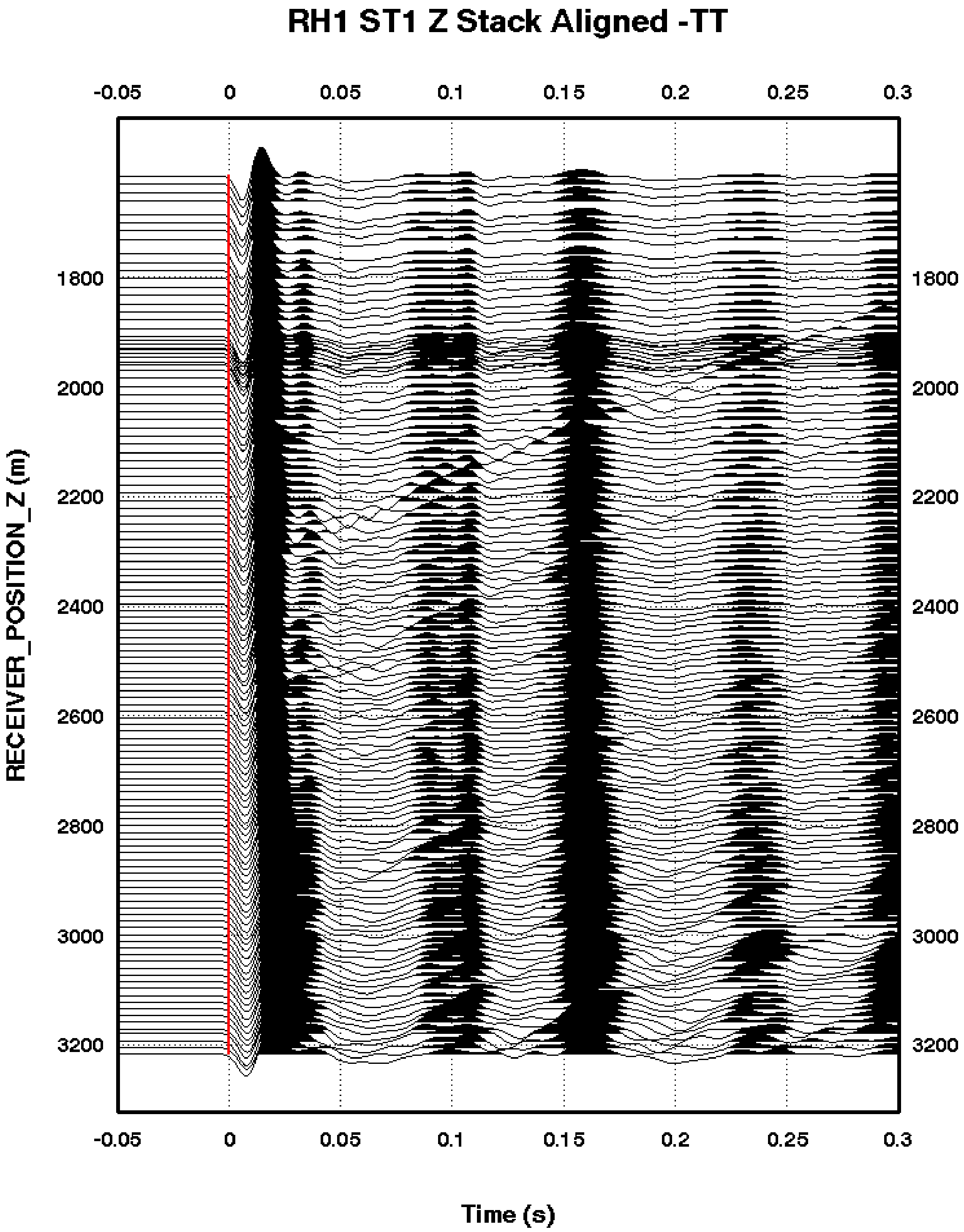


Figure 4d. Rockhopper-1 ST1 VSP: Z Component Stack Aligned -TT

(Trace Normalised)

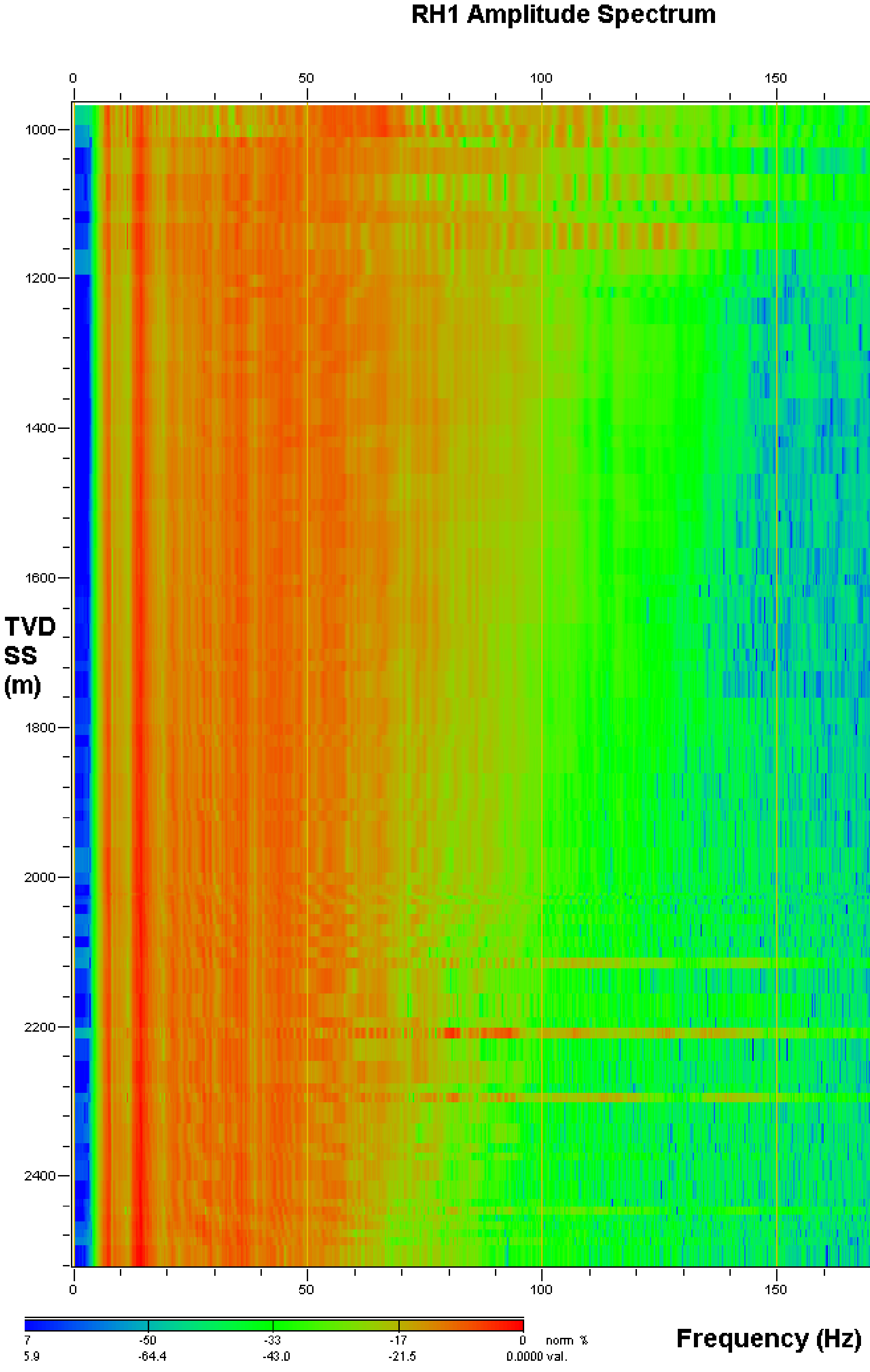


Figure 5a. Rockhopper-1 VSP: Amplitude Spectrum of Downhole Data

(Amplitude in dB)

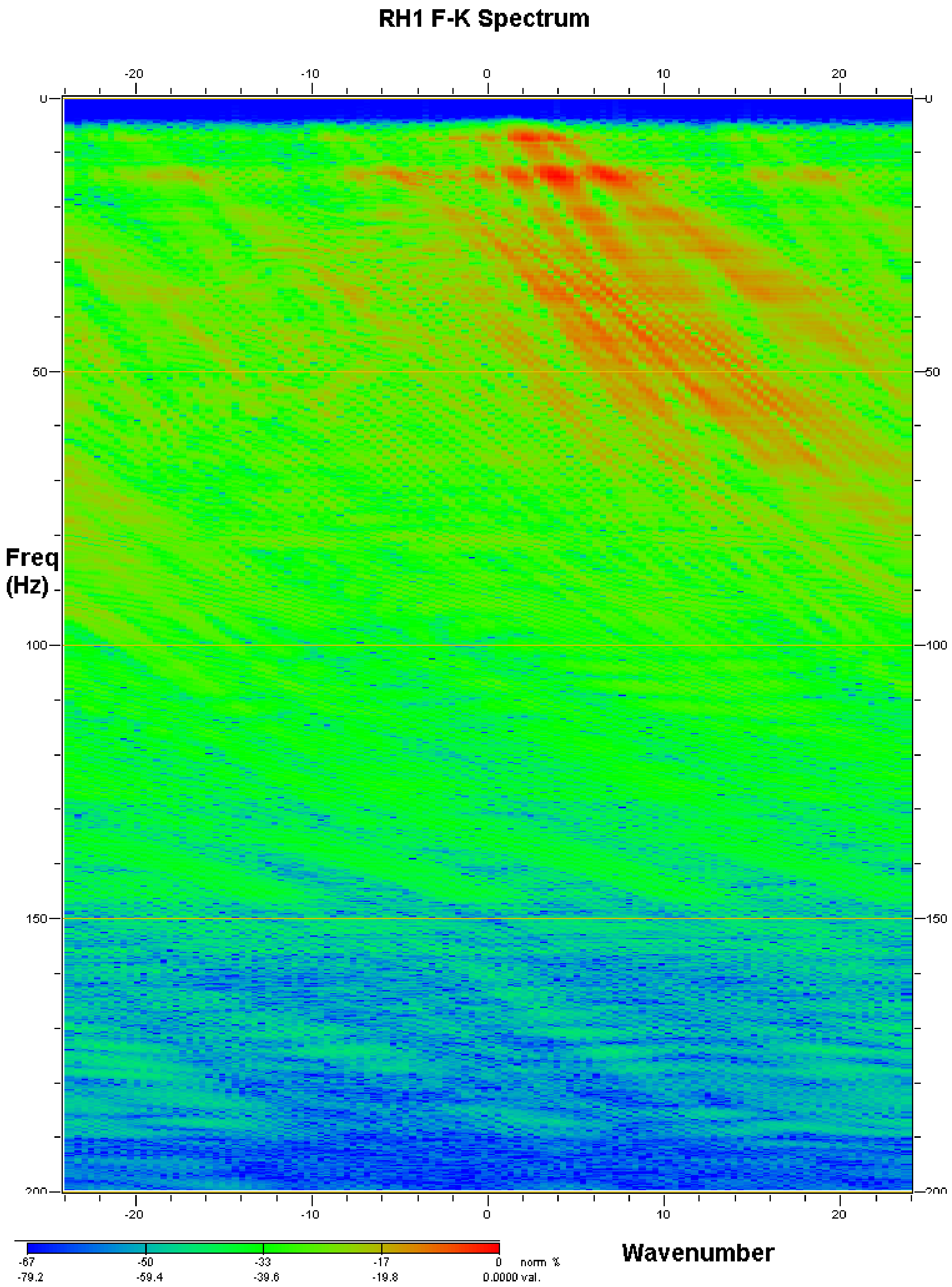


Figure 5b. Rockhopper-1 VSP: F-K Spectrum of Downhole Data

(Amplitude in dB)

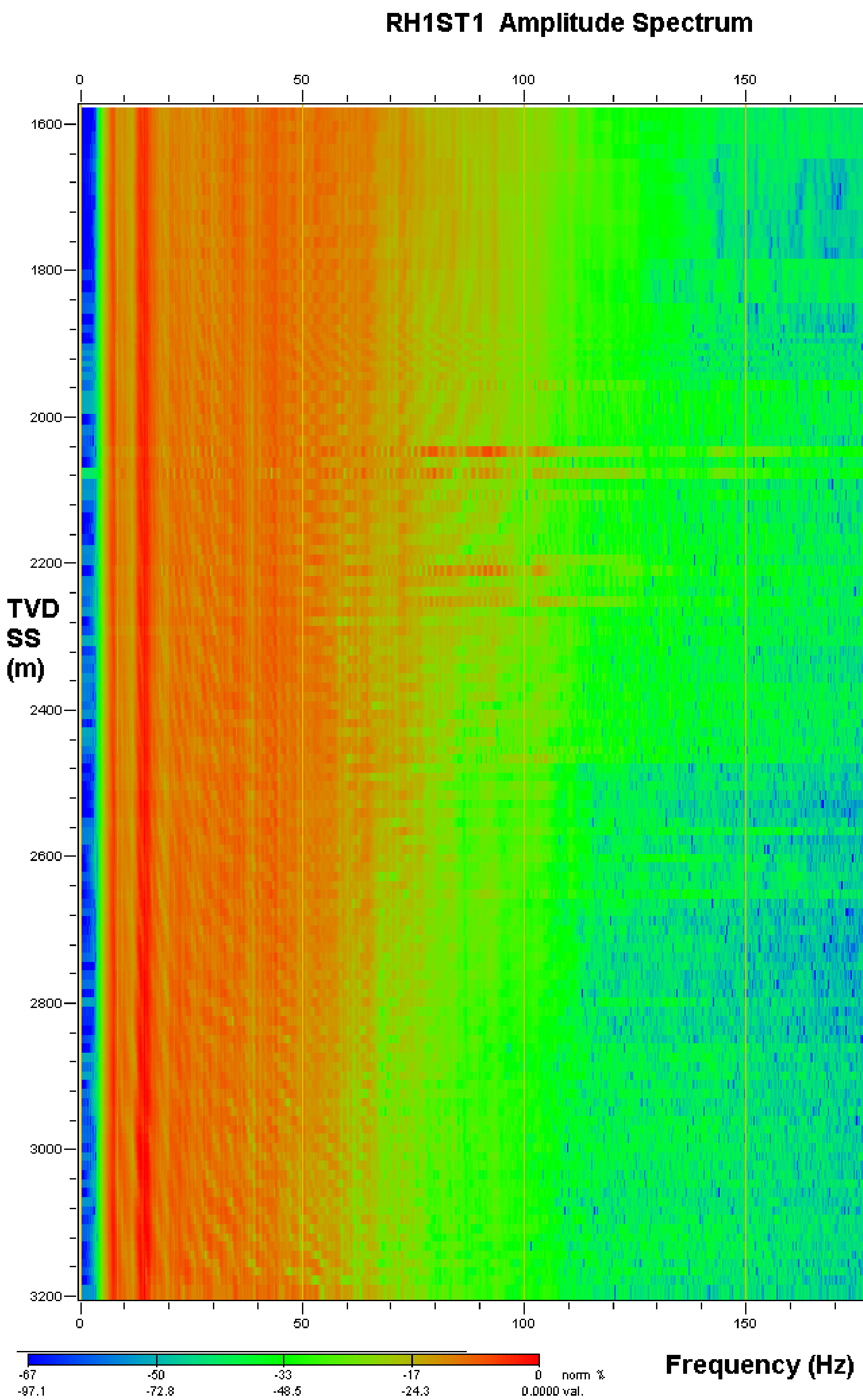


Figure 6a. Rockhopper-1 ST1 VSP: Amplitude Spectrum of Downhole Data

(Amplitude in dB)

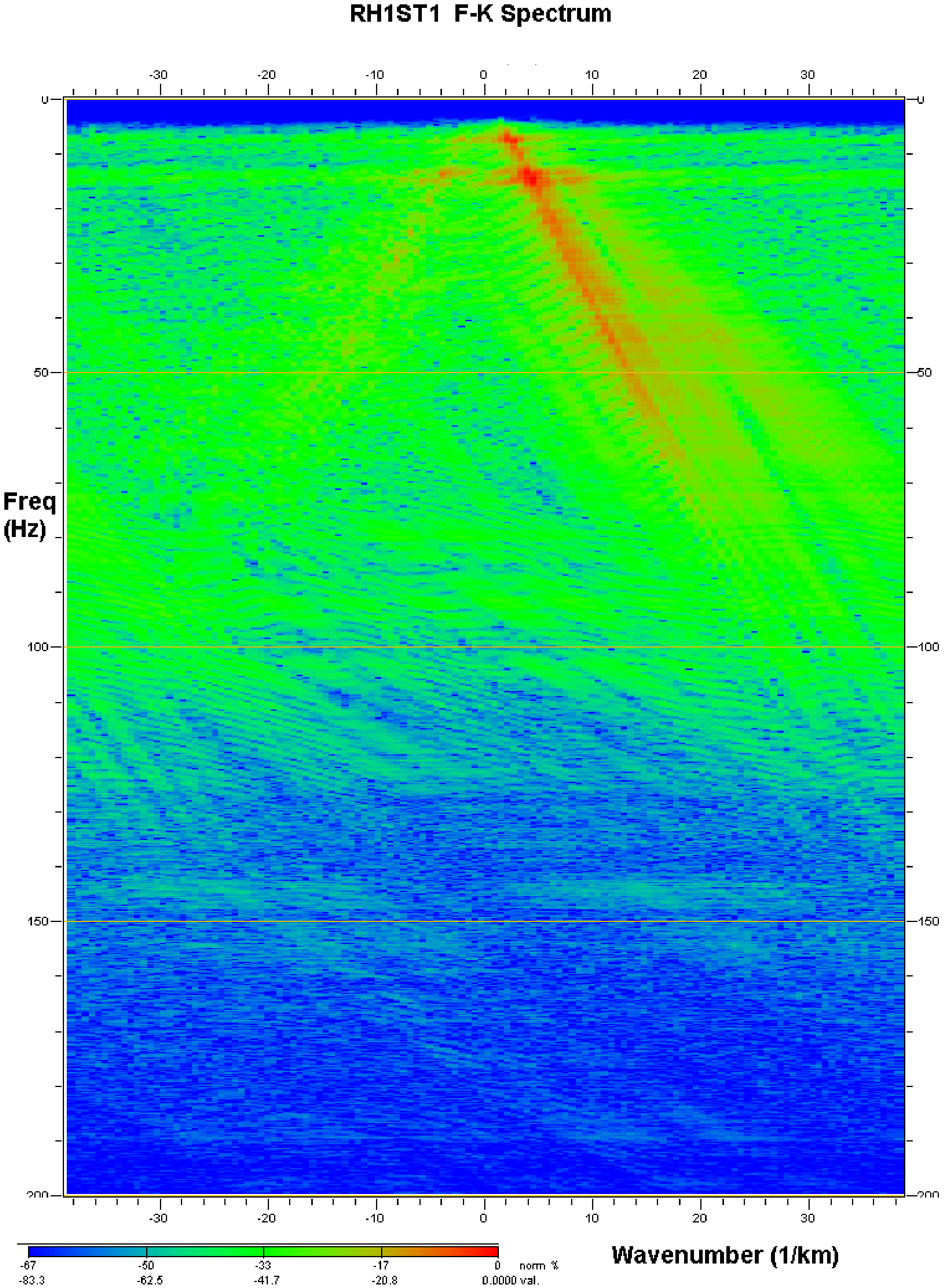


Figure 6b. Rockhopper-1 ST1 VSP: F-K Spectrum of Downhole Data

(Amplitude in dB)

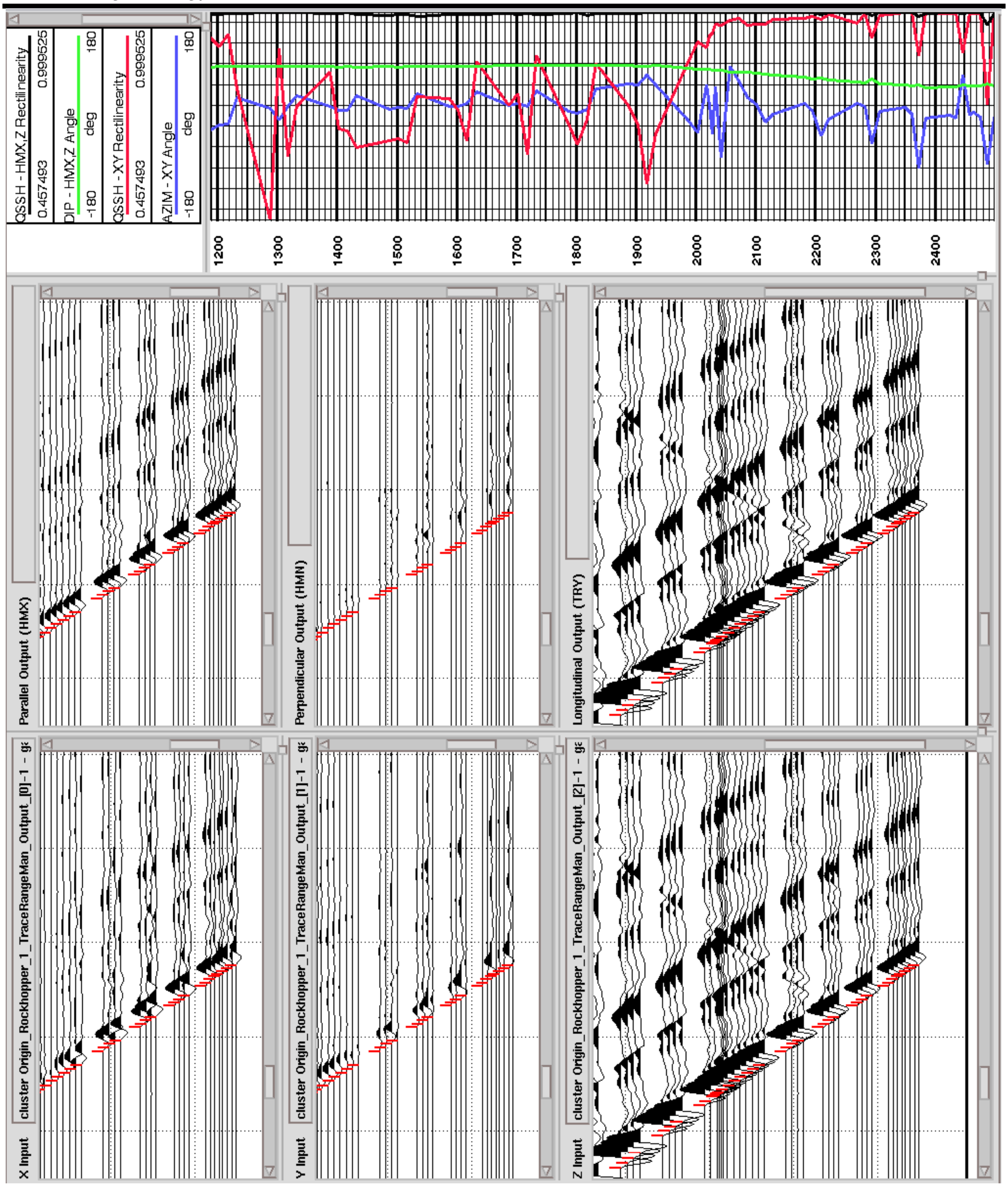


Figure 7a. Rockhopper-1 VSP: Example 3C Rotation

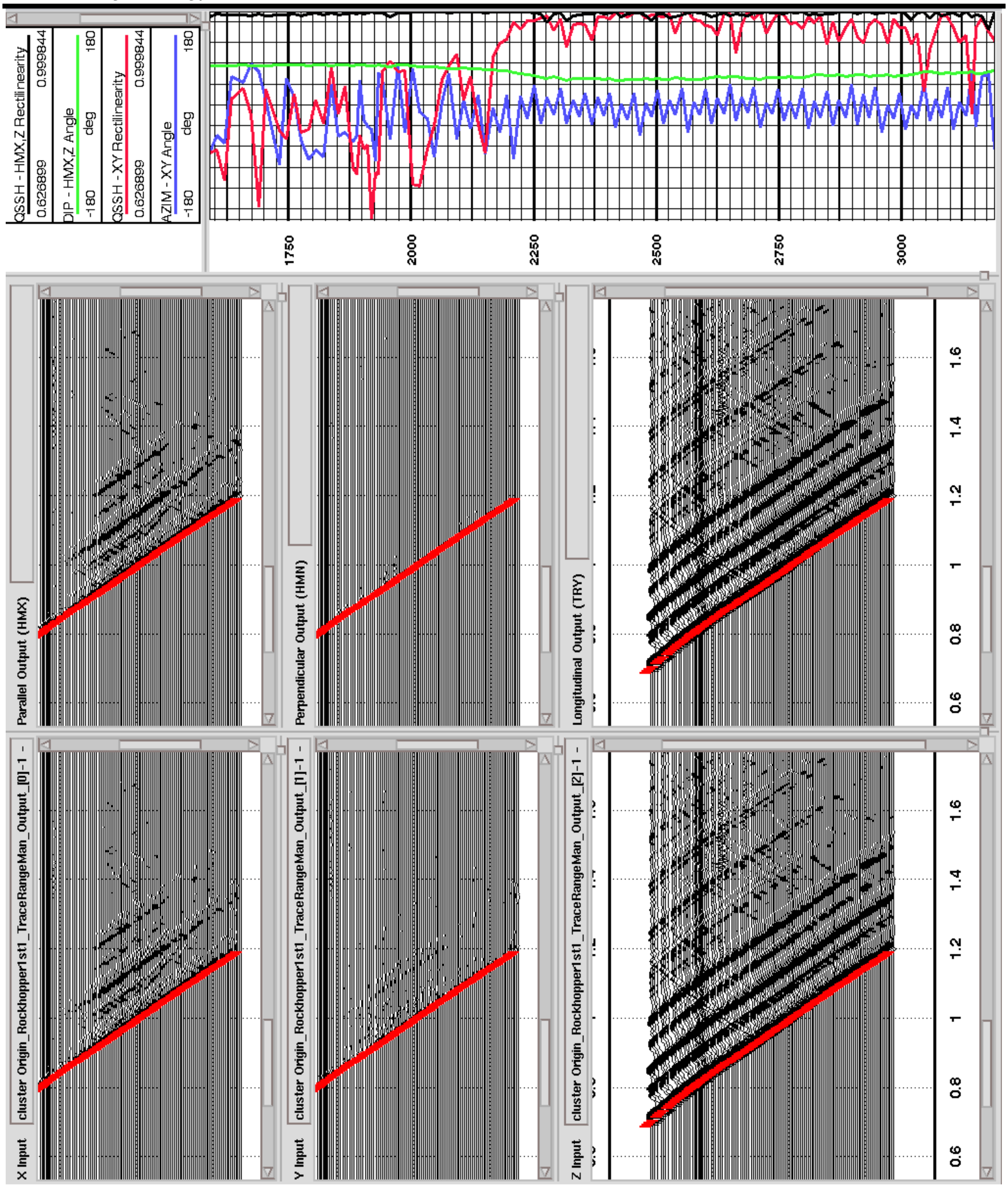


Figure 7b. Rockhopper-1 ST1 VSP: Example 3C Rotation

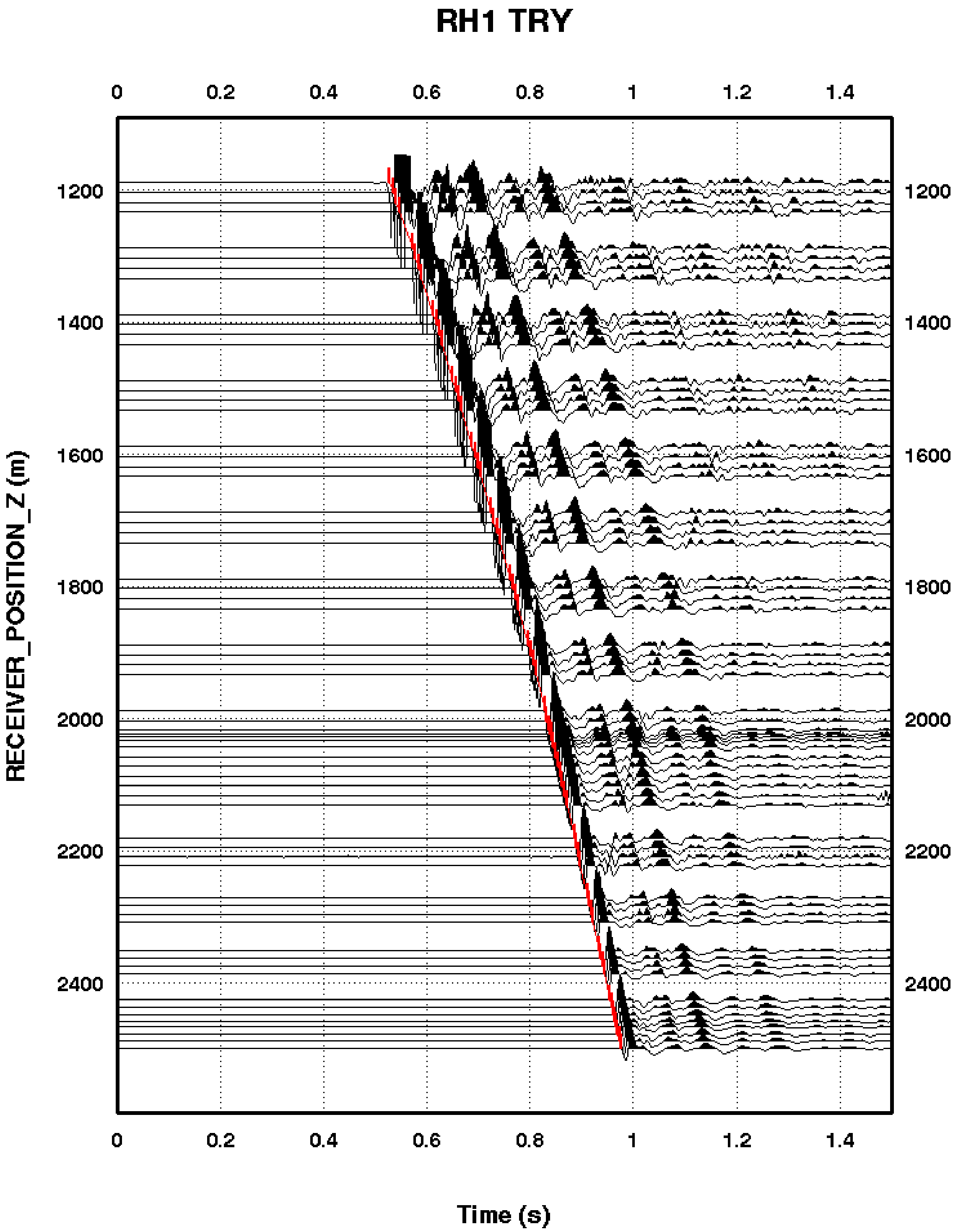


Figure 8a. Rockhopper-1 VSP: TRY Rotated Component

(Gather Normalised)

