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1. Data Acquisition & Processing

A Vertical Seismic Profile (VSP) was recorded in Rye Patch by LBNL between December 11 and December 13, 1997. Figure 1 shows the location of the Rye Patch Geothermal Field with Well 46-28 located within the marked Rye Patch Anomaly (this is Figure 1.2 from the GeothermEx [1997] report). The VSP in Well 46-28 used a vibroseis source and a single-level, high temperature, hydraulic wall-locking, 3-component seismometer. The vibroseis source was a Mertz P-wave vibrator. The source sweep was 10 Hz to 80 Hz, 10 seconds long, with a 0.2 s cosine taper. The borehole geophone was an SSC model LVHK 6001 using 14 Hz geophones. The recording system was a Geometrics Strataview. Six data channels were recorded: the three geophones, the source pilot, the vibrator reference and the vibrator baseplate accelerometer. The record length was 12,288 samples at a 1 ms sample rate, giving a 2.3 s correlated record length. A 10 Hz low cut filter was used and no high cut filter was used except the anti-alias filter.

Data was acquired from a 600 ft offset location northwest of the well, spanning the depth range in the well from 4200 ft to 1000 ft at 40 foot intervals. Four sweeps were summed in the field to produce one record. One to three sets of four were recorded at each depth. This is the far-offset data used for reflection processing. A second source offset location of 136 ft to the southwest of the well was used to acquire near-vertical raypaths for shallow velocity measurement. Depths from 1000 ft to 400 ft at 100 foot intervals were recorded at this near-offset location. Well depths were measured from the ground level of 4418 ft. Because of borehole fluid pressures, a lubricator and packer were used to place the borehole geophone in the well. The geophone had a temperature monitor which showed a maximum temperature of 259 degrees F.

The first break arrival times gives a direct measure of the P-wave velocity with depth. The two datasets (near- and far-offsets) were processed separately. The results of the velocity analysis for the near-offset is shown graphically in Figure 2a, with the input data on the left aligned to the first break times and the velocity function shown on the right. Figure 2b shows the results for the far-offset analysis. Tables 1 and 2 give these data in tabular format. LBNL processed the data using the Seislink VSP Processing package written by Western Altas Logging Services.

The far-offset dataset was processed to image any reflections in the data. The first step was to balance trace amplitudes with an automatic gain control (AGC) of 200 ms, followed by a frequency-wavenumber (F-K) filter to remove the downgoing energy. After this process, there still was some coherent tube wave noise that was removed using a median dip filter. This was followed by 200 ms AGC for display and the final processed VSP is shown in Figure 3a. Two prominent, coherent reflectors can be seen in this figure. The upper reflector arrives at about 575 ms two-way travel time at a depth of about 3000 ft. The lower reflector is at about 775 ms and is below the deepest sensor (4200 ft).

Using the velocity model from Table 2, the VSP data are mapped to depth using the Common Depth Point (CDP) transform module and the results are shown in Figure 3b. The reflectors are mapped in depth to their correct location in relation to the source and receivers. The uppermost reflector spans the elevation range of 1300-1500 feet above sea level and is strongly coherent to about 180 feet northwest of the well. At this point, there is a loss of the reflection, possibly due to changes in rock properties or the presence of a fault. The lower reflector is about 400 feet below sea level and is coherent over 285 feet northwest of the well. This spans the entire CDP transform range, indicating that this reflector is more continuous and may continue beyond the mapped extent. The depth of this reflector is not certain because it occurs below the last sensor and there is no velocity control from direct arrivals.

2. Interpretation of VSP

To interpret the VSP data, we superimpose the VSP data at the correct scale onto a geologic cross section in order to compare the reflections with mapped geologic units. Figure 4 (from the GeothermEx [1997] Figure 4.13) is a north-south cross section that intersects Well 46-28. The upper reflector correlates with the sandstone/siltstone (upper member) of the Natchez Pass Formation. This is the main permeable clastic unit which produces the thermal fluids at the Rye Patch wells. The deeper reflector appears within the lower member of the Natchez Pass Formation, and may occur at a limestone/siltstone interface. Again, the depth of this reflector is not certain because it occurs below the deepest sensor where there is no velocity control.

3. Conclusions

The VSP data collected at Well 46-28 did produce a coherent reflection from the permeable clastic unit which is the main production unit in this geothermal field at a depth of about 3000 feet. The reflection was continuous for about 180 feet northwest of the well. A second, deeper reflector was seen at about 400 below sea level, probably within the lower member of the Natchez Pass Formation, and was coherent over 285 feet northwest of the well.

Also obtained in this study was a velocity versus depth function to a depth of 4200 feet, which can be very useful in designing a 3-D seismic survey.

4. References

GeothermEx (1997), *Geology of the Rye Patch Geothermal Field, Pershing County, Nevada*, GeothermEx, Inc., Richmond, California, December, 1997.

