Azimuthal anisotropy in isotropic heterogeneous elastic model and anisotropic homogeneous equivalent

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ABSTRACT

In this study, we compared a 3D finite-difference elastic modeling of an isotropic heterogeneous elastic model with a 3D finite difference anisotropic modeling of an anisotropic homogeneous equivalent model in order to verify the suitability of these two modeling approaches for anisotropic studies. We focused on reflection amplitude and interval traveltime comparison of these two models. Although, geophysicists often prefer to use anisotropic homogeneous equivalent models for various seismic modeling and imaging tasks, there are however some benefits of using heterogeneous models over anisotropic homogeneous equivalent models. We show that the anisotropic equivalent modeling predicts strong interbed multiples and multimodes which are much weaker in the heterogeneous elastic model. This is because a heterogeneous medium will cause irregular scattering of multiples and multimode events, thus diminishing these events. Both modeling results reveals AVAZ signatures which shows more significant azimuthal variations in the elastic model than in the equivalent model. Also, we investigated the effect of offset on PP and PS azimuthal anisotropy from the two HTI models with the aim of using the modeling results as guidance in seismic data application. AVAZ analysis shows that the major axes of the radial-component PS-wave amplitude elliptical fit are perpendicular to the fracture strike, which is opposite to the PP-wave amplitude elliptical fit whose major axes are parallel to the fracture strike. In general, homogeneous equivalent models have a tendency to amplify multiples and mode conversions than heterogeneous elastic models, and may further degrade interpretations.

Modeled Raw Dataset

The numerical modeling results generated from using isotropic heterogeneous elastic model and anisotropic homogeneous equivalent model is shown in figure 1. The vertical dataset of the equivalent model is noisier and shows amplified multiples and multimode events compared to the elastic modeling. We also notice that the finite-difference generates shear waves at the source which further contaminate the results from the equivalent modeling.

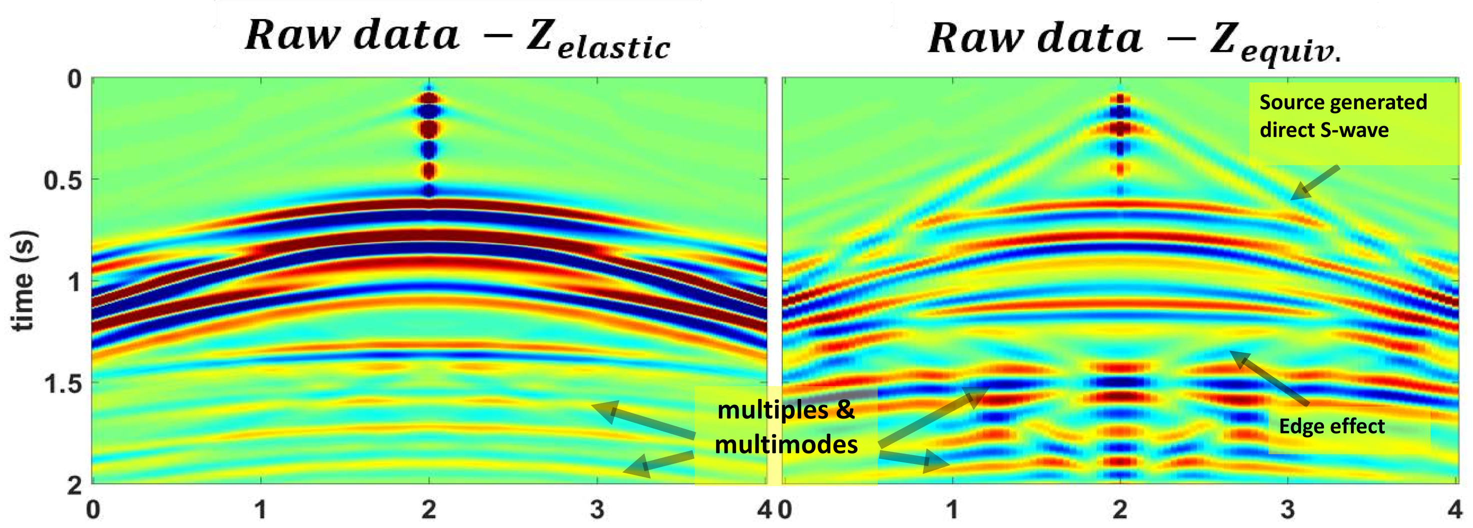


Fig. 1a. Z-component raw shot record.