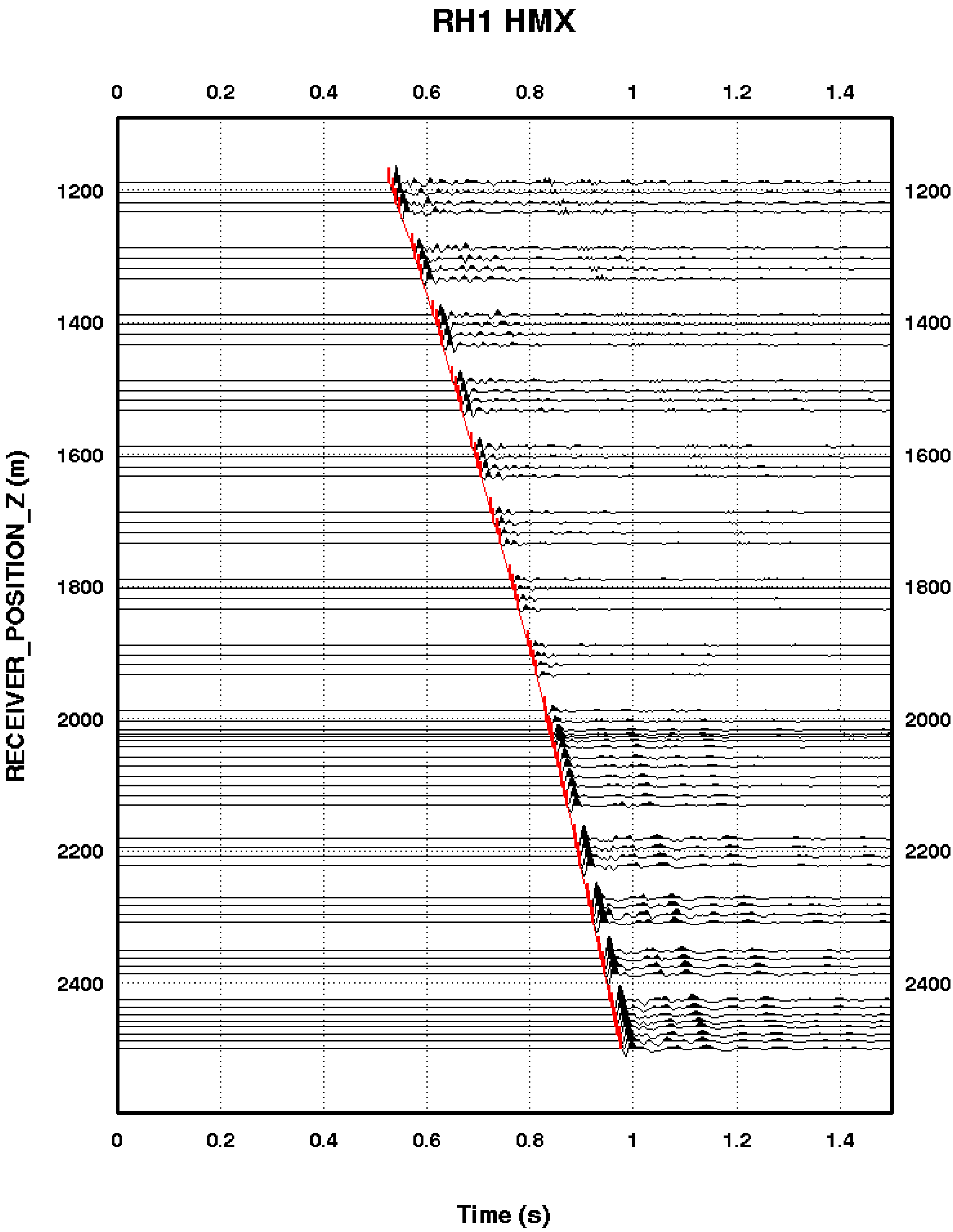


Figure 8b. Rockhopper-1 VSP: HMX Rotated Component

(Gather Normalised)

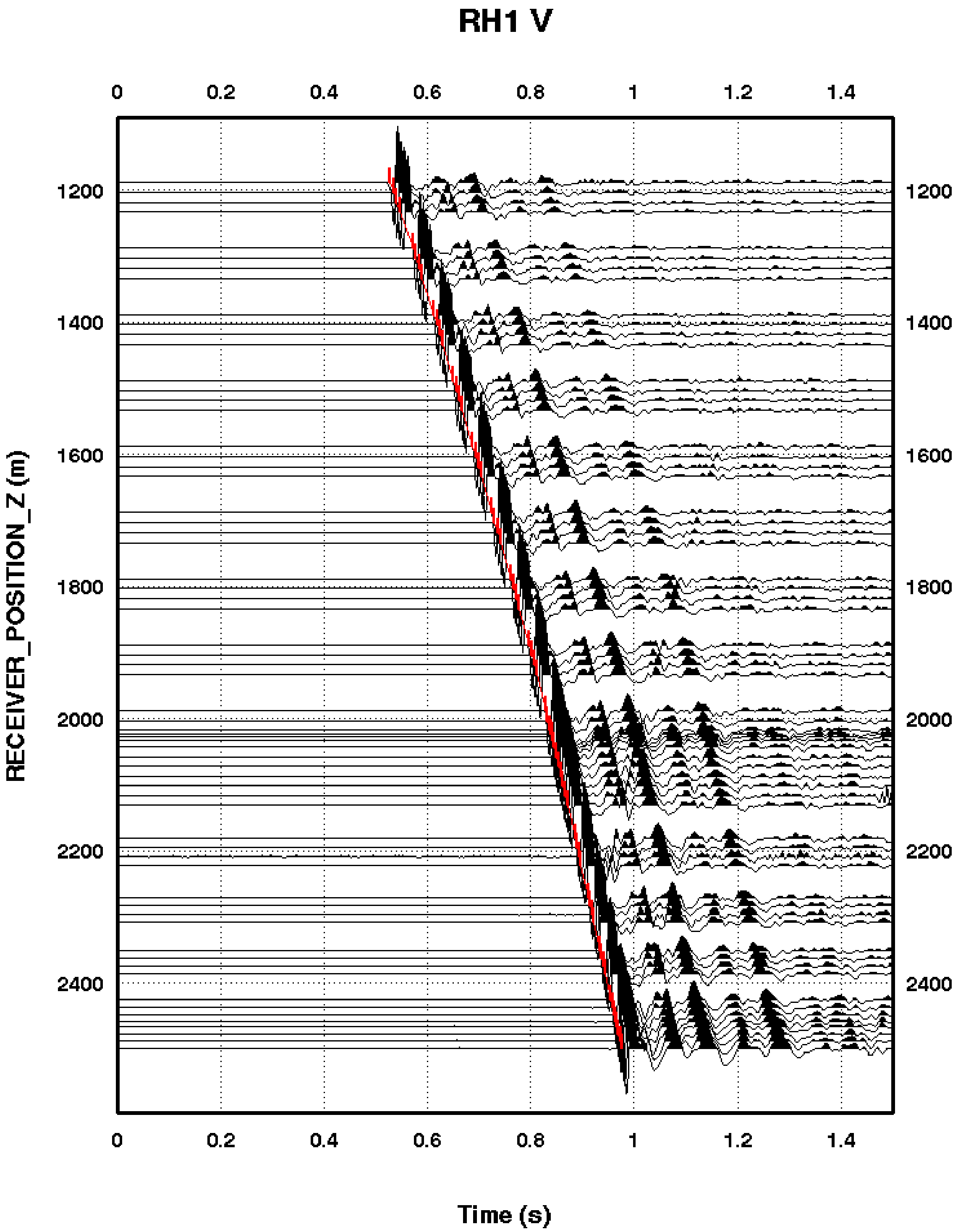


Figure 8c. Rockhopper-1 VSP: V, Rotated True Vertical Component

(Trace Normalised)

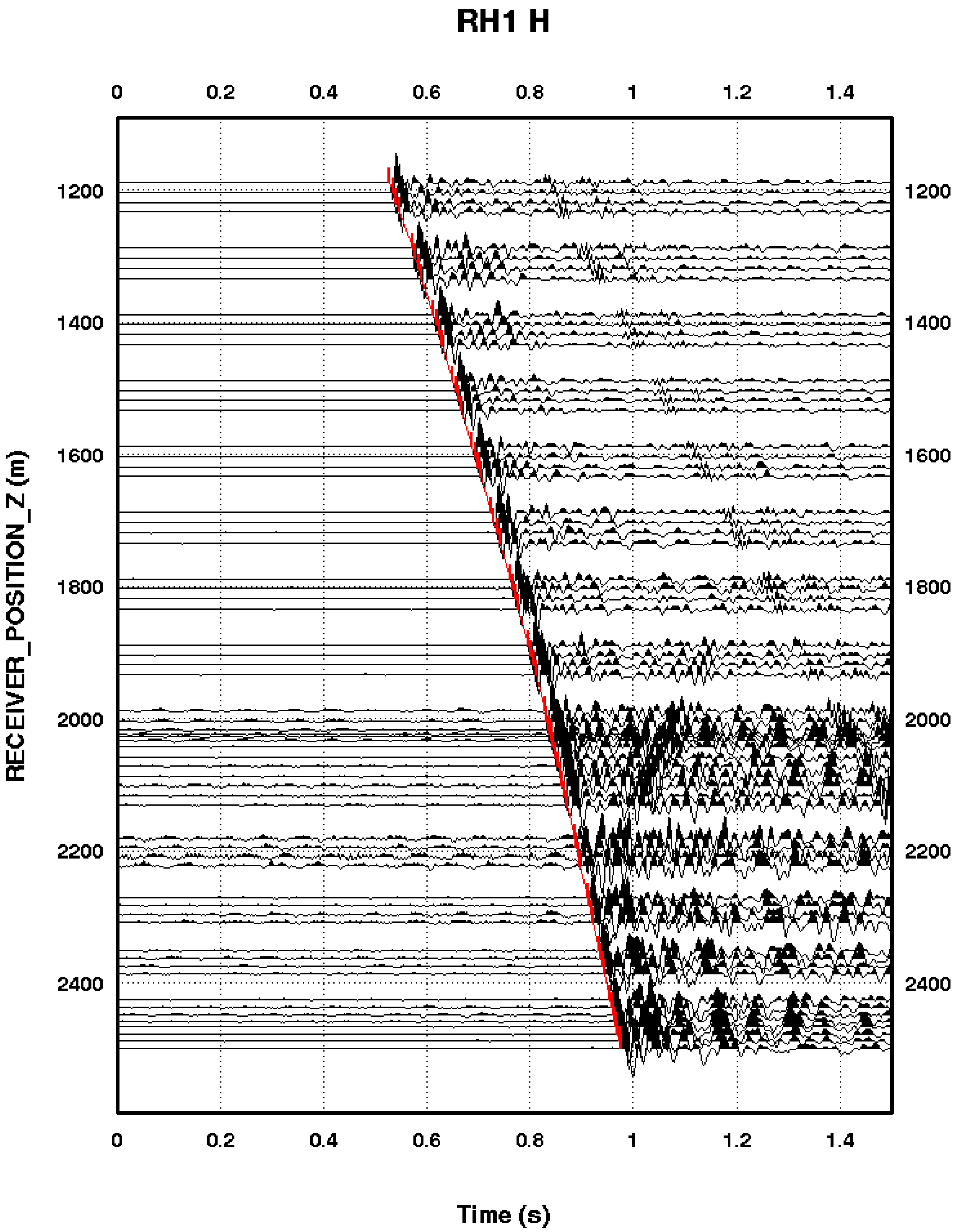


Figure 8d. Rockhopper-1 VSP: H, Rotated True Inline Horizontal Component

(Trace Normalised)

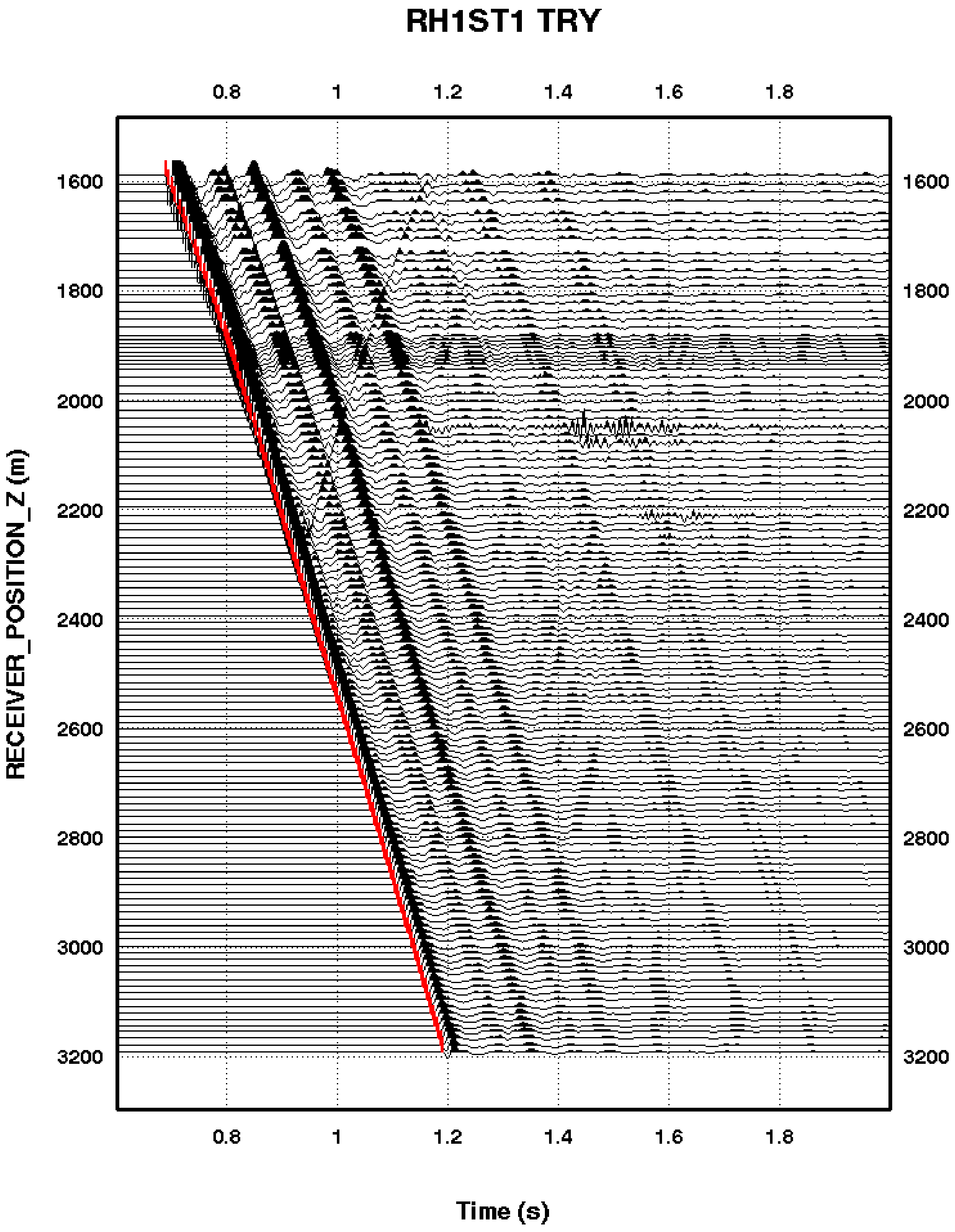


Figure 9a. Rockhopper-1 ST1 VSP: TRY Rotated Component

(Gather Normalised)

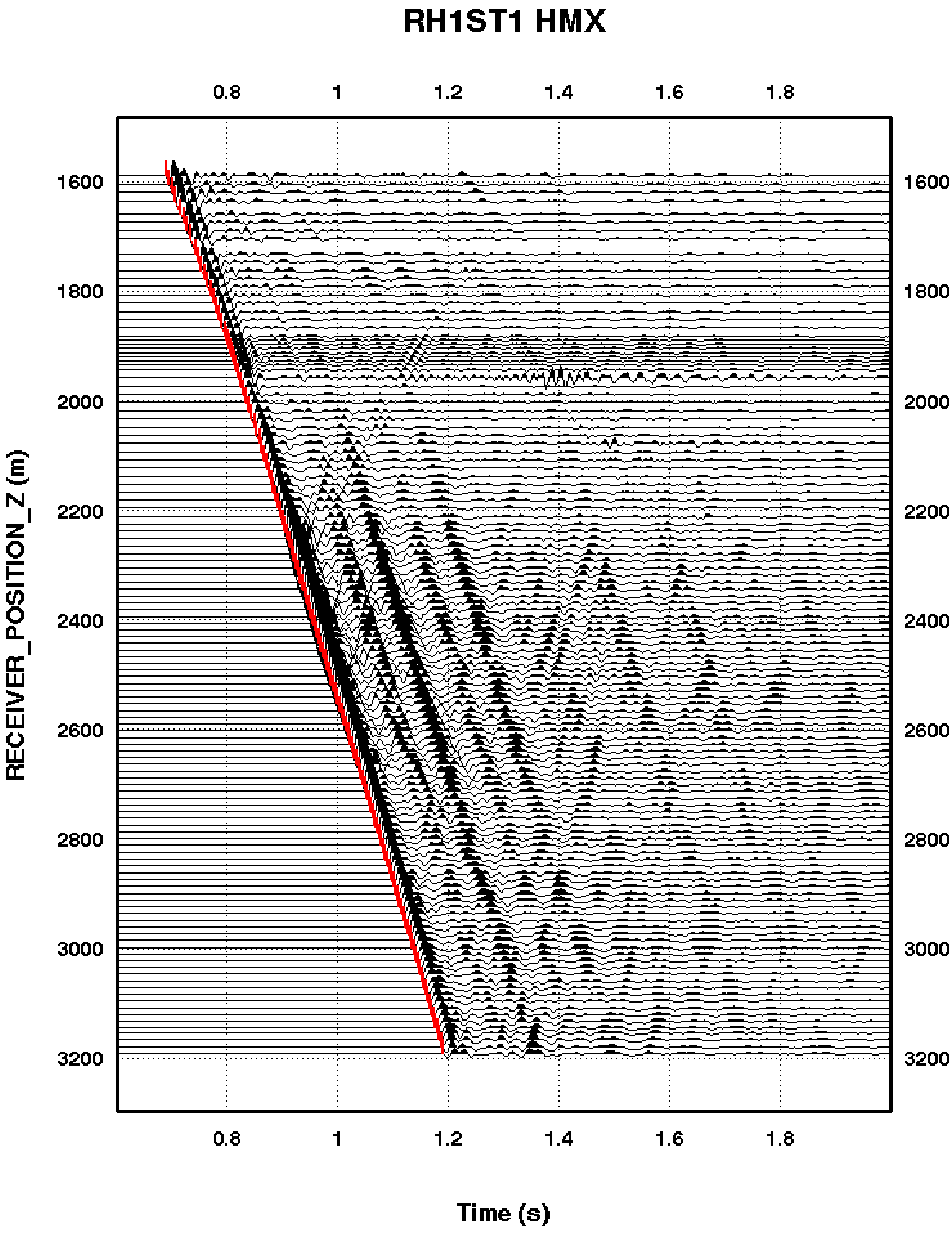


Figure 9b. Rockhopper-1 ST1 VSP: HMX Rotated Component

(Gather Normalised)

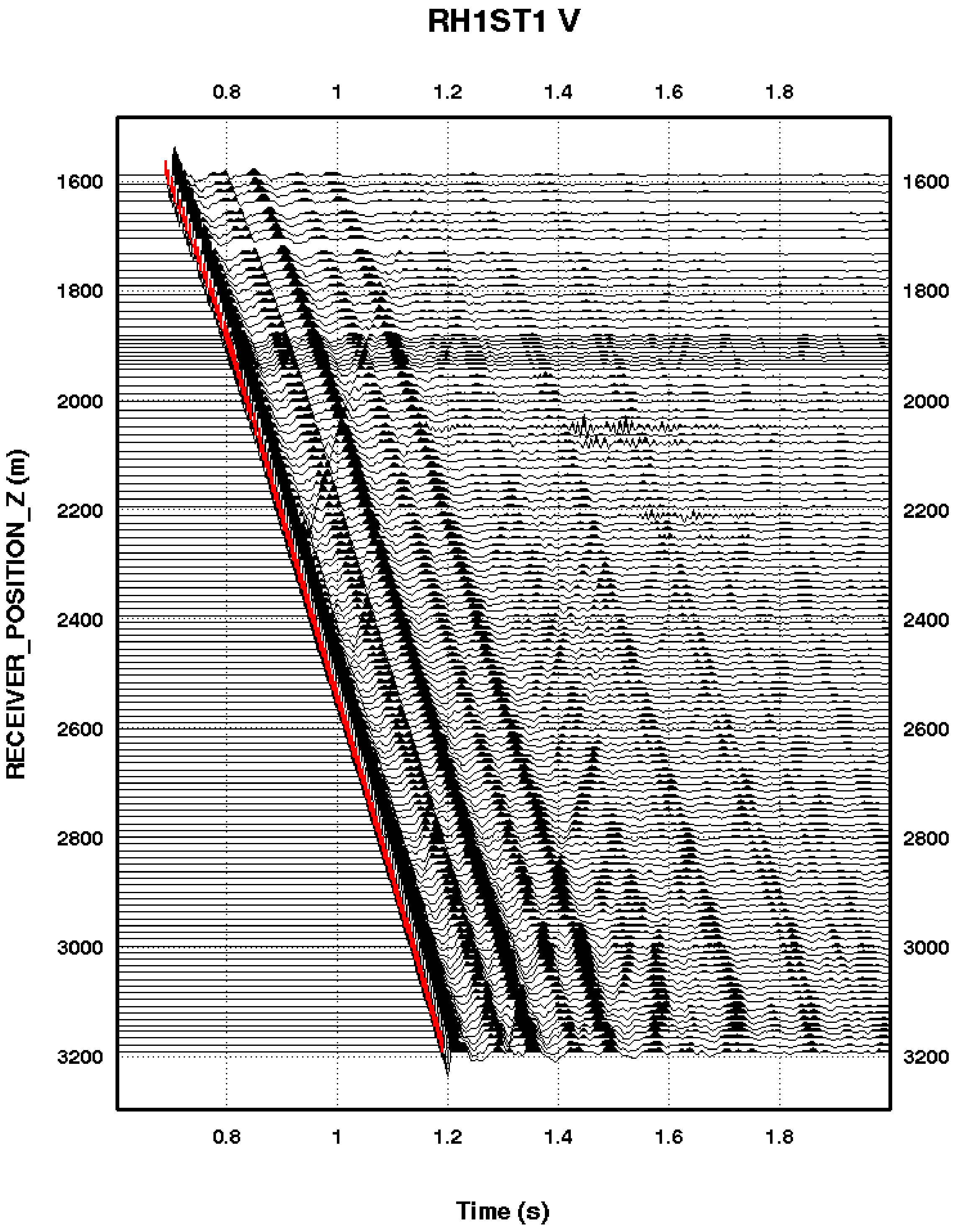


Figure 9c. Rockhopper-1 ST1 VSP: V, Rotated True Vertical Component

(Trace Normalised)

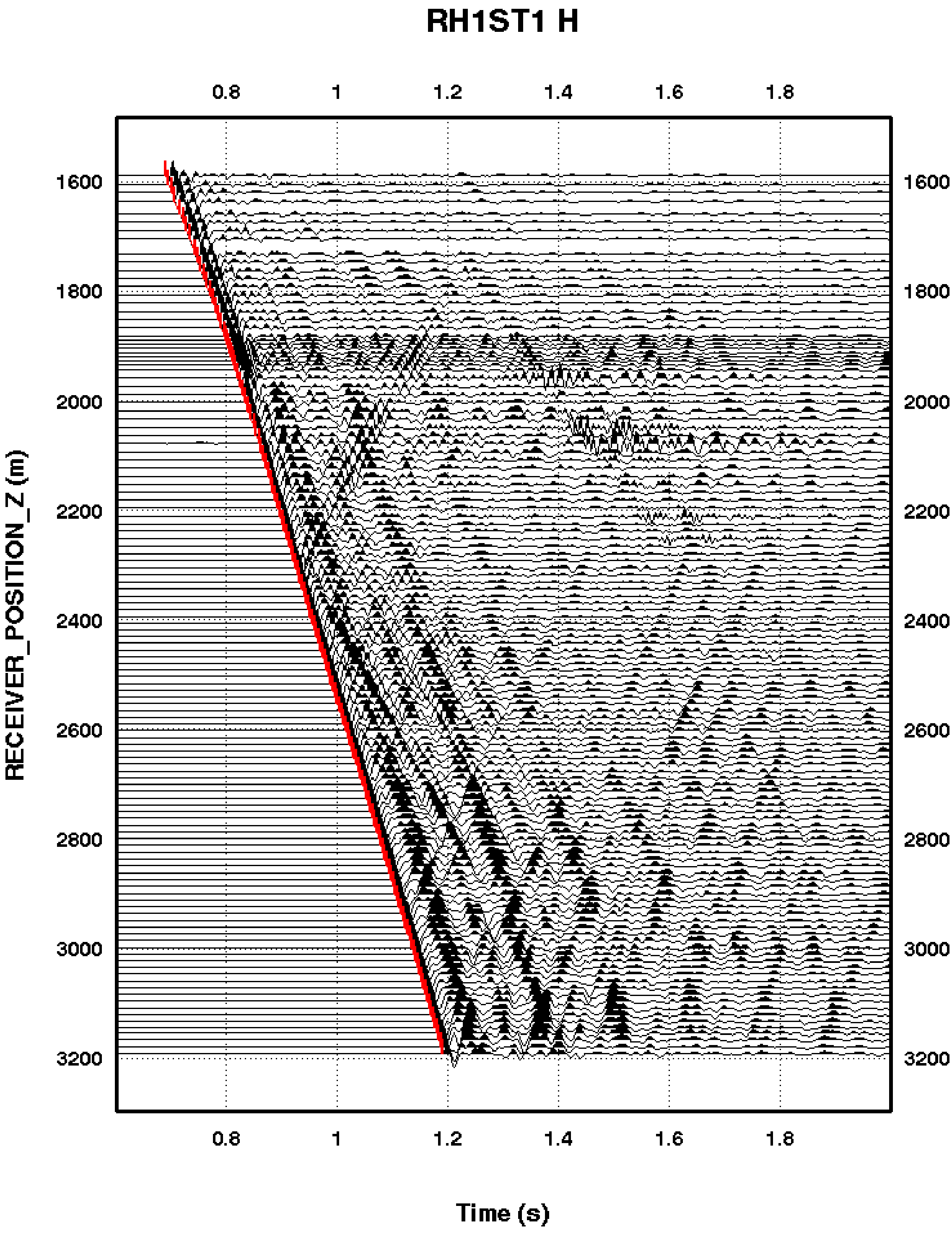


Figure 9d. Rockhopper-1 ST1 VSP: H, Rotated True Inline Horizontal Component

(Trace Normalised)