TABLE 1. NEAR OFFSET VELOCITY TABLE

DOE
WELL 46-28

VELOCITY TABLE

RECEIVER REFERENCE ELEVATION = 4418.00 FT ABOVE SEA LEVEL

DATUM ELEVATION 4418.00 FT ABOVE SEA LEVEL
DATUM CORRECT. VELOCITY 5000.00 FT/SEC

MEASURED GEOPHONE DEPTH (DGM) (FT)	DEPTH CORR. TO DATUM (DGD) (FT)	TIME CORR. TO DATUM (TGD) (MS)	AVERAGE VELOCITY (FT/SEC)	RMS VELOCITY (FT/SEC)	INTERVAL DEPTH (DELDGD) (FT)	INTERVAL TIME (DELDGT) (MS)	INTERVAL VELOCITY (FT/SEC)
					400.0	58.7	6808.6
400.0	400.0	58.7	6808.6	6808.6			
					100.0	8.9	11176.4
500.0	500.0	67.7	7385.9	7532.5			
					100.0	10.2	9773.0
600.0	600.0	77.9	7699.3	7863.2			
					100.0	9.8	10252.0
700.0	700.0	87.7	7983.3	8163.6			
					100.0	9.8	10185.6
800.0	800.0	97.5	8205.0	8389.3			
					100.0	10.7	9378.0
900.0	900.0	108.2	8320.7	8491.9			
					100.0	10.4	9650.1
1000.0	1000.0	118.5	8436.9	8599.4			

TABLE 2. FAR OFFSET VELOCITY TABLE

DOE
WELL 46-28

VELOCITY TABLE

RECEIVER REFERENCE ELEVATION = 4418.00 FT ABOVE SEA LEVEL

DATUM ELEVATION 4418.00 FT ABOVE SEA LEVEL
DATUM CORRECT. VELOCITY 5000.00 FT/SEC

MEASURED GEOPHONE DEPTH (DGM) (FT)	DEPTH CORR. TO DATUM (DGD) (FT)	TIME CORR. TO DATUM (TGD) (MS)	AVERAGE VELOCITY (FT/SEC)	RMS VELOCITY (FT/SEC)	INTERVAL DEPTH (DELDGD) (FT)	INTERVAL TIME (DELDGT) (MS)	INTERVAL VELOCITY (FT/SEC)
					1000.0	112.8	8867.5
1000.0	1000.0	112.8	8867.5	8867.5			
					40.0	3.5	11497.0
1040.0	1040.0	116.3	8946.2	8957.4			
					40.0	4.5	8969.7
1080.0	1080.0	120.7	8947.0	8957.8			
					40.0	4.4	9051.7
1120.0	1120.0	125.1	8950.7	8961.2			
					40.0	4.1	9822.3
1160.0	1160.0	129.2	8978.2	8989.6			
					40.0	4.2	9524.9
1200.0	1200.0	133.4	8995.4	9006.9			
					40.0	4.4	9001.8
1240.0	1240.0	137.8	8995.6	9006.7			
					40.0	4.9	8085.2
1280.0	1280.0	142.8	8964.1	8976.4			
					40.0	5.0	7947.8
1320.0	1320.0	147.8	8929.5	8943.3			
					40.0	4.3	9301.3
1360.0	1360.0	152.1	8940.0	8953.6			
					40.0	5.2	7689.4
1400.0	1400.0	157.3	8898.6	8914.7			
					40.0	4.8	8308.3
1440.0	1440.0	162.1	8881.1	8897.3			
					40.0	5.8	6885.8
1480.0	1480.0	168.0	8812.1	8835.4			
					40.0	5.5	7230.8
1520.0	1520.0	173.5	8761.7	8788.7			
					40.0	5.4	7366.6
1560.0	1560.0	178.9	8719.3	8749.0			
					40.0	4.5	8862.0
1600.0	1600.0	183.4	8722.8	8751.8			
					40.0	4.3	9363.5
1640.0	1640.0	187.7	8737.4	8766.2			
					40.0	5.0	7975.9
1680.0	1680.0	192.7	8717.6	8746.5			
					40.0	4.9	8188.0
1720.0	1720.0	197.6	8704.5	8733.1			
					40.0	4.4	9022.3
1760.0	1760.0	202.0	8711.5	8739.6			
					40.0	4.3	9321.9
1800.0	1800.0	206.3	8724.2	8752.1			
					40.0	4.8	8382.1
1840.0	1840.0	211.1	8716.4	8743.9			