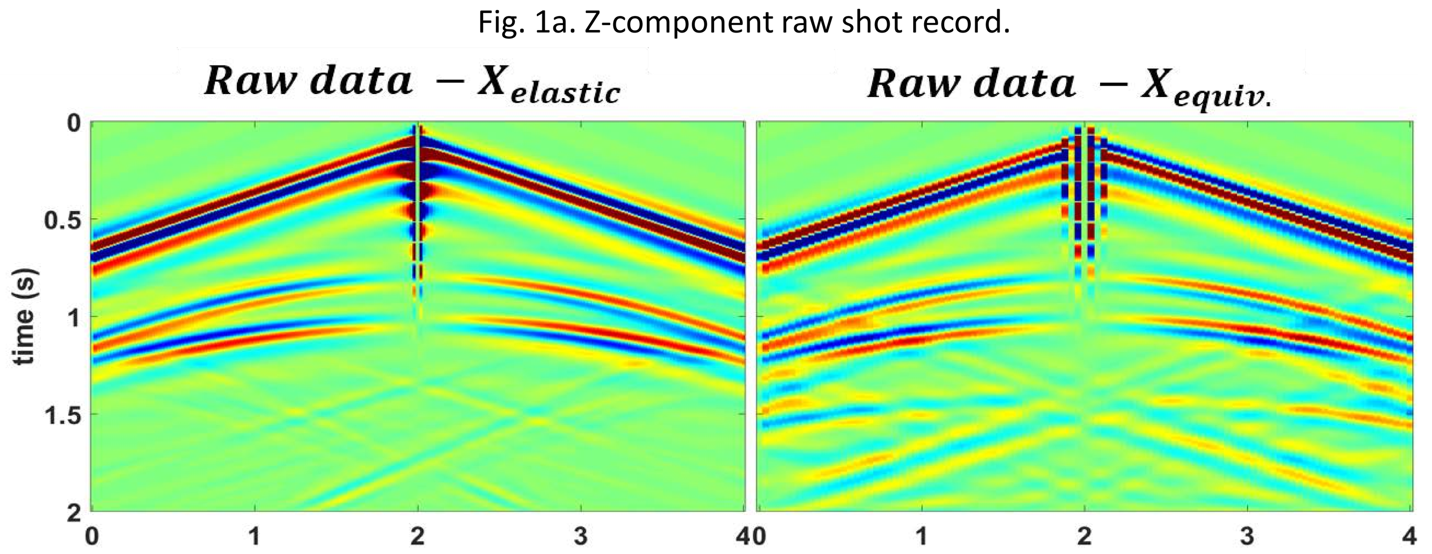


Fig. 1b. Horizontal X-component of raw shot record

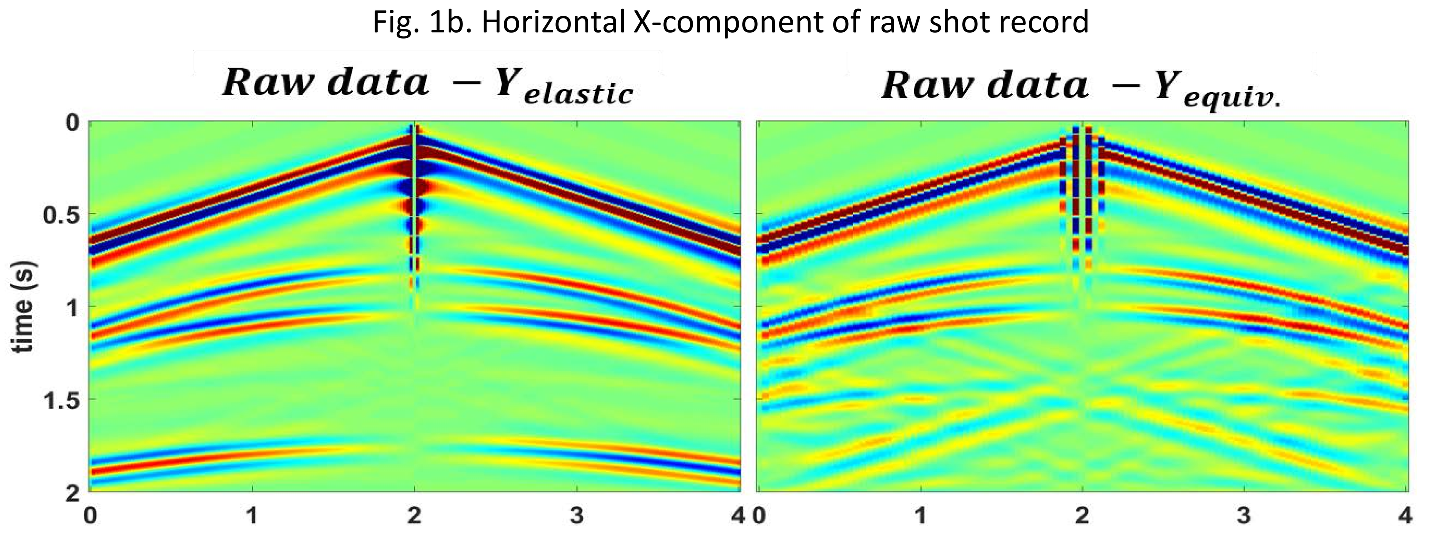


Fig. 1c. Horizontal Y-component of raw shot record

Radial and Azimuthal Scan

Figure 2 and 4 show the radial and azimuthal scans. After applying a bandpass filter to the raw datasets, the filtered datasets were then rotated into ZRT components. We then applied a 2D linear interpolation at every time-slice and transformed the dataset from its acquisition domain to the offset-azimuth domain for further amplitude/time picking analysis and interpretations. Figure 2 shows that equivalent modeling amplifies multiples and multiple-conversion events.

