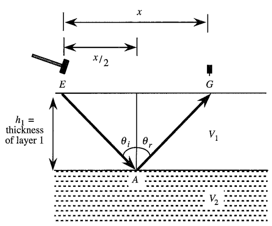
Seismic Reflection



$$\text{time} = \frac{EA + AG}{V_1}$$

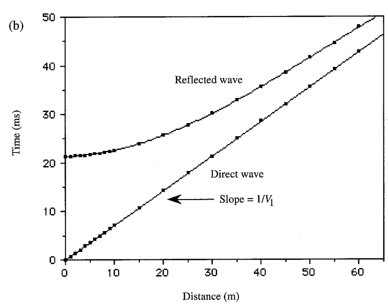
$$EA = AG = \left[\left(\frac{x}{2}\right)^2 + h_1^{\,2}\right]^{1/2}$$

$$\text{time} = \frac{\left(x^2 + 4h_1^{\,2}\right)^{1/2}}{V_1}$$

Hyperbola

$$\frac{y^2}{a^2} - \frac{x^2}{b^2} = 1$$

Asymptotic with Direct Wave

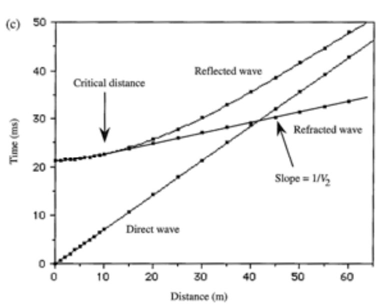


Asymptote
to Hyperbola

$$y = \frac{a}{b}\,x$$

$$y = \frac{1}{V_1}\,x$$

Early Overlap with Head Wave



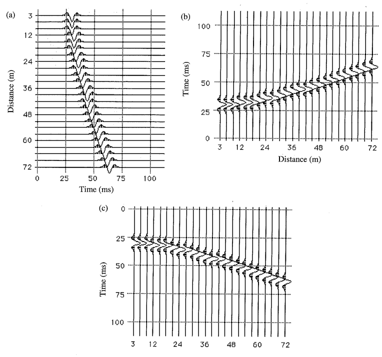
Normal Move-Out

TABLE 4-1 Travel Times for Reflected Waves and Normal Move-Out

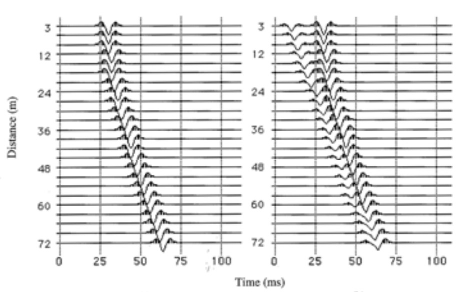
Geophone	Distance (m)	Time (ms)	NMO (ms)
Source	0	21.4	00.0
1	5	21.7	00.3
2	10	22.6	01.2
3	15	24.0	02.5
4	20	25.8	04.3
5	25	27.9	06.5
6	30	30.3	08.9
7	35	32.9	11.5
8	40	35.7	14.3
9	45	38.6	17.2
10	50	41.6	20.2
11	55	44.7	23.3
12	60	47.9	26.5

Velocity (m/s)	**1400**
Thickness (m)	**15**
Increment (m)	**5**

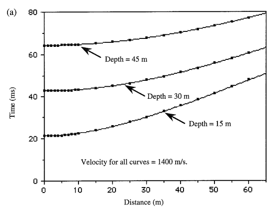
Seismic Section (Seismogram)



Reflected and Direct Waves

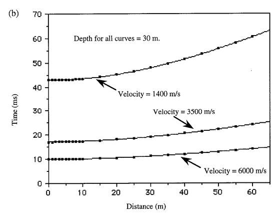


Curvature vs Depth/Velocity

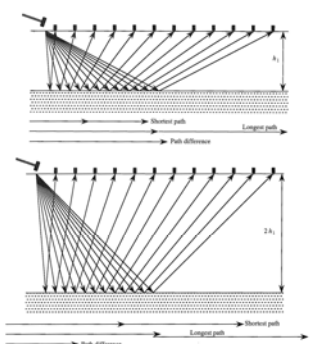


Constant Velocity
Variable Depth

Constant Depth
Variable Velocity



Curvature vs Depth/Velocity



Normal Move Out (Depth)

$$T_{\mathrm{NMO}} = \frac{\left(x^2 + 4h_1^2\right)^{1/2}}{V_1} - \frac{2h_1}{V_1}$$

