Attenuation for TIV Media: An Experience with Osiris Modelling Software

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ABSTRACT

Synthetic seismograms were created using Osiris modelling software. Assuming an isotropic media, a constant high value for Q was first used where we could recognize the amplitude of P waves decaying with offset and depth. Similarly for the converted waves the amplitude decays with depth but increases with offset. There was a phase change of 180 degrees for the converted waves. The effect of Q factors was noticeable in both P and PS seismograms, when different values of Q were used in the process in the case of isotropic media.

The transverse isotropic media was assumed in the modelling with different values of Q. The seismograms showed a frequency losses and phase changes for both reflected P waves and converted waves as a result of both Q factors and the existing of TI media.

INTRODUCTION

Seismic waves propagating in an infinite homogenous medium are dispersed as a consequence of intrinsic attenuation. The shape of a pulse propagating in a medium of finite Q, will change with offset or traveltime. When considered in the frequency domain, different frequency components will propagate with different velocities and therefore have different phase.

There are many approaches to seismic pulse propagation and dispersion in attenuating solids. A common approach assumes a constant or nearly constant Q for an isotropic layer (Kjaartansson, 1979). The Q is then used to calculate pulse broadening and dispersion.

In some cases, when waves have a wavelength much larger than the width of the strata, such stratified regions exhibit mechanical properties that appear to be space-independent depending only on the elevation angle with respect to the axis perpendicular to the plane of stratification. Such a medium is said to be transversely isotropic (TI) (Schoenberg, 1983). When the angle of symmetry is equal to zero the medium is said to be transversely isotropic vertically (TIV) where usually the velocities are higher in the horizontal direction than the vertical direction.

THEORY

Osiris modelling software is based on the direct global matrix method (Schmidt, 1987). It is derived from an approach using continuous wave systems in the frequency domain. It is a general method for solving elastic wave propagation problem in layered media. The media are regarded as stacked homogenous visco-elastic layers with visco-elastic half-spaces at the top and at the bottom.

For a given frequency the solution is represented either by an integrals over all horizontal wavenumbers or by an integral over slownesses. This is achieved using the Fourier transform for Cartesian coordinates or the Hankel transform for cylindrical

coordinates. Within each layer the entire solution is represented as the sum of two terms:

- A general solution to the homogenous equations represented in terms of suitable integral transform function.

- A particular solution to the source associated within the particular layer.

THE MODEL

A three-layer geological model was built in terms of depth, P wave velocities, S wave velocities, densities and Q factors for both P and S waves (figure 1).
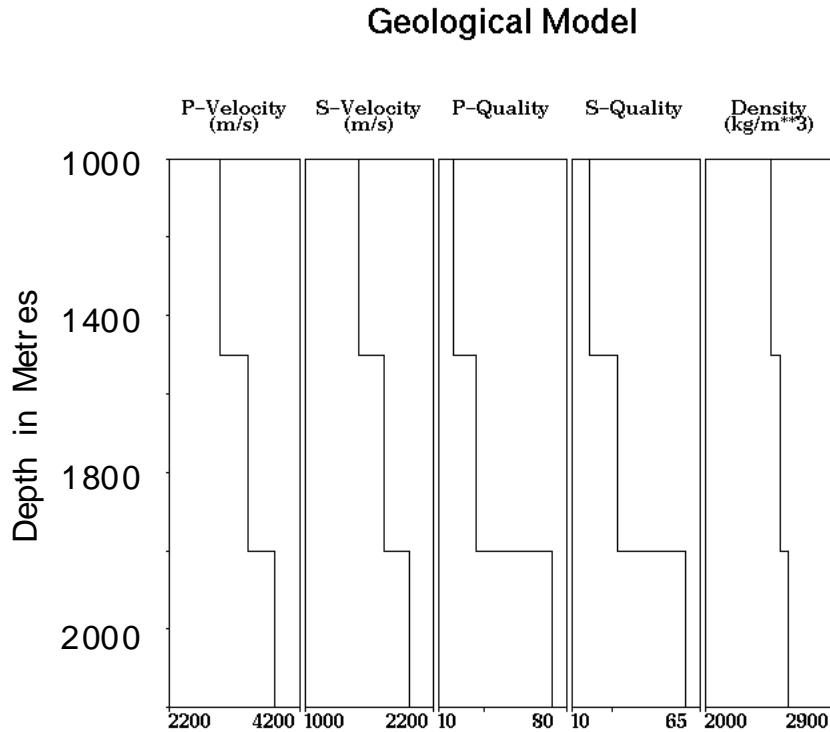

Figure (1).