					40.0	5.4	7427.4
1880.0	1880.0	216.5	8684.4	8713.5			
					40.0	5.0	7975.0
1920.0	1920.0	221.5	8668.3	8697.5			
					40.0	4.4	9003.9
1960.0	1960.0	225.9	8674.9	8703.6			
					40.0	5.5	7295.4
2000.0	2000.0	231.4	8642.2	8672.9			
					40.0	4.9	8194.4
2040.0	2040.0	236.3	8633.0	8663.3			
					40.0	3.5	11274.9
2080.0	2080.0	239.9	8672.1	8707.6			
					40.0	2.6	15604.6
2120.0	2120.0	242.4	8745.4	8808.9			
					40.0	3.4	11625.0
2160.0	2160.0	245.9	8785.7	8854.5			
					40.0	2.9	14016.1
2200.0	2200.0	248.7	8845.7	8930.6			
					40.0	1.4	28614.6
2240.0	2240.0	250.1	8956.2	9159.0			
					40.0	2.8	14187.8
2280.0	2280.0	252.9	9014.5	9230.1			
					40.0	2.3	17289.2
2320.0	2320.0	255.2	9089.5	9334.5			
					40.0	1.4	28638.3
2360.0	2360.0	256.6	9195.9	9545.8			
					40.0	2.2	18287.2
2400.0	2400.0	258.8	9272.7	9652.9			
					40.0	2.0	19784.5
2440.0	2440.0	260.8	9354.2	9771.9			
					40.0	1.6	25329.4
2480.0	2480.0	262.4	9450.3	9938.6			
					40.0	1.9	20517.5
2520.0	2520.0	264.4	9531.9	10057.4			
					40.0	2.2	18302.6
2560.0	2560.0	266.6	9603.8	10152.3			
					40.0	1.5	27437.0
2600.0	2600.0	268.0	9700.9	10324.9			
					40.0	2.4	16844.5
2640.0	2640.0	270.4	9763.6	10400.0			
					40.0	1.6	25504.4
2680.0	2680.0	272.0	9854.4	10549.2			
					40.0	1.9	20603.3
2720.0	2720.0	273.9	9930.6	10653.9			
					40.0	2.3	17596.9
2760.0	2760.0	276.2	9993.7	10729.4			
					40.0	2.5	16213.6
2800.0	2800.0	278.6	10048.7	10790.2			
					40.0	2.1	18875.0
2840.0	2840.0	280.8	10115.3	10873.8			
					40.0	2.6	15523.6
2880.0	2880.0	283.3	10164.5	10925.0			
					40.0	1.1	35386.6
2920.0	2920.0	284.5	10264.8	11129.1			
					40.0	3.2	12364.9
2960.0	2960.0	287.7	10288.4	11143.8			
					40.0	3.0	13468.7
3000.0	3000.0	290.7	10320.9	11170.0			
					40.0	1.8	21946.7
3040.0	3040.0	292.5	10393.3	11269.1			
					40.0	2.1	18983.8
3080.0	3080.0	294.6	10454.7	11342.9			
					40.0	2.1	18901.4
3120.0	3120.0	296.7	10515.0	11414.5			
					40.0	2.8	14092.4
3160.0	3160.0	299.6	10548.9	11442.9			

					40.0	1.4	27879.4
3200.0	3200.0	301.0	10631.5	11576.7			
					40.0	2.7	14953.2
3240.0	3240.0	303.7	10669.6	11610.7			
					40.0	1.2	32730.4
3280.0	3280.0	304.9	10758.0	11771.3			
					40.0	1.6	25230.4
3320.0	3320.0	306.5	10832.9	11880.2			
					40.0	2.0	19827.8
3360.0	3360.0	308.5	10891.7	11949.3			
					40.0	2.0	20116.3
3400.0	3400.0	310.5	10950.8	12019.3			
					40.0	2.3	17615.1
3440.0	3440.0	312.8	10999.1	12069.3			
					40.0	0.9	46127.8
3480.0	3480.0	313.6	11096.3	12294.3			
					40.0	2.5	16070.4
3520.0	3520.0	316.1	11135.4	12328.5			
					40.0	1.2	34355.2
3560.0	3560.0	317.3	11220.7	12480.6			
					40.0	2.3	17470.7
3600.0	3600.0	319.6	11265.4	12523.4			
					40.0	2.0	20324.4
3640.0	3640.0	321.5	11320.9	12585.9			
					40.0	3.3	12202.5
3680.0	3680.0	324.8	11329.8	12582.1			
					40.0	1.1	36058.3
3720.0	3720.0	325.9	11413.9	12735.6			
					40.0	2.1	18908.5
3760.0	3760.0	328.0	11462.3	12785.0			
					40.0	2.3	17381.5
3800.0	3800.0	330.3	11503.5	12822.7			
					40.0	1.8	22418.9
3840.0	3840.0	332.1	11562.2	12893.3			
					40.0	2.0	20053.2
3880.0	3880.0	334.1	11612.8	12947.8			
					40.0	2.5	16183.3
3920.0	3920.0	336.6	11646.4	12974.5			
					40.0	2.0	20352.2
3960.0	3960.0	338.5	11697.0	13029.4			
					40.0	2.1	19488.2
4000.0	4000.0	340.6	11743.9	13077.9			
					40.0	1.7	24081.3
4040.0	4040.0	342.3	11803.8	13153.5			
					40.0	2.6	15309.8
4080.0	4080.0	344.9	11830.3	13171.2			
					40.0	3.1	13068.9
4120.0	4120.0	347.9	11841.2	13170.3			
					40.0	3.7	10947.1
4160.0	4160.0	351.6	11831.9	13149.1			
					40.0	0.7	53903.6
4200.0	4200.0	352.3	11920.5	13366.2			

