Lab Assignment #4: Problems 3 & $Inverting Velocity Structure using Dix Equations, and NMO

TRUE MODEL

V1	1502	h1	400
V2	2504	h2	500
V3	3506	h3	500

VARIABLE KEY

x	distance	*hn*	Thickness of layer n (n=1, 2, or 3)
t0	arrival time at zero offset	*VRMSn^2*	Root mean squared velocity for layer n (n=1, 2, or 3)
Vn	Velocity of layer n (n=1, 2, or 3)	*TNMO_n*	Normal-moveout layer n (n=1, 2, or 3)

DATA

x (m)	Layer 1 arrival (ms)	Layer 2 arrival (ms)	Layer 3 arrival (ms)
0	533.333	933.333	1219.048
30	533.707	933.455	1219.11
60	534.829	933.819	1219.298
90	536.695	934.426	1219.61
120	539.296	935.276	1220.047
150	542.623	936.367	1220.608
180	546.659	937.698	1221.294
210	551.394	939.269	1222.103
240	556.807	941.074	1223.037
270	562.881	943.119	1224.094
300	569.589	945.395	1225.274
330	576.918	947.904	1226.575
360	584.833	950.642	1228
390	593.322	953.609	1229.545

Parameters for t2-x2 plot

x2	t1^2	t2^2	t3^2
0	0.284	0.871	1.486
900	0.285	0.871	1.486
3600	0.286	0.872	1.487
8100	0.288	0.873	1.487
14400	0.291	0.875	1.489
22500	0.294	0.877	1.490
32400	0.299	0.879	1.492
44100	0.304	0.882	1.494
57600	0.310	0.886	1.496
72900	0.317	0.889	1.498
90000	0.324	0.894	1.501
108900	0.333	0.899	1.504
129600	0.342	0.904	1.508
152100	0.352	0.909	1.512

TNMO_1	TNMO_2	TNMO_3	x2/2t0_1	x2/2t0_2	x2/2t0_3
2.416E-06	-4.942E-06	-1.161E-06	0.000E+00	0.000E+00	0.000E+00
3.764E-04	1.171E-04	6.084E-05	8.438E+02	4.821E+02	3.691E+02
1.498E-03	4.811E-04	2.488E-04	3.375E+03	1.929E+03	1.477E+03
3.364E-03	1.088E-03	5.608E-04	7.594E+03	4.339E+03	3.322E+03
5.965E-03	1.938E-03	9.978E-04	1.350E+04	7.714E+03	5.906E+03
9.292E-03	3.029E-03	1.559E-03	2.109E+04	1.205E+04	9.229E+03
1.333E-02	4.360E-03	2.245E-03	3.038E+04	1.736E+04	1.329E+04
1.806E-02	5.931E-03	3.054E-03	4.134E+04	2.362E+04	1.809E+04
2.348E-02	7.736E-03	3.988E-03	5.400E+04	3.086E+04	2.362E+04
2.955E-02	9.781E-03	5.045E-03	6.834E+04	3.905E+04	2.990E+04
3.626E-02	1.206E-02	6.225E-03	8.438E+04	4.821E+04	3.691E+04
4.359E-02	1.457E-02	7.526E-03	1.021E+05	5.834E+04	4.467E+04
5.150E-02	1.730E-02	8.951E-03	1.215E+05	6.943E+04	5.316E+04
5.999E-02	2.027E-02	1.050E-02	1.426E+05	8.148E+04	6.238E+04

Velocity Model (single-layer assumption)

V1	1500.145	*t01*	0.533	*h1*	400.037	
V2	1993.662	*t02*	0.933	*h2*	930.380	530.34357
V3	2432.443	*t03*	1.219	*h3*	1482.634	552.253866

