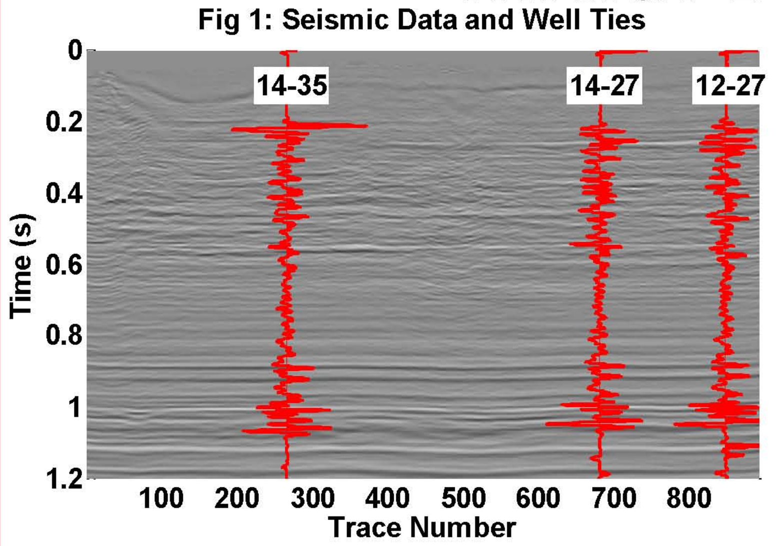
Investigating methods to transform acoustic impedance inversions into depth

Heather J. E. Lloyd*, Roy O. Lindseth and Gary F. Margrave

hjelloyd@ucalgary.ca

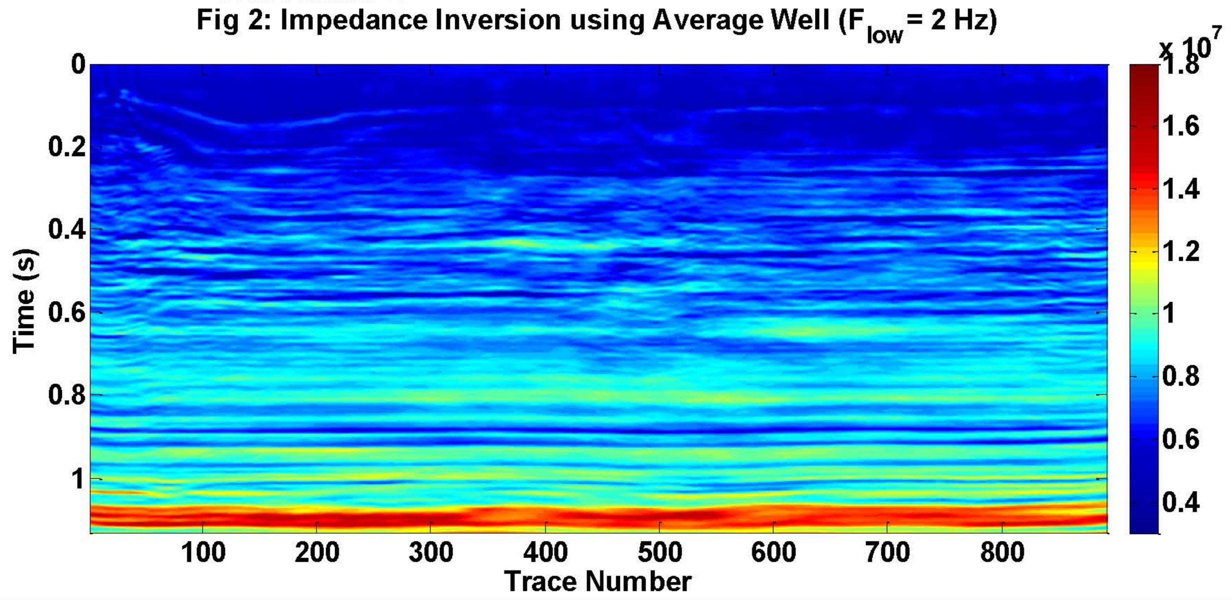
Initial Data

Fig 1: Seismic Data and Well Ties



The Hussar data set will be used in this study. The wells were tied to the seismic data and the seismic data was balanced, Figure 1. An average well log created by averaging the three well logs was used in BLIMP (Ferguson and Margrave, 1996) with a low-frequency cut-off of 2 Hz to create the impedance section in Figure 2.