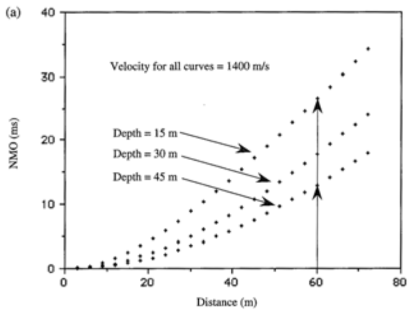
TABLE 4-2 Normal Move-Out Comparisons for Different Velocities and/or Depths

Geophone	Distance (m)	NMO-1 (ms)	NMO-2 (ms)	NMO-3 (ms)
Source	0	00.0	00.0	00.0
1	3	00.1	00.1	00.0
2	6	00.4	00.2	00.1
3	9	00.9	00.5	00.3
4	12	01.7	00.8	00.6
5	15	02.5	01.3	00.9
6	18	03.6	01.9	01.3
7	21	04.7	02.5	01.7
8	24	06.0	03.3	02.2
9	27	07.4	04.1	02.8
10	30	08.9	05.1	03.5
11	33	10.4	06.1	04.2
12	36	12.0	07.1	05.0
13	39	13.7	08.3	05.8
14	42	15.4	09.5	06.7
15	45	17.2	10.7	07.6
16	48	19.0	12.0	08.6
17	51	20.8	13.4	09.6
18	54	22.7	14.8	10.7
19	57	24.6	16.3	11.8
20	60	26.5	17.8	13.0
21	63	28.4	19.3	14.2
22	66	30.4	20.9	15.4
23	69	32.3	22.5	16.7
24	72	34.3	24.1	18.0

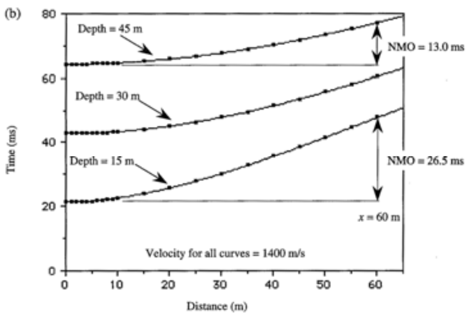
Increment (m)	**3**

Velocity-1 (m/s)	**1400**	Thickness-1 (m)	**15**
Velocity-2 (m/s)	**1400**	Thickness-2 (m)	**30**
Velocity-3 (m/s)	**1400**	Thickness-3 (m)	**45**

Normal Move Out (Depth)



Normal Move Out (Depth)



Velocity/Thickness (x^2-t^2) One Interface

If we square both sides of the basic reflection travel-time equation,

$$\text{time} = \frac{\left(x^2 + 4h_1^2\right)^{1/2}}{V_1} \qquad (4\text{-}1)$$

we arrive at an equation that can be written in the form of the equation for a straight line, $y = mx + b$,

$$t^2 = \frac{x^2 + 4h_1^2}{V_1^2} = \frac{1}{V_1^2}x^2 + \frac{4h_1^2}{V_1^2} \qquad (4\text{-}6)$$

Thus, on an x^2 - t^2 graph, the data points plot as a straight line with slope equal to the inverse of V_1^2 (see Fig. 4-8(a)). This line is projected back to $x = 0$, which gives us t_0^2 (see Fig. 4-8(a)). Velocity and t_0 now are known. If we examine the form of Eq. 4-6 at $x = 0$, we see that

