Short note: A proposed polarity check for multi-component seismic data

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ABSTRACT

The issue of polarity is deceptively simple, and prior to joint AVO inversion (amplitude variation with offset) the correct polarity of the PP and PS data must be considered. An AVO inversion of compressional data (PP inversion) can provide a good P-impedance estimate, and an AVO inversion of converted shear data (PS inversion) can provide a good S-impedance estimate. This fact is used to propose a polarity check for compressional and converted shear data.

INTRODUCTION

The SEG polarity standard is a positive amplitude (peak) on a PP section indicating a P-impedance increase, whereas a positive amplitude on a PS section indicates an increase in the S-impedance (Thigpen et al. 1975). Since the SEG acquisition polarity standard was formulated in terms of single-component surface seismic conventions, it did not explicitly make provision for the horizontal-component geophones (Brown et al., 2002). Also, the polarity of the input data to an AVO inversion needs to conform to the Zoeppritz equations and not necessarily the SEG standard. Therefore, the issue of polarity is deceptively simple; and prior to joint AVO inversion we need to make sure that the correct polarity of the PP and PS data is considered.

Mahmoudian and Margrave (2003) showed that a good P-impedance (I) estimate is expected from AVO inversion of compressional (PP) data alone, and a good S-impedance (J) estimate is expected from the AVO inversion of converted shear (PS) data alone. This leads to a decision regarding the correct polarity of the PP and PS data.

POLARITY CHECK

In AVO inversion the amplitudes of compressional and converted shear surface seismic data are inverted both separately and jointly to yield estimates of the physical properties. These physical properties can be P-impedance, S-impedance, and density, or P-impedance and S-impedance using a constraint for the density term. The AVO inversions including PP, PS and joint (PP and PS) inversions are outlined in Mahmoudian and Margrave (2003). Using Smith and Gidlow (1987) weighted stacking methods, they showed that the compressional data contributes dominantly to the P-impedance estimate in the joint inversion, compared to the shear converted data; similarly, converted shear data contributes dominantly to the S-impedance estimate in the joint inversion, compared to the compressional data.

Margrave et al. (1999) and Zhang and Margrave (2003) showed that the joint AVO inversion is significantly more accurate than PP inversion. Mahmoudian and Margrave showed that joint inversion is more accurate than PP or PS inversion (especially for noisy datasets). Nevertheless, the PP inversion can provide a good P-impedance estimate (comparable to the joint inversion estimate) and PS inversion can provide a good S-impedance estimate (comparable to the joint inversion estimate). This can force a choice of polarity for both the PP and PS data. A simple rule for checking the correct PP and PS polarity is presented as follows:

1. Prepare the PP inversion and examine the P-impedance estimate.

2. Compare the P-impedance estimate to the estimate from the well control. Change the PP polarity to match the well, if necessary.

3. Prepare the PS inversion and examine the *J* estimate.

4. Compare the *J* estimate to the estimate from the well control. Change the PS polarity to match the well, if necessary.

The proposed polarity check is tested before the joint AVO inversion of a walkaway VSP data from Red Deer Alberta.

POLARITY CHECK; TESTING

Figure 1 shows a schematic of a walkaway VSP near Red Deer, Alberta. Figures 2 and 3 show the PP and PS reflection data from the VSP, in depth. The required PP and PS data (extracted from the VSP survey) for an AVO inversion are the deconvolved upgoing wavefields in two-way-time. For a detailed explanation of VSP AVO inversion see Mahmoudian (2006). These VSP data were acquired at the Cygnet 9-34-38-28W4 lease located northwest of Red Deer, Alberta, by Suncor Energy Inc. and Alberta Research Council. The four walkaway shot points east of the borehole were at the following offsets: 100 m, 150 m, 191 m, and 244 m from the borehole (Figure 1). Data were acquired between 294.5 m and 114.5 m at 15 m intervals for the walkaway VSPs (Richardson, 2003).