A point source was used and thirty receivers with near offset of 150 m and an interval of 50 m were placed at the top of the first layer at a depth of 1 m. The wavenumber computational domain with 3-D wave propagation were chosen for the modelling. There are many program options which affect both accuracy and runtime, we have chosen the highest accuracy without regard for the runtime. The seismograms were created and the results explained below.

APPLICATION AND RESULTS

There are four options in the Osiris modelling Software allow us to study different media in terms of their properties:

Isotropic - The layer is assumed to be isotropic.

Periodically Stratified - The layer is assumed to be transversely isotropic. It consists of a number of horizontal isotropic layers which can be specified individually.

Lame Orthotropic - The layer is assumed to be transversely isotropic. Five Lame parameters for transversely isotropic materials must be specified.

General Elastic Constant - The layer is assumed to be transversely isotropic. Five linearly independent elastic constants must be specified.

Different values for elastic constants and Lame parameters were tried unsuccessfully to use the last two options, then only the first two options were considered in the modelling while the last two were left for further investigation.

In this study, a zero phase Ricker wavele was used in the process with a dominant frequency of 25 HZ

Isotropic Media

The three-layer medium was first assumed to be isotropic with a constant high value of Q equal to 300 for each layer. A seismogram for the reflected P wave was created (figure 2). As we can see from this figure that the amplitude is decaying with offset and the phase is constant along the horizons. The Matlab function "Zoepplot" was used to compute and plot the amplitude of the first layer as function of offset (figure 3). This function uses raytracing to determine the incidence angles of offset and computes the true Zoeppritz reflection coefficient.

The converted waves for this model were also computed and are shown in figure (4) where we can see the amplitude increases for certain offsets and decreases in others. The function "Zoepplot" was also used for this case to suggest the behavior of the converted waves amplitude in relation to the offset (figure 5). The same function had been used to identify the phase of the same waves as a function of offset for the first layer. Figure (6) shows this relation where we can see the phase is 180 degrees.

The Q factors for both P and S waves were then introduced as one of the parameters of the model. Those factors vary according to the type of the wave and depth of the layer (figure 1). A seismogram for the P wave reflection was created (figure 7) and the effect of Q factor is quite clear in both the amplitude and frequency. To study this effect in detail, the NMO had been removed for both reflected P wave where the Q factor is constant and equal to 300 (figure 2) and when it starts with 20 and varies with depth (figure 7), then all receivers were stacked to give one trace. Figure (8) shows the stacked receiver for Q=300 and figure (9) is the stack for different values for Q. Comparing the last two figures (8 &9) we can see that the amplitude and the frequency are higher in figure (8) than what it shown in figure (9). In general we should expect phase difference between the two stacked traces as effect of Q, but since we are using a zero phase wavelet we won't be able to notice a phase difference between the two stacked traces which we should expect.