Fig 2: Impedance Inversion using Average Well (F_{low} = 2 Hz)



Abstract

The prime use of seismic data is to map time structure in the subsurface. Converting the seismic data to depth is helpful to not only increase the accuracy of the structure map but help geologists and engineers ,who require depth for reservoir characterization.

One method to convert seismic into depth is to calculate an impedance section and estimate the density such that the velocity remains. The time –depth curve can easily be calculated now that the velocity is isolated.

Three methods of density estimation were used including:

- Gardner's equation with standard parameters
- Density logs from the wells
- Gardner's equation using time-variant parameters

Of these three methods using the time-variant option provided the most consistent results with the least amount of error.

A systematic error that was evident in all the results was the overburden not being properly characterized in the inversion and the separation. This caused events to appear consistently deeper (50 to 125 meters) than they were in the wells. This systematic error needs further investigation before this method can be perfected.

Time-Variant Gardner Parameters

Fig 5: Depth Transformations using Time-Variant Gardner Parameters

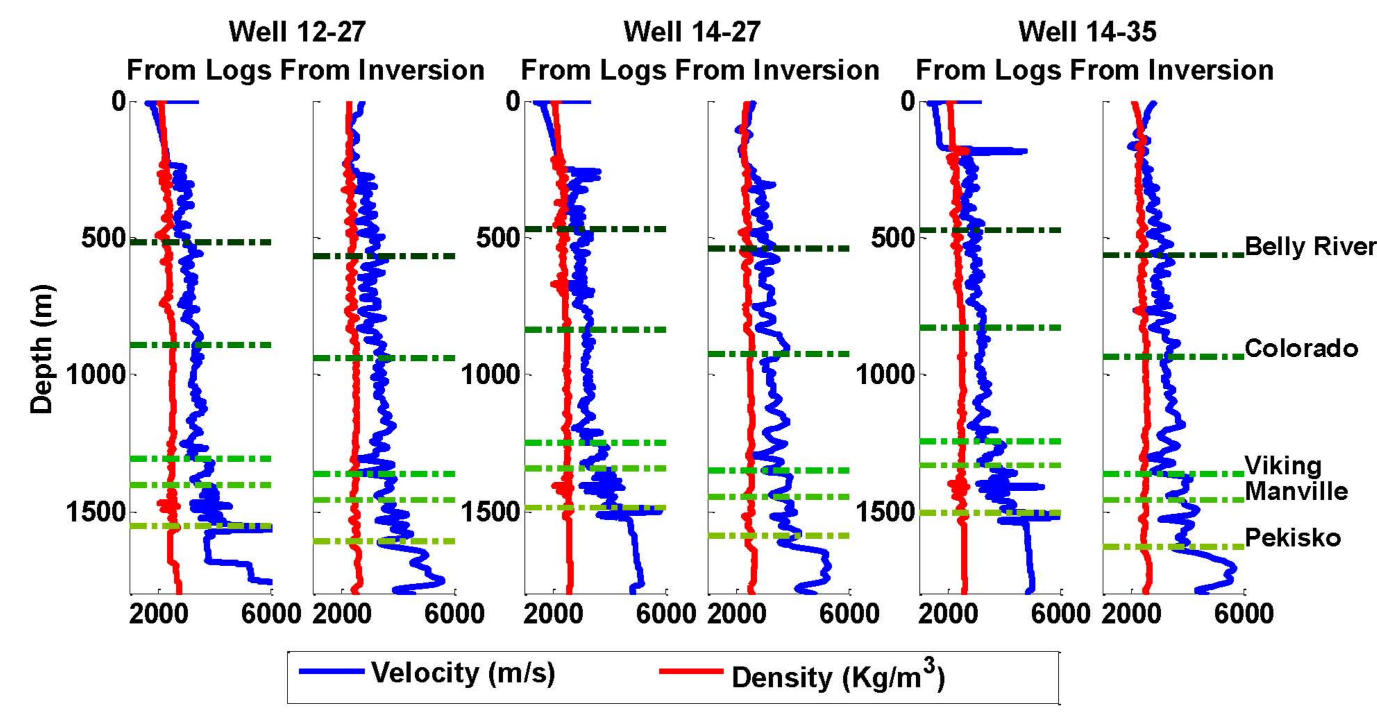
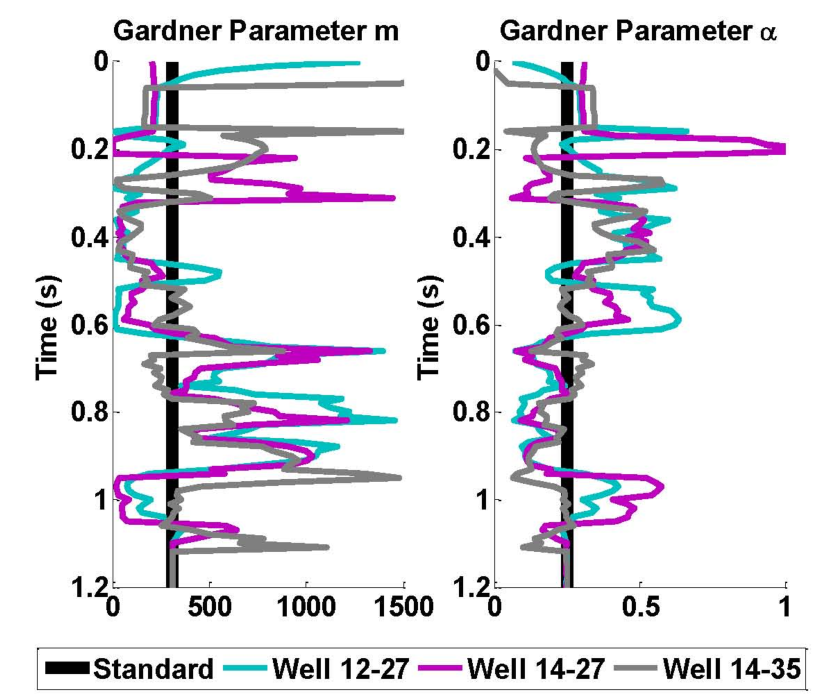


