Incorporating spectral colour into impedance inversion

Heather J. E. Lloyd* and Gary F. Margrave

hjelloyd@ucalgary.ca

Reflectivity Modeling

FIG 1: Seismic and Well Ties from Hussar

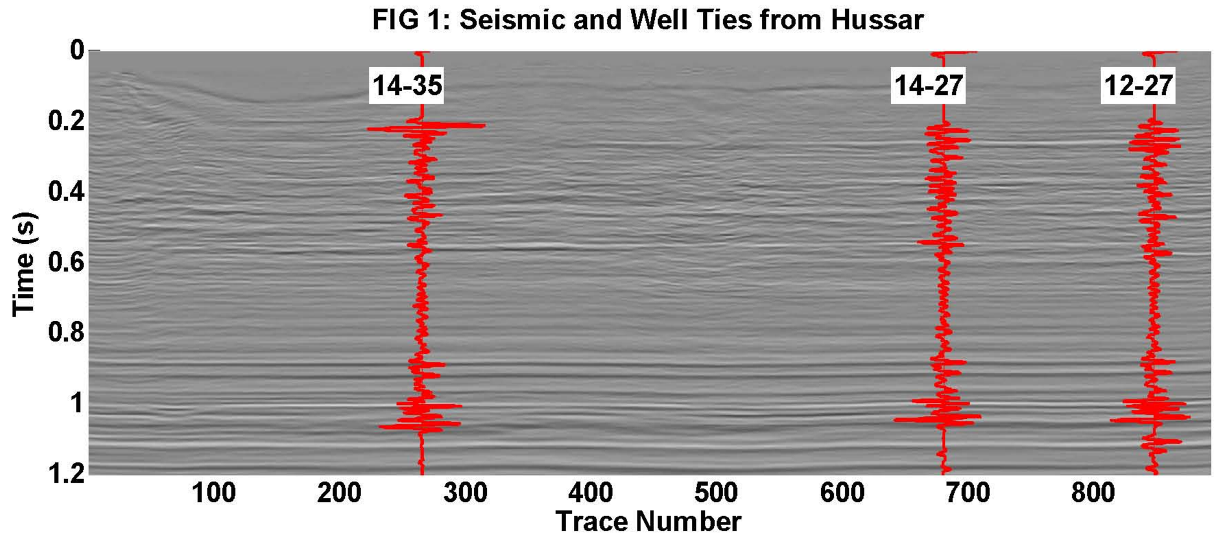


FIG 2a: Trace Reflectivity Polynominal Approximations

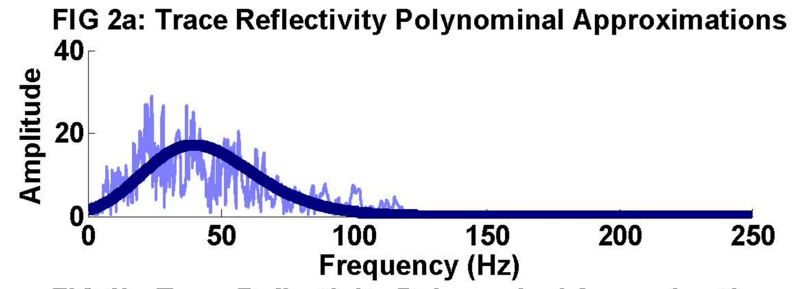


FIG 2b: Trace Reflectivity Polynominal Approximations

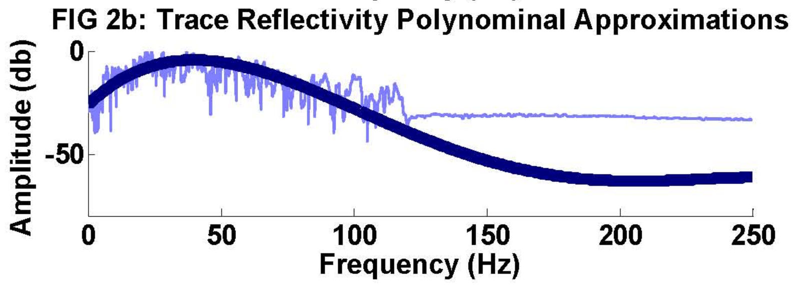


FIG 3a: Well Reflectivity $log_{10}(f)$ Polynominal Approximations

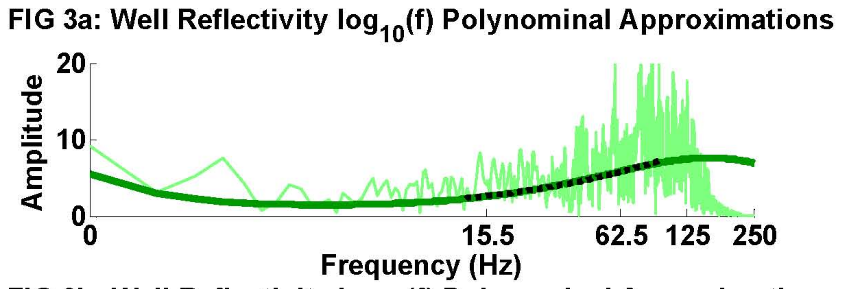


FIG 3b: Well Reflectivity $log_{10}(f)$ Polynominal Approximations

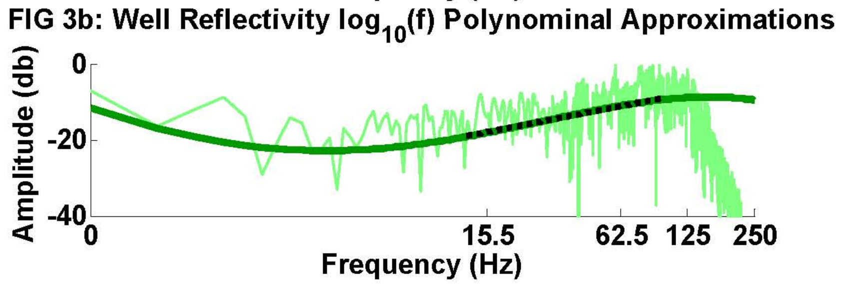


Figure 1 shows the migrated stacked seismic data and well ties from Hussar. To compute colour corrections the trace spectra (wavelet) and well spectra (representing the true reflectivity) need to be estimated. The trace