The converted waves seismogram was generated for this case and plotted in figure (10) where it shows low frequencies and amplitude for the three horizons as a result of Q factor.
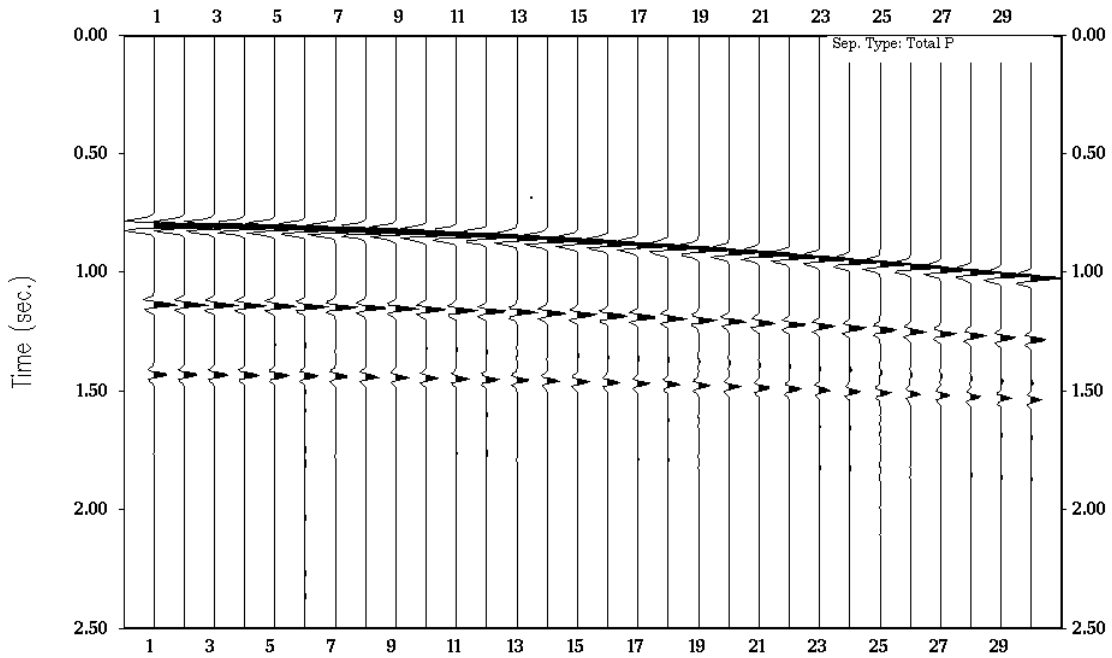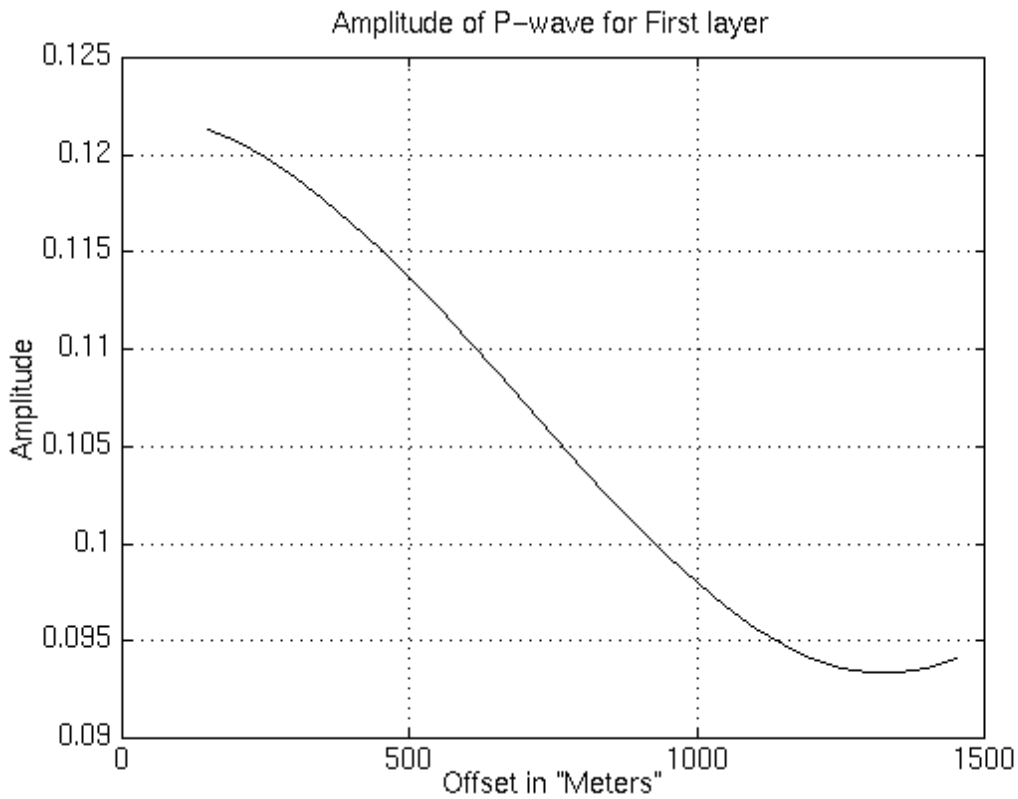