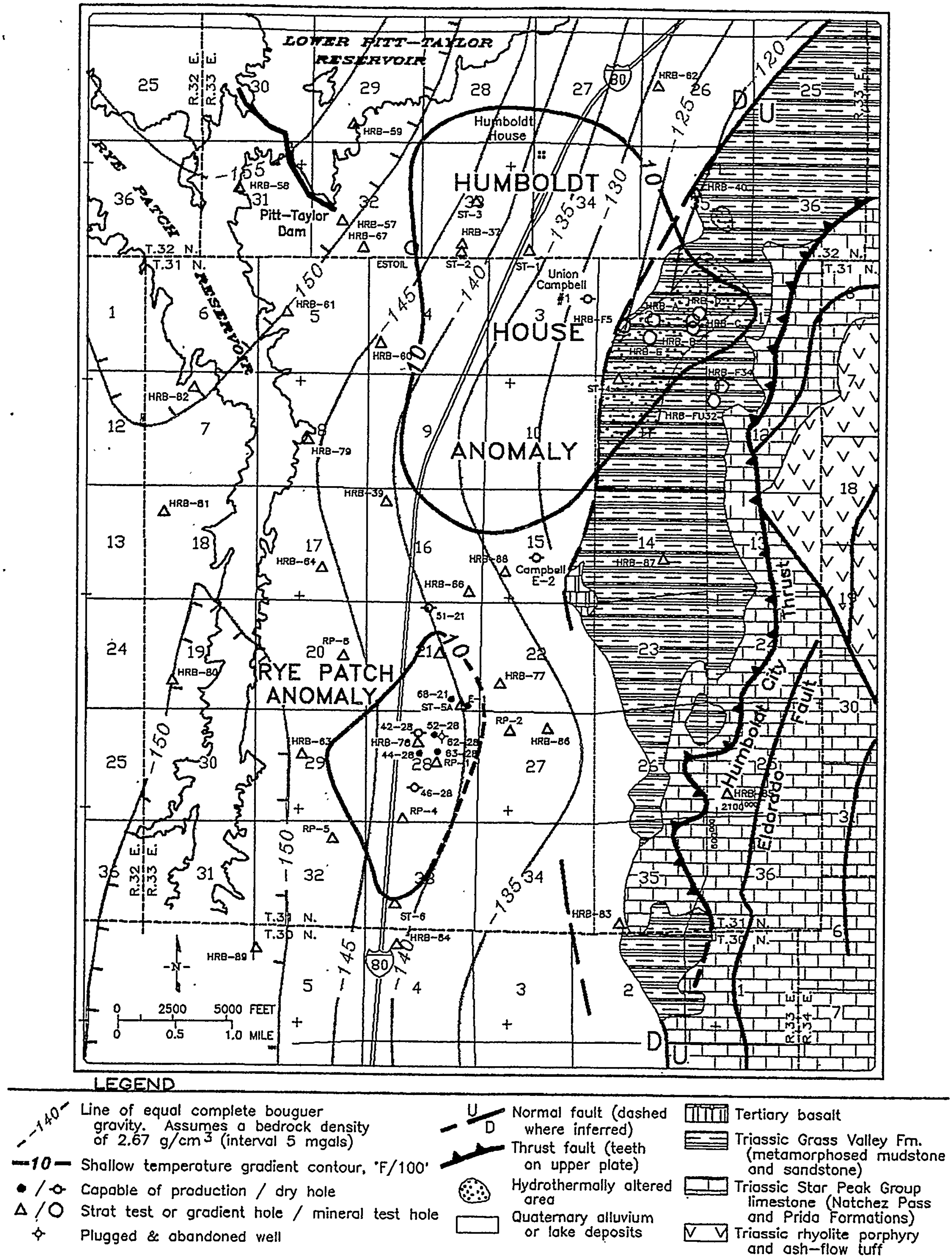

Figure 1. Geologic map, Rye Patch and Humboldt House, Nevada

1997, GeothermEx, Inc. RP_HHMAP/18DEC97/P1845/EMY1=6000/BASICRT.JP

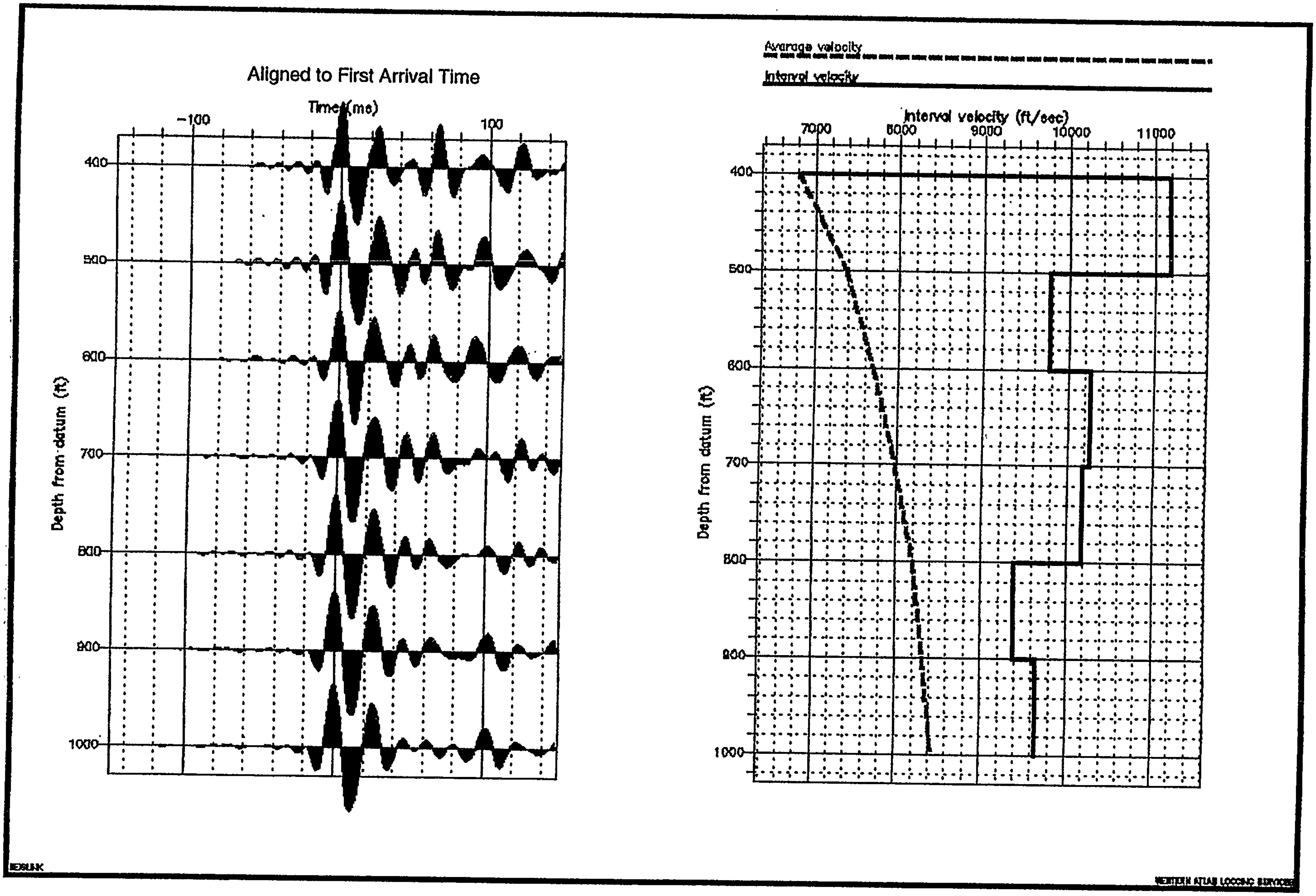

Figure 2a. Near-offset velocity analysis from 400 to 1000 feet depth.