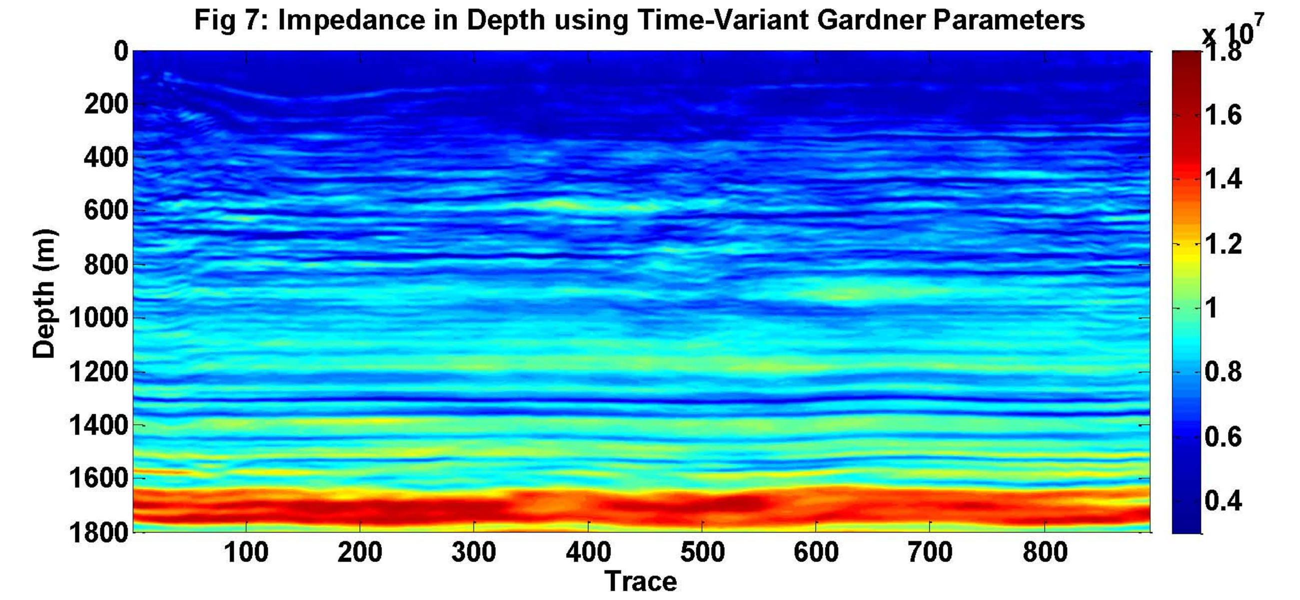
Fig 6: Time-Variant Gardner Parameters



This method, Figure 5, is similar to the Gardner method but uses time-variant parameters in Figure 6. The top picks from this method can be seen in Table 3, where the difference between the well picks and inversion picks vary less with depth and the overall shift is less than the log density method. There is still a problem with the overburden and this will need to be addressed in the future.

Table 3: Time-Variant Gardner Top Picks	Belly River	Colorado	Viking	Manville	Pekisko	Range