Figure (2). the total P wave field

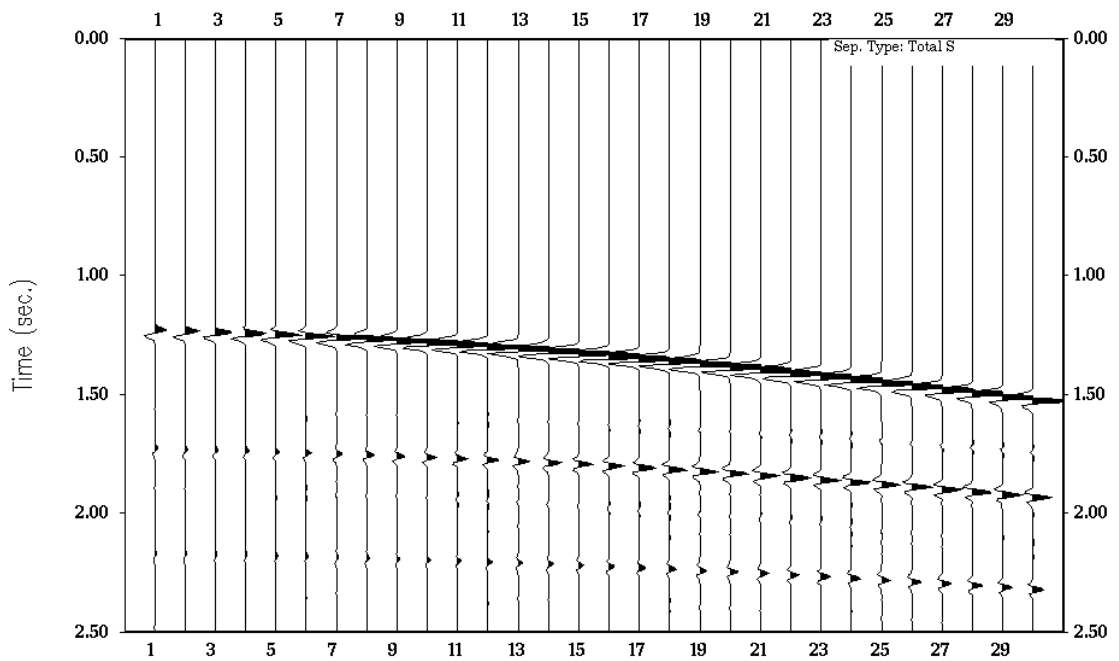Figure (3). The amplitude as function of offset for reflected P wave
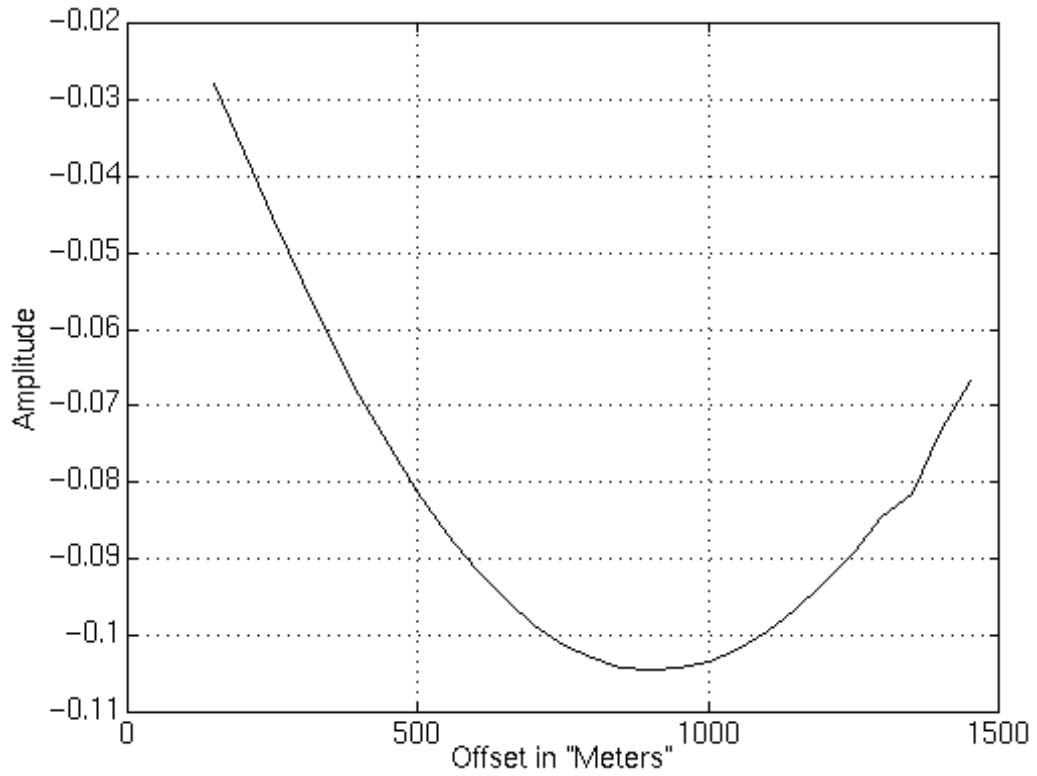
Figure (4). The total converted wave field