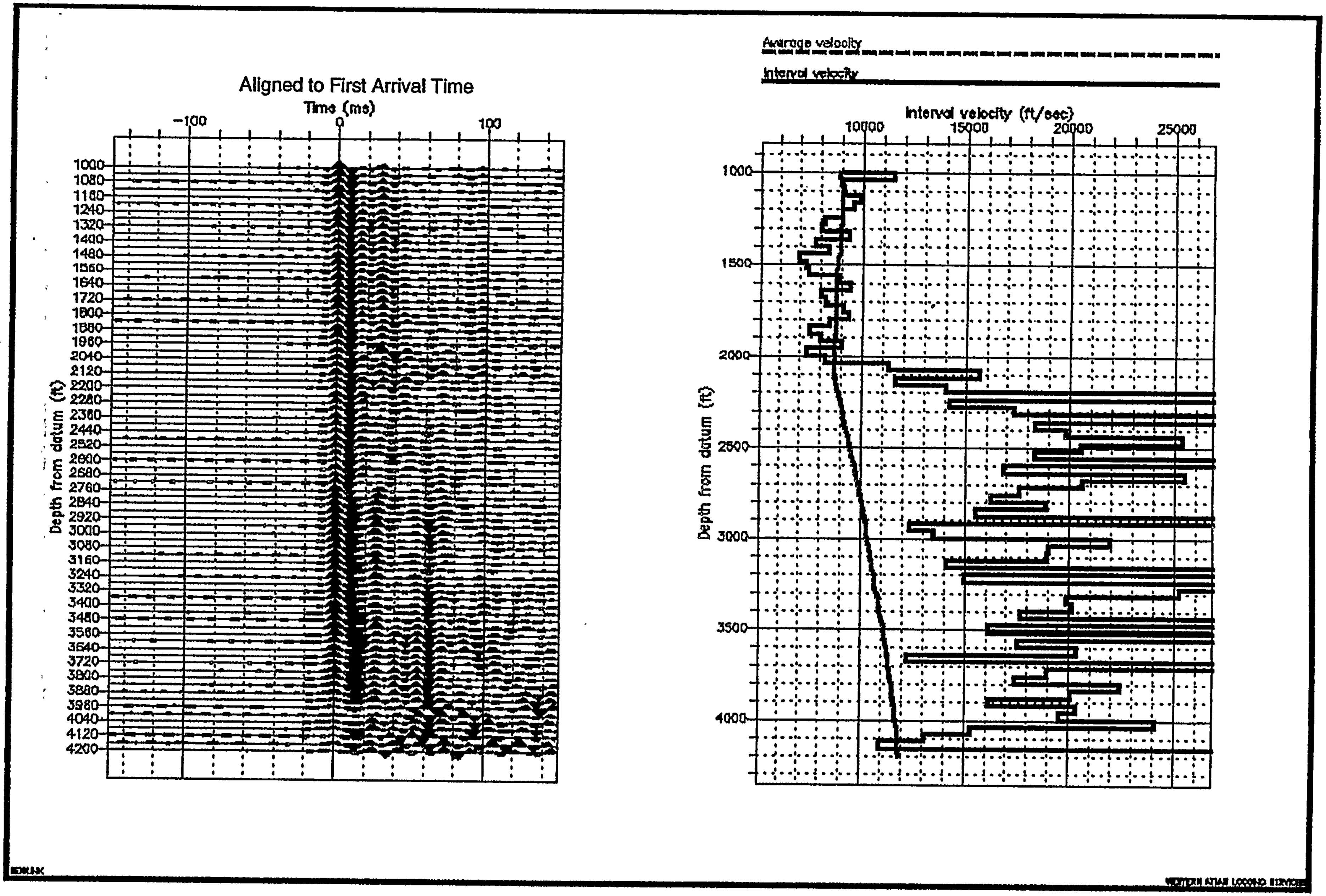

Figure 2b. Far-offset velocity analysis from 1000 to 4200 feet depth.

