

Applied Hydrogeology | (4th Edition)

Chapter 12, Problem 2P

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Problem

This is a three-layer seismic problem. Table 12.2 contains first-arrival times that were measured in both the forward and reverse directions. Find the seismic velocities for each layer in each direction, then average them and use the average values to find Z_1 and Z_2 as well as the critical angle between layer 1 and layer 2.

Step-by-step solution

Step 1 of 16

Show the plot between the forward time and distance as in Figure (1).

Comment

Step 2 of 16

Forward time:
Refer Figure (1).
From Figure (1) slope of the first segment is 140 ft per 22 ms.
From Figure (1) slope of the second segment is 280 ft per 16 ms.
From Figure (1) slope of the third segment is 120 ft per 6.0 ms.
Take the value of distance X_1 as 340 ft.
Take the value of distance X_2 as 720 ft.
Take the intercept time T_{1i} as 30 ms.
Take the intercept time T_{2i} as 64 ms.

Comment

Step 3 of 16

Determine the seismic velocity V_1 in the top layer using the relation;
$$\frac{x}{y} = \frac{1}{V_1}$$

Substitute 140 ft for x and 22 ms for y .
$$\frac{140}{22} = \frac{1}{V_1}$$

$$V_1 = 6.36 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_1 = 6,360 \text{ ft/s}$$

Therefore, the seismic velocity in top layer is $6,360 \text{ ft/s}$.

Comment

Step 4 of 16

Determine the seismic velocity V_2 in the middle layer using the relation;
$$\frac{x}{y} = \frac{1}{V_2}$$

Substitute 280 ft for x and 16 for y .
$$\frac{280}{16} = \frac{1}{V_2}$$

$$V_2 = 17.5 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_2 = 17,500 \text{ ft/s}$$

Therefore, the seismic velocity in the middle layer is $17,500 \text{ ft/s}$.

Comment

Step 5 of 16

Determine the seismic velocity V_3 in the bottom layer using the relation;
$$\frac{x}{y} = \frac{1}{V_3}$$

Substitute 120 ft for x and 6.0 ms for y .
$$\frac{120}{6.0} = \frac{1}{V_3}$$

$$V_3 = 20 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_3 = 20,000 \text{ ft/s}$$

Therefore, the seismic velocity in the bottom layer is $20,000 \text{ ft/s}$.

Comment

Step 6 of 16

Show the plot between the reverse time and distance as in Figure (2).

Comment

Step 7 of 16

Reverse time:
Refer Figure (2).
From Figure (2) slope of the first segment is 80 ft per 16 ms.
From Figure (2) slope of the second segment is 160 ft per 12 ms.
From Figure (2) slope of the third segment is 60 ft per 4.0 ms.
Take the value of distance X_1 as 340 ft.
Take the value of distance X_2 as 720 ft.
Take the intercept time T_{1r} as 48 ms.
Take the intercept time T_{2r} as 62 ms.

Comment

Step 8 of 16

Determine the seismic velocity V_1 in the top layer using the relation;
$$\frac{x}{y} = \frac{1}{V_1}$$

Substitute 80 ft for x and 16 ms for y .
$$\frac{80}{16} = \frac{1}{V_1}$$

$$V_1 = 5.0 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_1 = 5,000 \text{ ft/s}$$

Therefore, the seismic velocity in the top layer is $5,000 \text{ ft/s}$.

Comment

Step 9 of 16

Determine the seismic velocity V_2 in the middle layer using the relation;
$$\frac{x}{y} = \frac{1}{V_2}$$

Substitute 160 ft for x and 12 for y .
$$\frac{160}{12} = \frac{1}{V_2}$$

$$V_2 = 13.3 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_2 = 13,300 \text{ ft/s}$$

Therefore, the seismic velocity in the middle layer is $13,300 \text{ ft/s}$.