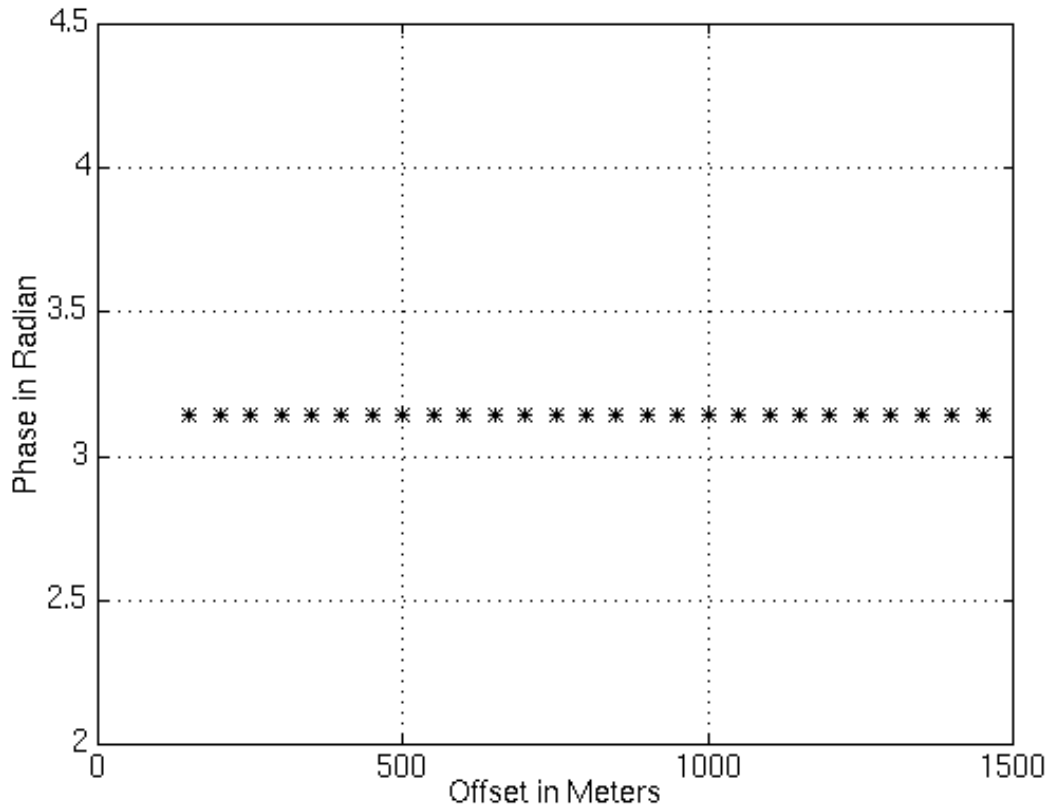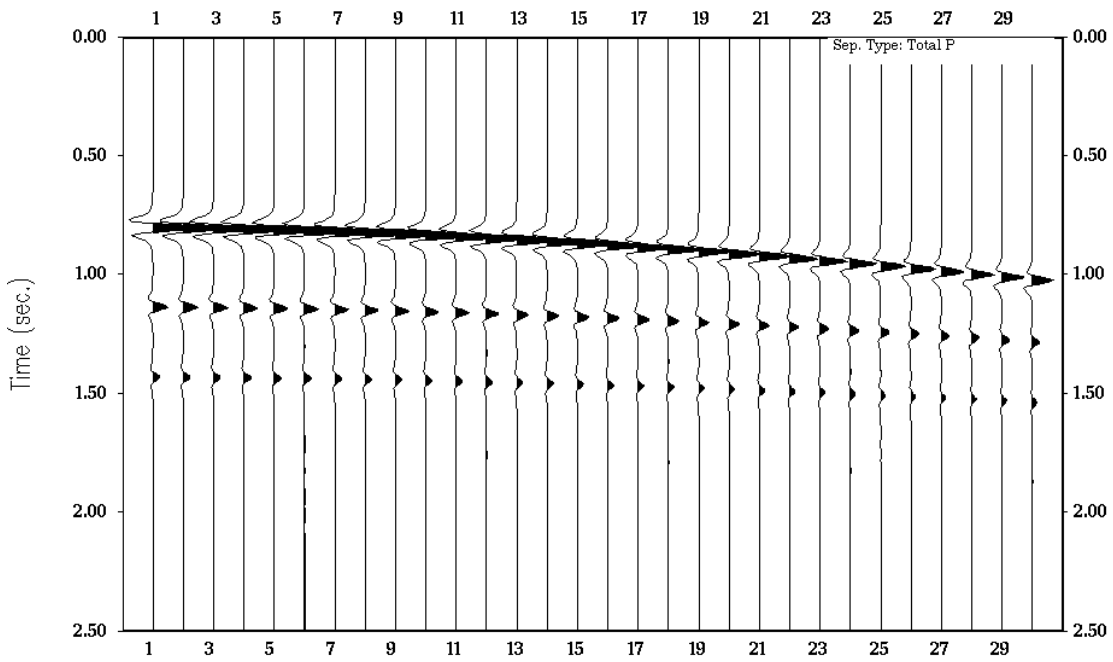Figure (5). The amplitude as function of offset for converted waves