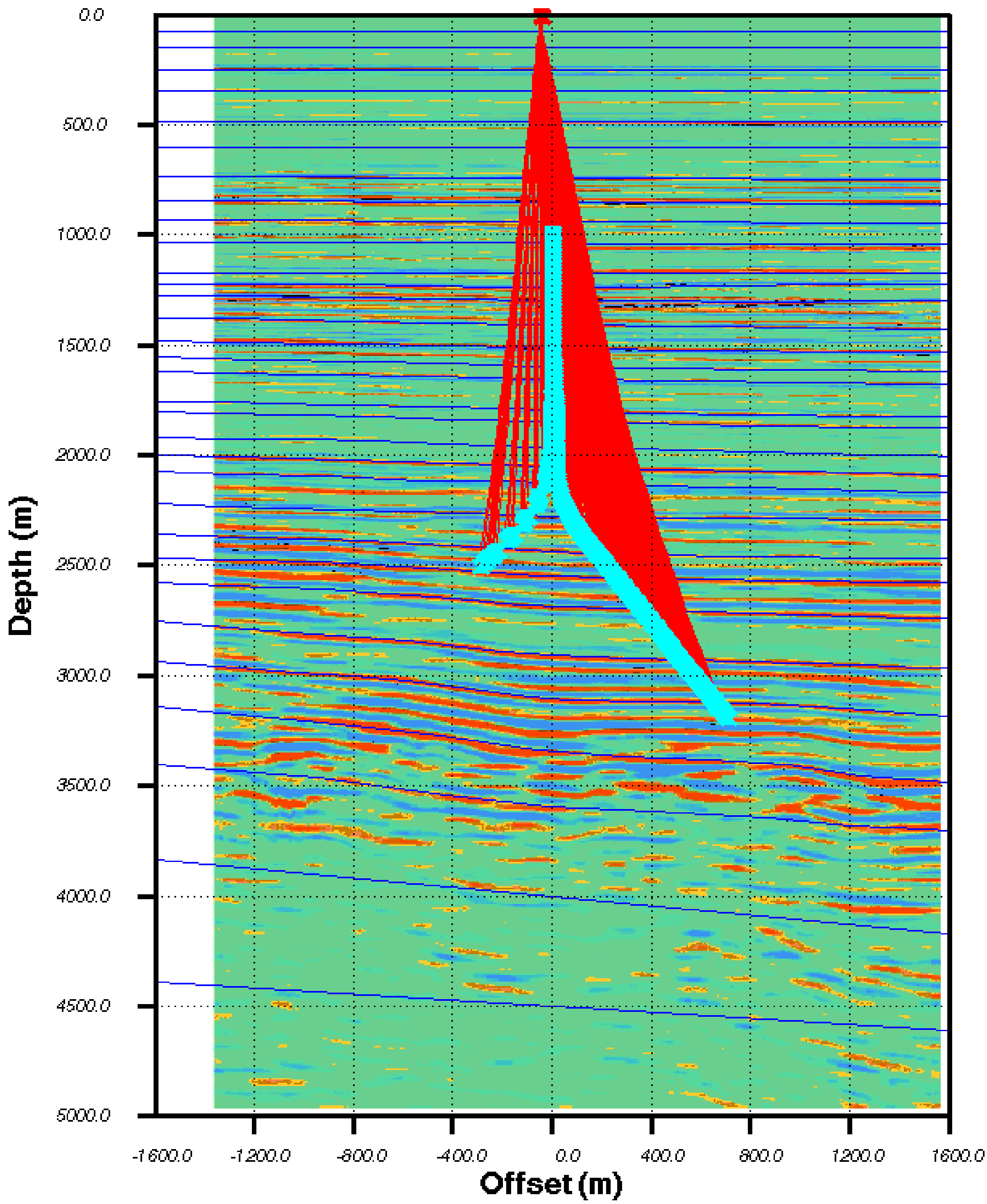


Figure 10a. 2D Model Building: Surface Seismic Line

RH1 and RH1ST1 Receivers (cyan)
Down P Rays (red)

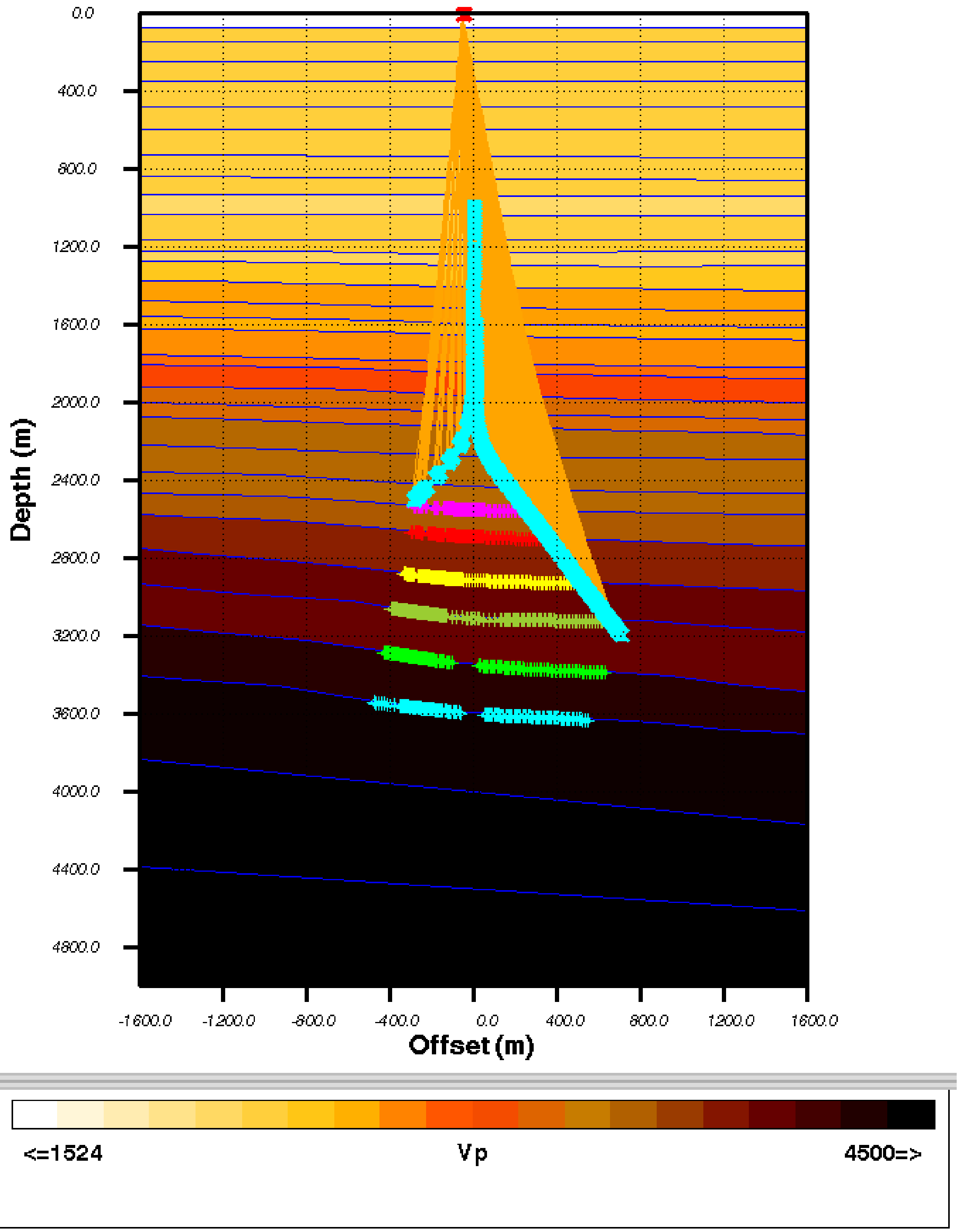


Figure 10b. 2D Model Building: Inverted Velocities

RH1 and RH1ST1 Receivers (cyan)
Down P Rays (orange)
Reflection Points (x)

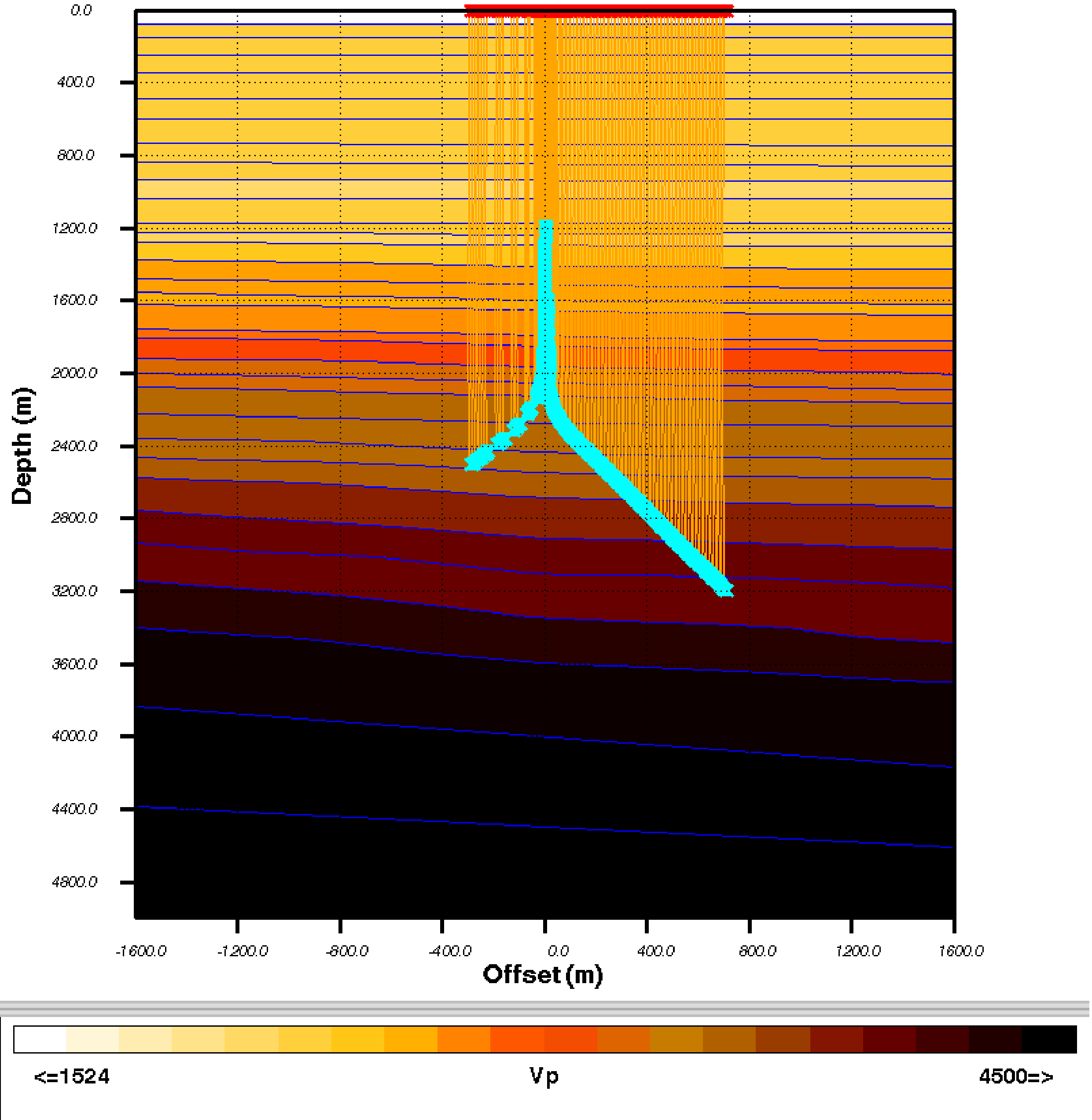


Figure 10c. 2D Model Building: Pseudo VIVSP

RH1 and RH1ST1 Receivers (cyan)
Down VIVSP P Rays (orange)

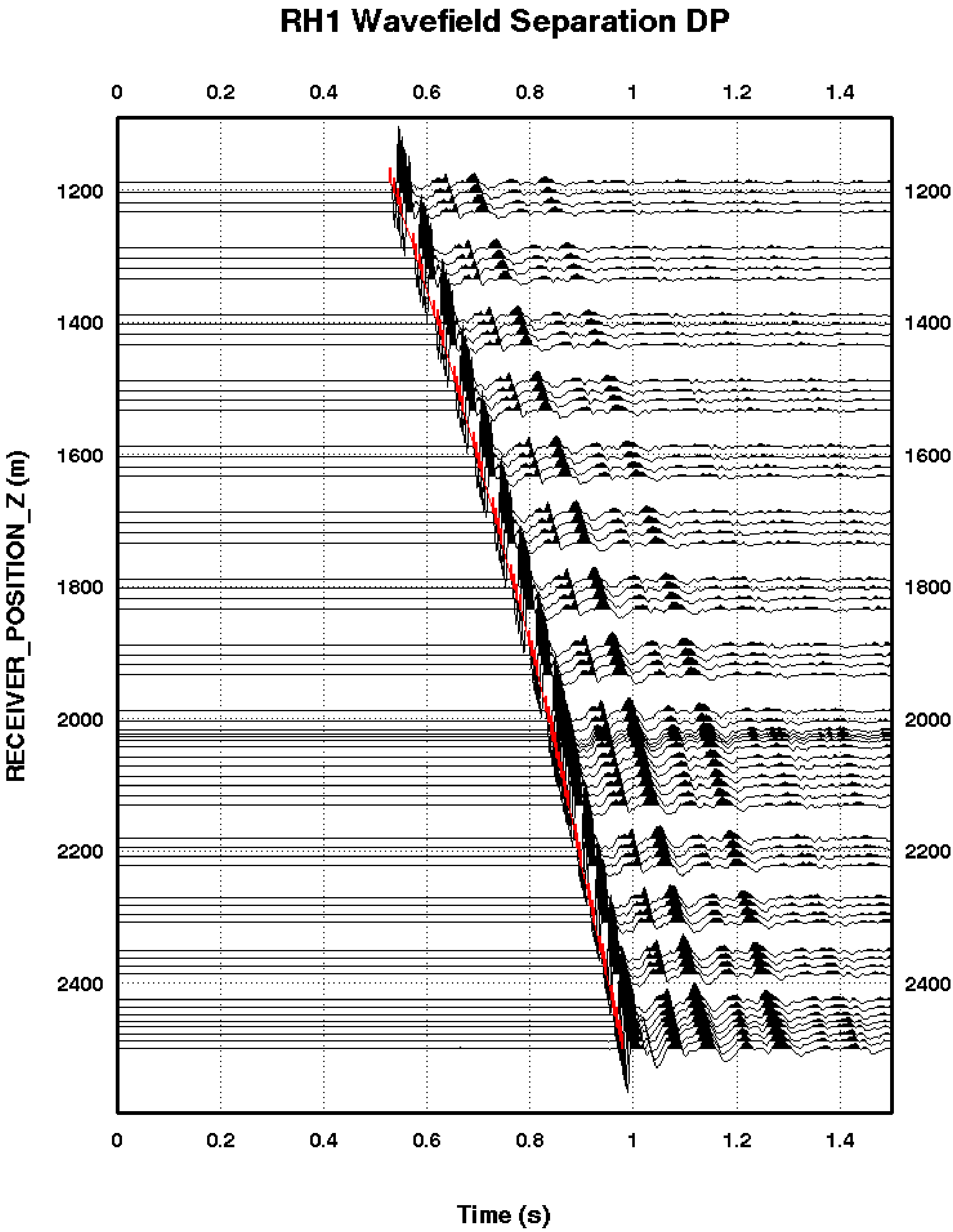


Figure 11a. Rockhopper-1 VSP: Down going P Wavefield after Wavefield Separation

(Trace Normalised)

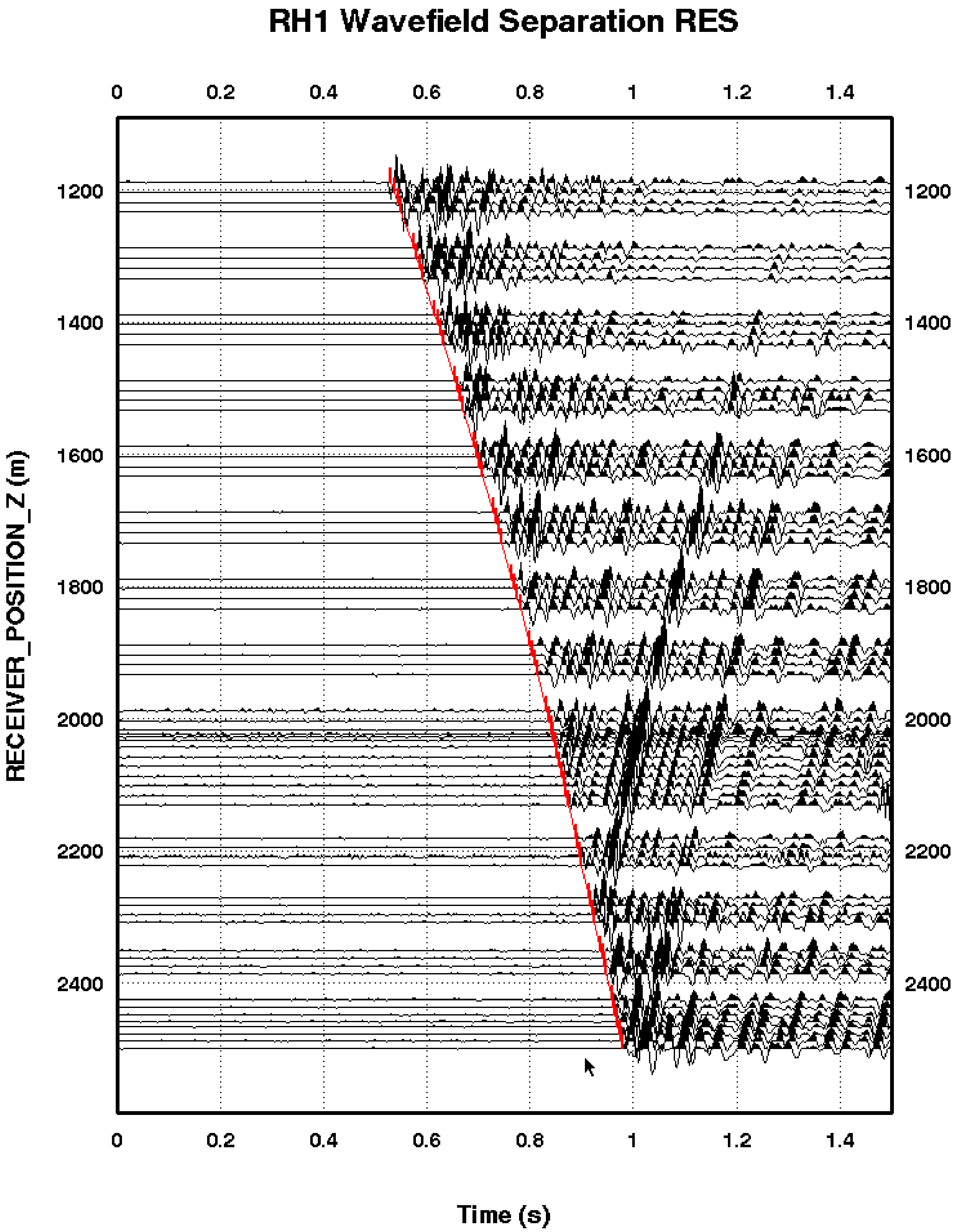


Figure 11b. Rockhopper-1 VSP: Up going P Wavefield after Wavefield Separation

(Trace Normalised)

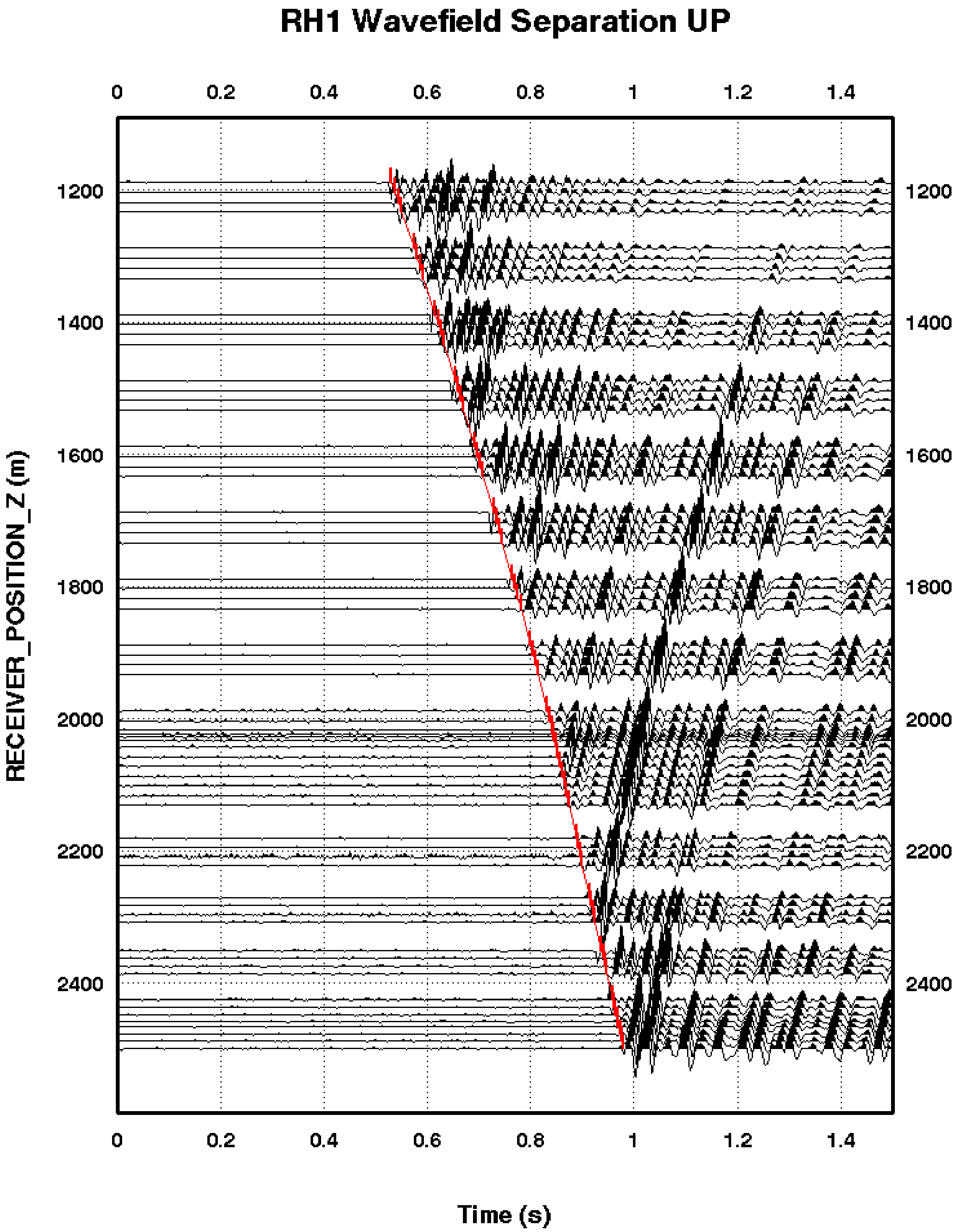


Figure 11d. Rockhopper-1 VSP: Enhanced Up going P Wavefield after Wavefield Separation

(Trace Normalised)

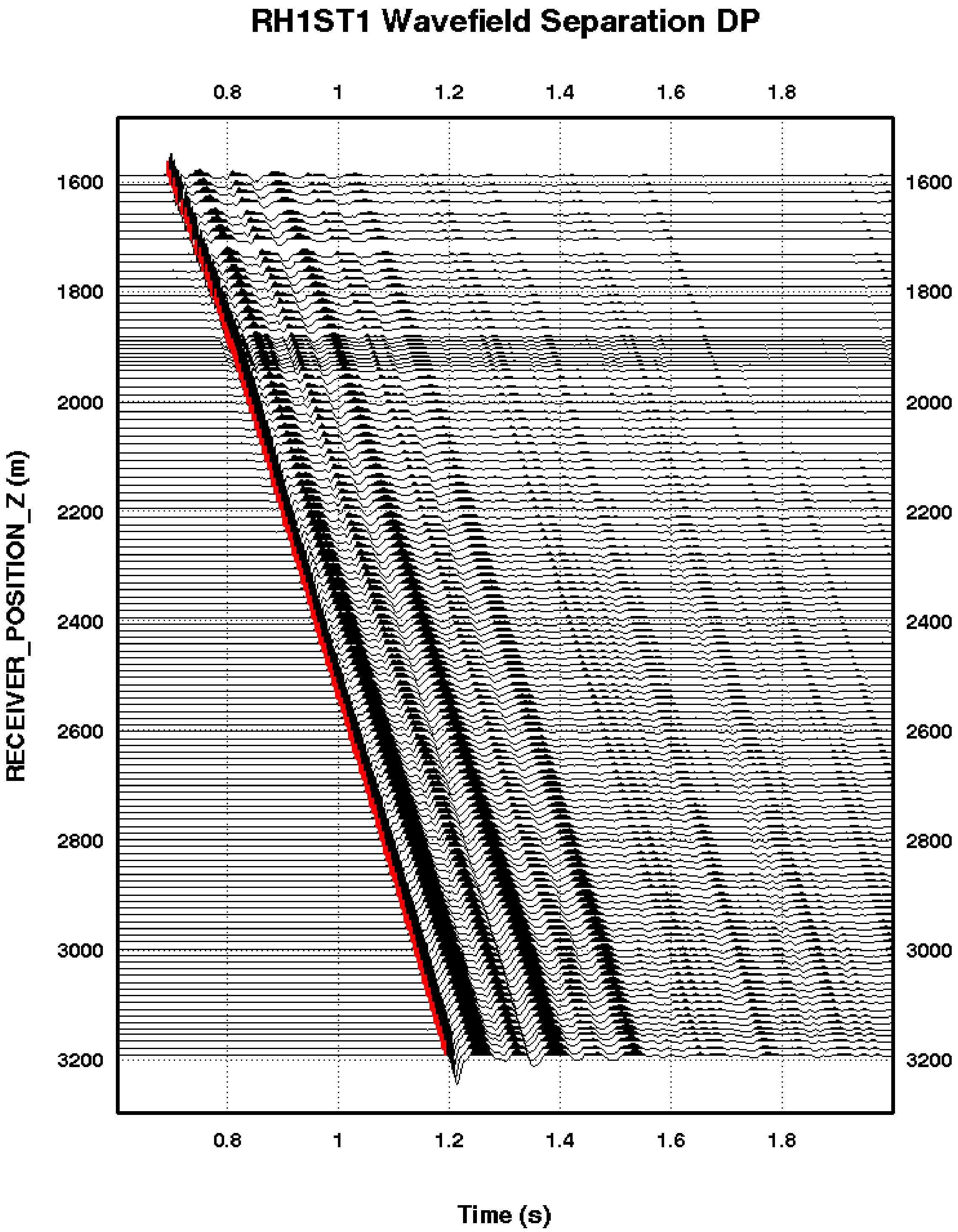


Figure 12a. Rockhopper-1 ST1 VSP: Down going P Wavefield after Wavefield Separation

(Trace Normalised)