spectra is estimated using a fourth order polynomial that is fitted to the log of the amplitude spectra (figure 2). The well reflectivity is modeled in log frequency space and is a fourth order polynomial fitted to the log amplitude spectra from 0 to 125Hz (Figure 3).

The colour operator is formed by dividing the reflectivity shape by the wavelet. Figure 4 shows this result however the high frequency amplitudes are blown up. An additional low-pass filter must be determined to eliminate the high-frequency instability. Several different filters were tested and the highest frequency filter that still shows stability was determined to be [0 0 80 25], Figure 5. A similar study was done to test the low-frequency cut-off and it was found to be 2Hz.

Colour Operator Amplitude Spectra

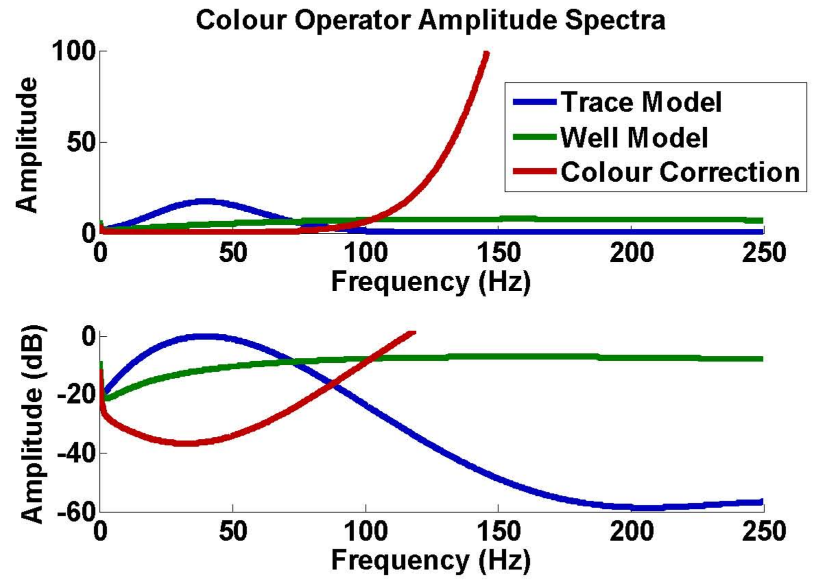
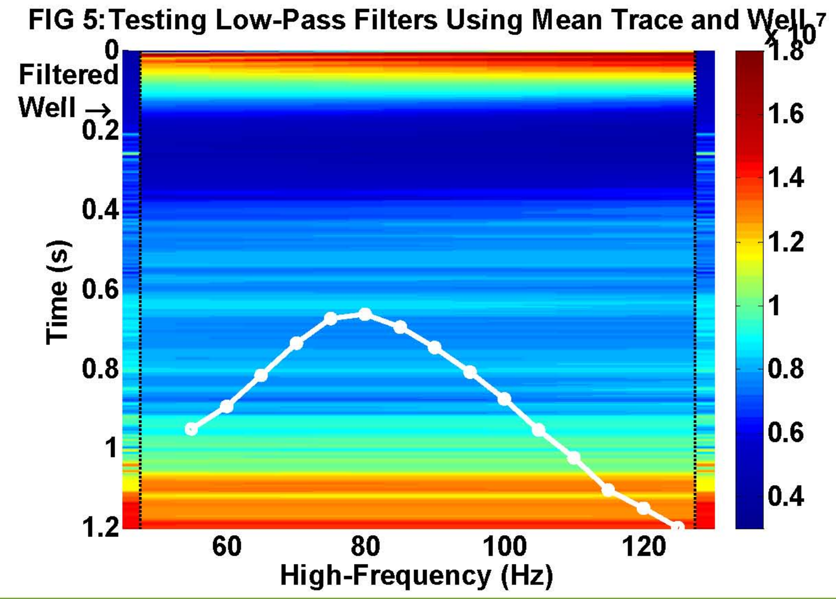