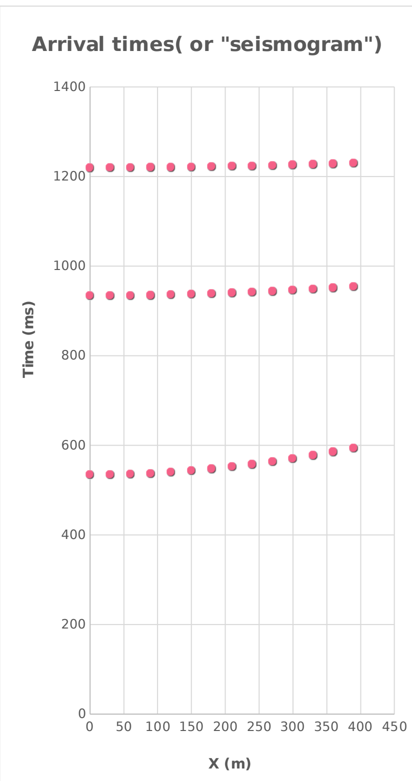
Normal Move-Out model

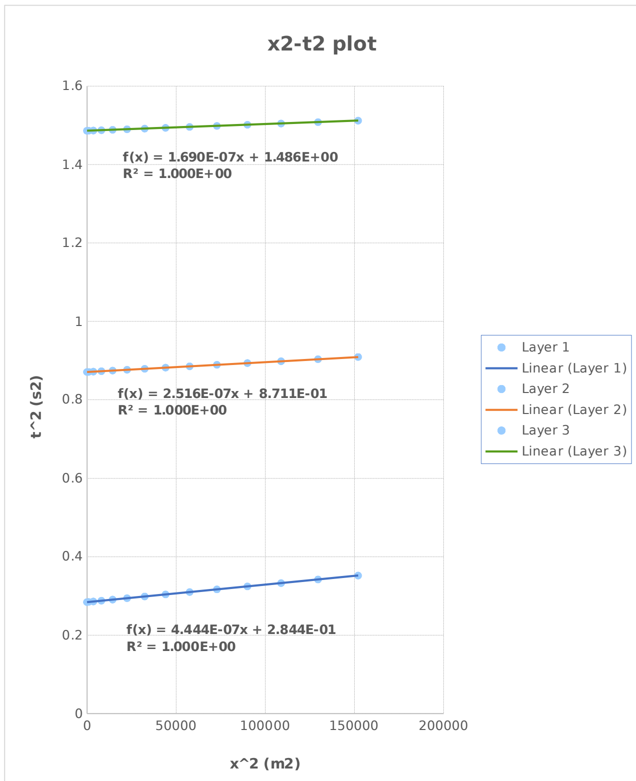
VRMS_1^2	2366052.95	*V1*	1538.198	*h1*	410.184
VRMS_2^2	4013897.12	*V2*	2492.182	*h2*	498.446
VRMS_3^2	5939899.88	*V3*	3497.372	*h3*	499.619

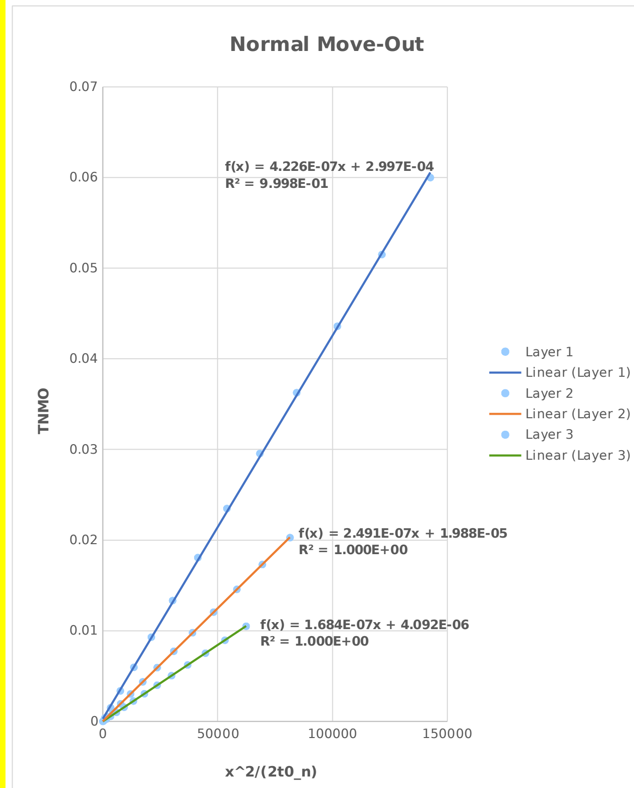
Velocity Model (Dix)

VRMS1^2	2250435.074	*v1^2*	2250435.074	*v1*	1500.145	*h1*	400.037
VRMS2^2	3974688.041	*v2^2*	6273637.858	*v2*	2504.723	*h2*	500.954
VRMS3^2	5916780.906	*v3^2*	12261050.351	*v3*	3501.578	*h3*	500.220

Note: VrmsN^2=VN above squared







Reflection Method

- ***Seismic Reflection Travel-Times*** have eqns of a hyperbola. For single layer over halfspace,

$$t^2 = \frac{x^2}{V_1^2} + \frac{4h_1^2}{V_1^2}$$

has ***intercept*** $2h_1/V_1$ and ***slope of the asymptote*** is $1/V_1$!