Figure (6). The phase of converted waves in relation to offset

Figure(7). The total P wave field for layered Q model
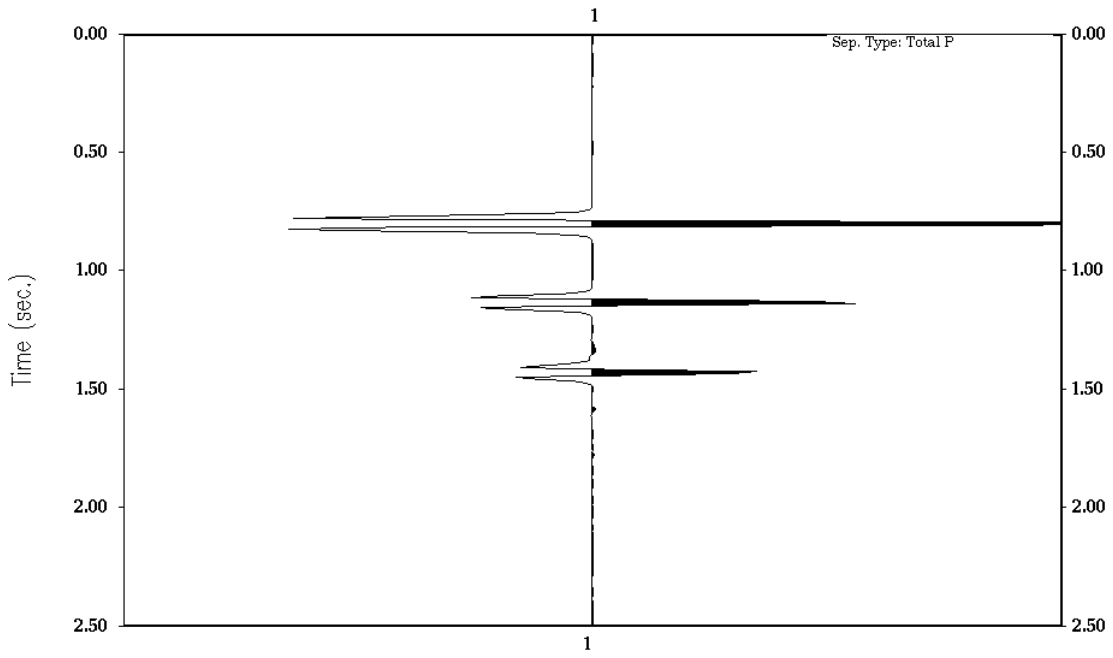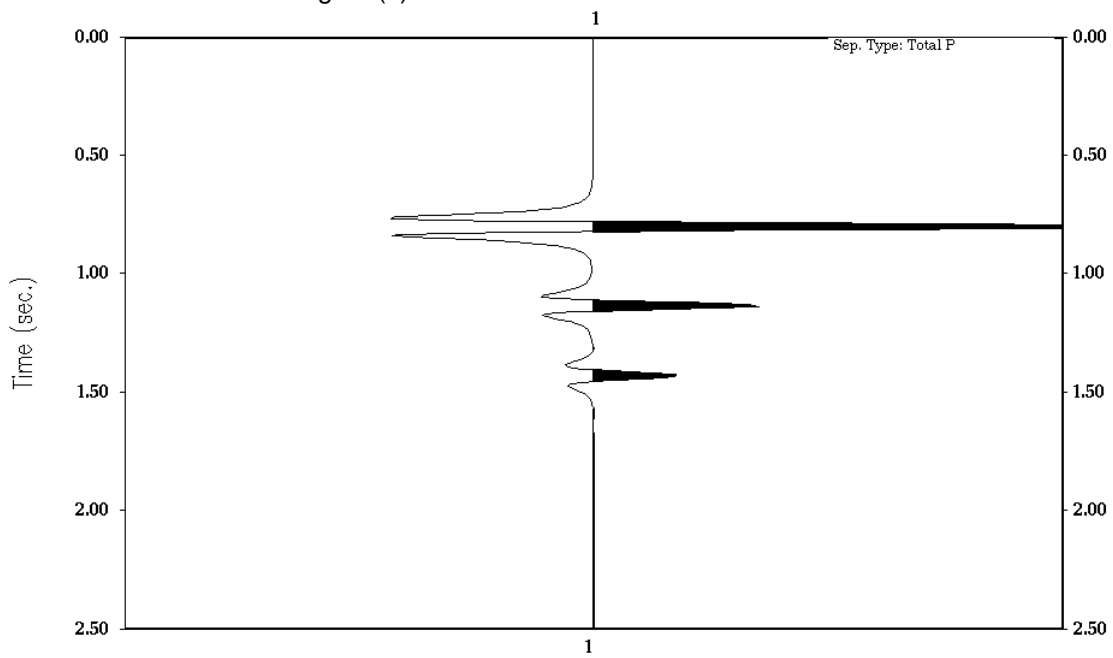
Figure (8). P wave Stacked trace for Q = 300