FIG 5:Testing Low-Pass Filters Using Mean Trace and Well



Walden, A.T. and Hosken J.W.J., 1985, An investigation of the spectral properties of primary reflection coefficients: Geophysical Prospecting Volume 33, pp 400-435.

Abstract

When the wavelet is removed from the data during deconvolution the spectrum is often left in a white state. Naturally reflectivity has a roll off in the low frequencies due to cyclical geologic events. It is important that the seismic reflectivity contains this shape.

This study "colours" the seismic data before it is inverted. This requires modeling the trace spectra and the reflectivity spectra from the well. The trace spectra was modeled using a fourth order polynomial that was fit to the log of the amplitude spectra. The well reflectivity was modeled using a fourth order polynomial that was also fit to the log amplitude spectra were the frequency axis was also converted to a logarithmic scale. To create the colour operator the reflectivity model is divided by the wavelet. This result boosted the high frequencies exponentially so a low-pass filter [0 0 80 25] was selected to attenuate the high frequency noise.

The Inversion was then computed using the BLIMP algorithm and a low-frequency cut-off of 2 Hz. The coloured result contained more error during the cross-validation tests therefore better models may be needed to increase the accuracy of coloured inversion.

Colour Operators

FIG 6: Effects of Colour Correction

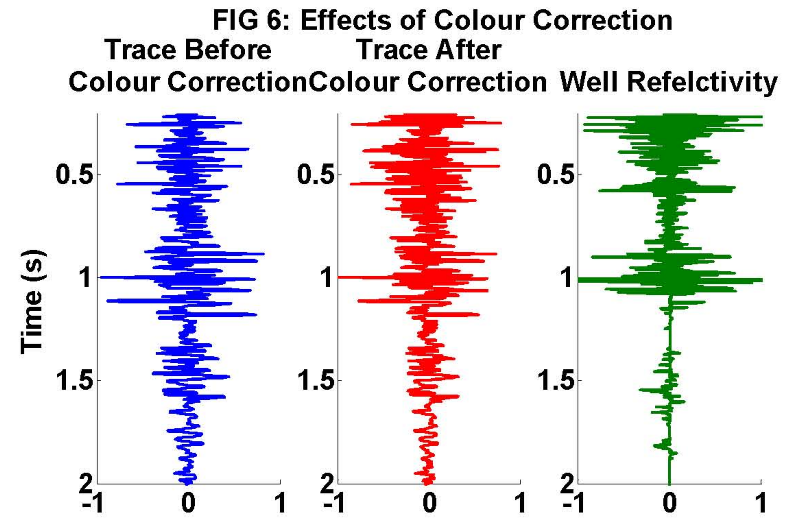


FIG 7: Amplitude Spectra of Coloured Trace

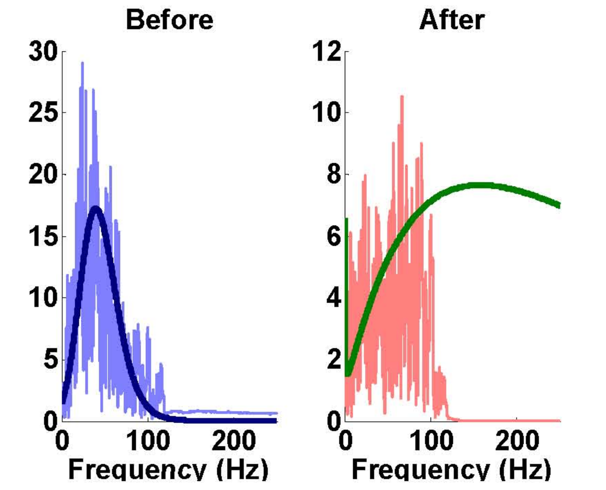


FIG 8: Coloured Seismic and Well Ties

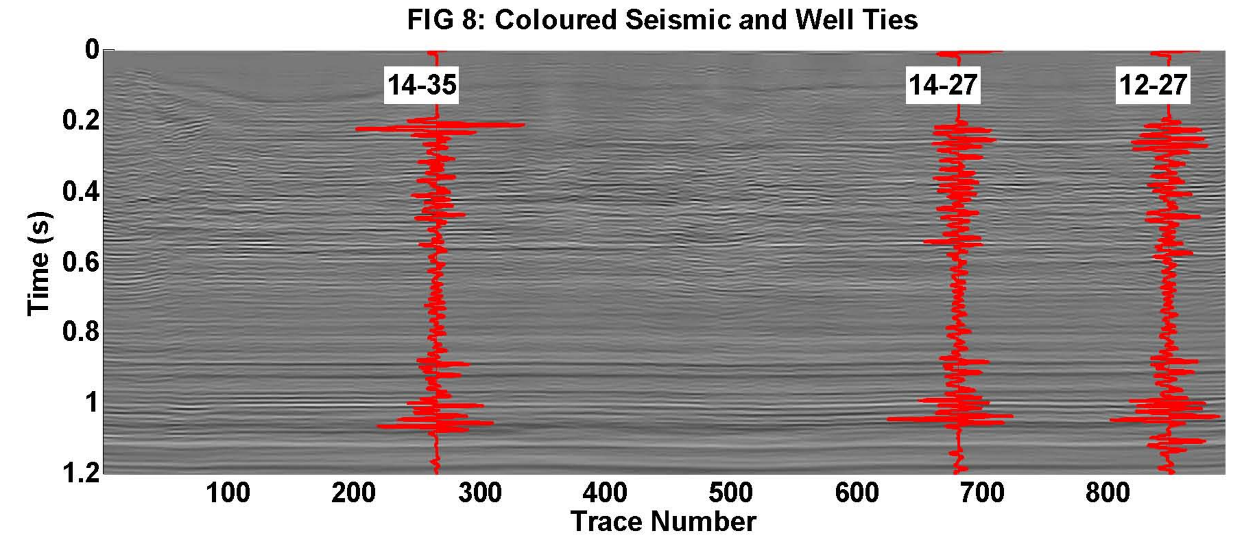


Figure 6 shows the average trace before and after colouring. We can see that the coloured trace is a hybrid of the trace and the well reflectivity. Figure 7 shows how the amplitude spectra has changed. The coloured trace now has low frequencies that have larger amplitudes than before. A similar result can be seen for the high frequencies. Figure 8 shows the coloured seismic section, which visibly contains higher frequencies in the mid section (.2 to .7seconds), than when compared to the non-coloured section in Figure 1.

Inversions

FIG 9: Impedance Inversion using Average Well (F_{low} = 2 Hz)