Top Depth From 12-27	516	892	1307	1402	1554	-
Top Depth from Inversion	566	939	1362	1456	1608	-
Difference	-50	-47	-55	-54	-54	8
Top Depth From 14-27	469	838	1250	1342	1487	-
Top Depth from Inversion	541	925	1351	1446	1590	-
Difference	-72	-87	-101	-104	-103	32
Top Depth From 14-35	472	828	1243	1333	1505	-
Top Depth from Inversion	565	934	1362	1457	1629	-
Difference	-93	-106	-119	-124	-124	31

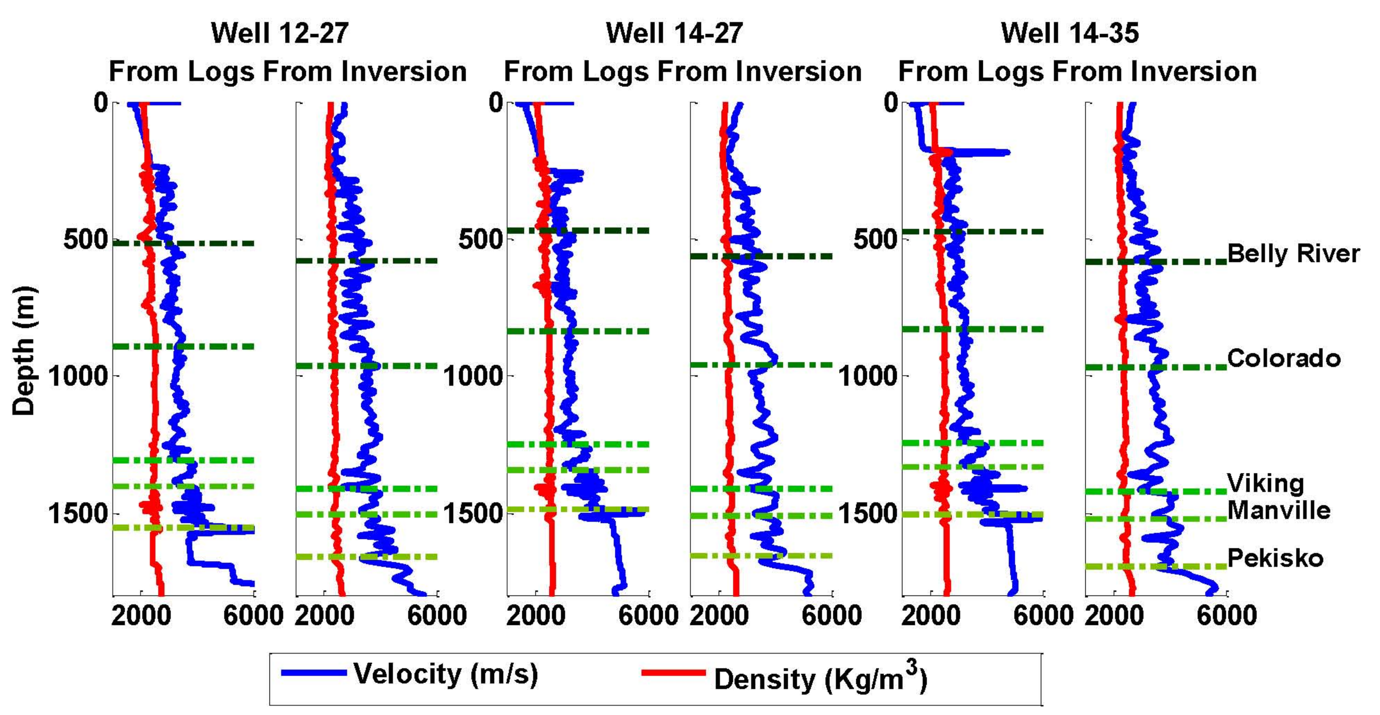
Fig 7: Impedance in Depth using Time-Variant Gardner Parameters