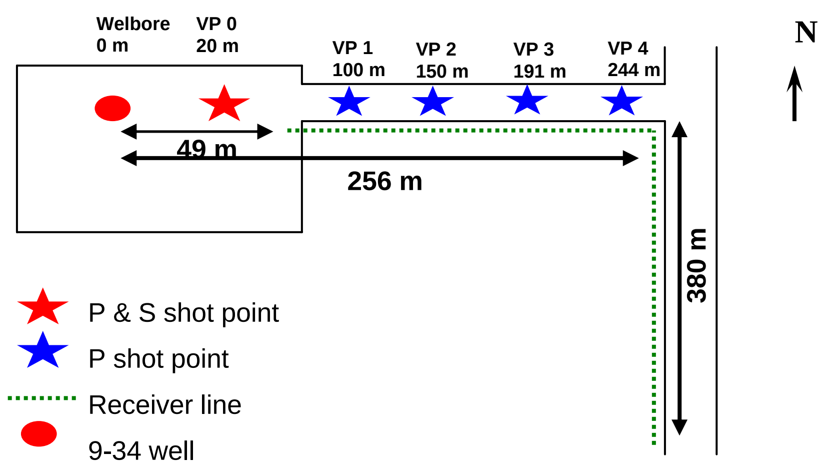

FIG 1. Survey geometry for zero-offset and walkaway VSP surveys acquired on the Cygnet 9-34 lease. Zero-offset sources were located at VP0. Walkaway sources were located from VP1 to VP4 (courtesy of Richardson, 2003).

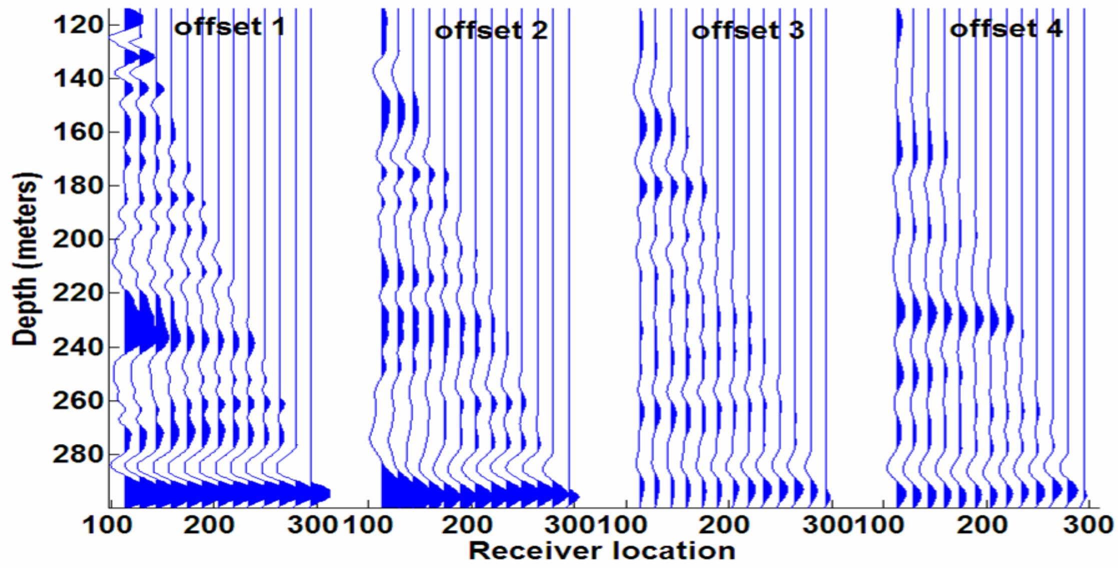

FIG. 2. PP data (deconvolved upgoing PP wavefield) at the four walkaway offsets in depth.

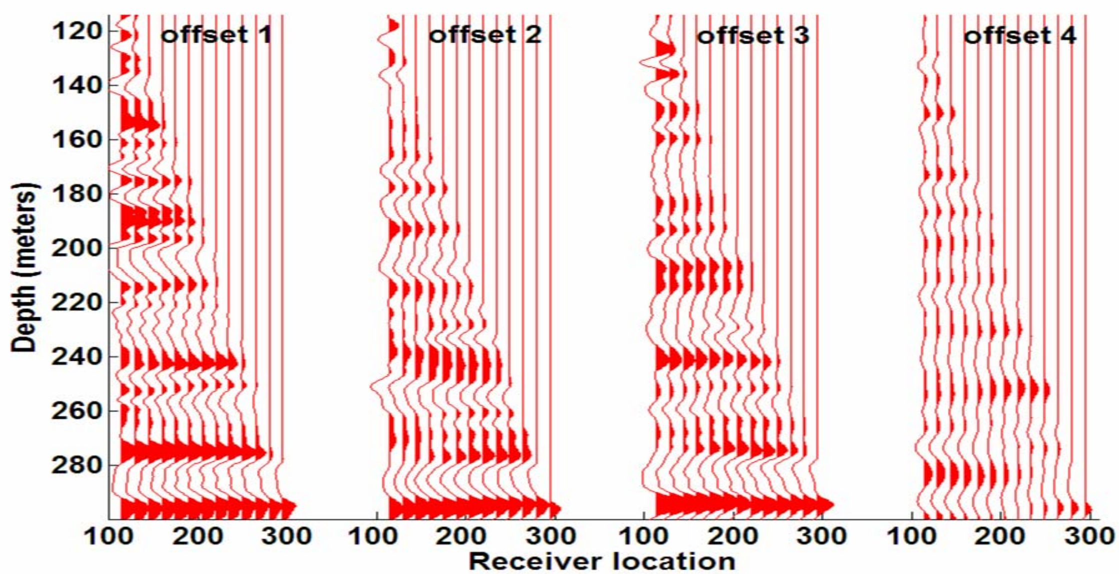

FIG. 3. Deconvolved upgoing PS wavefield at the four walkaway offsets in depth.