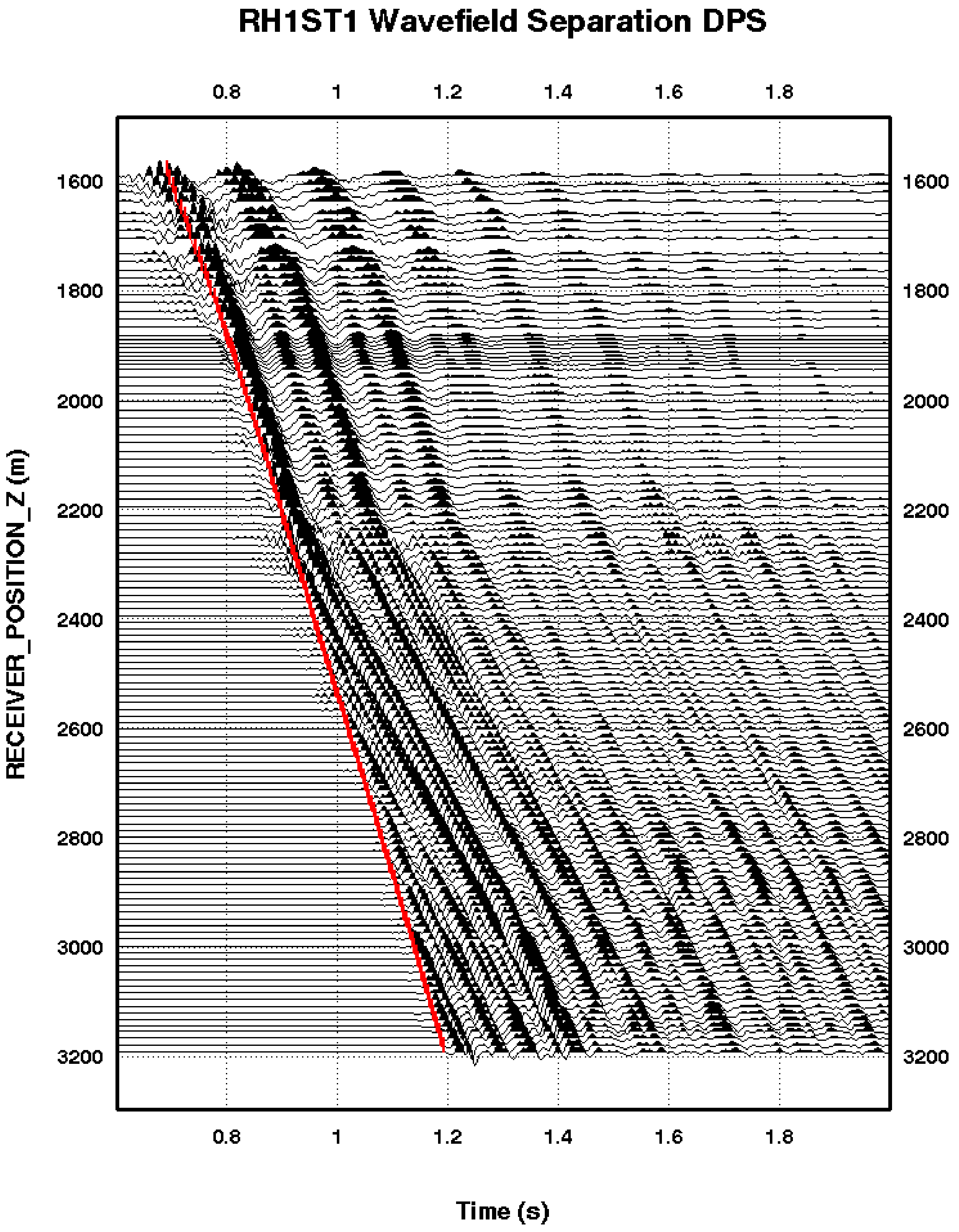


Figure 12b. Rockhopper-1 ST1 VSP: Down going PS Wavefield after Wavefield Separation

(Trace Normalised)

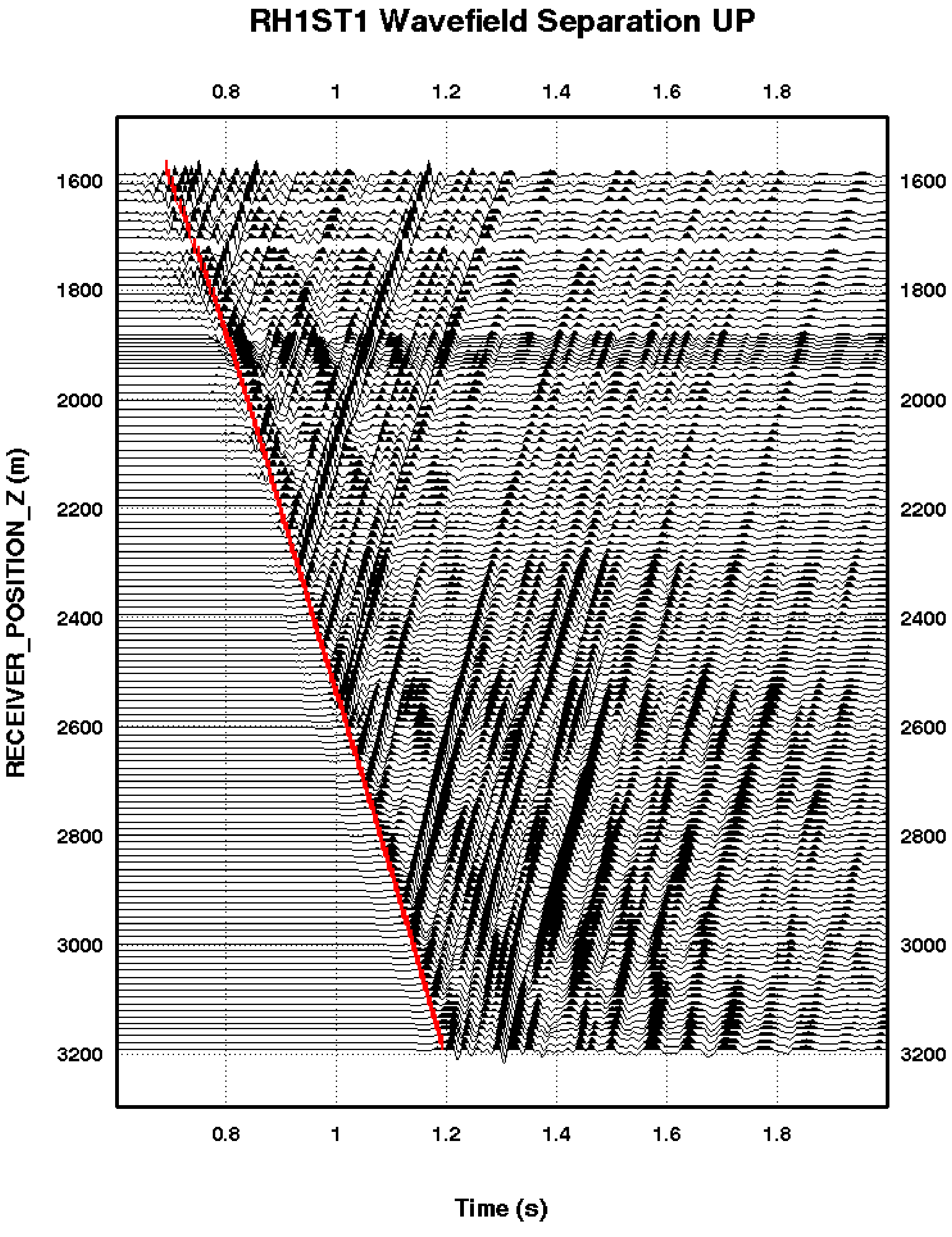


Figure 12c. Rockhopper-1 ST1 VSP: Up going P Wavefield after Wavefield Separation

(Trace Normalised)

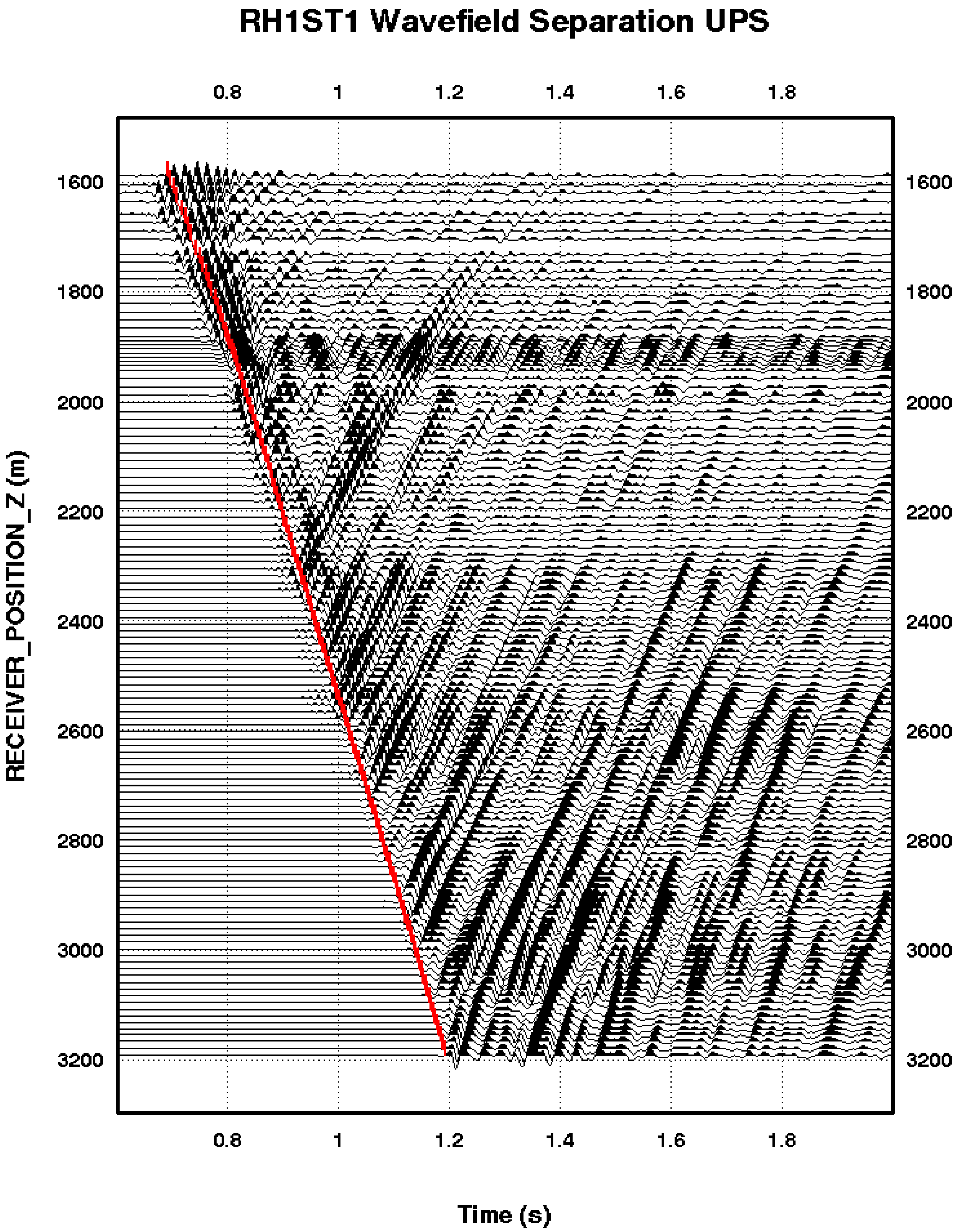


Figure 12d. Rockhopper-1 ST1 VSP: Up going PS Wavefield after Wavefield Separation

(Trace Normalised)

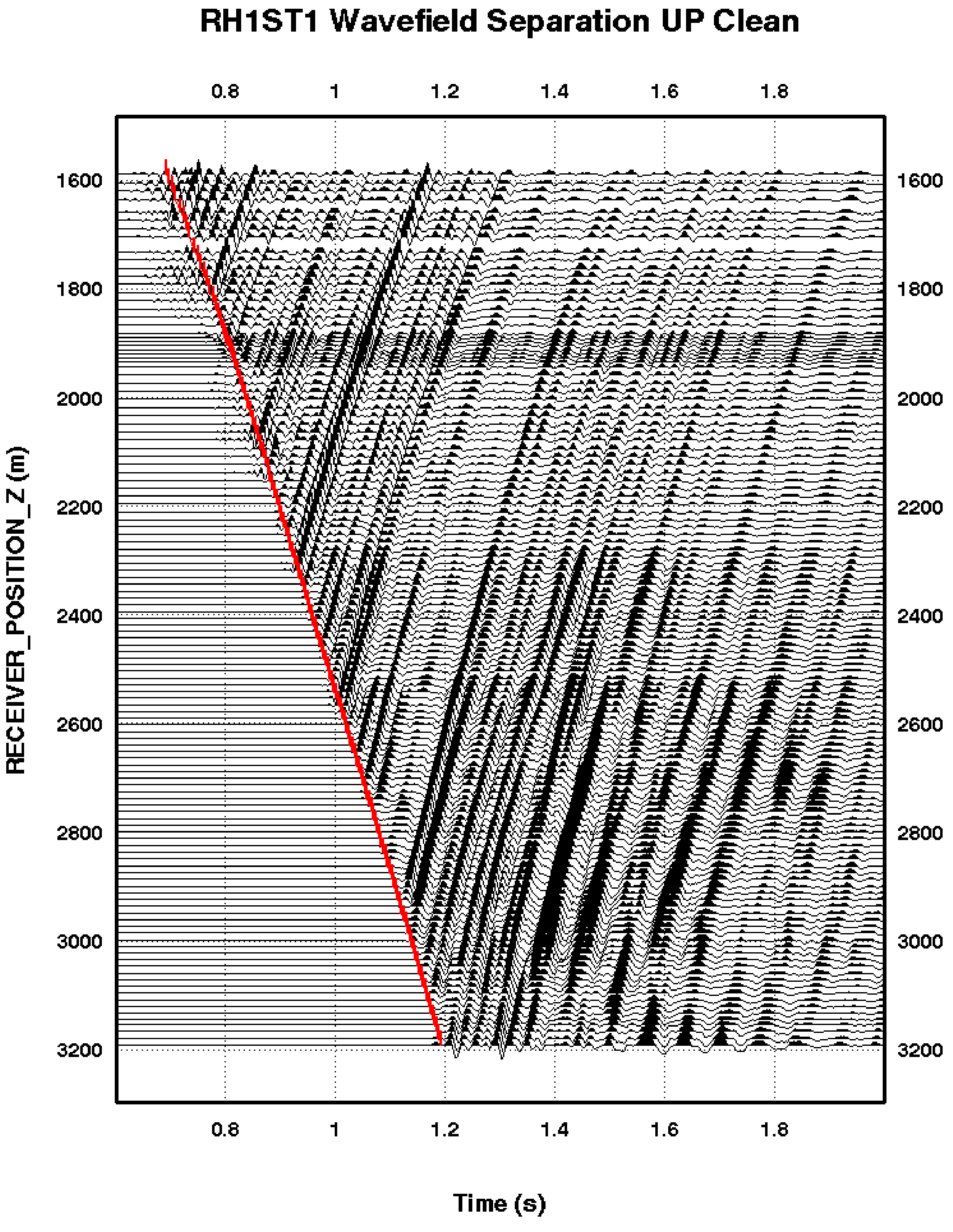


Figure 12e. Rockhopper-1 ST1 VSP: Cleaned Up going P Wavefield after Wavefield Separation

(Trace Normalised)

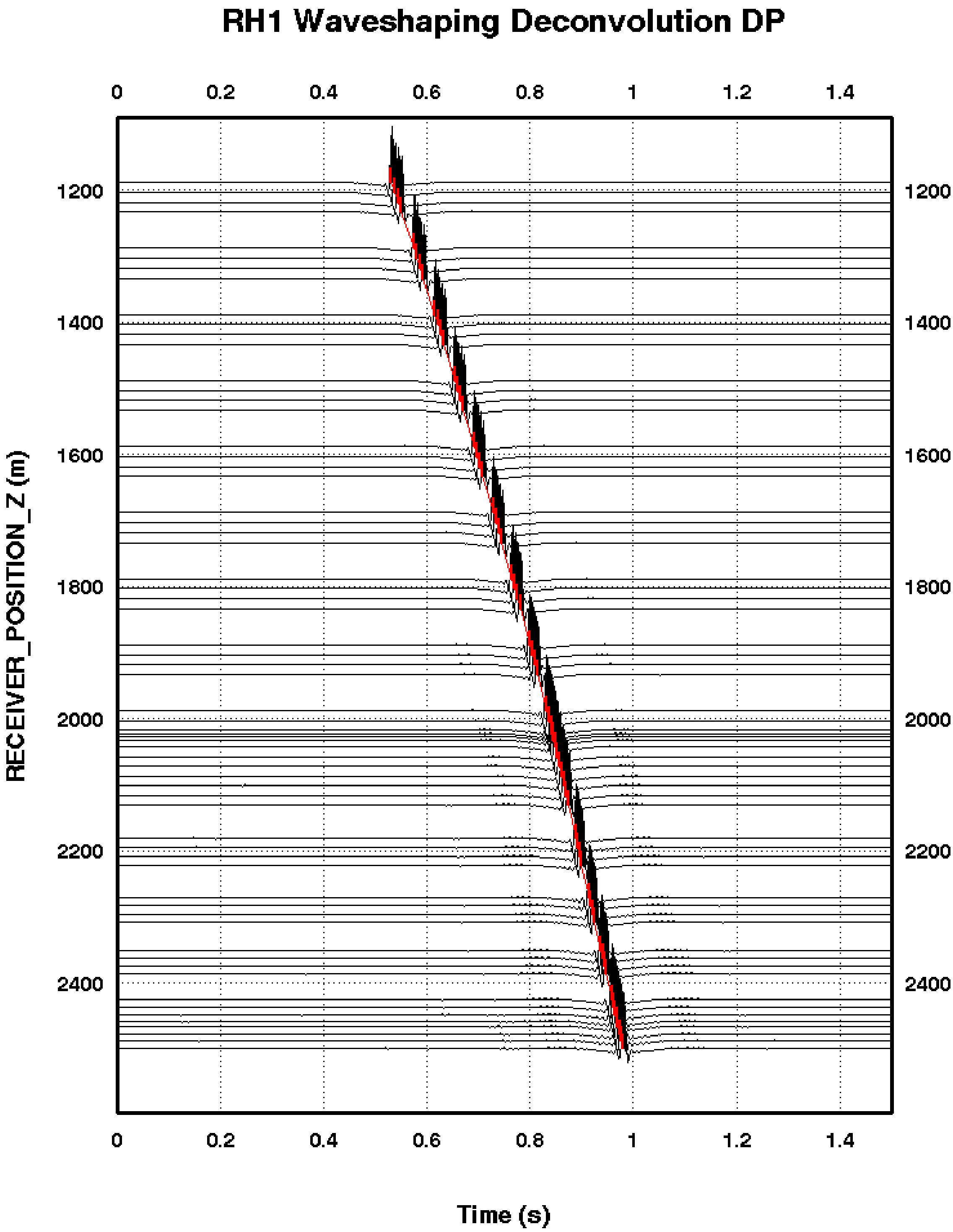


Figure 13a. Rockhopper-1 VSP: Down going P Wavefield after Waveshaping Deconvolution

(Gather Normalised)

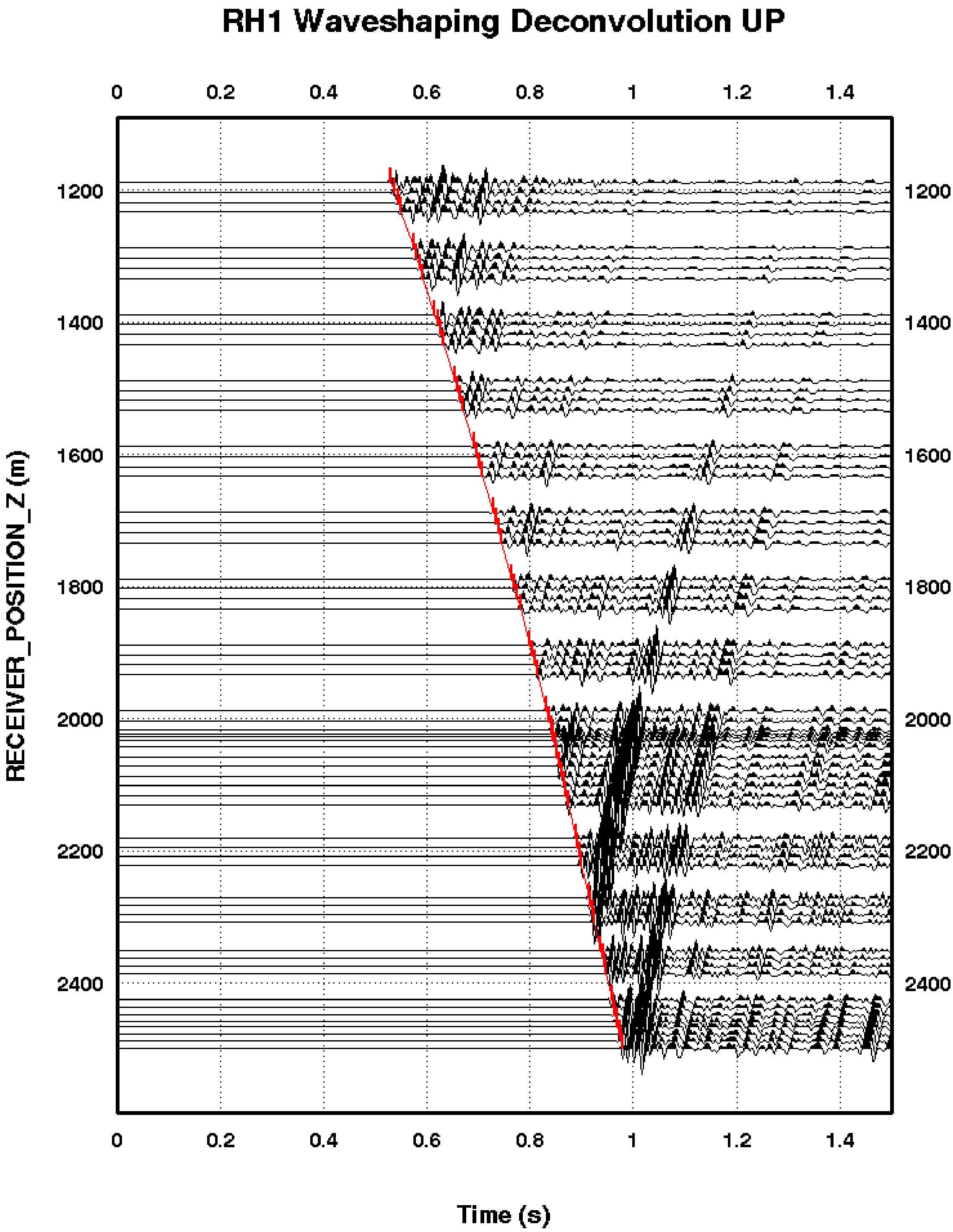


Figure 13b. Rockhopper-1 VSP: Up going P Wavefield after Waveshaping Deconvolution

(Gather Normalised)

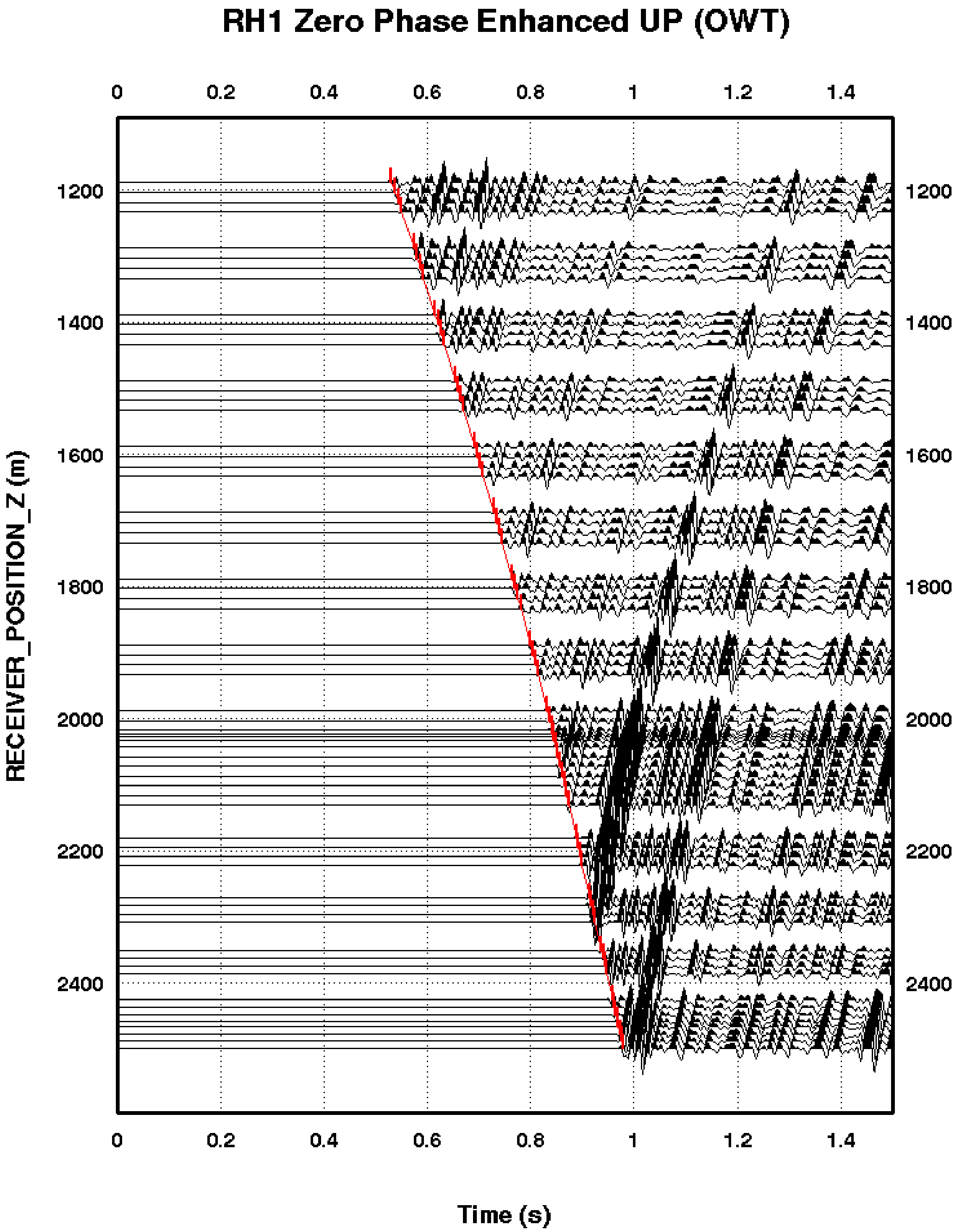


Figure 13c. Rockhopper-1 VSP: Enhanced Zero Phase Up going P Wavefield (OWT)

(Gather Normalised)

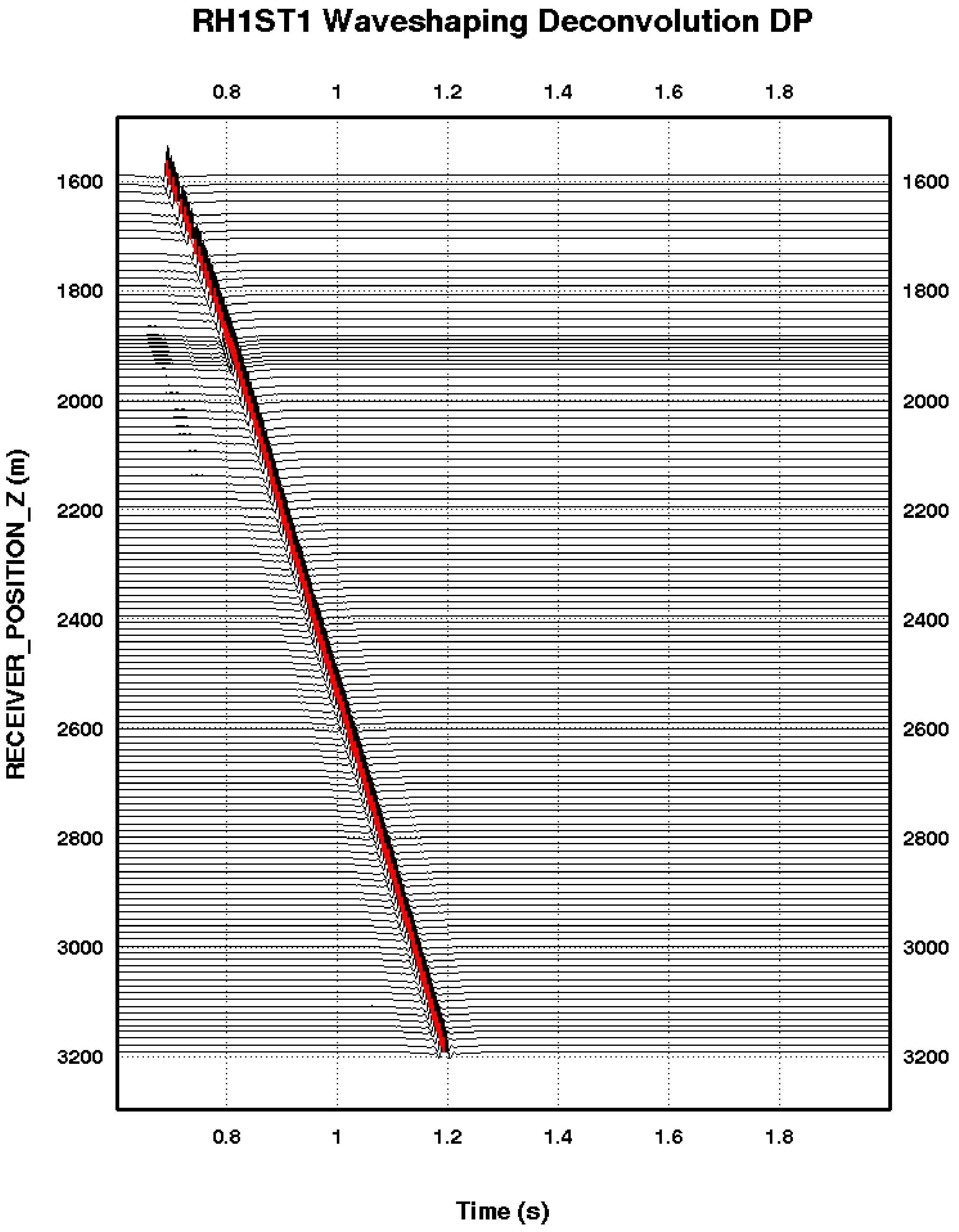


Figure 14a. Rockhopper-1 ST1 VSP: Down going P Wavefield after Waveshaping Deconvolution