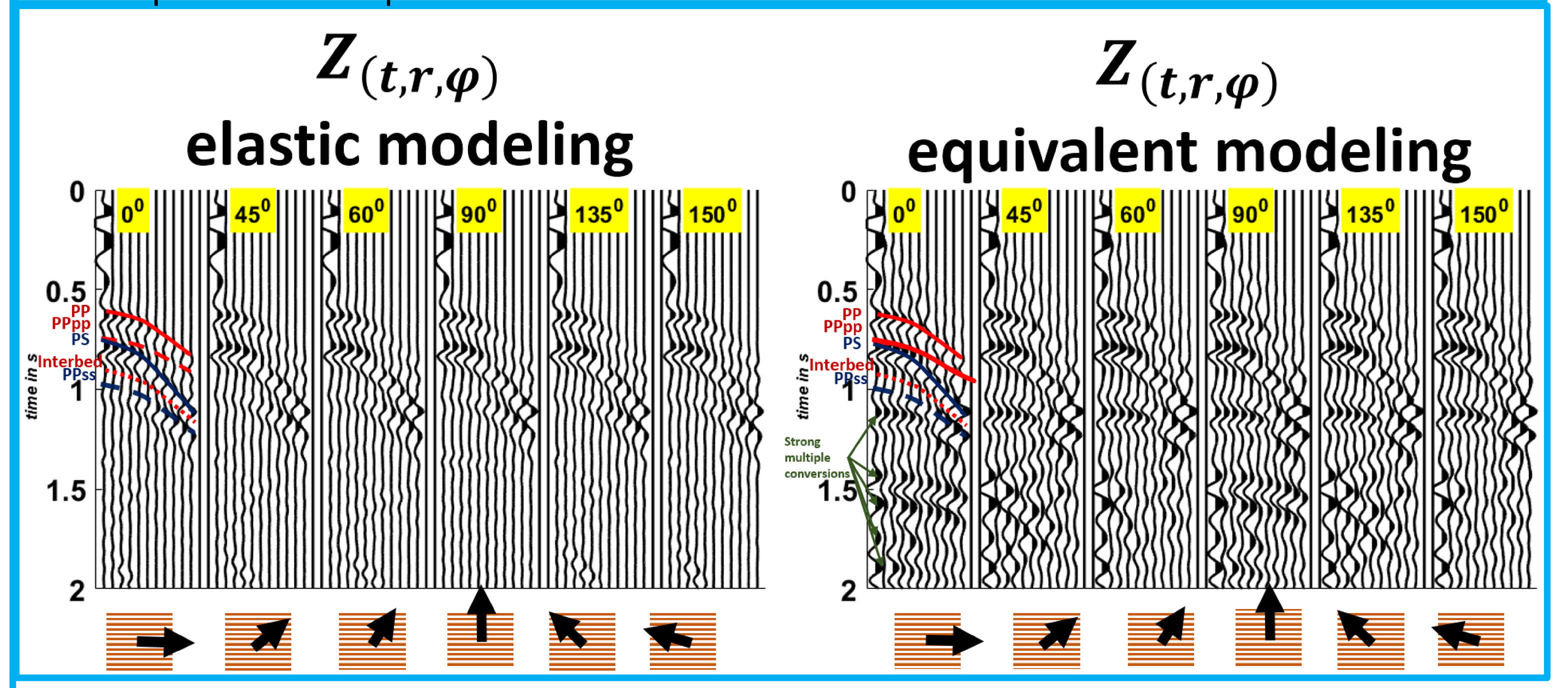


Fig 2a: Z component- radial scans at various fixed azimuths. The yellow labels are the azimuthal