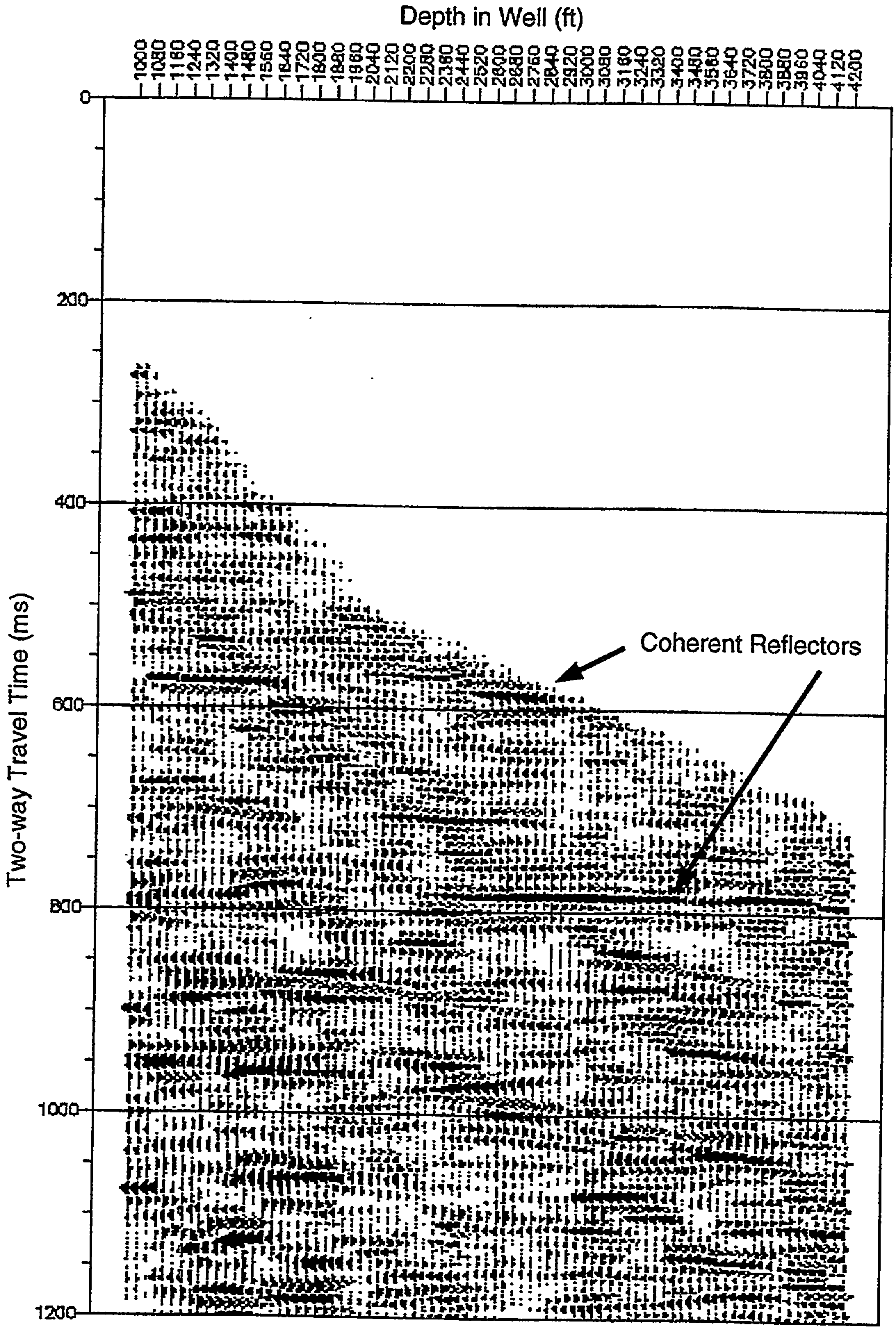

Figure 3a. Processed VSP showing reflected energy.