Once we have extracted the velocity we can obtain the depth. We can then use the time-depth relationship to transform the impedance section or seismic data into depth. Figure 7 is the impedance section from Figure 2 but now displayed in depth. The near surface layers are thinner while the lower section is wider. We can also see variation along the bottom event much easier than in the time section. This depth conversion has not been corrected for the bulk time shift error seen in the error analysis.

Standard Gardner Parameters

Fig 3: Depth Transformations using Standard Gardner Parameters

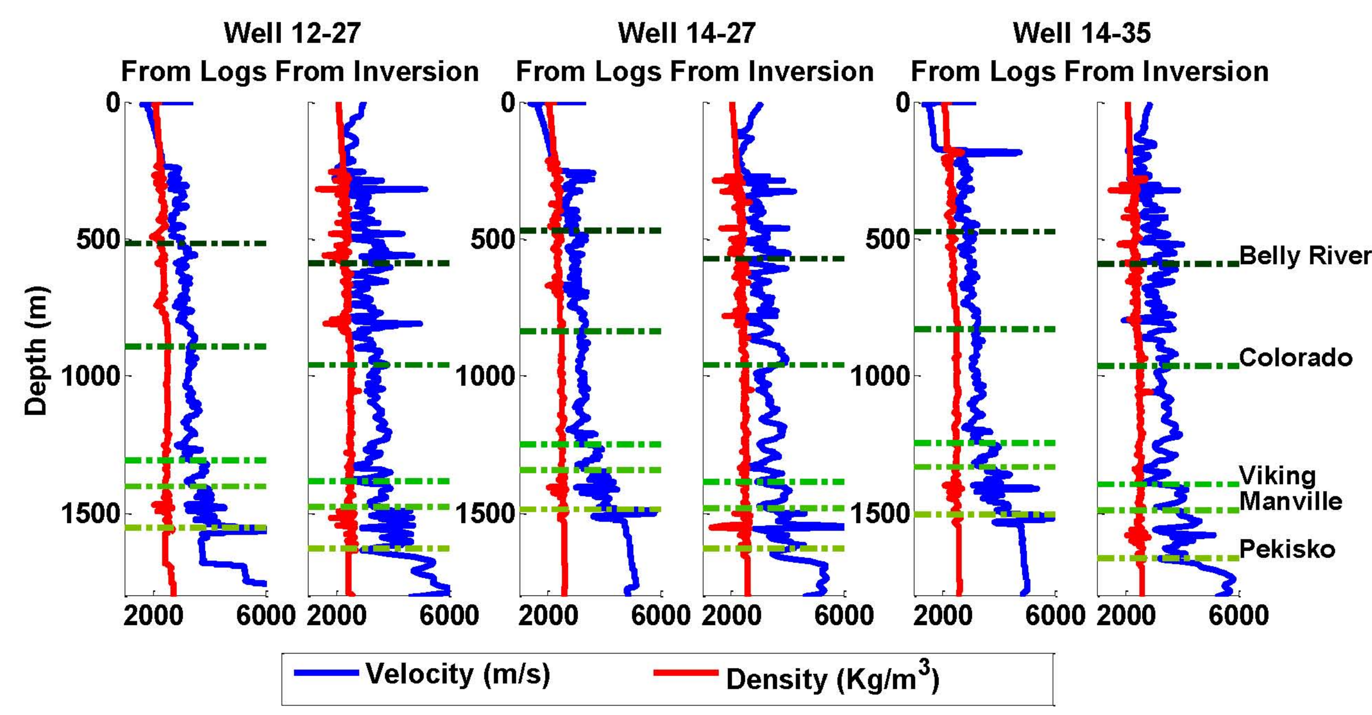


It is possible to convert seismic data to depth if we can generate an impedance section. Then by assuming that Gardner's Rule (Gardner et al, 1974) holds true, we can estimate the velocity, V, using $V = \left(\frac{I}{m}\right)^{1/(1+\alpha)}$, where I is the impedance, m=311 and α=.25. Figure 3 shows the depth conversions at each well location. Tops were used to check the accuracy of the transformation. Table 1 shows the top picks and the error between the well and the inversion result. The difference between the picks increase with depth indicating that the density approximation is not optimal.

Table 1: Standard Gardner Top Picks	Belly River	Colorado	Viking	Manville	Pekisko	Range
Top Depth From 12-27	516	892	1307	1402	1554	-
Top Depth from Inversion	581	964	1409	1505	1659	-
Difference	-65	-72	-102	-103	-105	40
Top Depth From 14-27	469	838	1250	1342	1487	-
Top Depth from Inversion	563	961	1411	1508	1654	-
Difference	-95	-123	-161	-166	-168	73
Top Depth From 14-35	472	828	1243	1333	1505	-