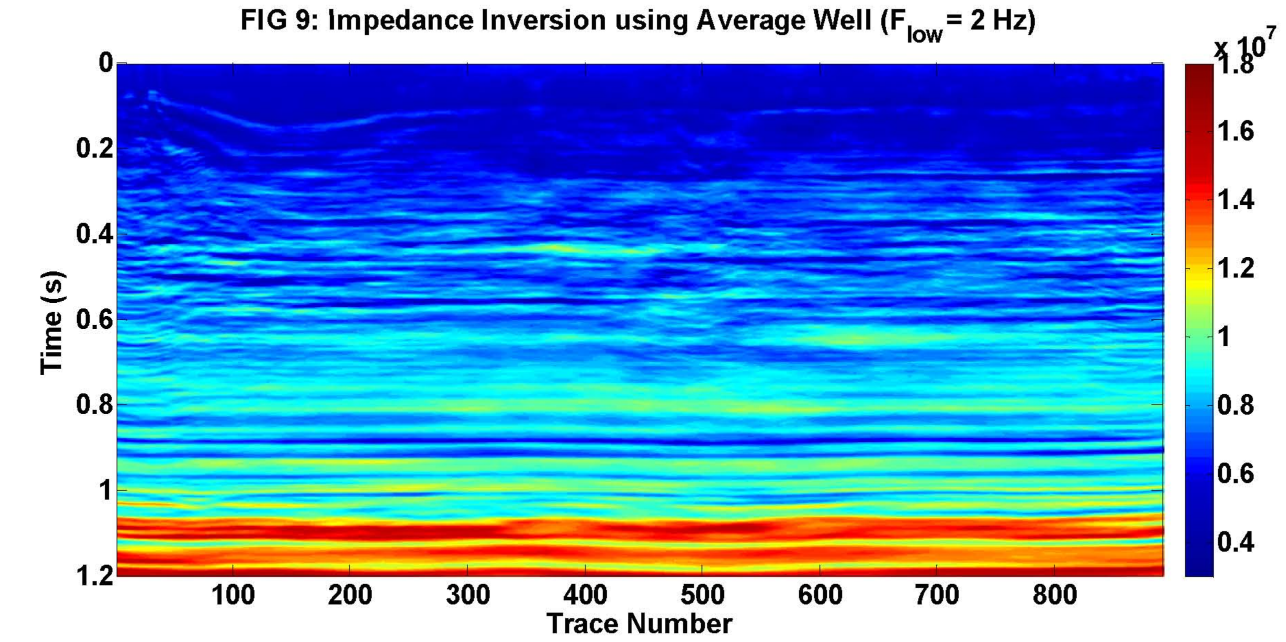
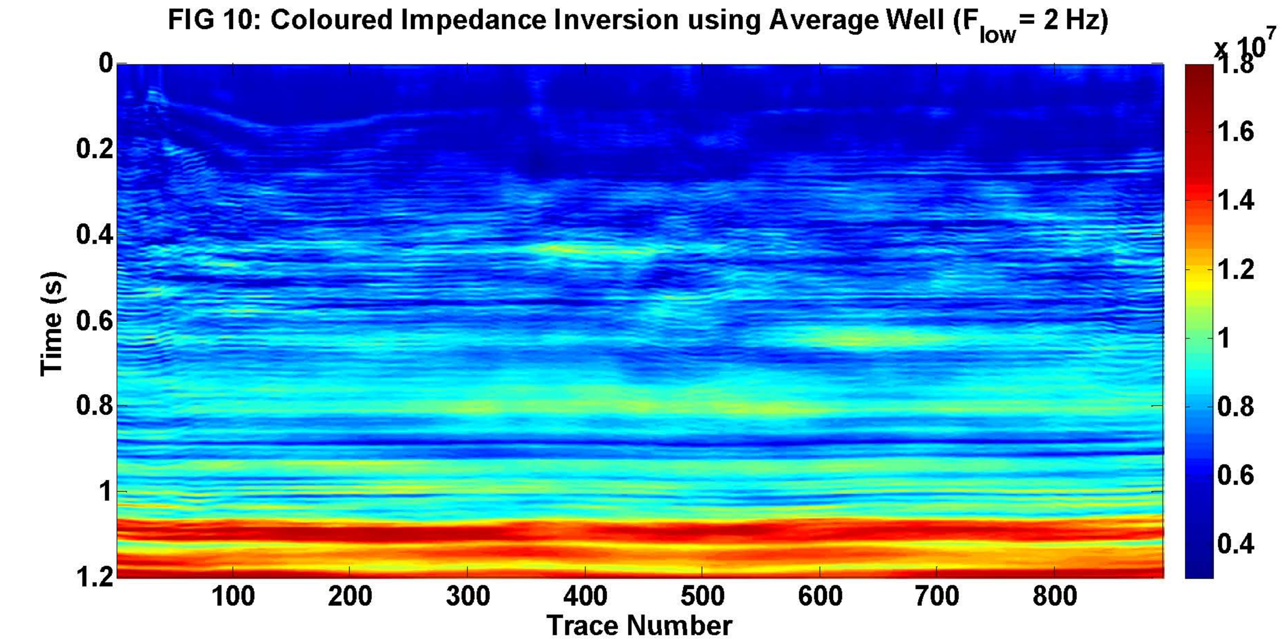


FIG 10: Coloured Impedance Inversion using Average Well (F_{low} = 2 Hz)



The BLIMP algorithm (Ferguson and Margrave, 1996) was used with a low-frequency cut-off of 2 Hz to compute the inversion in Figure 9 and the coloured inversion in Figure 10. The coloured inversion definitely contains more high frequencies although they do appear to be mostly noise.