(Gather Normalised)

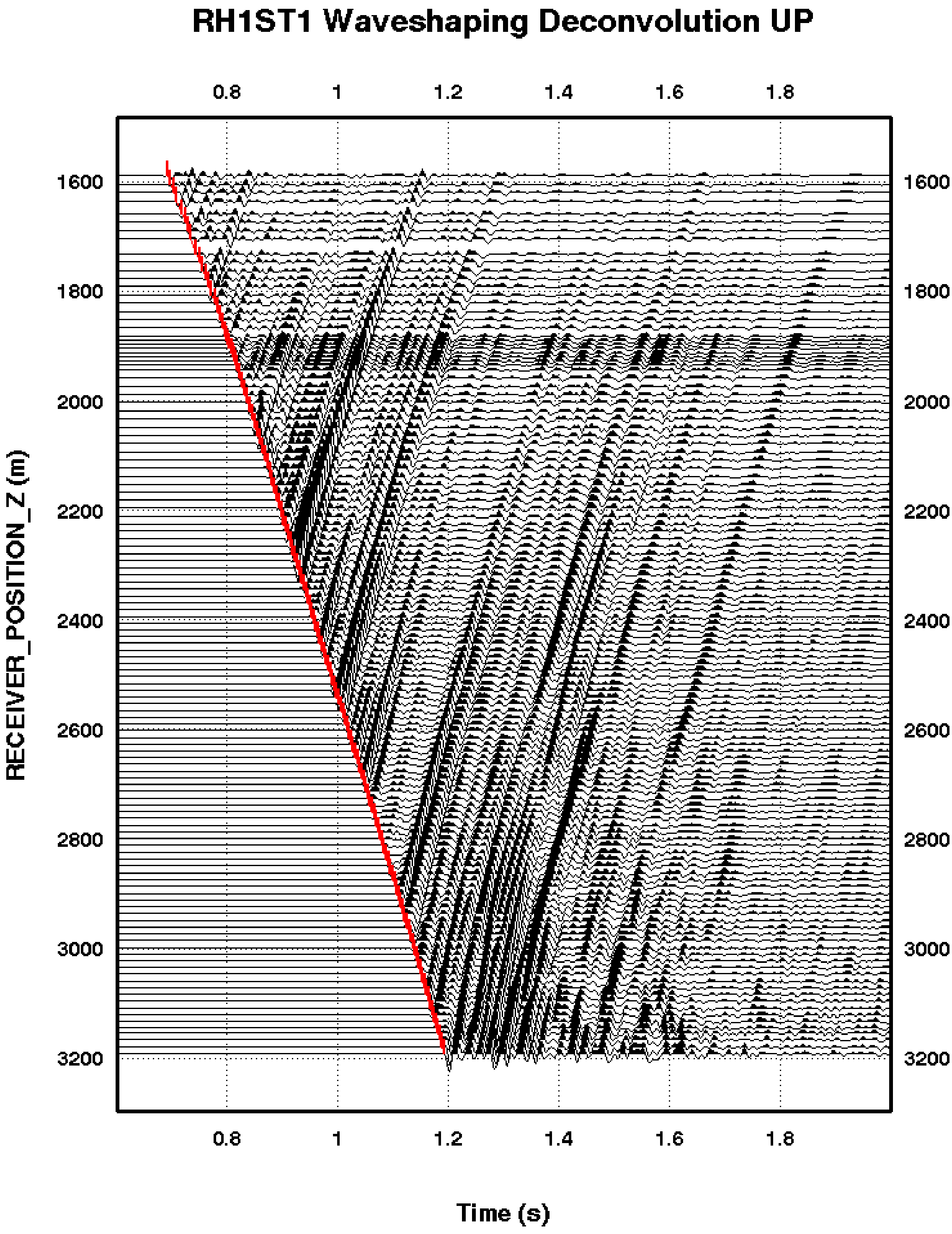


Figure 14b . Rockhopper-1 ST1 VSP: Up going P Wavefield after Waveshaping Deconvolution

(Gather Normalised)

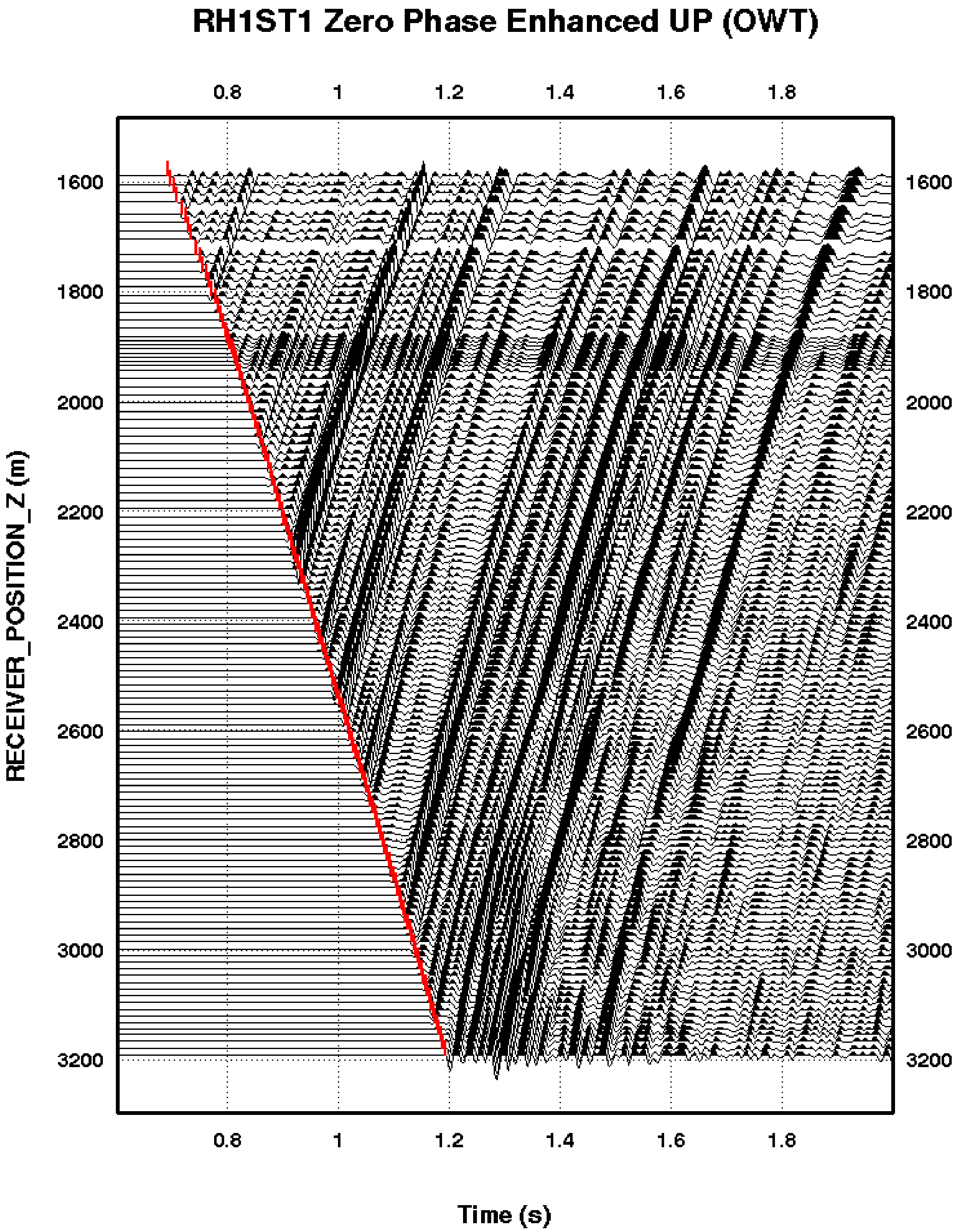


Figure 14c. Rockhopper-1 ST1 VSP: Enhanced Zero Phase Up going P Wavefield (OWT)

(Gather Normalised)

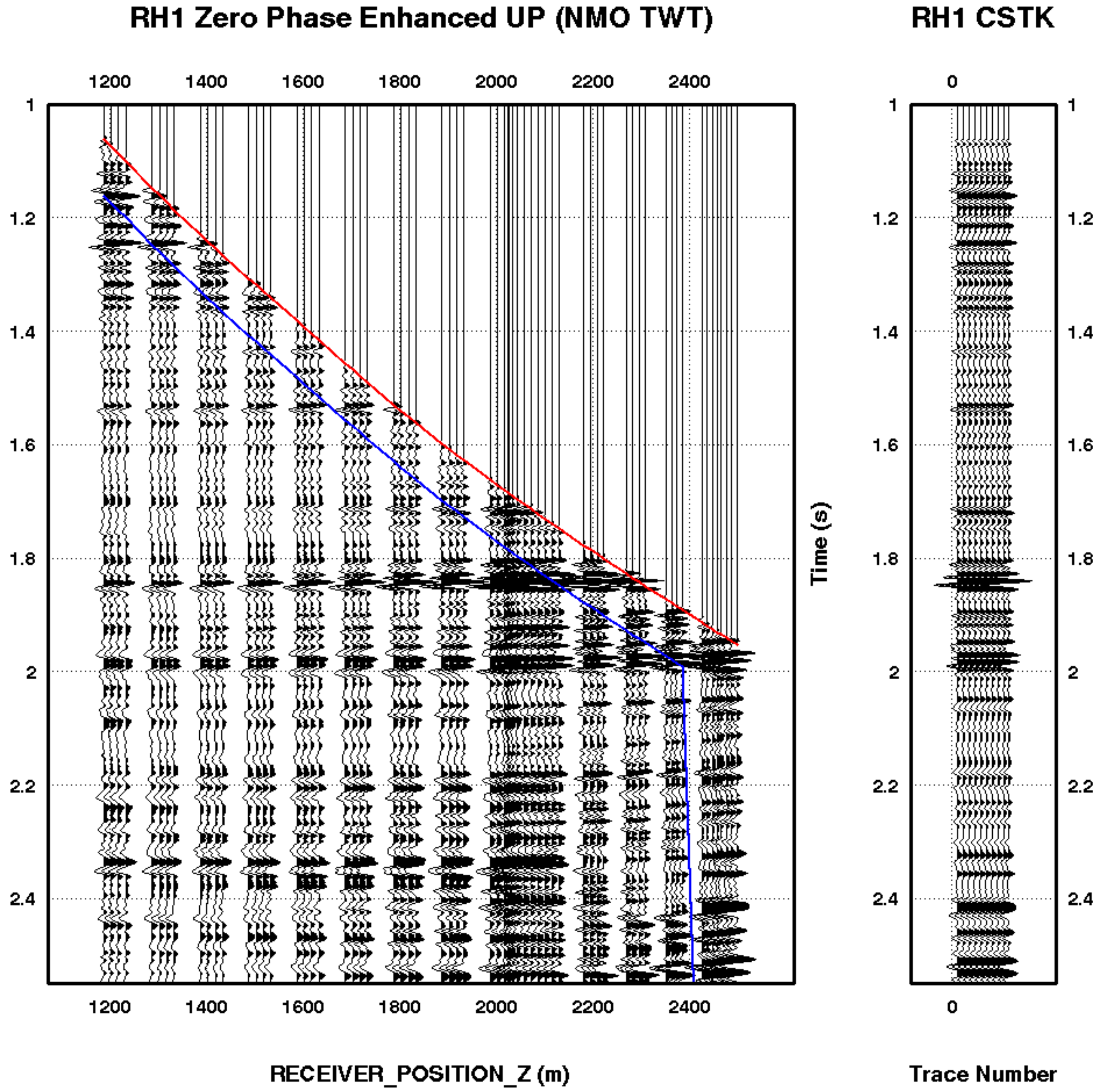


Figure 15a . Rockhopper-1 VSP: Enhanced Zero Phase Up going P Wavefield after NMO correction and Corridor Stack

(Gather Normalised)

The blue line on this plot of the Enhanced Upgoing Wavefield indicates the limit of the corridor stack.

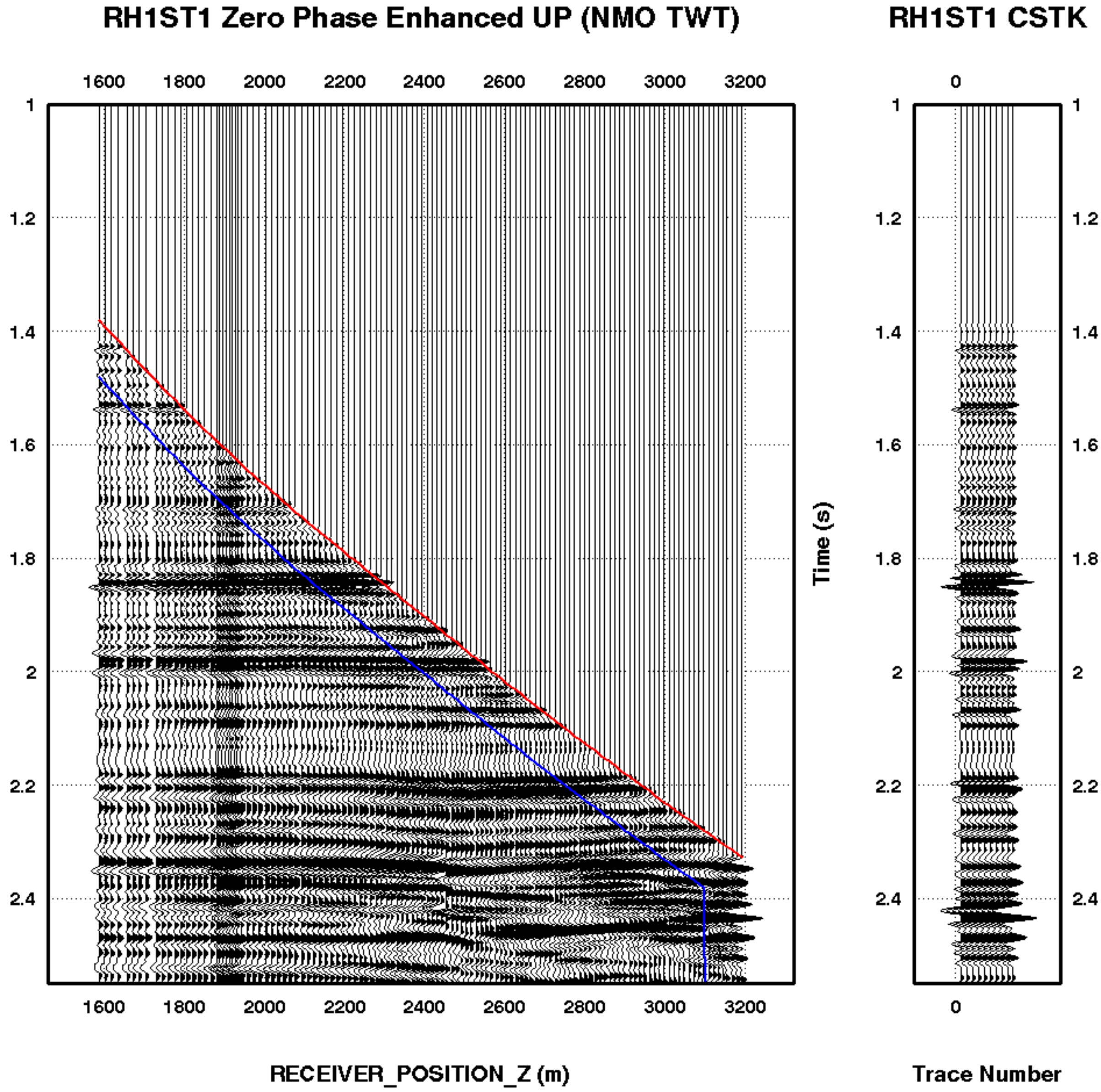


Figure 15b . Rockhopper-1 ST1 VSP: Enhanced Zero Phase Up going P Wavefield after NMO correction and Corridor Stack

(Gather Normalised)

The blue line on this plot of the Enhanced Upgoing Wavefield indicates the limit of the corridor stack.

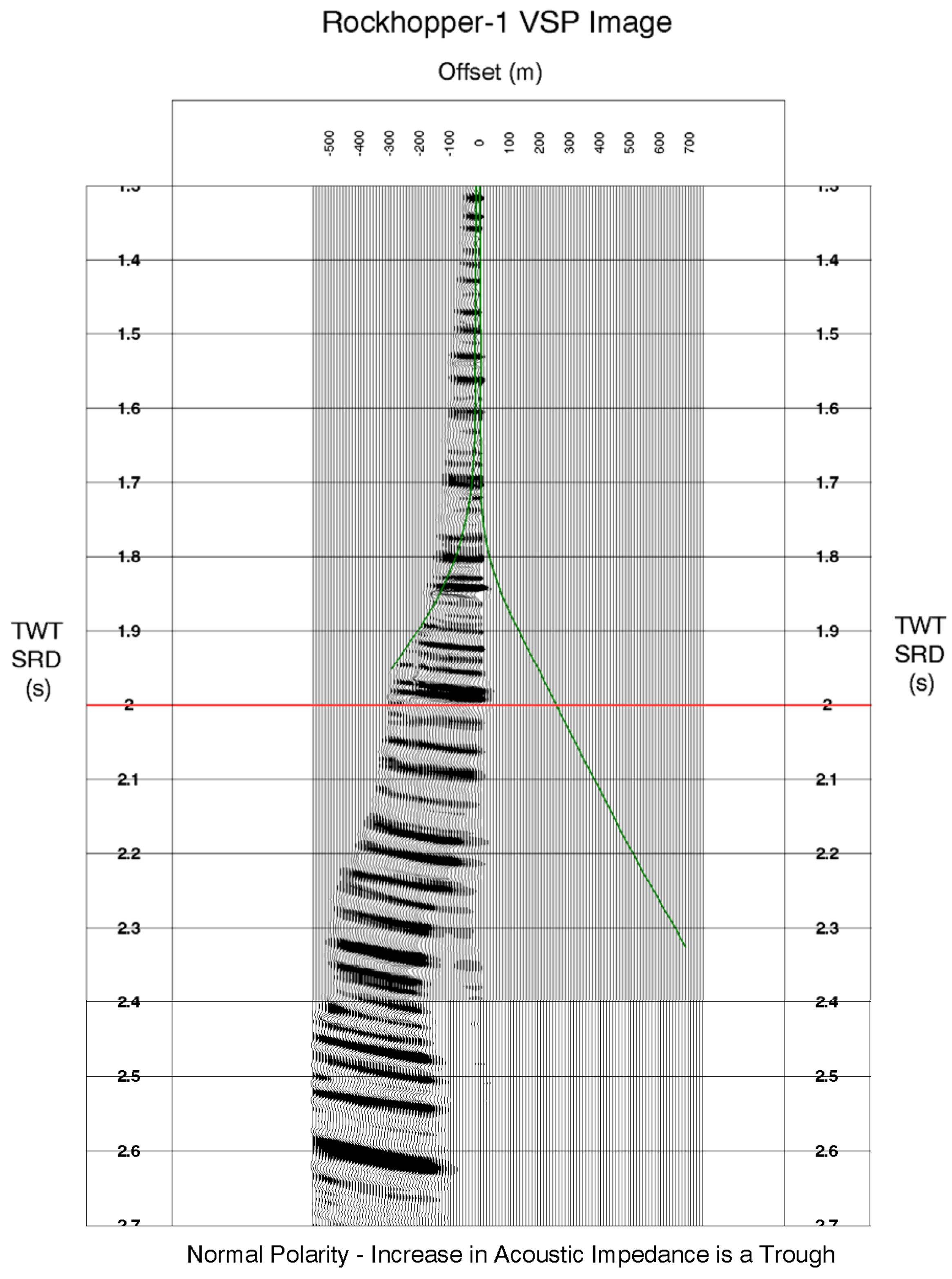


Figure 16a. Rockhopper-1 VSP: VSP GRT Migration Image

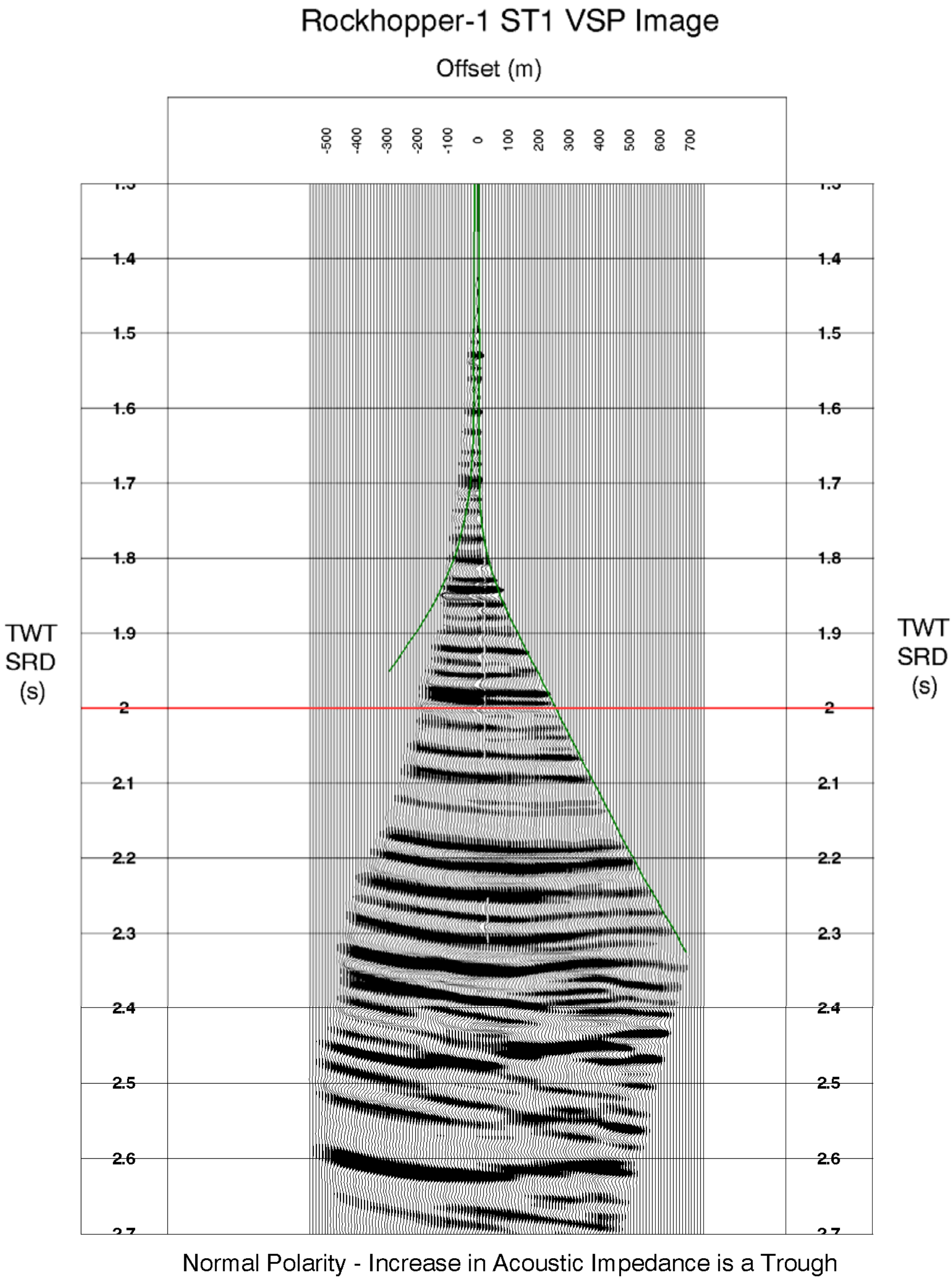


Figure 16b. Rockhopper-1 ST1 VSP: VSP GRT Migration Image

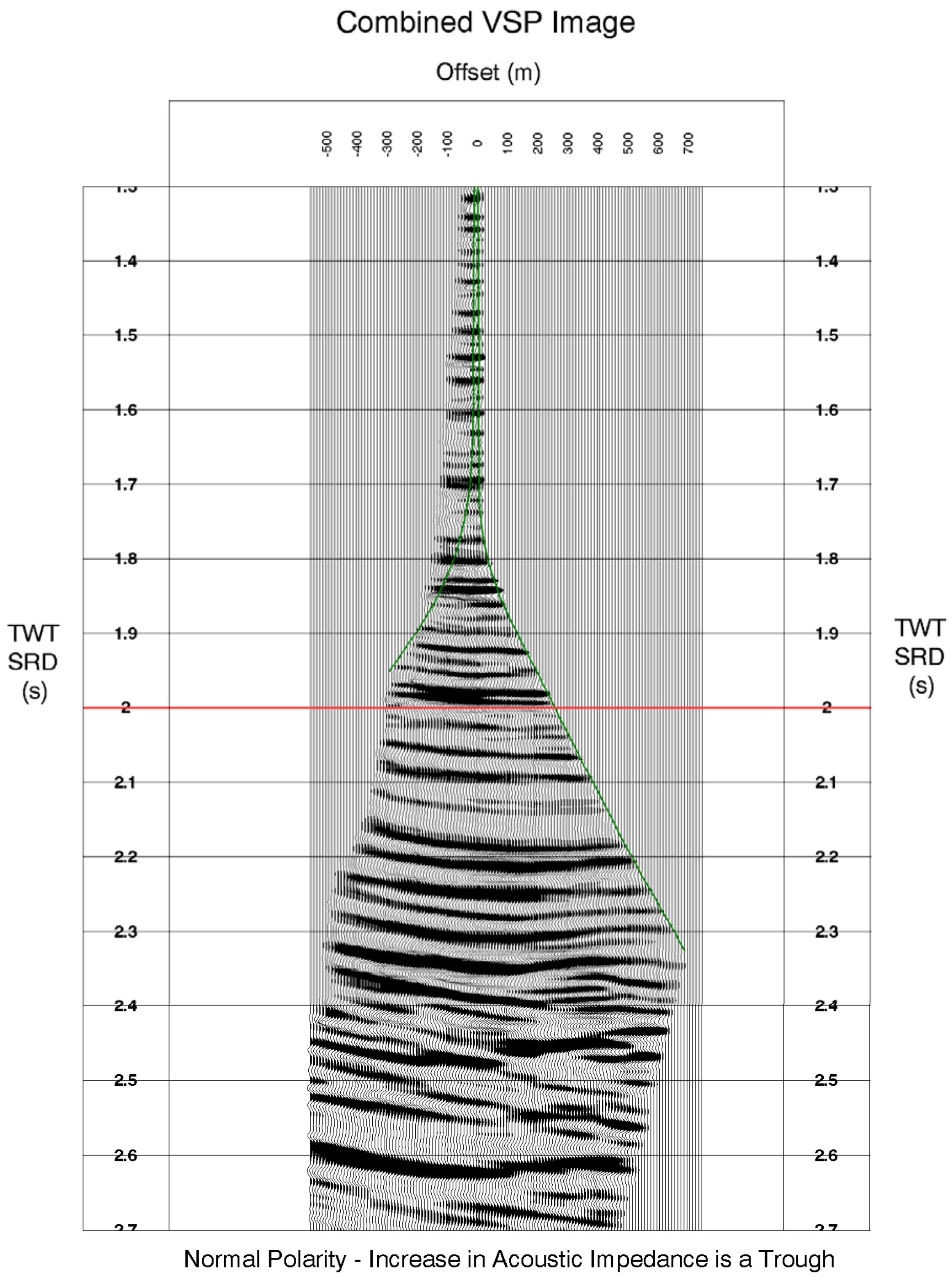


Figure 16c. Rockhopper-1 and ST1 VSP: Combined VSP GRT Migration Image

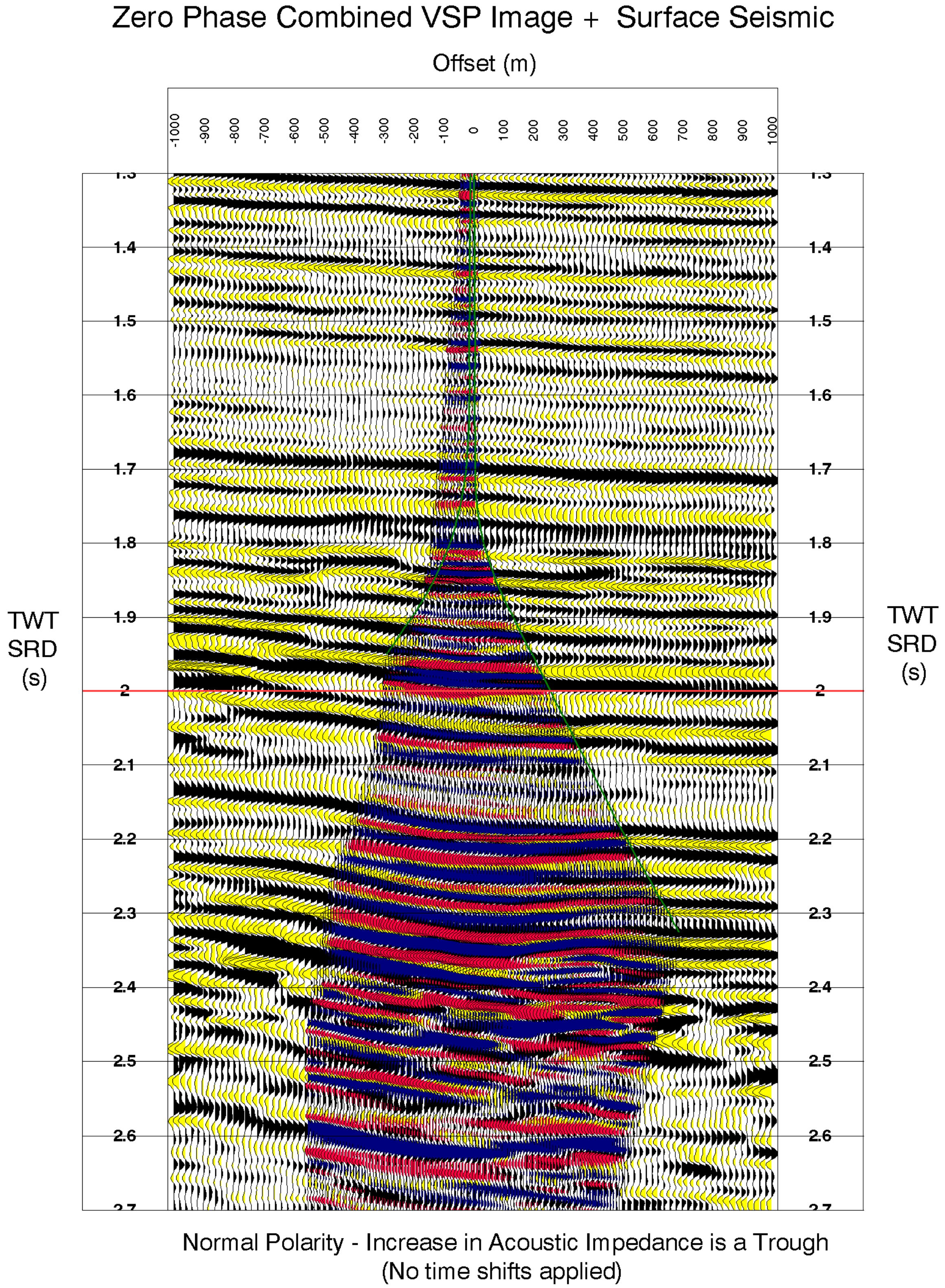


Figure 17a. Combined VSP Image and Surface Seismic (Normal Polarity)

