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Seismic Modelling of in Viscoelastic Medium

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Summary

Synthetic seismograms have been computed at the surface of a three layered earth model in which the second layer is viscoelastic. The differences from the classical case have been brought out.

Introduction

When a seismic experiment is conducted, e.g., for discovering geological situations that favor oil accumulation, the seismic wave propagation takes place in a real earth. The amplitudes and travel times of seismic waves are influenced by a number of effects, e.g., frequency dependent attenuation due to anelasticity of earth materials, propagation porous media containing fluids, anisotropic nature of media, wave scatterring caused by a number of inhomogenieties, etc. besides energy partitioning at the lithological boundaries. For interpreting recorded seismograms, assumption of wave propagation through ideal elastic solids oversimplifies the problem. For a more realistic interpretation, the assumption of ideal elasticity should be dropped and replaced with appropriate models that take into account anelastic behavior and presence of fluids in pore spaces of subsurface rocks. In this work a three layer earth model has been considered wherein the middle layer is composed of an attenuating medium and enclosed between elastic media. Reflection coefficients of P-waves reflected from the top and bottom of the attenuating layer have been computed as functions of angle of incidence and compared with the case when the middle layer is elastic. Synthetic seismograms have also been computed simulating an AVO situation. The results have been compared with those obtained for the elastic case.

Results

Model parameters are given in Table I. Fig. 1 shows the model with raypaths of incident and reflected waves. The attenuating layer is characterized by Q_p and Q_s that are not dependent on frequency. The viscoelastic behavior of this layer has been modeled as a standard linear solid. Following Aki and Richards (2002) the seismic wave velocities are taken as frequency dependent to account for causal absorption. The frequencies used in this work extend over 0-100Hz that is most common in seismic prospecting. The frequency dependent behavior follows Eq.(27) of Toverud and Ursin (2005) for the standard linear solid.

Table 1: Model parameters

Layer No.	P-wave velocity (m/s)	S-wave velocity (m/s)	Density (gm/cm^3)	Q_p	Q_s	Depth (m)
1.	3600	1900	2.70	-	-	1000
2.	4700	2460	2.66	80	50	100
3.	3600	1900	2.70	-	-	Half space

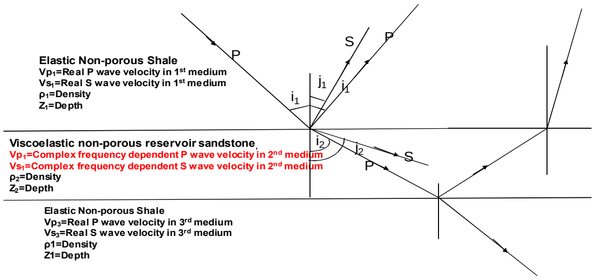

Fig 1:Three layer model used for our experiment

This variation of velocity with frequency is shown in Fig. 2. Using Zoepprtiz equations reflection coefficients and resulting amplitudes on the free surface have been computed for each frequency and the reflected seismic wavelet has been synthesized. This process has been carried out for the top and bottom of the attenuating layer. Due to viscoelastic nature of the middle layer, reflection coefficients are complex at all incidence angles. Only the real parts of these coefficients have plotted versus angle of incidence and shown Fig. 4 along with the variation for classical case.

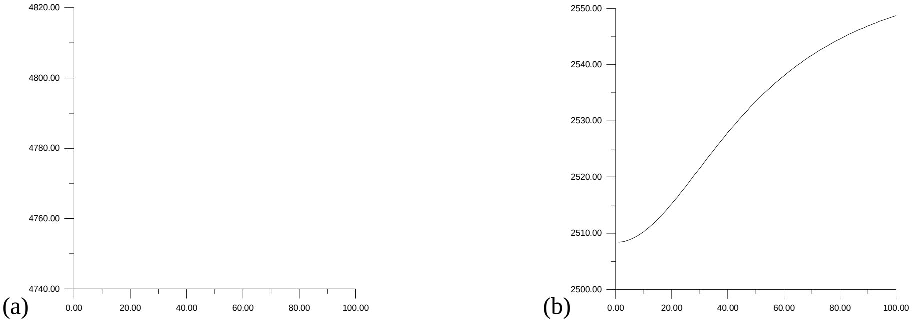

Fig 2: (a) Variation of P-wave velocity with frequency;(b)variation of S-vawe velocity with frequency.