FIG 11: Average Well Impedance Cross-Validation

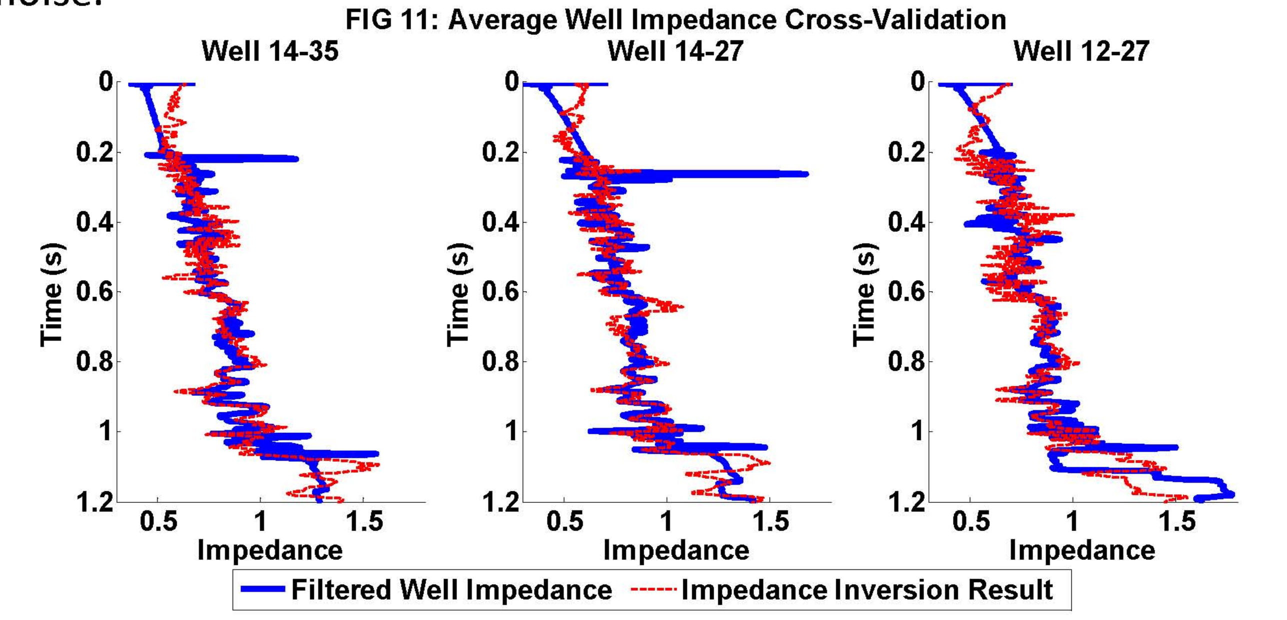


Table 1: Cross-Validation Errors	0-1.2s	0-0.2s	0.2-0.4s	0.4-0.6s	0.6-.8s	0.8-1.0s	1.0 -1.2s
(12-27) Non-Coloured	12.8%	15%	11.9%	13.3%	4.9%	7.2%	24.4%
(12-27) Coloured	14%	18%	13.6%	14.4%	6.4%	7.4%	24.5%
(14-27) Non-Coloured	10.7%	18.7%	12.7%	8.6%	7.6%	7.7%	9.5%
(14-27) Coloured	11.1%	19.9%	12.8%	8.3%	8.6%	7.3%	9.7%
(14-35) Non-Coloured	10.3%	17.7%	12.2%	8.6%	4.8%	6.4%	11.8%
(14-35) Coloured	10.9%	18.5%	13%	9.4%	6%	7.1%	11.2%

Cross-validation tests were used to determine the accuracy of the coloured impedance inversion (Figure 11). Error analysis was done in 200ms windows and the whole trace for both the coloured inversion and the non-coloured inversion (Table 1). The coloured inversion is has a larger percent error than the non-coloured inversion suggesting that further development of coloured inversion is needed.

Ferguson, R. J. and Margrave, G. F., 1996, A simple algorithm for bandlimited impedance inversion: CREWES Research Report, Vol. 8, No. 21.