values in degree.

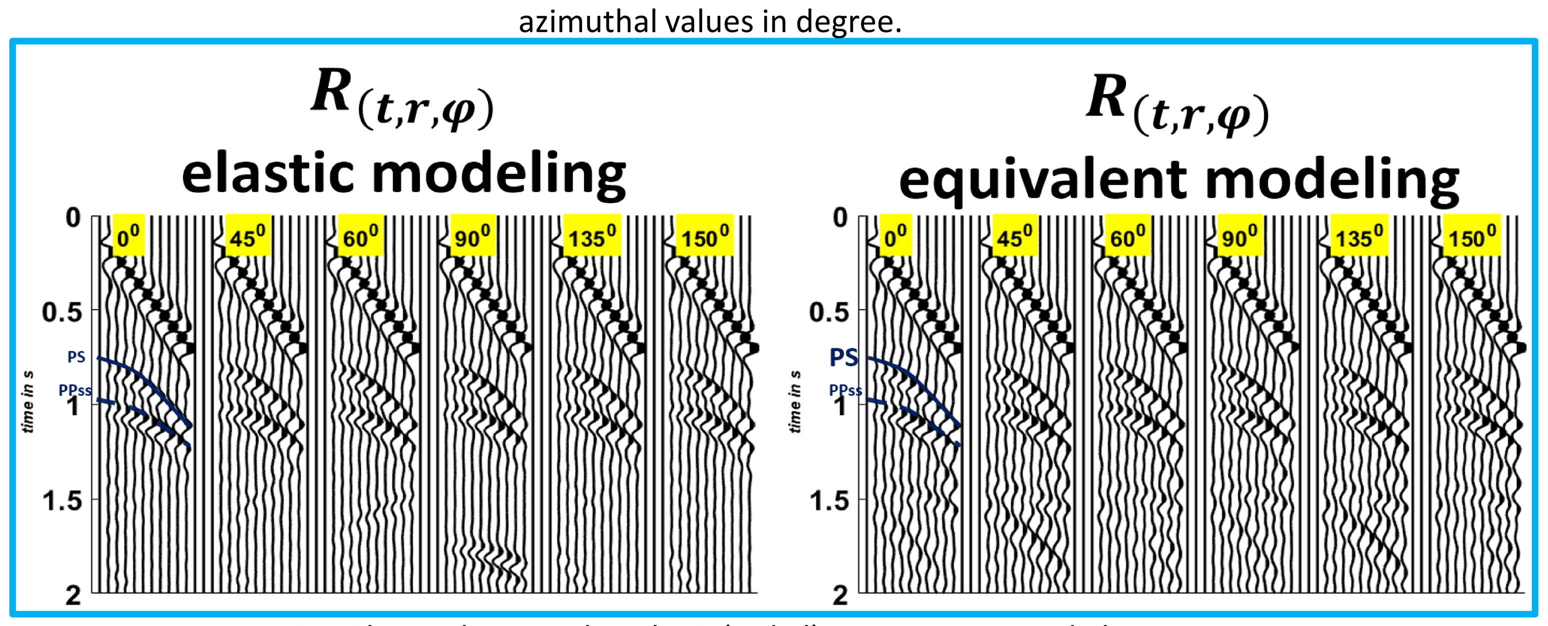


Fig. 2b. Similar to 2a but the R (radial) components - radial scans.