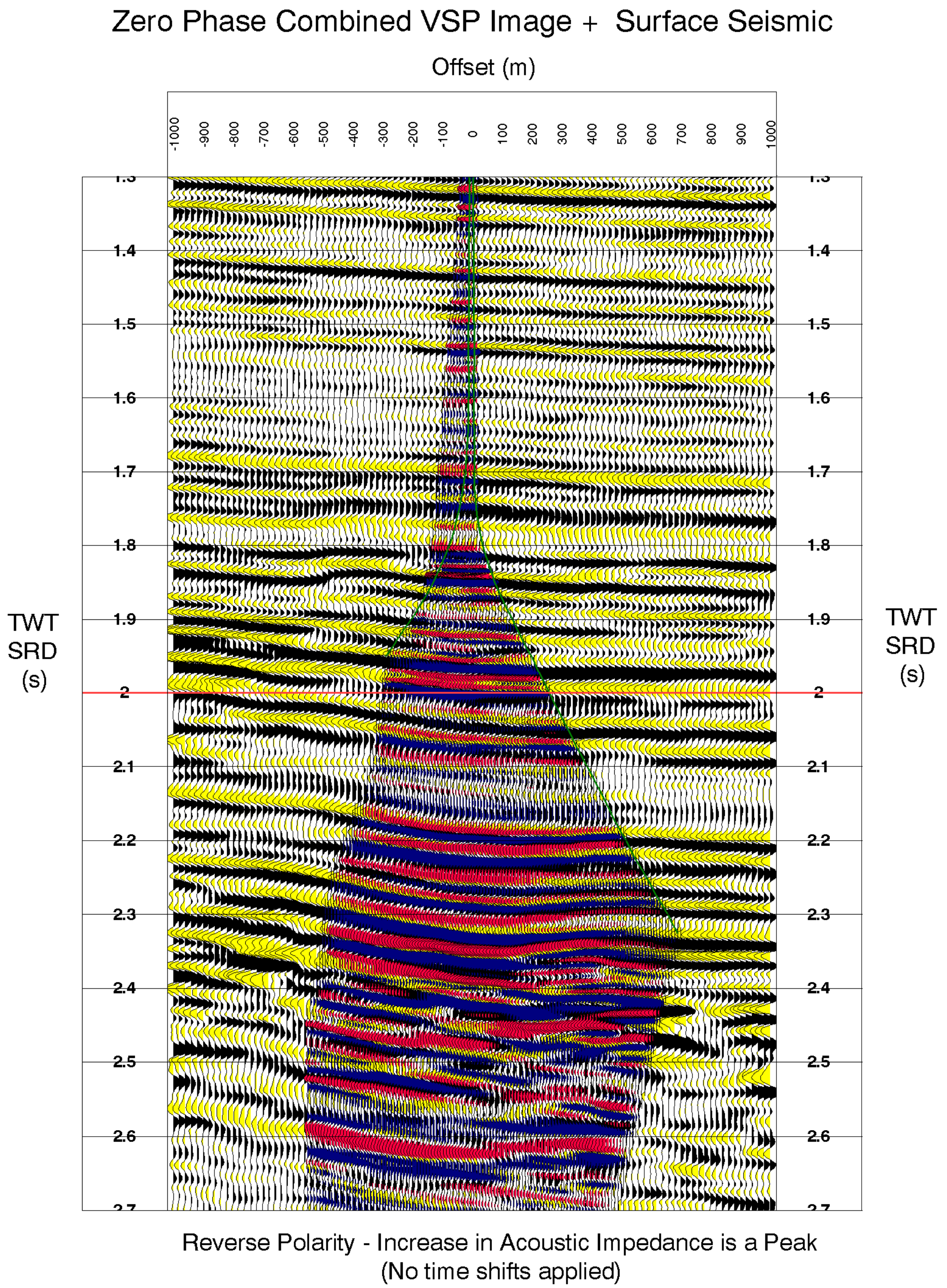


Figure 17b. Combined VSP Image and Surface Seismic (Reverse Polarity)

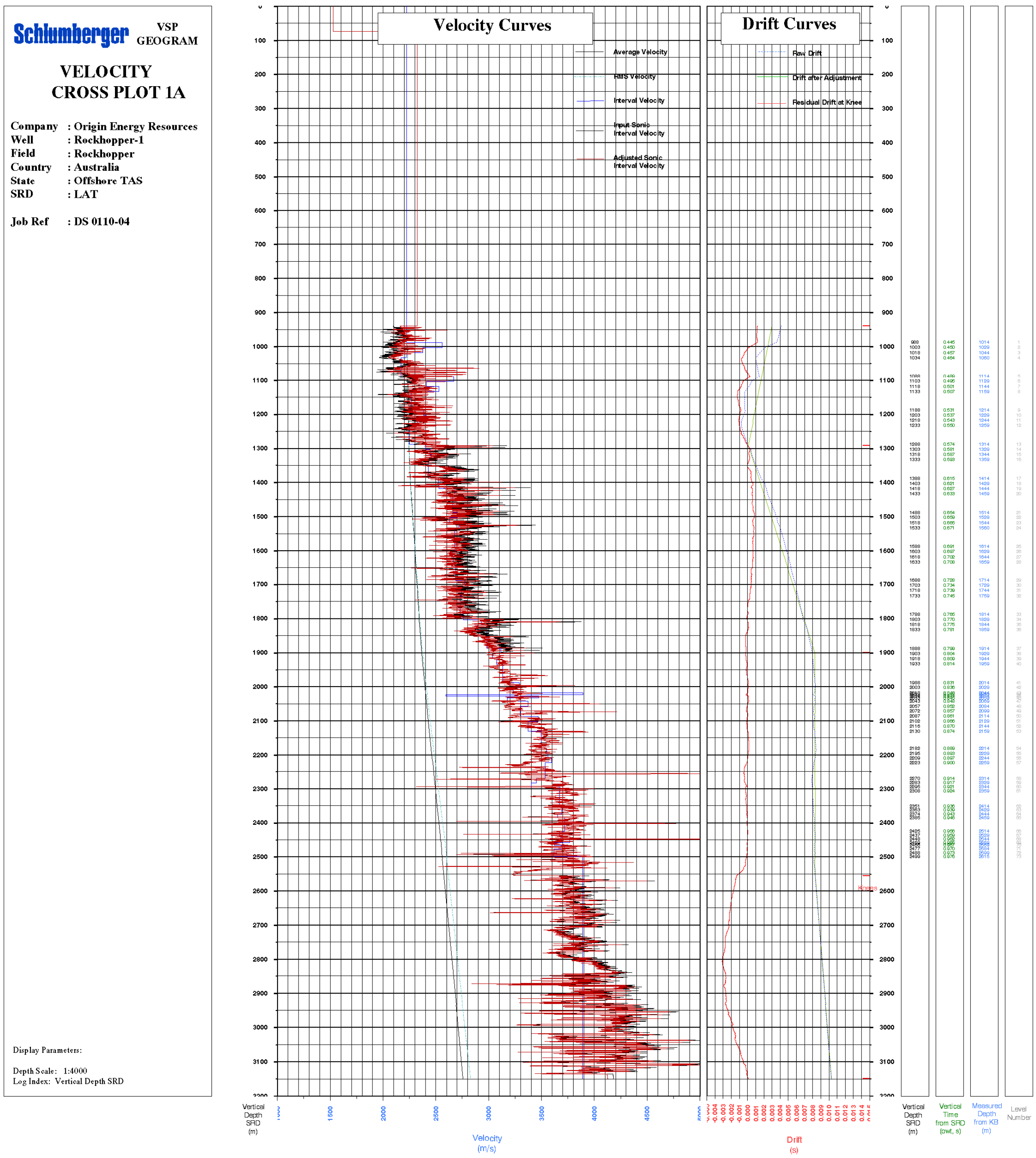


Figure 18a. Time-Depth relation and velocities vs TVD SS and drift curves (RH1)

Note that this plot is provided on the 36" plot with this report.

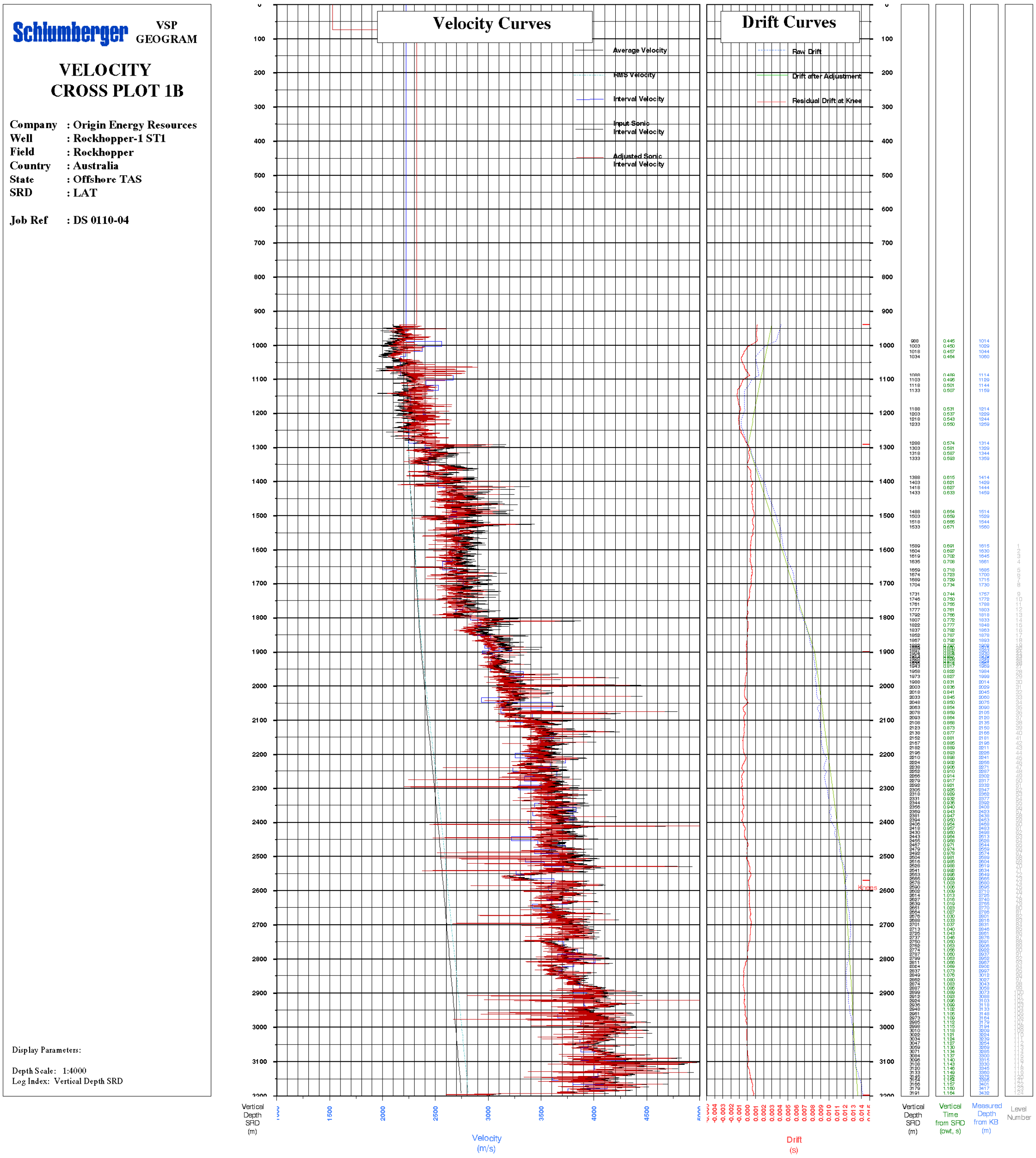


Figure 18b. Time-Depth relation and velocities vs TVD SS and drift curves (RH1 ST1)

Note that this plot is provided on the 36" plot with this report.

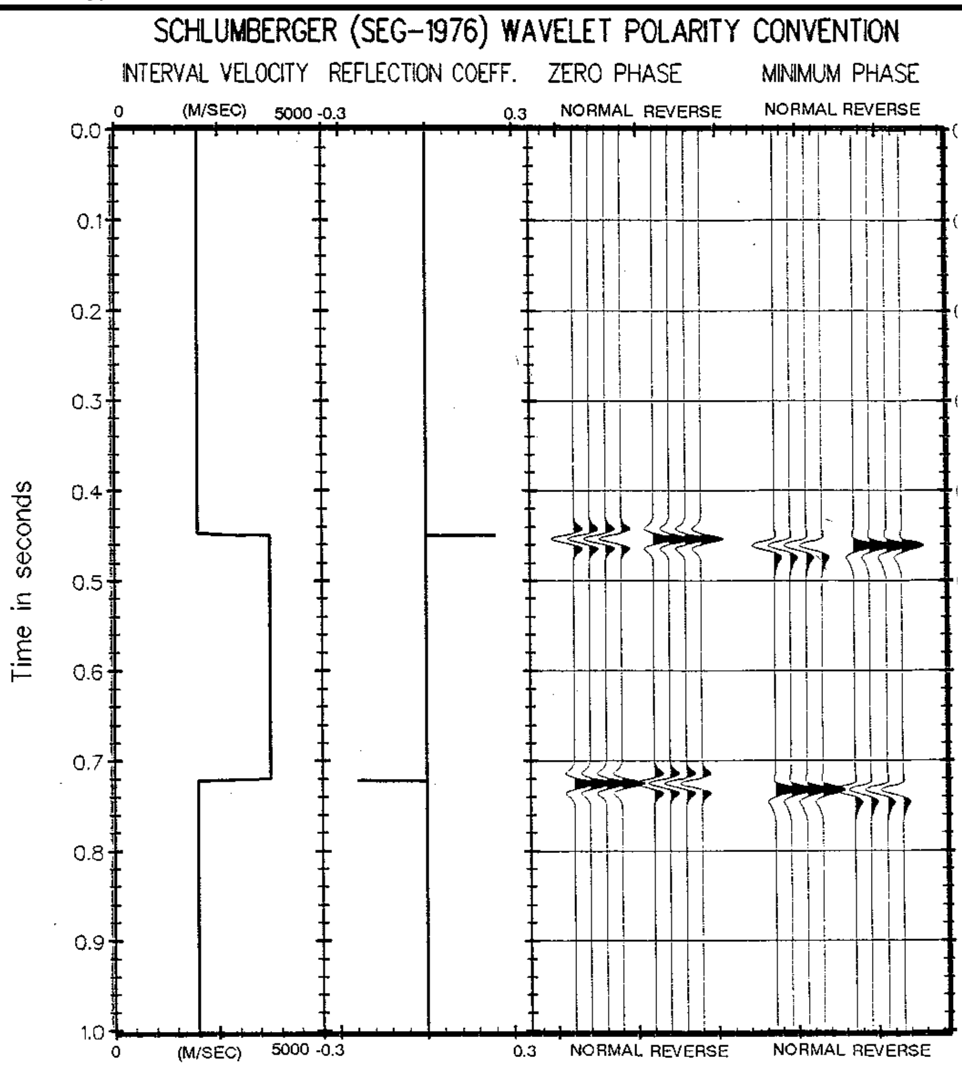


Figure 19. Schlumberger Wavelet Polarity Convention

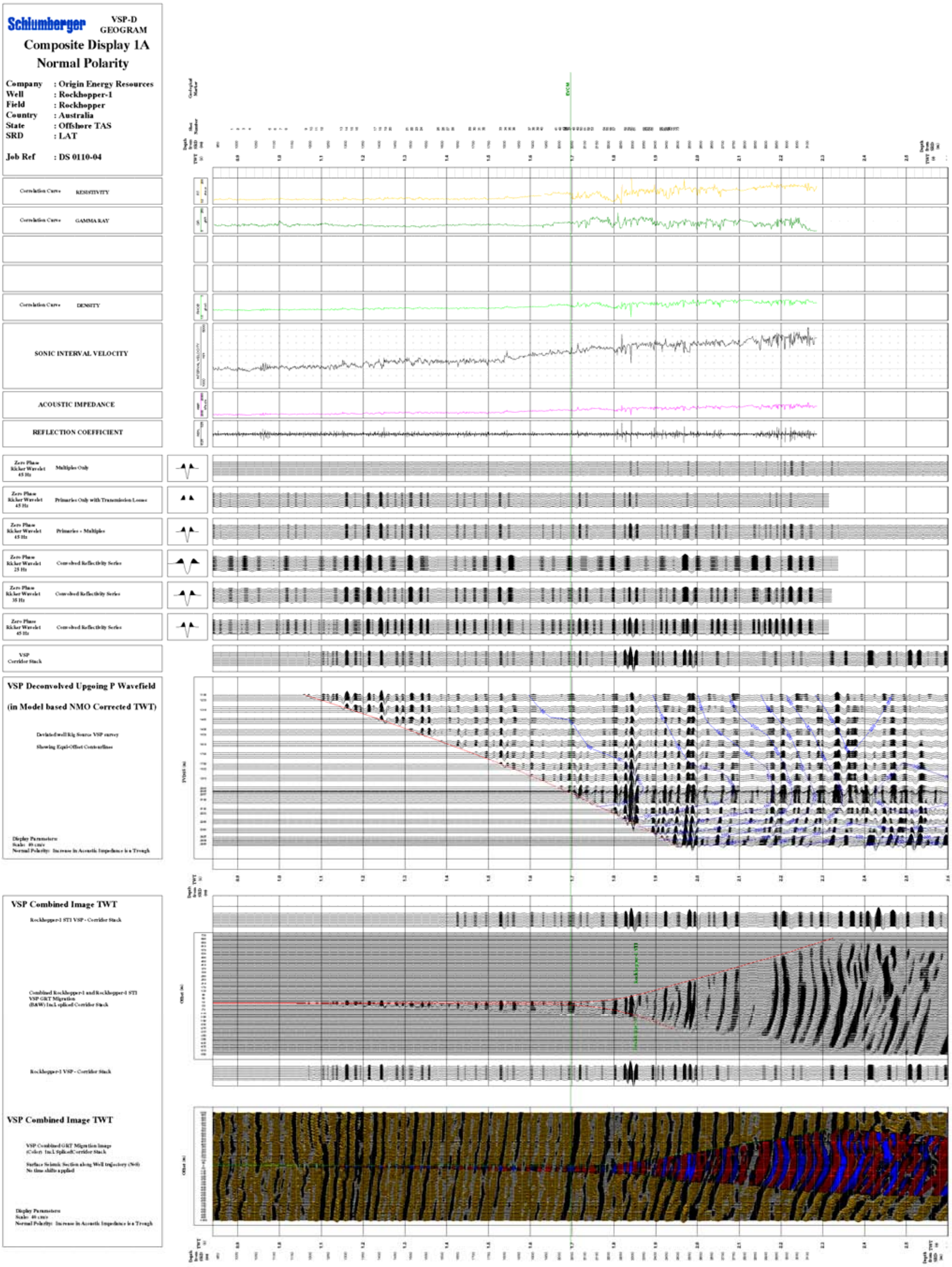


Figure 20a. Rockhopper-1 Composite Display – Normal Polarity (See Plot 1A)

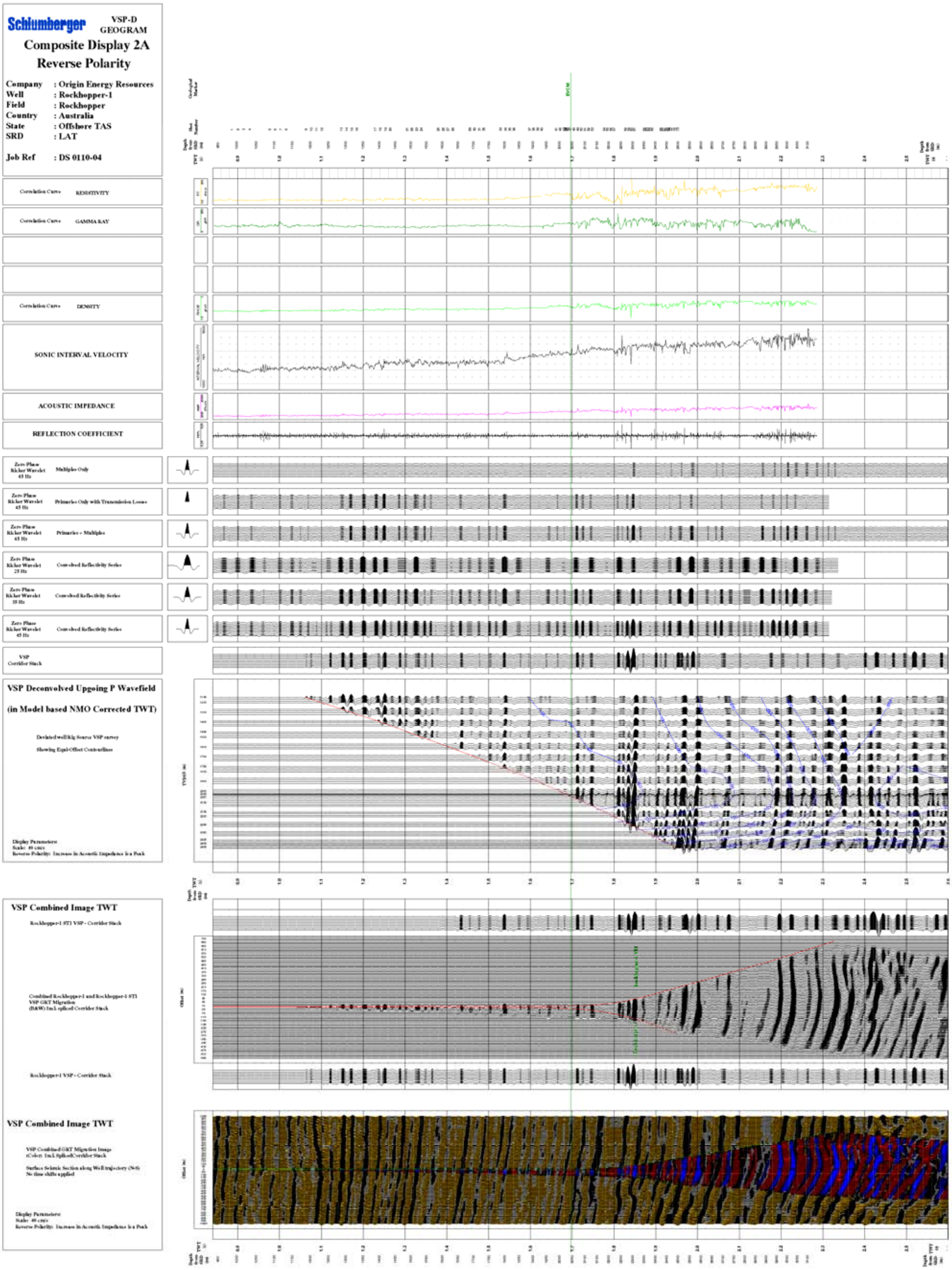


Figure 20b. Rockhopper-1 Composite Display – Reverse Polarity (See Plot 2A).