The polarity of the input PP and PS datasets prior to the AVO inversion was checked to ensure that they had the correct polarity. The following is an example of the polarity analysis for the walkaway offset 1 datasets. The I estimate from PP inversion correlates well to the I estimate from the well log, (Figure 4). However, there is no correlation between the J estimate from the PS inversion and the J estimate from well logs

(Figure 5). Therefore, for the offset 1 data the PS polarity is reversed. The PS inversion of reversed polarity shows a good correlation for the *J* estimate (Figure 6). Examining the PP and PS inversion for each individual walkaway offset data, the polarity of the PS data at offset 1 to offset 3 was reversed while the polarity of PP data from all walkaway offsets was correct.

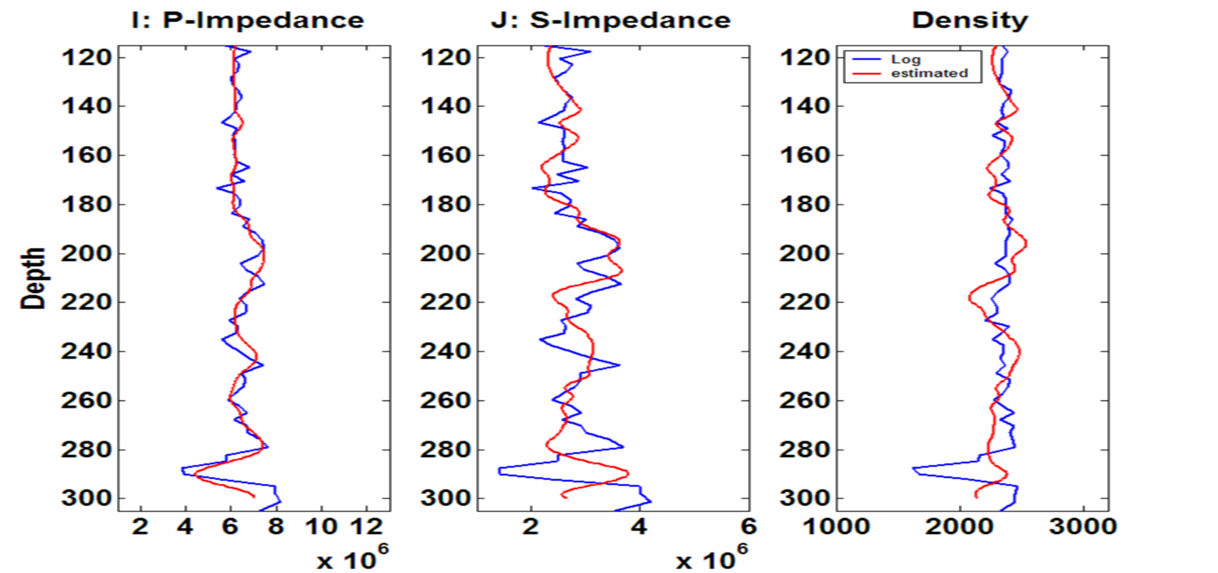

FIG. 4. PP inversion of PP data from walkaway offset 1. Note that the *I* estimate (red) correlates well to the log estimate (blue).