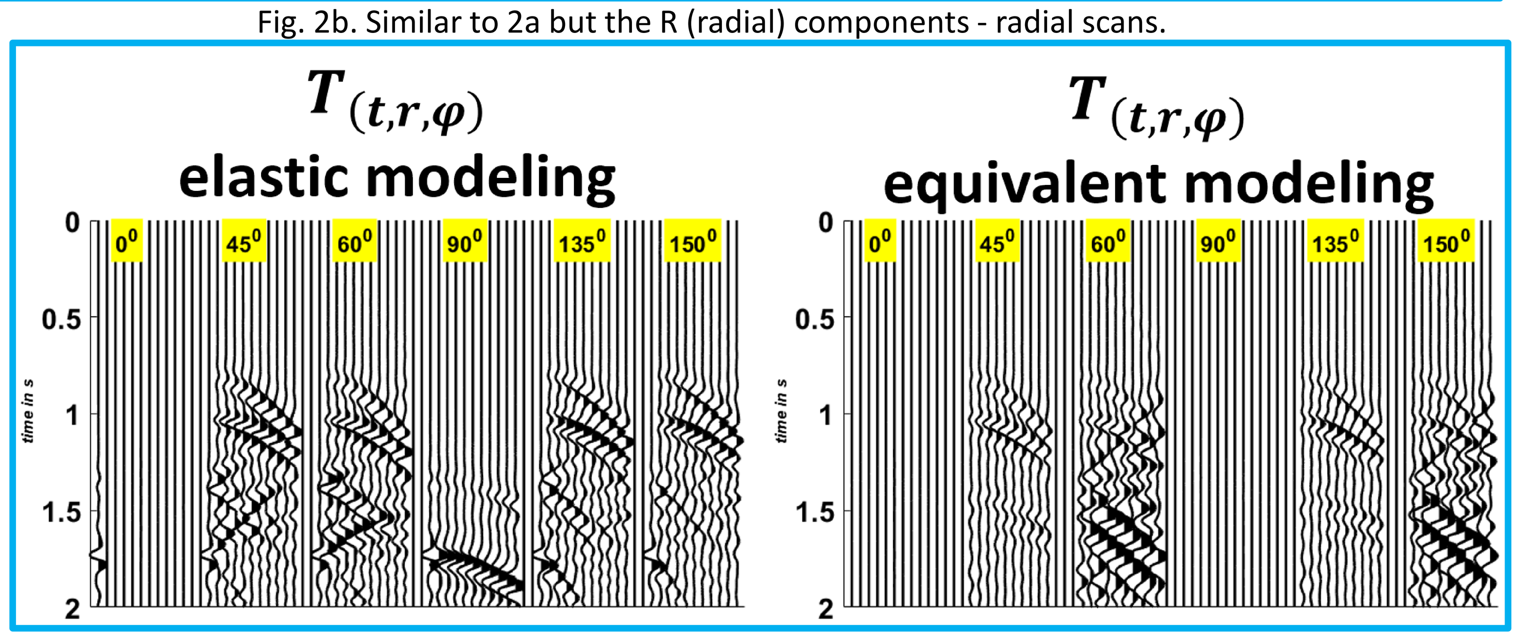


Fig. 2c. Similar to 2a but the transverse T component- radial scans

AVOAZ analysis

Figure 3 shows the 2D scans of the vertical, radial and transverse components recorded from the top of the HTI reflector. The azimuthal amplitude behavior is much earlier in offset in the radial and transverse component(figure 3b and 3c) compared to the vertical scan PP panel (figure 3a). Also the elastic modeling shows clearer offset-azimuth behavior than equivalent modeling.