- For two layers:

$$\frac{(t-t_0)^2}{a^2} - \frac{x^2}{b^2} = 1 \Rightarrow a = 2\left(\frac{h_1}{V_1} + \frac{h_2}{V_2}\right); \frac{b}{a} = \frac{1}{V_2}; t_0 = \frac{2h_1\sqrt{V_2^2 - V_1^2}}{V_1 V_2}$$

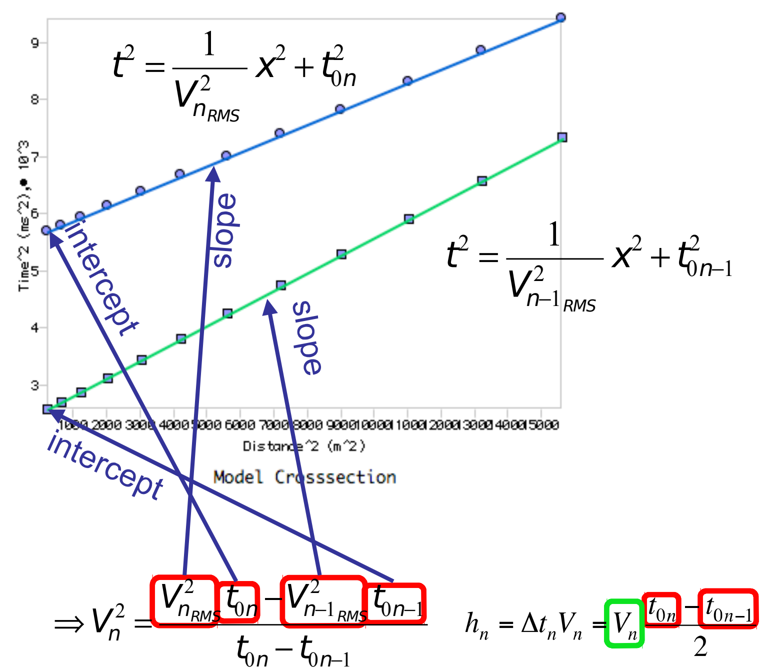
- For a dipping layer,

$$t^2 = \frac{x^2}{V_1^2} - \frac{4h_1\sin(\alpha)}{V_1^2}x + \frac{4h_1^2}{V_1^2}$$

- ***Dix Equations*** multiple layers:

$$V_{n_{RMS}}^2 \cong \frac{\sum_{i=1}^{n} V_i^2 \Delta t_i}{\sum_{i=1}^{n} \Delta t_i}$$

$$V_n^2 = \frac{V_{n_{RMS}}^2 t_{0n} - V_{n-1_{RMS}}^2 t_{0n-1}}{t_{0n} - t_{0n-1}}$$



- ***Normal Move-Out (NMO)***: reflection travel-time at distance x minus t at $x = 0$:

  * For single layer case:

$$T_{NMO} = t - t_0 = \frac{\sqrt{x^2 + 4h_1^2}}{V_1} - \frac{2h_1}{V_1} \qquad t = \frac{\sqrt{x^2 + 4h_1^2}}{V_1} = \sqrt{\frac{x^2}{V_1^2} + \frac{4h_1^2}{V_1^2}} = t_0\sqrt{1 + \frac{x^2}{V_1^2 t_0^2}}$$

  * First-order binomial series approximation:

$$T_{NMO} \doteq \frac{x^2}{2t_0V_1^2}$$

(& second-order): $$T_{NMO} \doteq \frac{x^2}{2t_0V_1^2} - \frac{x^4}{8t_0^3V_1^4}$$

(Useful to write travel-time in terms of only V & observed t_0)

  * Can also be applied to multiple layers using the ***Dix equation*** approximation for V_{rms}:

$$T_{NMO} = \frac{x^2}{2t_0V_{rms}^2}$$