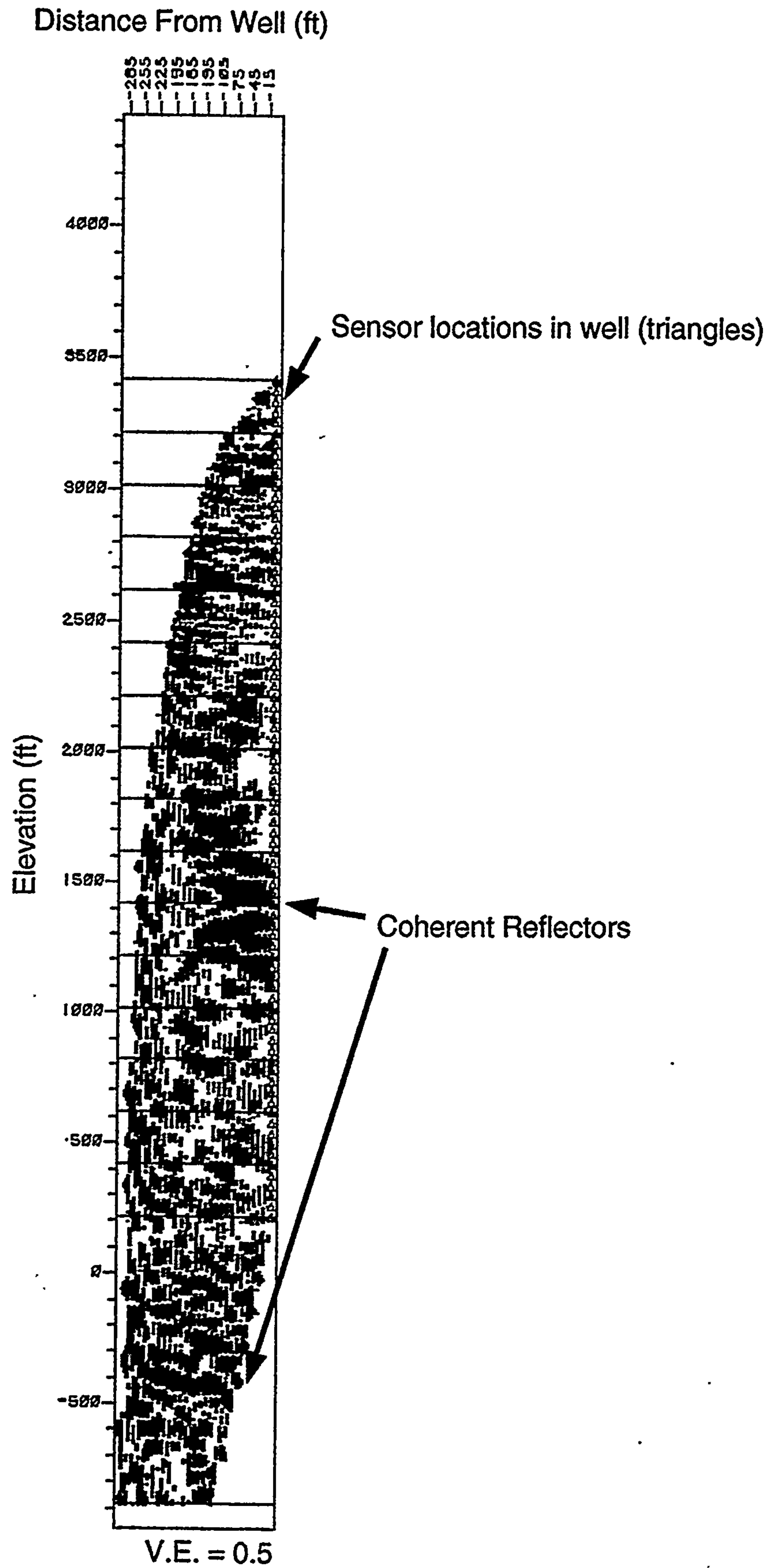

Figure 3b. CDP transform of the VSP data maps the reflectors to depth.