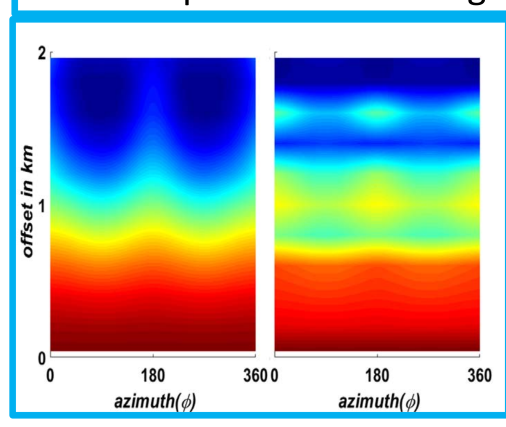
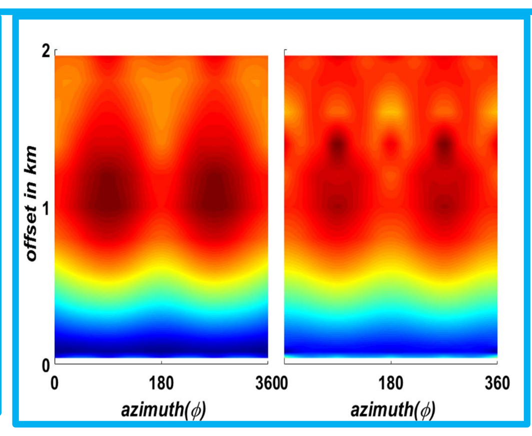
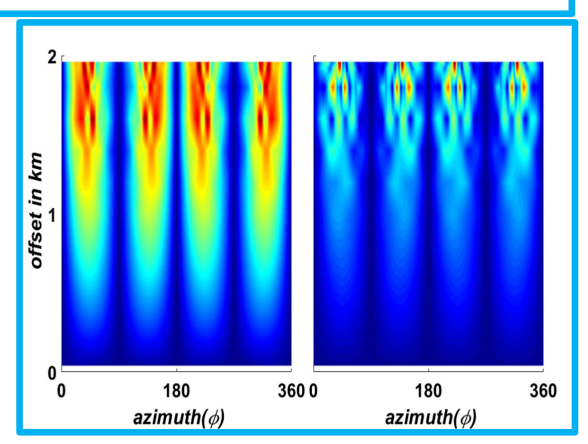


FIG. 3a. PP refl. from HTI top, elastic (left), equivalent. (right).



(3b). PS-Radial, elastic (left), equivalent. (right)



(3c). PS-Transverse, elastic (left), equivalent. (right)

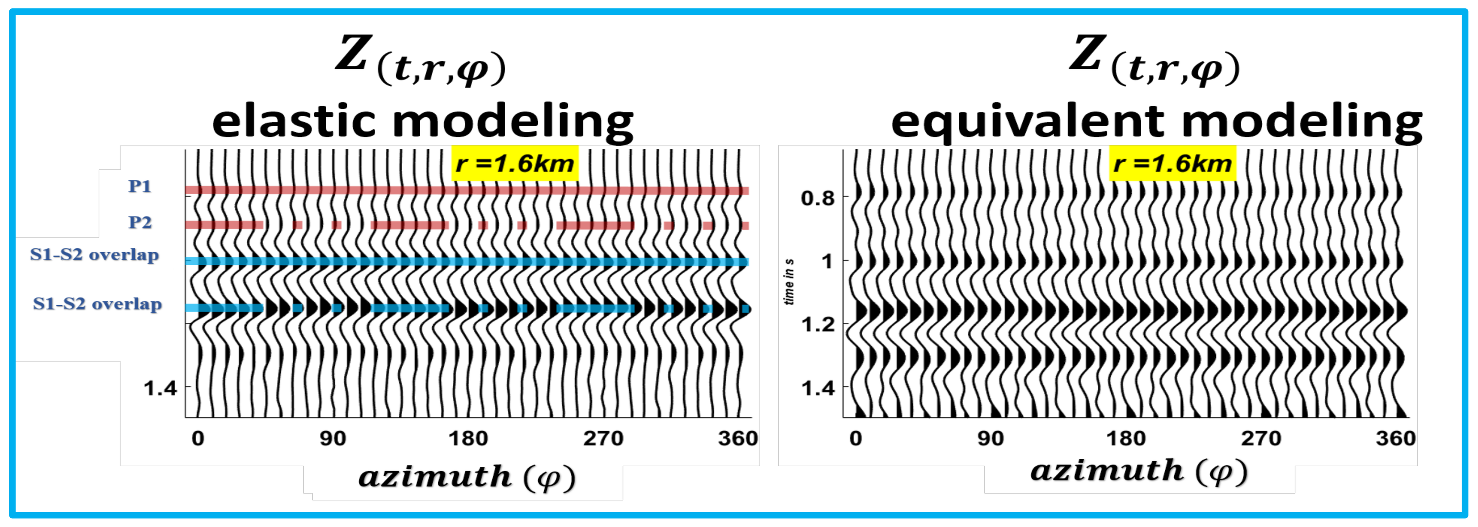


Fig 4a: Z- component azimuthal scans at source-receiver constant offset of 1.6km. The yellow labels are the azimuthal values in degree.