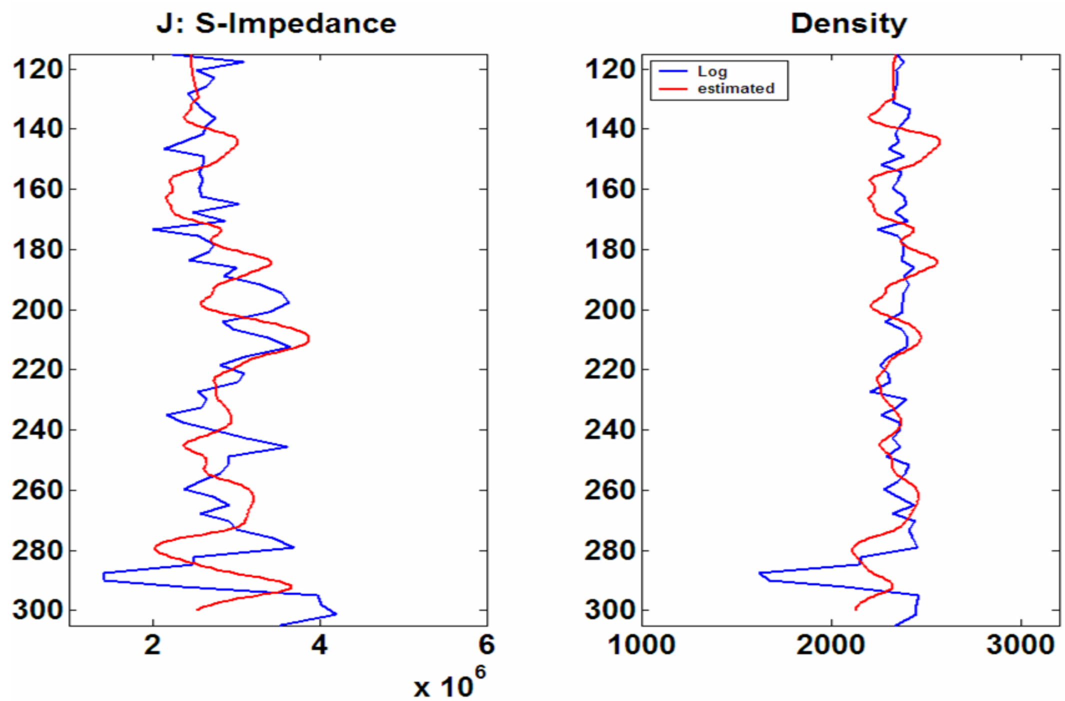

FIG. 5. PS inversion estimates, for *J* and *ρ*, from the walkaway offset1 data. Note the *J* estimate (red) doesn't correlate to the log estimates (blue).

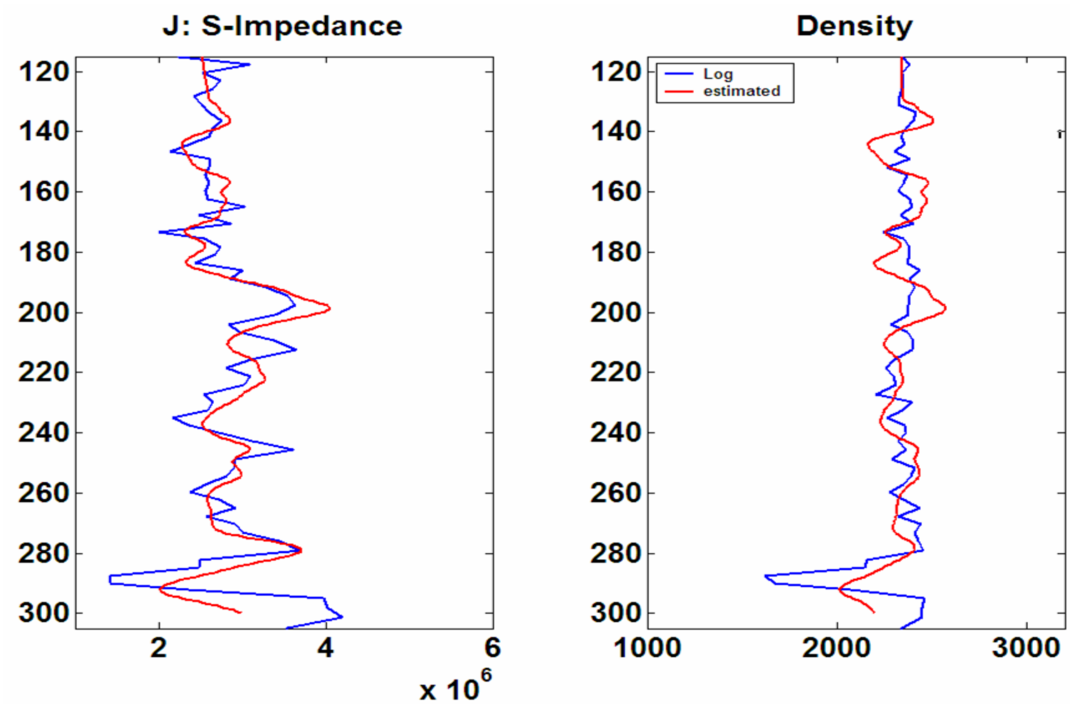

FIG. 6. PS inversion estimates, for *J* and *ρ*, from reversed PS data of walkaway offset 1. Note that the *J* estimate (red) correlates well with the log estimate (blue).

CONCLUSION

A polarity check is recommended during joint AVO inversion, due to the fact that even with a flipped polarity for one of the datasets, the joint inversion still shows a reasonable result.

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