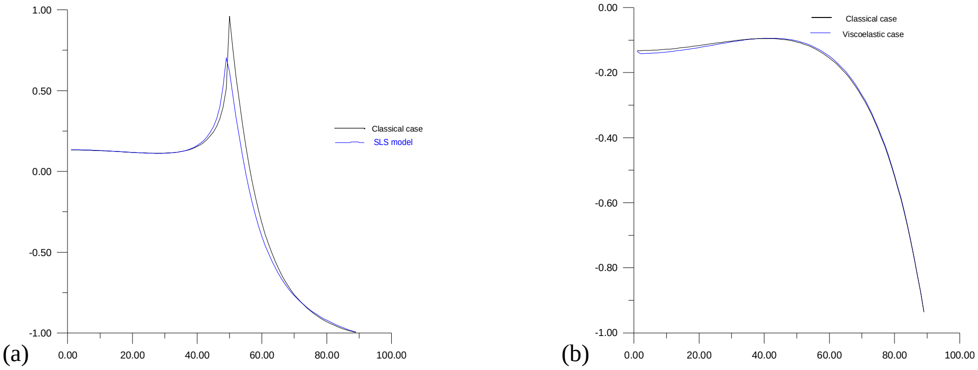

Fig 3: (a) Variation of reflection co-efficient with angle of incidence along with classical case for first interface; (b) Variation of reflection co-efficient with angle of incidence along with classical case for second interface. The frequency is 50 Hz.

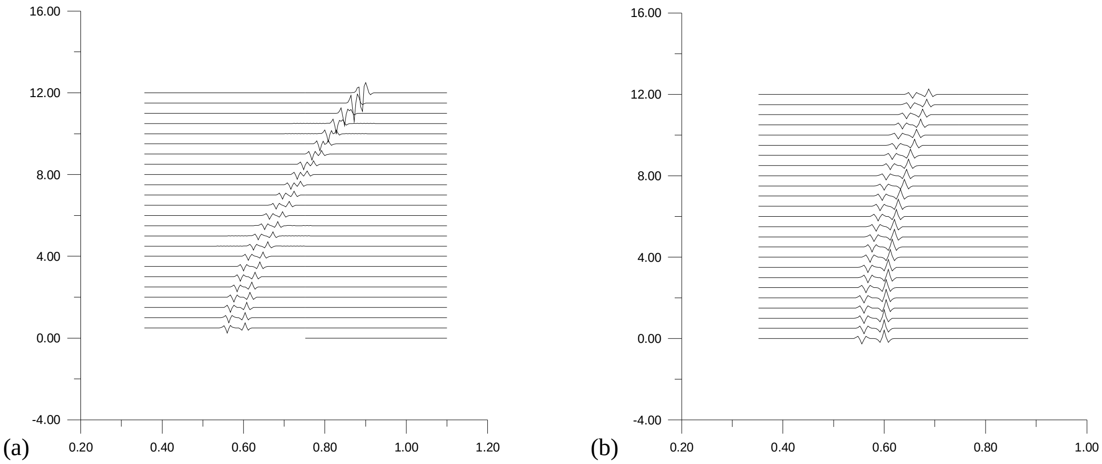

Fig 4: (a) Synthetic seismogram for viscoelastic case; (b) Synthetic seismogram for classical case.

Synthetic seismograms have been computed for a number of offsets. An example is shown in Fig. 3 along with the corresponding seismograms for the classical case. The seismic wavelets from he top and bottom of the attenuating layer are observed to come closure at far offsets. This is due to the frequency dependence of seismic wave velocity in the viscoelastic layer. The seismic wave velocity increases with frequency and hence the travel time gets smaller at longer distances.

Discussions & Conclusions

An closer examination of Figs. 3 and 4 reveals that there are significant differences in reflection coefficients and nature of synthetic seismograms in the presence of a viscoelastic layer as compared to classical case. The reflected pulse from the bottom interface for viscoelastic case travels at greater velocity at higher frequencies and so its travel time becomes shorter as offset increases. Also due to frequency dependent attenuation in the viscoelastic layer, the reflection coefficients have a somewhat reduced amplitude for the top interface. This difference is likely to be accentuated at higher frequencies.

References

1. Aki, K. and P.C. Richards (2002) Quantitative Seismology. University Science Books, Sausalito, California.
2. Teverud, T. and B. Ursin (2005) Comparison of seismic attenuation models using zero-offset vertical seismic profiling (VSP) data, Geophysics, **70(2)**, F17-F25