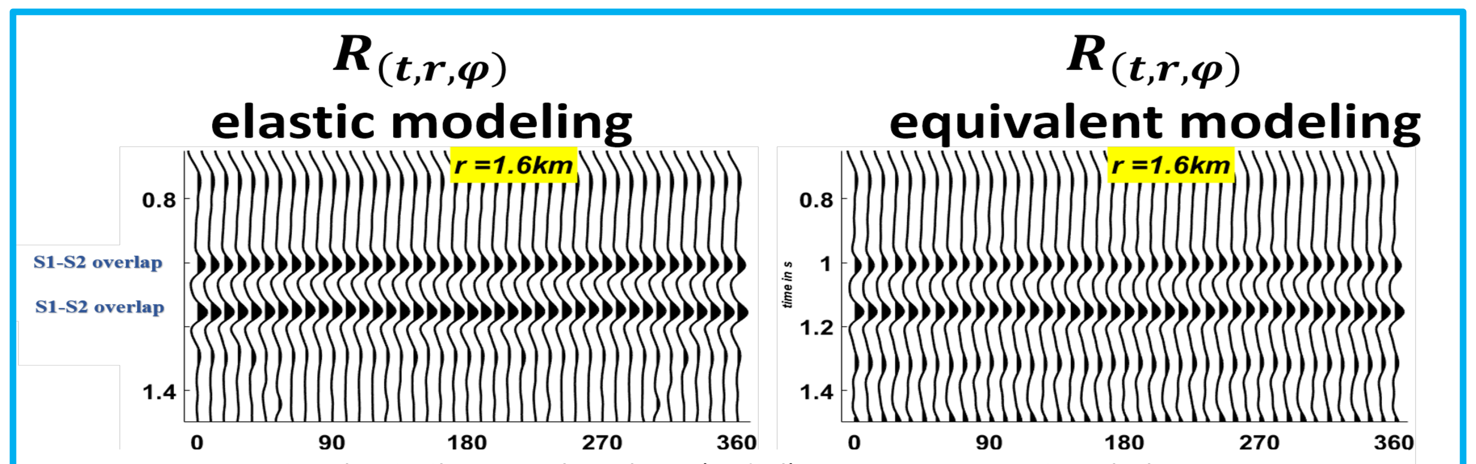


Fig. 4b. Similar to 4a but the R (radial) components – azimuthal scan.