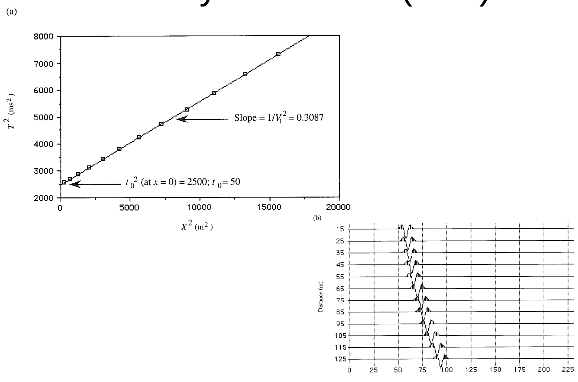
$$t_0^2 = \frac{4h_1^2}{V_1^2}$$

$$t_0 = \frac{2h_1}{V_1}$$

and

$$h_1 = \frac{t_0 V_1}{2} \qquad (4\text{-}7)$$

Velocity/Thickness (x^2-t^2)



Field Seismogram

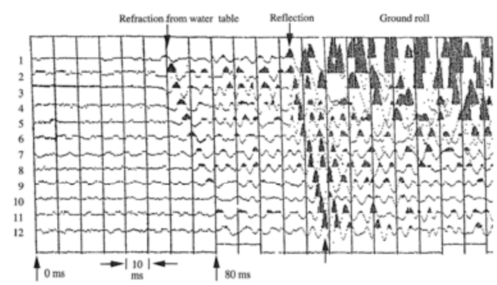


Figure 4-9 Field seismogram from the Connecticut Valley, Massachusetts. Geophone traces are labeled 1–12. The first geophone is located 30 m from the energy source. The geophone interval is 3 m. The reflection selected for analysis is marked by arrows. Timing lines are at 10-ms intervals. The record encompasses 200 ms. Other wave arrivals of interest are noted and will be discussed in detail at a later point in this chapter.

Velocity/Thickness (x^2-t^2)

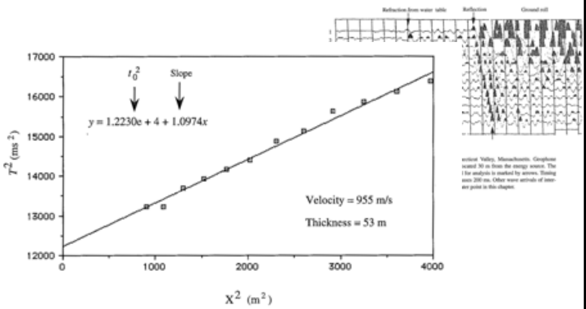


Figure 4-10 An x^2-t^2 plot for the reflection identified in Figure 4-9.

Velocity/Thickness (x^2-t^2)

Slope = 1.097

T_o^2 = 1.223

V = 1/sqrt(1.097) = 955 m/s

T_o = sqrt(12230) = 110 ms

Ht = 0.11*955/2 = 53 m

If we square both sides of the basic reflection travel-time equation,

$$\text{time} = \frac{\left(x^2 + 4h_1^2\right)^{1/2}}{V_1} \tag{4-1}$$

we arrive at an equation that can be written in the form of the equation for a straight line, $y = mx + b$,

$$t^2 = \frac{x^2 + 4h_1^2}{V_1^2} = \frac{1}{V_1^2}x^2 + \frac{4h_1^2}{V_1^2} \tag{4-6}$$

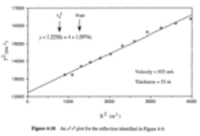
Thus, on an x^2 - t^2 graph, the data points plot as a straight line with slope equal to the inverse of V_1^2 (see Fig. 4-8(a)). This line is projected back to $x = 0$, which gives us t_0^2 (see Fig. 4-8(a)). Velocity and t_0 now are known. If we examine the form of Eq. 4-6 at $x = 0$, we see that

$$t_0^2 = \frac{4h_1^2}{V_1^2}$$

$$t_0 = \frac{2h_1}{V_1}$$

and

$$h_1 = \frac{t_0 V_1}{2}$$



Enhancing Normal Move Out