Why is there a phase difference of -90^o between the seismic data and impedance data obtained after inversion?

The seismic reflections are a measure of the impedance contrast at subsurface rock layer interfaces. Impedance is a layer property. Thus, the impedance data obtained after inversion essentially show layer impedances. In simple terms, the peaks or troughs on an impedance display are depicting layers, and not their edges.

In Figure 1a we show reflection coefficients (in black) corresponding to the top and base of a low-impedance layer. The dashed blue wiggle is what we would get after bandpass filtering the reflection coefficients. In Figure 1b we show the low impedance layer, and the magenta wiggle is the wiggle that one might consider obtained after impedance inversion of the blue trace in Figure 1a. Notice, the minima on the magenta impedance wiggle trough corresponds to the zero-crossing on the dashed blue seismic wiggle. The zero crossing is a quarter-wavelength below the top of the layer. Thus, the trough tracked on the seismic wiggle will be -90^o out of phase with the impedance wiggle.

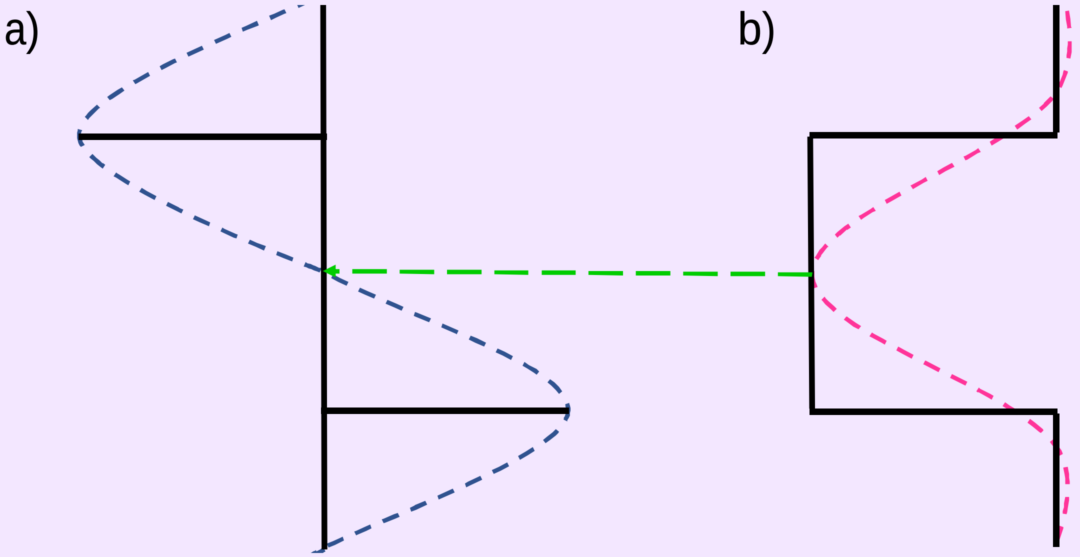

Figure 1: (a) Reflection coefficients representing the top and base of a low-impedance layer (black). The dashed blue wiggle is what we expect from bandpass filtering of the reflection coefficients, neglecting any interference one might expect from the adjacent layers. (b) The low-impedance layer corresponding to the reflection coefficients shown in (a), which may be considered obtained after inversion. The magenta dashed wiggle is the impedance trace and is seen to be out of phase with respect to the seismic wiggle in (a).

This observation is not suggestive of anything wrong with the seismic data or the inverted impedance data. It is just that they both represent different things. In Figure 2 we show a comparison of the segments of

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sections from the seismic amplitude and inverted impedance data volumes. Notice how the seismic horizon (trough) is -90^o off on the impedance section compared with the seismic section.

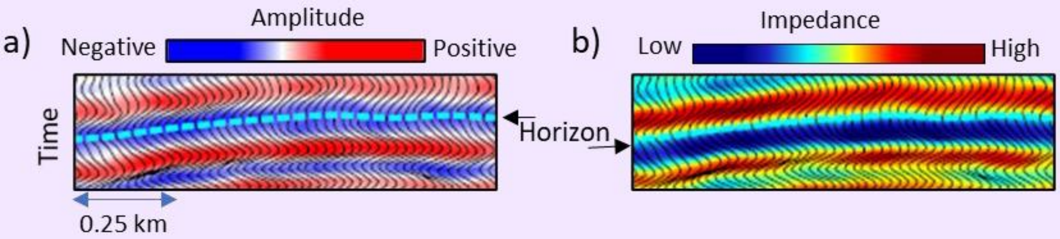

Figure 2: Comparison of segments of sections from (a) seismic, and (b) impedance data. Notice the phase difference of 90^o between the two sections.

Mathematically, the reflection coefficients are defined as the rate of change of impedance contrast. For normal incidence, the reflection coefficient R at the jth interface is given as

$$R_j = \frac{Z_{j+1} - Z_j}{Z_{j+1} + Z_j}$$

where Z_{j+1}, and Z_j are the acoustic impedance in the $(j+1)^{th}$ layer and j^{th} layer respectively. If the vertical changes in impedance are reasonably smooth, we can approximate

$$R_j \approx \frac{\Delta Z_j}{2Z_j} = \frac{1}{2}\frac{\partial}{\partial t}[lnZ].$$

The differential operator is associated with a phase change of -90^o.

Thus, the observed phase difference (-90^o) can be explained both graphically and mathematically.

- Satinder Chopra and Kurt Marfurt