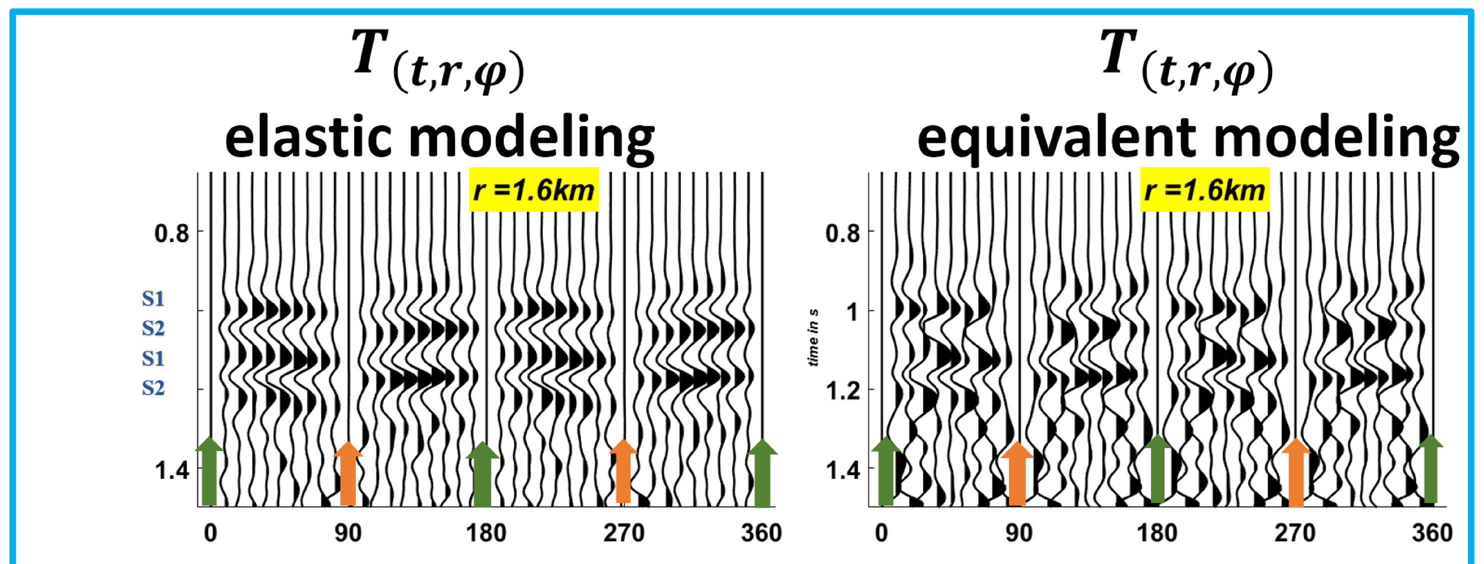
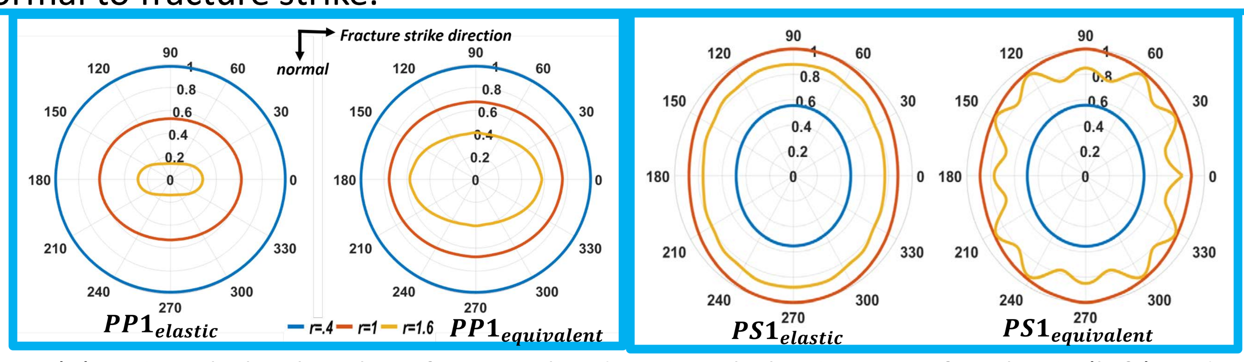


Fig. 4c. Similar to 4a but the T component- azimuthal scan.

AVOAZ analysis(cont.)

Given three different offsets (0.4, 1, and 1.6km) for example in figure 5, Both elastic modeling dataset and equivalent modeling dataset show coherence in its diagnosis of fracture orientation, i.e. the major axis of the P-wave amplitude azimuthal anisotropy in both models point in the direction of strike while the major axis of the PS amplitude anisotropy in both models are in the direction normal to fracture strike.



(5). Azimuthal polar plot of PP amplitude azimuthal anisotropy for elastic (left) and equivalent modeling (right), and PS amplitude azimuthal anisotropy from top of HTI layer

Conclusion

We have explored the differences in seismic responses from an isotropic heterogeneous elastic model and from an anisotropic homogeneous equivalent model. We observed that both model give similar results however the homogeneous equivalent modeling is susceptible to strong multiple and multimode interferences which are attenuated in heterogeneous models due to layering and irregular scattering effect caused by lateral heterogeneity. We infer that in some circumstances modeling using heterogeneous elastic models might be of higher processing and imaging value than with equivalent media.

Acknowledgements

This work was funded by CREWES industrial sponsors and NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 461179-13. I gratefully acknowledge Faranak Mahmoudian, Kevin Hall, and Raul Cova for their assistance.