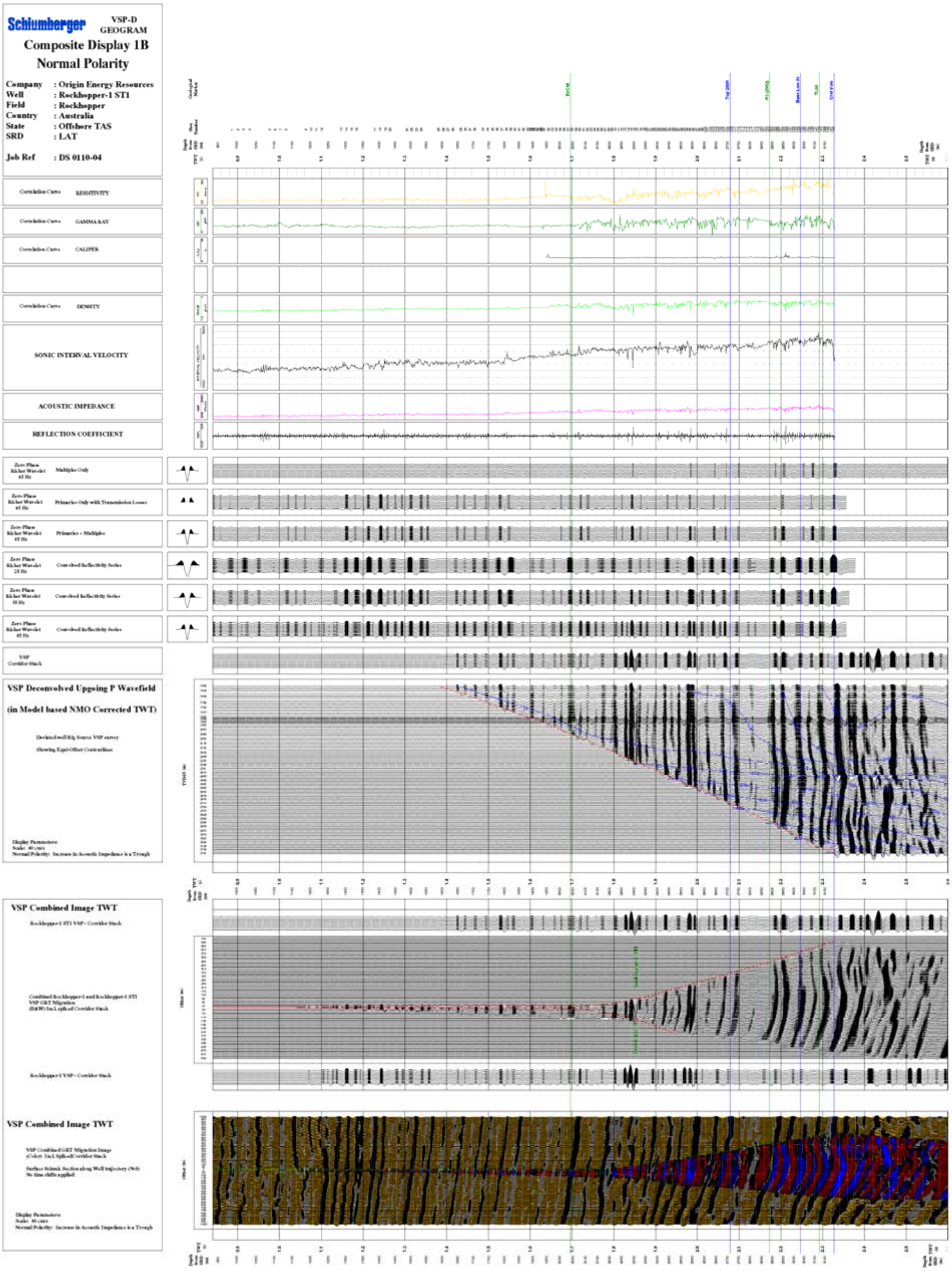


Figure 21a. Rockhopper-1 ST1 Composite Display – Normal Polarity (See Plot 1B)

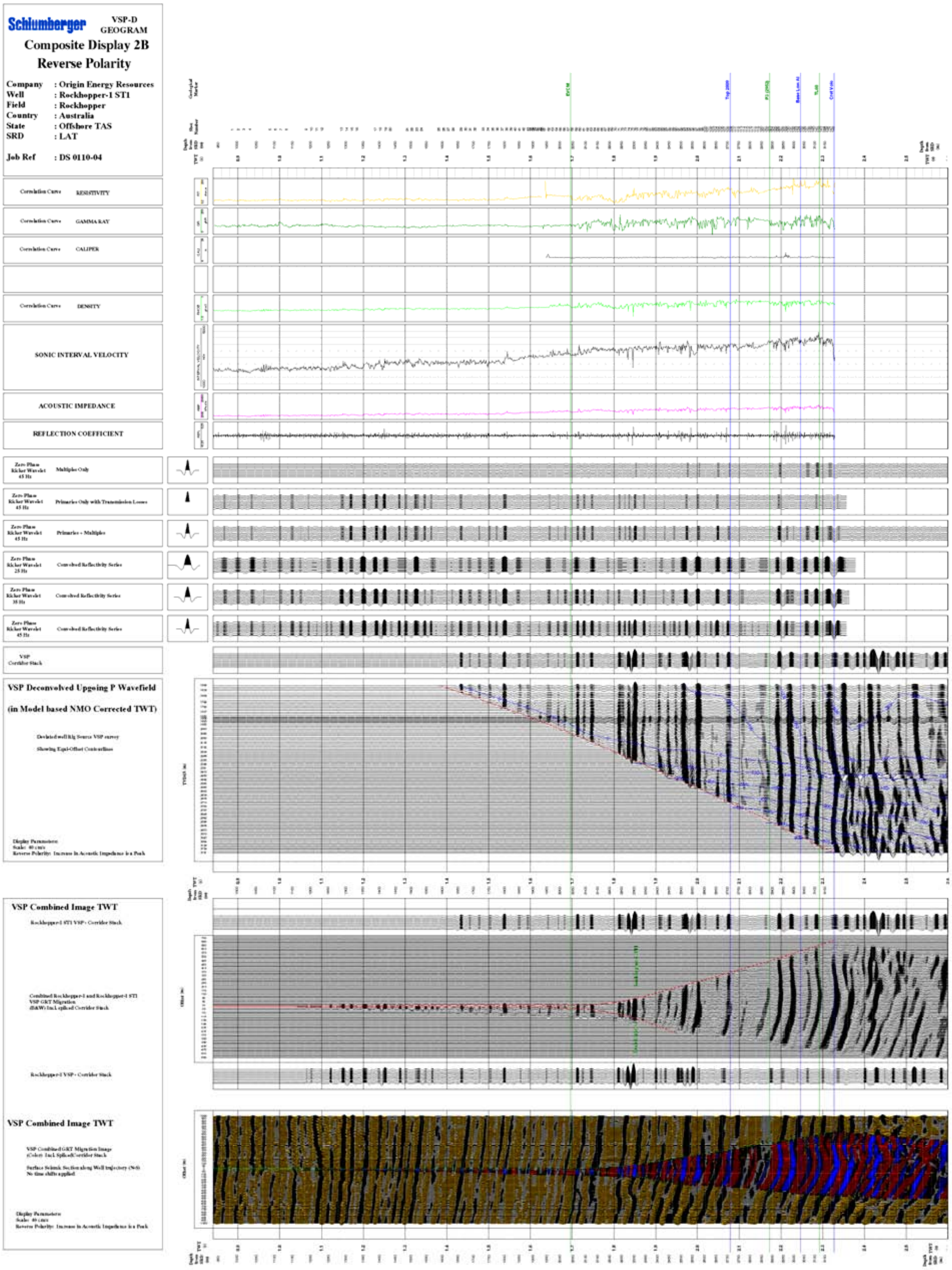


Figure 21b. Rockhopper-1 Composite Display – Reverse Polarity (See Plot 2B)

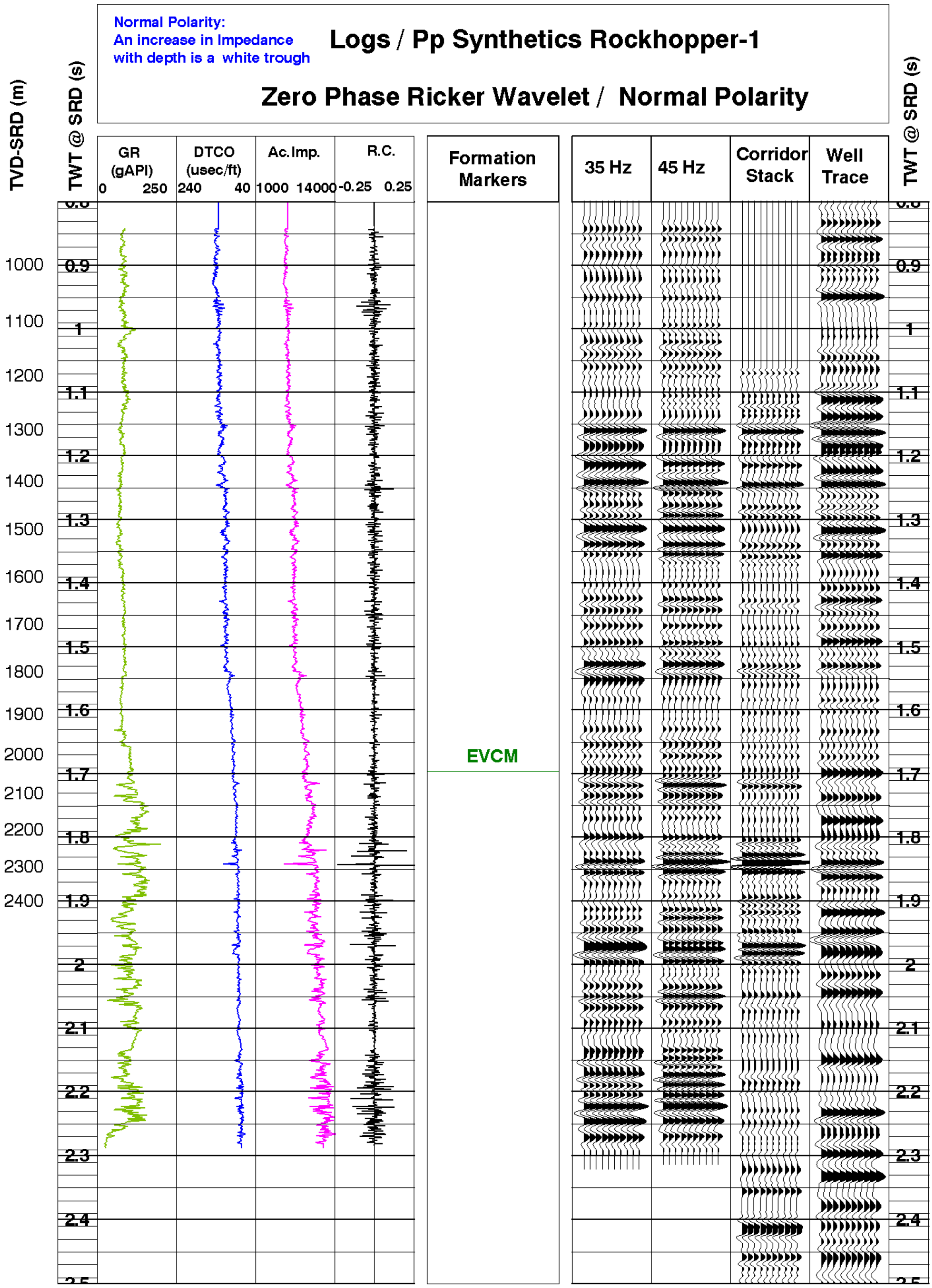


Figure 22a. RH1 Surface Seismic Well trace, Corridor Stack, Synthetics and Logs (Normal polarity)

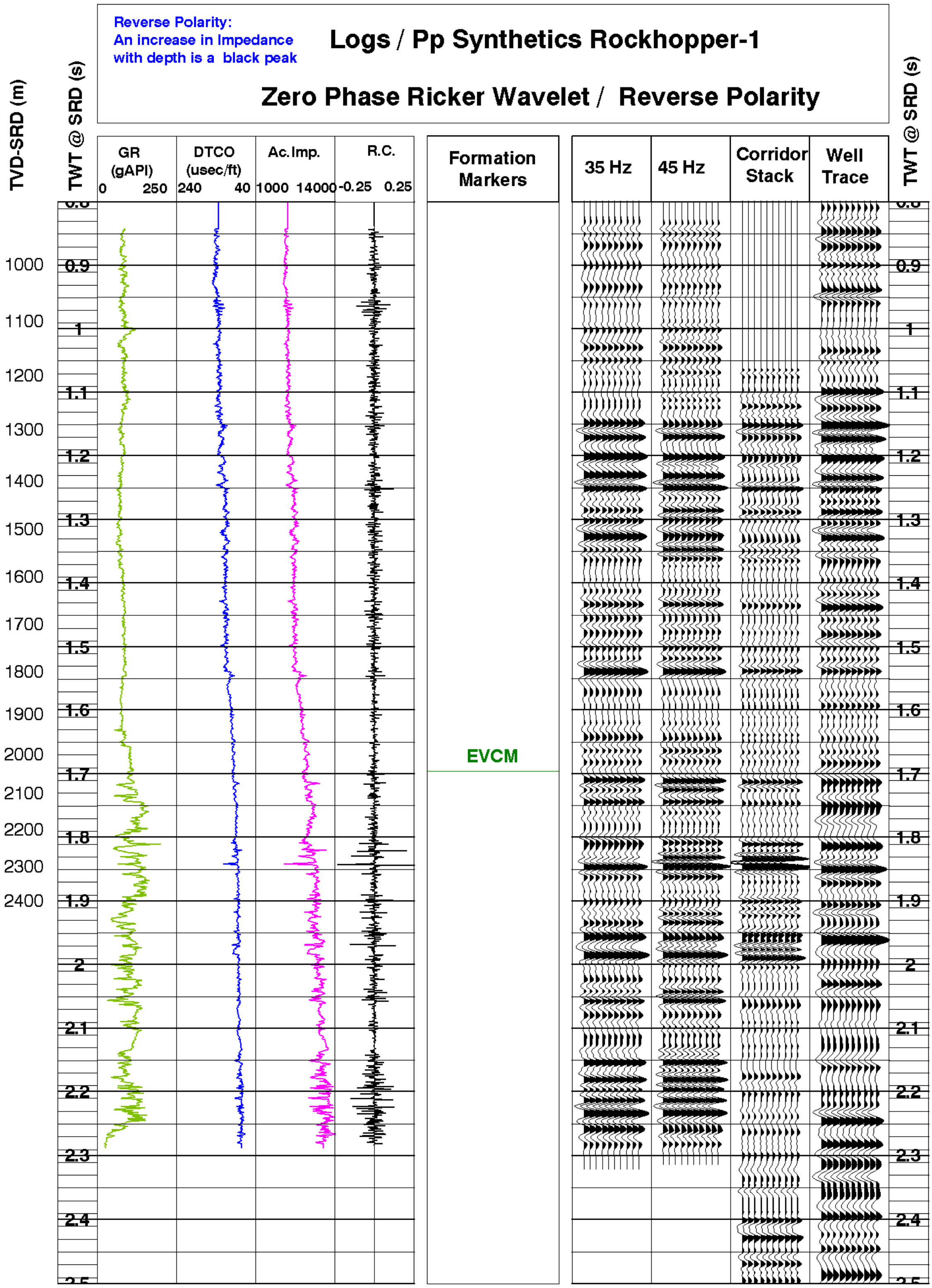


Figure 22b. RH1 Surface Seismic Well trace, Corridor Stack, Synthetics and Logs (Reverse polarity)

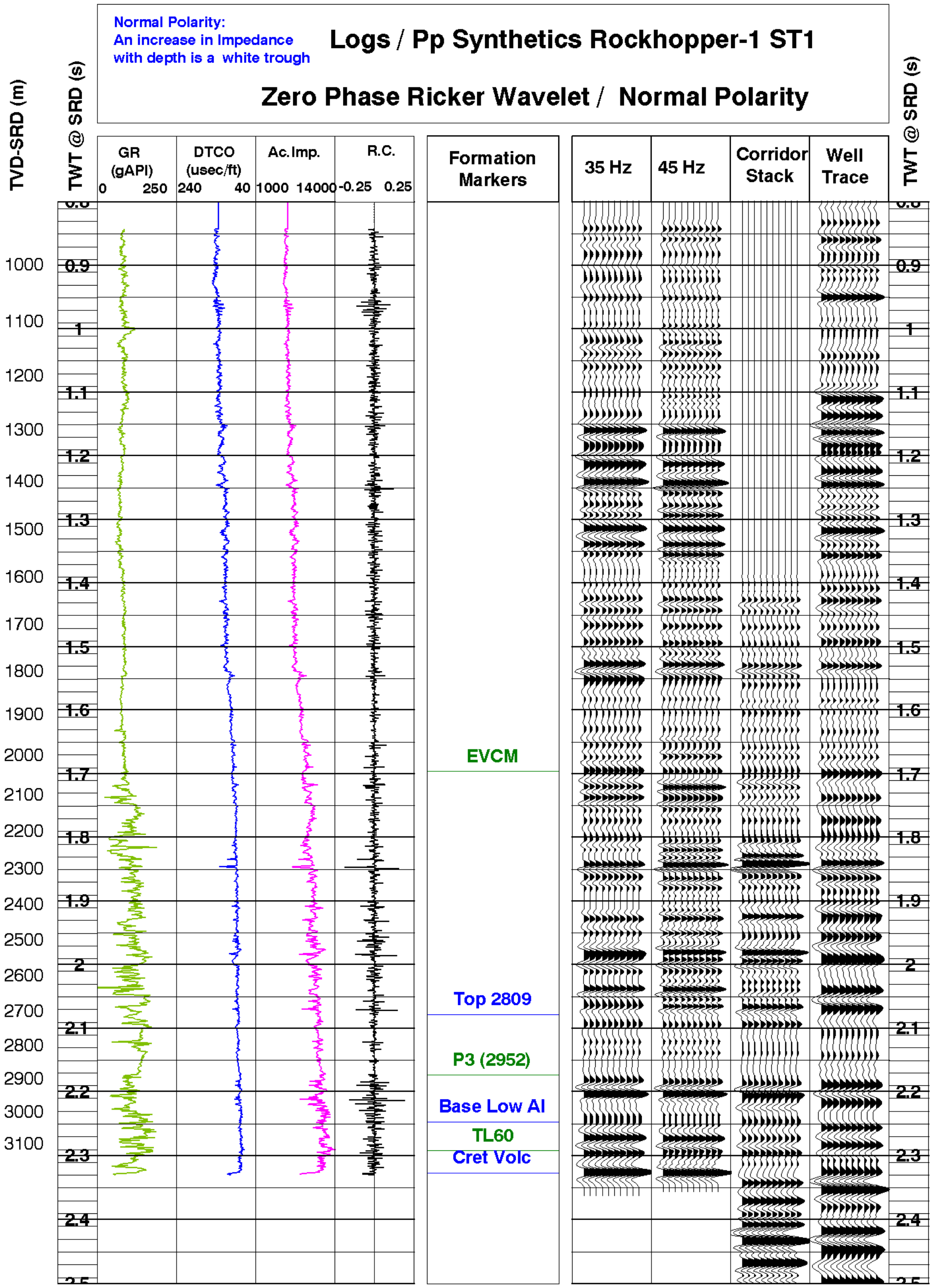


Figure 23a. RH1 ST1 Surface Seismic Well trace, Corridor Stack, Synthetics, Logs (Normal polarity)

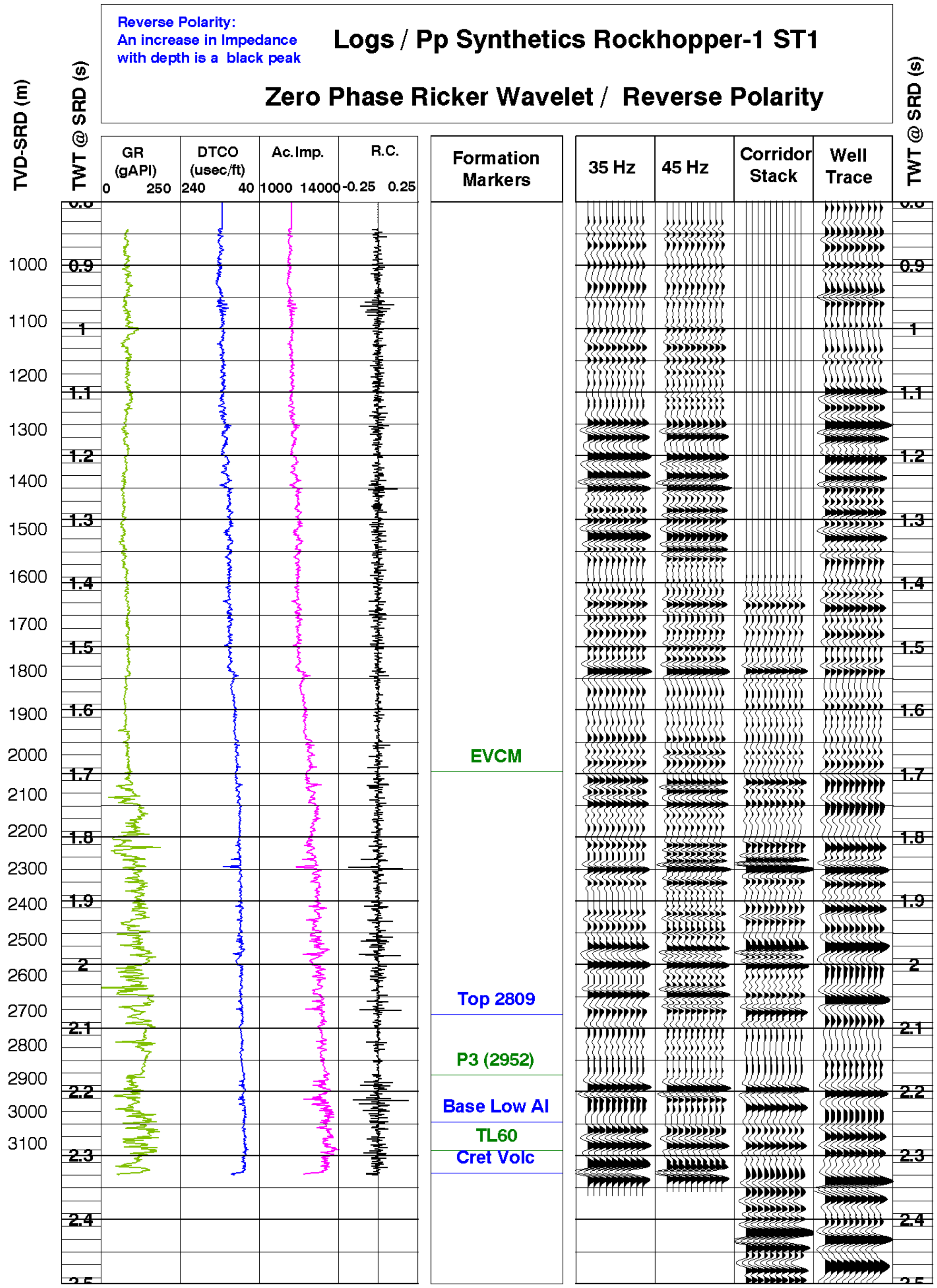


Figure 23b. RH1 ST1 Surface Seismic Well trace, Corridor Stack, Synthetics, Logs (Reverse polarity)

Attachment 1: Summary of Geophysical Listings

Five geophysical data listings are provided for each survey. A1 is included in the report; A2 to A5 are provided in electronic form on the CD-ROM. Following is a brief description of the format.

A1 Check Shot Data

1. Level number: the level number starting from the top level (includes any imposed shots).
2. Vertical depth form SRD: *dsrd*, the depth in meters from seismic reference datum (LAT).
3. Measured depth from DF: *dkb*, the depth in meters from DF.
4. Observed travel time HYD to GEO: *tim*0, the transit time picked form the stacked data by subtracting the surface sensor first break time from the downhole sensor first break time.
5. Vertical travel time SRD to GEO: *shtm*, is *timv* – vertical time, corrected for the vertical distance between source and datum. Here calculated using model based NMO correction.
6. Delta depth between shots: Δ*depth*, the vertical distance between each level.
7. Delta time between shots: Δ*time*, difference in vertical travel time (*shtm*) between each level.
8. Interval velocity between shots: average velocity between each level, Δ*depth/*Δ*time*
9. Average velocity SRD to GEO: average velocity from datum to checkshot level, shtm/dsrd
10. RMS velocity SRD to GEO: RMS velocity from datum to the checkshot level

A2 Drift & Sonic Adjustment

Zone Set Data

1. Knee number: the knee number starting from the highest knee. (The first knees listed will generally be at SRD and the top of sonic. The drift imposed at the knees will normally be zero.)
2. Measured depth from DF: the depth in meters from DF
3. Vertical depth from SRD: the depth in meters from seismic reference datum.
4. Selected Drift at knee: the value of drift imposed at each knee.
5. Shift: the change in drift divided by the change in depth between any two levels.
6. Delta-T: see section 5 of report for an explanation of Δt_{min}.
7. Reduction factor G: see section 5 of report.
8. Selected Drift Gradient: the gradient of the imposed drift curve.

Sonic Adjustment Data

1. Measured depth from DF: the depth in meters from DF
2. Vertical depth from SRD: the depth in meters from seismic reference datum.
3. Vertical shot time SRD to GEO: the calculated vertical travel time from datum to geophone.
4. Adjusted Sonic Time.
5. Computed drift at level: the checkshot time minus the integrated raw sonic time.
6. Residual Shot Time - Adjusted Sonic Time.
7. Adjusted Interval Velocity.
8. Adjusted RMS Velocity.
9. Adjusted Average Velocity.

A3 Velocity Report

1. The data in this listing has been resampled in time.
2. Two way travel time from SRD: this is the index for the data in this listing. The first value is at SRD (0 ms) and is reported every 10 ms.
3. Measured depth from DF: the depth from DF at each corresponding value of two way time.
4. Vertical depth from SRD: the vertical depth from SRD at each corresponding value of two way time.
5. Average velocity SRD to GEO: the vertical depth from SRD divided by half the two way time.
6. RMS velocity: the root mean square velocity from datum to the corresponding value of two way time.

$$V_{rms} = \sqrt{\sum v_i^2 t_i \Big/ \sum t_i}$$

   where v_i is the velocity between each 2 ms interval.