Comment

Step 10 of 16

Determine the seismic velocity V_3 in the bottom layer using the relation;
$$\frac{x}{y} = \frac{1}{V_3}$$

Substitute 60 ft for x and 4.0 m for y .
$$\frac{60}{4.0} = \frac{1}{V_3}$$

$$V_3 = 15 \text{ ft/ms} \times \left(\frac{1 \text{ ms}}{0.001 \text{ s}} \right)$$

$$V_3 = 15,000 \text{ ft/s}$$

Therefore, the seismic velocity in the bottom layer is $15,000 \text{ ft/s}$.

Comment

Step 11 of 16

Determine the average velocity of top layer for both forward and reverse time using the formula;
$$V_1 = \frac{V_1 \text{ of forward time} + V_1 \text{ of reverse time}}{2}$$

Substitute 6,360 ft/s for V_1 of forward time and 5,000 ft/s for V_1 of reverse time.
$$V_1 = \frac{6,360 + 5,000}{2}$$

$$= 5,680 \text{ ft/s}$$

Comment

Step 12 of 16

Determine the average velocity of top middle for both forward and reverse time using the formula;
$$V_2 = \frac{V_2 \text{ of forward time} + V_2 \text{ of reverse time}}{2}$$

Substitute 17,500 ft/s for V_2 of forward time and 13,300 ft/s for V_2 of reverse time.
$$V_2 = \frac{17,500 + 13,300}{2}$$

$$= 15,400 \text{ ft/s}$$

Comment

Step 13 of 16

Determine the average velocity of bottom layer for both forward and reverse time using the formula;
$$V_3 = \frac{V_3 \text{ of forward time} + V_3 \text{ of reverse time}}{2}$$

Substitute 20,000 ft/s for V_3 of forward time and 15,000 ft/s for V_3 of reverse time.
$$V_3 = \frac{20,000 + 15,000}{2}$$

$$= 17,500 \text{ ft/s}$$

Comment

Step 14 of 16

Determine thickness Z_1 of layer 1 using the formula;
$$Z_1 = \frac{X_1}{2} \sqrt{\frac{V_2 - V_1}{V_1 V_2}}$$

Here, X_1 is the distance from shot to place where the direct wave and refracted wave arrive simultaneously.
Substitute 340 ft for X_1 , 5,680 ft/s for V_1 , and 15,400 ft/s for V_2 .
$$Z_1 = \frac{340}{2} \sqrt{\frac{15,400 - 5,680}{5,680 \times 15,400}}$$

$$= 115.44 \text{ ft}$$

Therefore, the thickness of layer 1 is 115.44 ft .

Comment

Step 15 of 16

Determine the thickness Z_2 of layer 2 using the formula;
$$Z_2 = \frac{1}{2} \left(T_{2r} - 2Z_1 \sqrt{\frac{V_3^2 - V_2^2}{V_2 V_3}} \right) \left(\frac{V_2 V_1}{V_2^2 - V_1^2} \right)$$

Substitute 62 ms for T_{2r} , 115.44 ft for Z_1 , 17,500 ft/s for V_3 , 5,680 ft/s for V_1 , and 15,400 ft/s for V_2 .
$$Z_2 = \frac{1}{2} \left(62 - 2(115.44) \sqrt{\frac{17,500^2 - 5,680^2}{17,500 \times 5,680}} \right) \left(\frac{15,400 \times 17,500}{17,500^2 - 15,400^2} \right)$$

$$= \frac{1}{2} (61.962 \times 3.90)$$

$$= 120.83 \text{ ft}$$

Therefore, the thickness of layer 2 is 120.83 ft .

Comment

Step 16 of 16

Determine the critical angle i_c between layer 1 and 2 using the formula;
$$i_c = \sin^{-1} \left(\frac{V_1}{V_2} \right)$$

Substitute 5,680 ft/s for V_1 and 15,400 ft/s for V_2 .
$$i_c = \sin^{-1} \left(\frac{5,680}{15,400} \right)$$

$$= 21.6^\circ$$

Therefore, the critical angle between layer 1 and 2 is 21.6° .

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