Top Depth from Inversion	583	968	1422	1519	1694	-
Difference	-111	-140	-179	-187	-189	78

Log Densities

Fig 4: Depth Transformations using Resampled Log Densities



Another method to estimate the density is to use the density values from the log itself. These densities need to be converted to time and then sampled at the same points as the seismic data. Once this is done the velocity can be calculated from dividing the impedance by the density logs, Figure 4. Then depth can be calculated by $z_i = \sum_{k=1}^{i} V_k * t_k$, where z_i is the depth at a particular location and V_k and t_k are the velocity and time at each sample. The depth picks have been tabled for error analysis in Table 2. The differences for this method are much more consistent especially for well 12-27. There is still a large bulk shift that is likely a result from the overburden not being correct in the inversion.

Table 2: Log Density Top Picks	Belly River	Colorado	Viking	Manville	Pekisko	Range
Top Depth From 12-27	516	892	1307	1402	1554	-
Top Depth from Inversion	587	960	1384	1477	1630	-
Difference	-71	-68	-77	-75	-76	9
Top Depth From 14-27	469	838	1250	1342	1487	-
Top Depth from Inversion	570	960	1387	1482	1628	-
Difference	-102	-122	-137	-140	-141	39
Top Depth From 14-35	472	828	1243	1333	1505	-
Top Depth from Inversion	590	964	1395	1490	1663	-
Difference	-118	-136	-153	-158	-158	40

Ferguson, R. J. and Margrave, G. F., 1996, A simple algorithm for bandlimited impedance inversion: CREWES Research Report, Vol. 8, No. 21.
Gardner, G.H.F., Gardner, L.W., and Gregory, A.R., 1974, Formation velocity and density – the diagnostic basics for stratigraphic traps: Geophysics, 39,770-780.