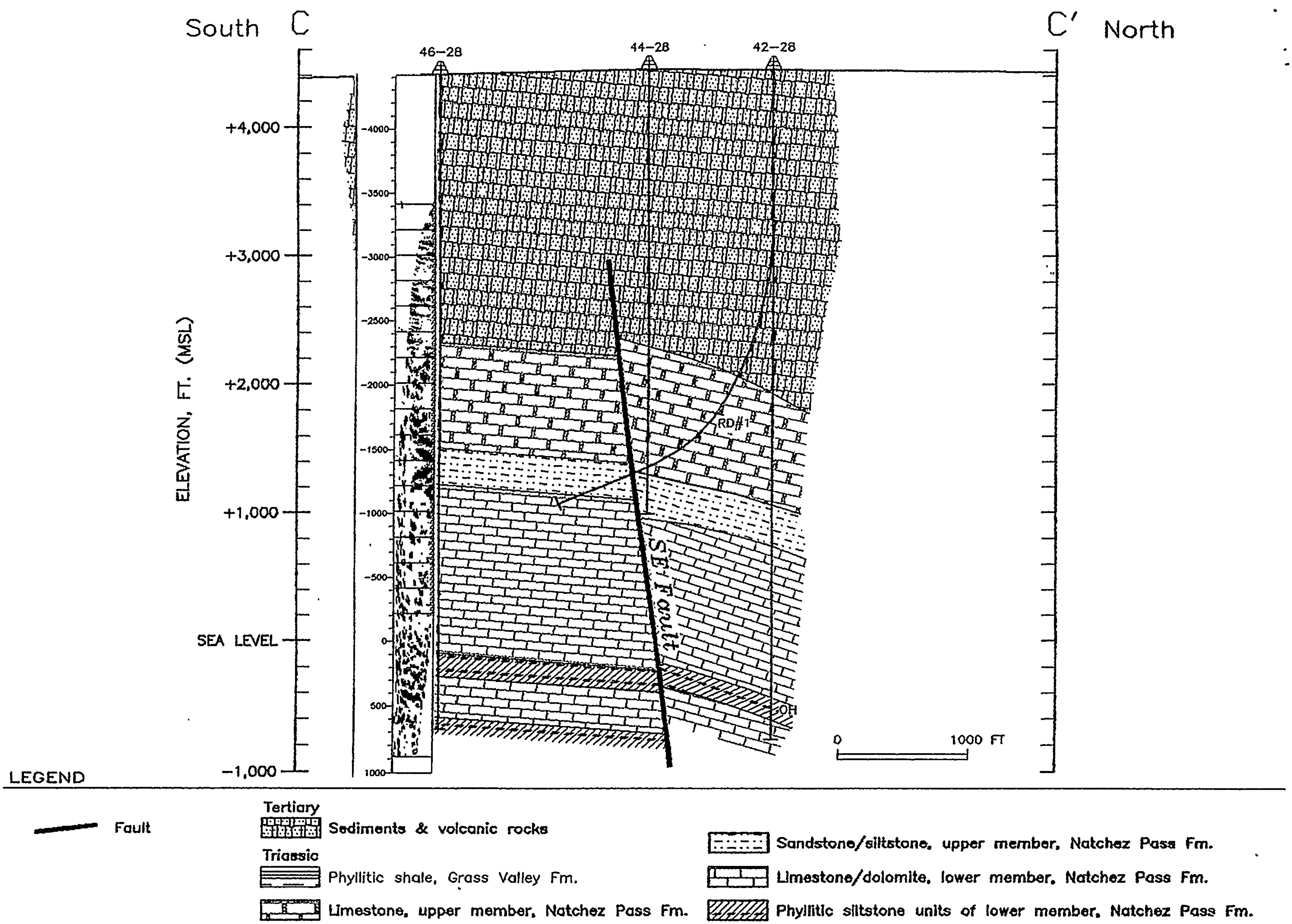

Figure 4. Vertical geologic section, C–C', Rye Patch, Nevada