7. Interval velocity: the velocity between each sampled depth.

A4 Time to Depth

1. Two Way Sonic Time from SRD

2-11. Depth at Time, ms: times every 1 ms

A5 Offset / Coordinates

1. Receiver Measured Depth from DF
2. Receiver True Vertical Depth from SRD
3. to 6. Source X, Y and Receiver X, Y Coordinates (Local Well reference)
7. to 8. Source to Well Offset, Receiver to Well Offset
9. True lateral Source – Receiver Offset

Attachment 2a: A1 Well Seismic Report (Rockhopper-1)

Client and Well Information

Country	Australia
Logging Date	4 Jan 2010
Company	Origin Energy Resources Ltd
Field	Rockhopper
Well	Rockhopper-1

Seismic Reference Datum : LAT Reference Velocity : 1524 m/s

DF Elevation above SRD : 26 m Time Picking on Geophone Transformed GAC Stacks

Table 4. VSP Data (Model based NMO Vertical Times)

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
1	0.0			0.0000					
							2223		
2	988.1	1014.1	0.4420	0.4446				2223	2223
					15.1	0.0059	2560		
3	1003.3	1029.3	0.4479	0.4505				2227	2228
					15.1	0.0064	2373		
4	1018.4	1044.4	0.4542	0.4568				2229	2230
					15.1	0.0068	2216		
5	1033.5	1059.5	0.4611	0.4637				2229	2229
					54.6	0.0252	2168		
6	1088.1	1114.1	0.4862	0.4888				2226	2226
					15.1	0.0057	2666		
7	1103.2	1129.2	0.4919	0.4945				2231	2232
					15.1	0.0063	2408		
8	1118.3	1144.4	0.4982	0.5008				2233	2234
					15.1	0.0060	2528		
9	1133.5	1159.5	0.5041	0.5068				2237	2238
					54.6	0.0240	2268		
10	1188.1	1214.1	0.5281	0.5309				2238	2239
					15.1	0.0064	2384		
11	1203.2	1229.2	0.5344	0.5372				2240	2241
					15.1	0.0063	2408		
12	1218.3	1244.4	0.5407	0.5435				2242	2243
					15.1	0.0067	2325		
13	1233.5	1259.5	0.5474	0.5500				2243	2244
					54.7	0.0243	2247		
14	1288.1	1314.1	0.5717	0.5743				2243	2244
					15.1	0.0061	2402		
15	1303.2	1329.3	0.5778	0.5806				2245	2246
					15.1	0.0062	2444		
16	1318.4	1344.4	0.5840	0.5868				2247	2248
					15.1	0.0061	2456		
17	1333.5	1359.5	0.5901	0.5930				2249	2250
					54.6	0.0227	2429		

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
18	1388.1	1414.1	0.6128	0.6155				2255	2257
					15.1	0.0058	2523		
19	1403.2	1429.2	0.6186	0.6214				2258	2260
					15.1	0.0061	2527		
20	1418.4	1444.4	0.6246	0.6274				2261	2262
					15.1	0.0056	2675		
21	1433.5	1459.5	0.6302	0.6331				2264	2266
					54.7	0.0206	2659		
22	1488.1	1514.1	0.6508	0.6536				2277	2280
					15.1	0.0055	2702		
23	1503.2	1529.3	0.6563	0.6592				2280	2284
					15.1	0.0059	2627		
24	1518.4	1544.4	0.6621	0.6650				2283	2287
					15.1	0.0055	2715		
25	1533.5	1559.5	0.6677	0.6706				2287	2291
					54.5	0.0205	2678		
26	1588.0	1614.0	0.6881	0.6909				2298	2303
					15.1	0.0056	2681		
27	1603.1	1629.1	0.6937	0.6965				2302	2306
					15.1	0.0057	2656		
28	1618.2	1644.3	0.6994	0.7022				2304	2310
					15.1	0.0056	2665		
29	1633.4	1659.4	0.7050	0.7079				2307	2313
					54.7	0.0204	2685		
30	1688.1	1714.1	0.7254	0.7283				2318	2324
					15.1	0.0054	2771		
31	1703.2	1729.2	0.7308	0.7338				2321	2327
					15.1	0.0056	2718		
32	1718.3	1744.3	0.7364	0.7393				2324	2331
					15.1	0.0055	2743		
33	1733.4	1759.5	0.7419	0.7448				2327	2334
					54.6	0.0200	2730		
34	1788.1	1814.1	0.7619	0.7648				2338	2345
					15.1	0.0056	2761		
35	1803.2	1829.2	0.7674	0.7703				2341	2348
					15.1	0.0051	2927		
36	1818.3	1844.4	0.7725	0.7755				2345	2353
					15.1	0.0052	2894		
37	1833.4	1859.5	0.7777	0.7807				2348	2357
					54.6	0.0184	2981		
38	1888.1	1914.1	0.7961	0.7990				2363	2373
					15.1	0.0048	3115		
39	1903.2	1929.2	0.8008	0.8039				2367	2378
					15.1	0.0050	3035		
40	1918.3	1944.4	0.8058	0.8089				2372	2383
					15.1	0.0049	3074		
41	1933.4	1959.5	0.8107	0.8138				2376	2387
					54.5	0.0175	3130		
42	1988.0	2014.1	0.8282	0.8312				2392	2405
					15.0	0.0046	3286		
43	2003.0	2029.2	0.8328	0.8358				2397	2411

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
					15.0	0.0048	3231		
44	2018.0	2044.4	0.8375	0.8404				2401	2416
					5.4	0.0011	3894		
45	2023.4	2049.8	0.8387	0.8418				2404	2420
					4.3	0.0020	2592		
46	2027.7	2054.2	0.8407	0.8435				2404	2420
					5.3	0.0014	3474		
47	2033.0	2059.5	0.8421	0.8450				2406	2422
					9.7	0.0032	3175		
48	2042.7	2069.3	0.8453	0.8480				2409	2425
					14.6	0.0043	3371		
49	2057.3	2084.1	0.8495	0.8524				2414	2431
					14.8	0.0045	3295		
50	2072.1	2099.2	0.8540	0.8569				2418	2436
					14.5	0.0044	3298		
51	2086.6	2114.1	0.8584	0.8613				2423	2442
					14.9	0.0041	3467		
52	2101.5	2129.5	0.8625	0.8656				2428	2448
					14.4	0.0042	3370		
53	2115.9	2144.4	0.8667	0.8698				2432	2453
					14.5	0.0043	3373		
54	2130.4	2159.5	0.8710	0.8742				2437	2458
					51.1	0.0147	3498		
55	2181.6	2214.1	0.8857	0.8888				2455	2479
					13.9	0.0039	3548		
56	2195.4	2229.2	0.8896	0.8927				2459	2485
					13.9	0.0038	3559		
57	2209.3	2244.4	0.8934	0.8966				2464	2490
					13.6	0.0037	3594		
58	2222.8	2259.5	0.8971	0.9003				2469	2496
					47.4	0.0134	3534		
59	2270.2	2314.1	0.9108	0.9138				2484	2514
					12.7	0.0038	3451		
60	2282.9	2329.2	0.9147	0.9174				2488	2519
					12.5	0.0039	3401		
61	2295.4	2344.4	0.9186	0.9211				2492	2523
					12.4	0.0033	3672		
62	2307.8	2359.5	0.9220	0.9245				2496	2528
					43.4	0.0115	3668		
63	2351.2	2414.1	0.9342	0.9363				2511	2546
					11.6	0.0030	3696		
64	2362.8	2429.2	0.9374	0.9395				2515	2550
					11.4	0.0030	3689		
65	2374.2	2444.4	0.9407	0.9425				2519	2555
					11.3	0.0030	3651		
66	2385.5	2459.5	0.9439	0.9456				2523	2559
					40.0	0.0103	3718		
67	2425.5	2514.1	0.9552	0.9564				2536	2575
					11.1	0.0029	3667		
68	2436.5	2529.2	0.9584	0.9594				2540	2579
					11.1	0.0029	3680		

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
69	2447.6	2544.3	0.9616	0.9624				2543	2584
					11.0	0.0027	3763		
70	2458.6	2559.4	0.9646	0.9653				2547	2588
					7.2	0.0019	3622		
71	2465.8	2569.2	0.9668	0.9673				2549	2591
					11.1	0.0028	3718		
72	2476.9	2584.4	0.9699	0.9703				2553	2595
					11.1	0.0030	3618		
73	2487.9	2599.5	0.9733	0.9734				2556	2599
					11.0	0.0030	3613		
74	2499.0	2614.6	0.9766	0.9764				2559	2602

Attachment 2b: A1 Well Seismic Report (Rockhopper-1 ST1)

Client and Well Information

Country	Australia
Logging Date	9 Feb 2010
Company	Origin Energy Resources Ltd
Field	Rockhopper
Well	Rockhopper-1 ST1

Seismic Reference Datum :	LAT	Reference Velocity :	1524 m/s
DF Elevation above SRD :	26 m	Time Picking on Geophone Transformed GAC Stacks	

Table 5. VSP Data (Model based NMO Vertical Times / merged with RH1)

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
1	0.0			0.0000					
							2223		
2	988.1	1014.1	0.4420	0.4446				2223	2223
					15.1	0.0059	2560		
3	1003.3	1029.3	0.4479	0.4505				2227	2228
					15.1	0.0064	2373		
4	1018.4	1044.4	0.4542	0.4568				2229	2230
					15.1	0.0068	2216		
5	1033.5	1059.5	0.4611	0.4637				2229	2229
					54.6	0.0252	2168		
6	1088.1	1114.1	0.4862	0.4888				2226	2226
					15.1	0.0057	2666		
7	1103.2	1129.2	0.4919	0.4945				2231	2232
					15.1	0.0063	2408		
8	1118.3	1144.4	0.4982	0.5008				2233	2234
					15.1	0.0060	2528		
9	1133.5	1159.5	0.5041	0.5068				2237	2238
					54.6	0.0240	2268		
10	1188.1	1214.1	0.5281	0.5309				2238	2239
					15.1	0.0064	2384		
11	1203.2	1229.2	0.5344	0.5372				2240	2241
					15.1	0.0063	2408		
12	1218.3	1244.4	0.5407	0.5435				2242	2243
					15.1	0.0067	2325		
13	1233.5	1259.5	0.5474	0.5500				2243	2244
					54.7	0.0243	2247		
14	1288.1	1314.1	0.5717	0.5743				2243	2244
					15.1	0.0061	2402		
15	1303.2	1329.3	0.5778	0.5806				2245	2246
					15.1	0.0062	2445		
16	1318.4	1344.4	0.5840	0.5868				2247	2248
					15.1	0.0061	2456		
17	1333.5	1359.5	0.5901	0.5930				2249	2250
					54.6	0.0227	2429		

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
18	1388.1	1414.1	0.6128	0.6155				2255	2257
					15.1	0.0058	2523		
19	1403.2	1429.2	0.6186	0.6214				2258	2260
					15.1	0.0061	2527		
20	1418.4	1444.4	0.6246	0.6274				2261	2262
					15.1	0.0056	2676		
21	1433.5	1459.5	0.6302	0.6331				2264	2266
					54.7	0.0206	2659		
22	1488.1	1514.1	0.6508	0.6536				2277	2280
					15.1	0.0055	2702		
23	1503.2	1529.3	0.6563	0.6592				2280	2284
					15.1	0.0059	2627		
24	1518.4	1544.4	0.6621	0.6650				2283	2287
					15.1	0.0055	2715		
25	1533.5	1559.5	0.6677	0.6705				2287	2291
					54.5	0.0205	2715		
26	1589.2	1615.2	0.6894	0.6911				2300	2305
					15.1	0.0056	2683		
27	1604.3	1630.4	0.6950	0.6967				2303	2308
					15.1	0.0057	2657		
28	1619.5	1645.5	0.7007	0.7024				2306	2311
					15.1	0.0056	2658		
29	1634.6	1660.6	0.7063	0.7081				2308	2314
					24.5	0.0098	2568		
30	1659.1	1685.1	0.7162	0.7176				2312	2317
					15.1	0.0056	2718		
31	1674.2	1700.2	0.7217	0.7232				2315	2321
					15.1	0.0056	2721		
32	1689.3	1715.3	0.7273	0.7287				2318	2324
					15.1	0.0054	2766		
33	1704.4	1730.4	0.7327	0.7342				2321	2328
					26.8	0.0097	2743		
34	1731.3	1757.3	0.7425	0.7440				2327	2334
					15.1	0.0055	2730		
35	1746.4	1772.4	0.7480	0.7495				2330	2337
					15.1	0.0056	2712		
36	1761.5	1787.5	0.7536	0.7551				2333	2340
					15.1	0.0054	2761		
37	1776.6	1802.7	0.7590	0.7606				2336	2343
					15.2	0.0058	2690		
38	1791.9	1817.9	0.7648	0.7663				2338	2346
					15.1	0.0054	2831		
39	1807.0	1833.0	0.7701	0.7716				2342	2350
					15.1	0.0050	2932		
40	1822.1	1848.1	0.7752	0.7767				2346	2354
					15.1	0.0052	2873		
41	1837.2	1863.3	0.7804	0.7820				2349	2358
					14.4	0.0052	2847		
42	1851.6	1877.7	0.7856	0.7871				2353	2361
					15.1	0.0051	3020		
43	1866.8	1892.8	0.7906	0.7921				2357	2366

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
					15.1	0.0049	3054		
44	1881.9	1907.9	0.7956	0.7970				2361	2371
					7.4	0.0026	2964		
45	1889.3	1915.3	0.7981	0.7995				2363	2373
					7.7	0.0023	3217		
46	1897.0	1923.0	0.8004	0.8019				2366	2376
					7.4	0.0026	2944		
47	1904.4	1930.5	0.8030	0.8044				2367	2378
					8.4	0.0028	3038		
48	1912.8	1938.8	0.8058	0.8072				2370	2381
					6.7	0.0022	3075		
49	1919.5	1945.6	0.8080	0.8094				2372	2383
					8.4	0.0028	3027		
50	1927.9	1954.0	0.8108	0.8122				2374	2385
					6.7	0.0021	3119		
51	1934.6	1960.7	0.8129	0.8143				2376	2387
					8.4	0.0028	3023		
52	1943.0	1969.1	0.8157	0.8171				2378	2390
					15.1	0.0050	3022		
53	1958.2	1984.2	0.8207	0.8221				2382	2394
					15.0	0.0042	3333		
54	1973.1	1999.2	0.8249	0.8266				2387	2400
					15.1	0.0049	3197		
55	1988.2	2014.3	0.8298	0.8313				2392	2406
					15.1	0.0047	3254		
56	2003.3	2029.4	0.8345	0.8359				2396	2411
					15.0	0.0047	3233		
57	2018.3	2044.5	0.8392	0.8406				2401	2416
					15.0	0.0047	3233		
58	2033.3	2059.6	0.8439	0.8452				2406	2422
					15.0	0.0057	2937		
59	2048.3	2074.8	0.8496	0.8503				2409	2425
					14.9	0.0037	3606		
60	2063.2	2089.9	0.8534	0.8545				2415	2432
					14.9	0.0050	3118		
61	2078.1	2105.0	0.8584	0.8593				2419	2437
					14.9	0.0042	3413		
62	2093.1	2120.2	0.8626	0.8636				2424	2442
					14.9	0.0046	3259		
63	2107.9	2135.3	0.8673	0.8682				2428	2447
					14.8	0.0041	3423		
64	2122.7	2150.4	0.8714	0.8725				2433	2453
					14.8	0.0041	3520		
65	2137.5	2165.5	0.8756	0.8767				2438	2459
					14.8	0.0039	3617		
66	2152.3	2180.8	0.8795	0.8808				2444	2466
					14.7	0.0042	3493		
67	2167.0	2195.9	0.8838	0.8850				2449	2472
					14.6	0.0042	3462		
68	2181.6	2211.0	0.8880	0.8892				2453	2478
					14.5	0.0044	3389		

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
69	2196.0	2226.1	0.8925	0.8935				2458	2483
					14.3	0.0047	3252		
70	2210.3	2241.2	0.8972	0.8979				2462	2487
					14.1	0.0035	3728		
71	2224.4	2256.3	0.9008	0.9017				2467	2494
					13.9	0.0037	3583		
72	2238.3	2271.4	0.9046	0.9055				2472	2499
					13.7	0.0045	3233		
73	2252.0	2286.6	0.9092	0.9098				2475	2503
					13.5	0.0035	3646		
74	2265.6	2301.7	0.9128	0.9135				2480	2509
					13.3	0.0041	3341		
75	2278.9	2316.8	0.9171	0.9175				2484	2513
					13.3	0.0037	3547		
76	2292.2	2331.9	0.9209	0.9212				2488	2518
					13.1	0.0042	3287		
77	2305.3	2347.1	0.9253	0.9252				2492	2522
					13.0	0.0036	3566		
78	2318.3	2362.2	0.9291	0.9289				2496	2527
					12.8	0.0035	3562		
79	2331.1	2377.3	0.9328	0.9325				2500	2532
					12.8	0.0036	3540		
80	2343.8	2392.4	0.9366	0.9361				2504	2536
					12.6	0.0037	3436		
81	2356.4	2407.5	0.9405	0.9397				2508	2540
					12.6	0.0030	3831		
82	2369.0	2422.7	0.9437	0.9430				2512	2546
					12.4	0.0037	3420		
83	2381.4	2437.8	0.9476	0.9466				2516	2550
					12.4	0.0030	3813		
84	2393.8	2452.9	0.9508	0.9499				2520	2555
					12.2	0.0037	3377		
85	2406.0	2468.0	0.9548	0.9535				2523	2559
					12.2	0.0037	3411		
86	2418.2	2483.1	0.9588	0.9571				2527	2563
					12.2	0.0031	3698		
87	2430.4	2498.2	0.9622	0.9604				2531	2568
					12.2	0.0033	3594		
88	2442.6	2513.3	0.9657	0.9638				2534	2572
					12.3	0.0041	3217		
89	2454.9	2528.4	0.9701	0.9676				2537	2575
					12.3	0.0035	3469		
90	2467.2	2543.6	0.9740	0.9711				2541	2579
					12.2	0.0030	3731		
91	2479.4	2558.8	0.9773	0.9744				2545	2583
					12.2	0.0036	3438		
92	2491.7	2573.9	0.9812	0.9780				2548	2587
					12.2	0.0032	3662		
93	2503.9	2589.0	0.9847	0.9813				2552	2591
					12.2	0.0038	3349		
94	2516.1	2604.1	0.9887	0.9850				2555	2595

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
					12.3	0.0034	3528		
95	2528.4	2619.2	0.9925	0.9884				2558	2598
					12.3	0.0031	3713		
96	2540.7	2634.3	0.9959	0.9918				2562	2603
					12.3	0.0040	3261		
97	2553.0	2649.4	1.0002	0.9955				2564	2606
					12.3	0.0038	3404		
98	2565.4	2664.5	1.0043	0.9992				2568	2609
					12.3	0.0033	3622		
99	2577.7	2679.7	1.0080	1.0026				2571	2613
					12.3	0.0034	3594		
100	2589.9	2694.8	1.0118	1.0060				2575	2617
					12.2	0.0034	3568		
101	2602.2	2709.9	1.0155	1.0094				2578	2621
					12.3	0.0031	3735		
102	2614.5	2725.1	1.0190	1.0127				2582	2625
					12.3	0.0034	3556		
103	2626.8	2740.2	1.0229	1.0162				2585	2629
					12.3	0.0031	3747		
104	2639.1	2755.3	1.0264	1.0194				2589	2633
					12.3	0.0037	3417		
105	2651.4	2770.4	1.0305	1.0230				2592	2637
					12.3	0.0035	3554		
106	2663.7	2785.6	1.0343	1.0265				2595	2640
					12.3	0.0034	3591		
107	2676.0	2800.7	1.0381	1.0299				2598	2644
					12.3	0.0034	3583		
108	2688.3	2815.8	1.0419	1.0334				2601	2648
					12.3	0.0034	3575		
109	2700.5	2830.9	1.0458	1.0368				2605	2651
					12.3	0.0031	3840		
110	2712.8	2846.0	1.0493	1.0400				2609	2656
					12.3	0.0032	3815		
111	2725.1	2861.1	1.0529	1.0432				2612	2660
					12.3	0.0032	3817		
112	2737.5	2876.3	1.0565	1.0464				2616	2664
					12.3	0.0034	3664		
113	2749.8	2891.4	1.0603	1.0498				2619	2668
					12.2	0.0033	3711		
114	2762.0	2906.4	1.0641	1.0531				2623	2672
					12.3	0.0033	3715		
115	2774.3	2921.6	1.0678	1.0564				2626	2676
					12.3	0.0031	3842		
116	2786.6	2936.7	1.0714	1.0596				2630	2680
					12.3	0.0034	3656		
117	2798.9	2951.8	1.0753	1.0630				2633	2684
					12.5	0.0029	4010		
118	2811.4	2967.0	1.0786	1.0661				2637	2689
					12.6	0.0032	3810		
119	2823.9	2982.1	1.0823	1.0694				2641	2693
					12.6	0.0034	3697		

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
120	2836.5	2997.2	1.0862	1.0728				2644	2697
					12.6	0.0035	3663		
121	2849.2	3012.3	1.0901	1.0762				2647	2700
					12.6	0.0034	3745		
122	2861.8	3027.4	1.0939	1.0796				2651	2704
					12.5	0.0032	3834		
123	2874.3	3042.6	1.0976	1.0829				2654	2708
					12.5	0.0031	3864		
124	2886.8	3057.7	1.1012	1.0861				2658	2713
					12.4	0.0032	3804		
125	2899.2	3072.8	1.1048	1.0894				2661	2716
					12.4	0.0030	3925		
126	2911.5	3087.9	1.1083	1.0925				2665	2721
					12.3	0.0032	3814		
127	2923.8	3103.0	1.1120	1.0957				2668	2725
					12.3	0.0031	3905		
128	2936.1	3118.2	1.1156	1.0989				2672	2729
					12.3	0.0031	3911		
129	2948.4	3133.3	1.1192	1.1020				2675	2733
					12.3	0.0034	3721		
130	2960.8	3148.4	1.1232	1.1053				2679	2736
					12.3	0.0035	3656		
131	2973.1	3163.6	1.1272	1.1087				2682	2740
					12.3	0.0032	3881		
132	2985.4	3178.7	1.1309	1.1119				2685	2743
					12.3	0.0032	3872		
133	2997.7	3193.8	1.1346	1.1151				2688	2747
					12.3	0.0026	4260		
134	3009.9	3208.9	1.1378	1.1179				2692	2752
					12.3	0.0029	4043		
135	3022.2	3224.0	1.1412	1.1210				2696	2757
					12.3	0.0030	3987		
136	3034.5	3239.1	1.1447	1.1240				2700	2761
					12.3	0.0032	3865		
137	3046.7	3254.3	1.1484	1.1272				2703	2764
					12.3	0.0031	3942		
138	3059.0	3269.4	1.1520	1.1303				2706	2768
					12.3	0.0032	3872		
139	3071.3	3284.5	1.1558	1.1335				2710	2772
					12.3	0.0028	4111		
140	3083.7	3299.6	1.1591	1.1365				2713	2776
					12.3	0.0032	3878		
141	3096.0	3314.7	1.1628	1.1397				2717	2780
					12.2	0.0026	4293		
142	3108.1	3329.7	1.1659	1.1425				2720	2785
					12.3	0.0030	4007		
143	3120.4	3344.8	1.1695	1.1456				2724	2789
					12.3	0.0030	3996		
144	3132.7	3360.0	1.1730	1.1487				2727	2793
					12.3	0.0029	4034		
145	3145.0	3375.1	1.1765	1.1517				2731	2797

LEVEL NUMBER	VERTICAL DEPTH FROM SRD m	MEASURED DEPTH FROM KB m	OBSERVED TRAVEL TIME s	VERTICAL NMO OWT FROM SRD s	DELTA DEPTH m	DELTA TIME s	ACOUSTIC INTERVAL VELOCITY m/s	ACOUSTIC AVERAGE VELOCITY m/s	ACOUSTIC RMS VELOCITY m/s
					9.1	0.0027	3608		
146	3154.1	3386.3	1.1796	1.1542				2733	2799
					12.3	0.0033	3799		
147	3166.4	3401.4	1.1835	1.1575				2736	2802
					12.2	0.0028	4124		
148	3178.6	3416.5	1.1869	1.1604				2739	2806
					12.2	0.0034	3751		
149	3190.9	3431.7	1.1908	1.1637				2742	2809

Attachment 3: Transit Time Picking Algorithms

The time picking can be broken down into several tasks:

First of all focus on the relevant parts of a data trace by selecting time intervals in form of constraints. To this end the user can select velocity, time header and/or initial guess constraints.

Detect a signal or a first break using a detection algorithm.

Tune on a particular phase of the event (e.g. zero-crossing, peak, trough, etc). It should be clear that tuning is only happening if a pick was either detected by an algorithm or retrieved from a header as initial guess.

Despike the picked transit time curve in order to eliminate mispicks either by median filtering or by cross-correlation. The cross-correlation option does not only have filtering features but also allows picking correlated events within a section after having picked only one event.

Detection algorithm

Energy break: the algorithm determines the maximum of the so-called energy function, which is the integrated signal energy within a sliding time window normalized by the total energy accumulated since the first time of data.

For a trace S(t) an energy function F(□) is calculated with algorithm proposed by (Coppens, 1985)

Geophone break: finds the first break of a downhole sensor. The algorithm compares amplitudes and slopes in consecutive arches. Input parameters are the center frequency of the data to be picked, a linear fit gate time which should be about half a wavelet period, and a detection threshold between 0.0 and 0.5.

Hydrophone break: provides the first break of a downhole sensor. The routine finds the global minimum and maximum amplitude along a trace, takes the smaller one of the corresponding sample indices and outputs the time of the preceding zero-crossing as the first break. The zero-crossing time is determined by linear regression over a selected length (linear fit gate time).

Tuning:

Peak: finds the time of the closest local maximum amplitude in the vicinity of an input break time.
Trough: finds the time of closest local minimum amplitude in the vicinity of an input break time.

Zero-crossing: finds the time of the closest zero-crossing in the vicinity of an input break time. The routine stores the sign of the derivative at the zero crossing that can be passed on for the tuning of the following trace. Thus artifacts created by cycle skipping can be reduced.

Inflection: finds the time of the closest inflection point in the vicinity of an input break time. The routine stores the sign of the derivative at the inflection point, which can be passed on for the tuning of the following trace. Thus artifacts created by cycle skipping can be reduced.

Inflection point tangent: finds the time of the closest inflection point in the vicinity of an input break time. The tuned break time is the zero-crossing time of the corresponding tangent at this inflection point. The routine stores the sign of the derivative at the inflection point which can be passed on for the tuning of the following trace. Thus artifacts created by cycle skipping can be reduced.

Cross-correlation

This option allows to tune transit times by considering the picked phase of a selected reference trace. The cross-correlation gate in time or length units can be specified in the Motif parameter panel of this option. The default value for the gate is three times the estimated center frequency of the first five traces of the seismic section to be picked. The window is put symmetrically around the transit times of the two traces to be cross-correlated if the option Use Existing Picks for the Gate Center Time is enabled and the transit times are not absent.

If the option Use Existing Picks for the Gate Center Time is disabled then the cross-correlation is started with the ambient traces around the reference trace. Those two traces, in turn, will be taken to set the time gates for the following ones, and so on. Thus an automatic picking can be provided after having picked only the reference trace.

Retuning can be selected to follow the cross-correlation. In this case the cross-correlation serves as a transit time curve despiker.

The cross correlation process can be stopped automatically if the picking quality degrades. This happens if the time difference between the break of the current and the previous trace exceeds a threshold value derived from a user-specified apparent velocity.

A polynomial amplitude interpolation is proposed in order provide "real" extreme values instead of extreme values at the nearest sample. The algorithm works as follows: the global extreme values are detected with the gate together with the corresponding sample indices. A minimum and maximum amplitude tuning provides an exact time estimate of these amplitudes. Polynomial interpolation determines the amplitudes at these times, which generally fall in between samples.

There are a variety of selectable and non-exclusive constraints available in order to stabilize the time picking process . The objective is to extract only the relevant part of the trace for the detection, tuning and/or cross-correlation process using.

Reference:

Coppens, F., 1985, First arrival picking on common offset trace collections for automatic estimation of static corrections, Geophys. Prosp. 33, 1212-1231.

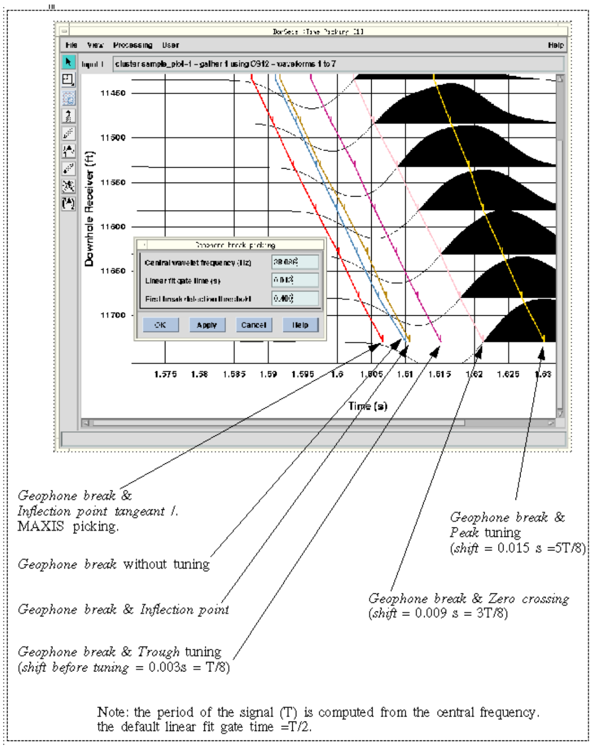


Figure A1 . Time Picking Options

Attachment 4: Listing of Deliverables (CD-ROM)

Report:

VSP_report	VSP/Geogram Processing Report	PDF
QC_VSP_report	VSP Level 1 QC Report	PDF
QBH_report	Q-Borehole Field Survey Report	PDF

Graphics Displays:

comp1A/B	Plot 1. Composite Display 1 – Normal Polarity	TIF / PDF / PDS / CGM
comp2A/B	Plot 2. Composite Display 2 – Reverse Polarity	TIF / PDF / PDS / CGM
vel1A/B	Plot 3. Velocity Crossplot	TIF / PDF / PDS / CGM

Data files plus Verification (.txt) listings:

Raw data is provided in nascent LDF format		LDF
xstk.sgy	stacked x axis data	SEGY
ystk.sgy	stacked y axis data	SEGY
zstk.sgy	stacked z axis data	SEGY
upp1.sgy	VSP enhanced upgoing wavefield (OWT)	SEGY
upp2.sgy	VSP enhanced upgoing wavefield (NMO Corrected TWT)	SEGY
corstk.sgy	VSP corridor stack	SEGY
Image.sgy	VSP GRT Migration Image (Time)	SEGY
R25.sgy	Zero Phase Synthetic Seismograms – Ricker 25Hz	SEGY
R35.sgy	Zero Phase Synthetic Seismograms – Ricker 35Hz	SEGY
R45.sgy	Zero Phase Synthetic Seismograms – Ricker 45Hz	SEGY
logs_depth.las	Depth indexed Logs	ASCII (LAS)
logs_time.las	Time indexed Logs	ASCII (LAS)
synthetics.las	Synthetic Compressional Seismograms and Corridor Stack	ASCII (LAS)

Listings:

A1	Well_Seismic_Report	EXCEL
A2	Drift_and_Sonic_Adjustment_Report	EXCEL
A3	Velocity_Report	EXCEL
A4	Time_to_Depth_Report	EXCEL
A5	Offset_Coordinates_Report	EXCEL
	Time_Analysis_All	EXCEL

NOTE: The filename pre-fix indicates if the data is for Rockhopper-1 (**RH1**) Rockhopper-1 ST1 (**RH1ST1**) or combined results (**RH1andST1**).

The Seismic Reference Datum used in this project was LAT.

Origin Energy requested the main digital deliverables to be provided as well using MSL as Seismic Reference Datum. These files are clearly marked with _MSL in the name. The corrections made are done with the following relations: TVD(msl) = TVD(lat) + 1.6 m and TWT(msl) = TWT(lat) + 2 ms.