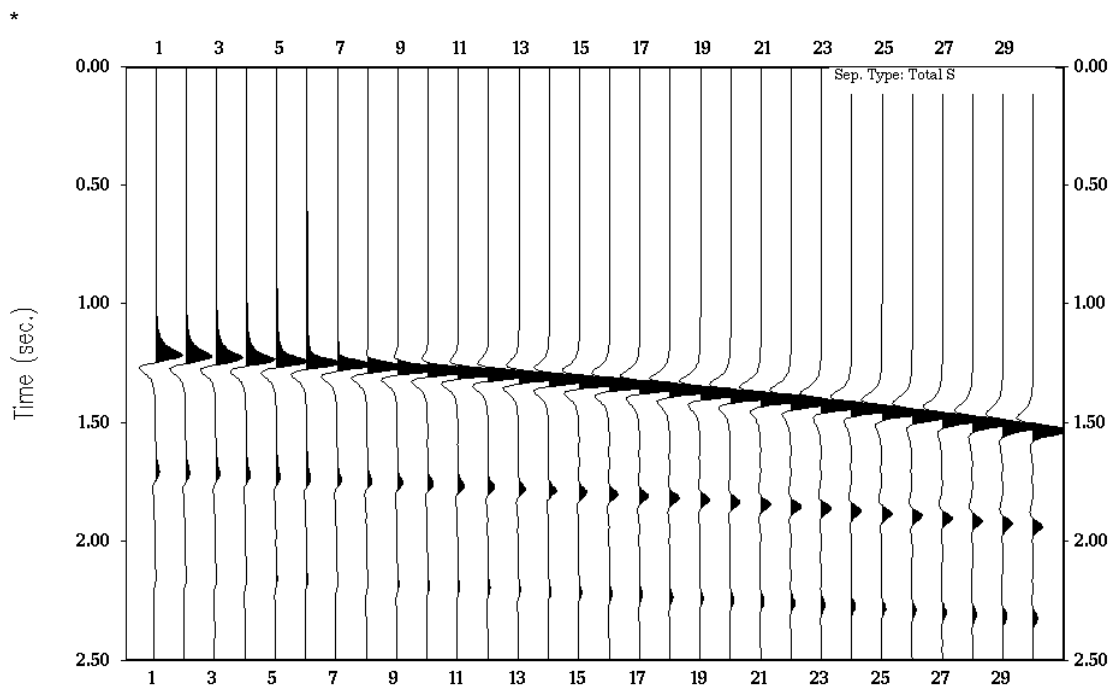Figure (9). P wave Stacked traces for layered Q model

Figure (10). The total converted wave field for layered Q model

Transversely Isotropic (TI)

The main idea in the transverse isotropic media is to describe the behavior of one layer as if it was built of a stack of infinitely many sublayers. The physical properties of this stack is an anisotropic layer

In this investigation, we were forced to use only two layers for TI cases as the program requires more specific values for the parameters.

Two cases were illustrated to describe the behavior of the first and second layer in our model.

Case A.

The model was rebuilt from two layers (two media). The first medium starts from 0 m to 1000 m it was divided to two sub-layers with different velocities and densities and same thing was done to the second medium (1000 m - 1500 m). The purpose of this division is to let the medium act as anisotropic medium. The result of application is represented in figure (11) which shows a phase change of the reflected P waves for both mediums.

As all the traces have the same phase, the NMO has been removed and they were stacked together to give one trace (figure 12) showing the phase difference between isotropic and anisotropic cases. Figure (13) shows the seismogram of the converted waves for TI media. Comparing figures (10 and 13). we can see that the frequency along with the amplitude have dropped for TI case.

Case B.

The model still contains two media. The first medium (0-1000 m) was divided to six sub-layers with different parameters and different volume for each layer. The second medium (1000- 1500 m) was kept the same as last case.

Depth (m)	Vp (m/s)	Vs (m/s)	Qp	Qs	Roh (kg/m3)	volume fraction
1000	1100	520	15	10	1100	15%
"	1300	600	16	12	1400	15%
"	1500	720	17	13	1600	15%
"	1800	850	17	13	1800	15%
"	2100	980	18	14	2100	20%
"	2500	1200	20	15	2300	20%

Table shows the parameters used for case B (first medium only)

A seismogram for P wave was generated for the last case where we can see a difference in the amplitude of the horizon representing the first medium and the amplitude of the horizon of the second medium (figure 14). The frequency losses of the converted waves is obvious in the seismogram shown in figure (15).
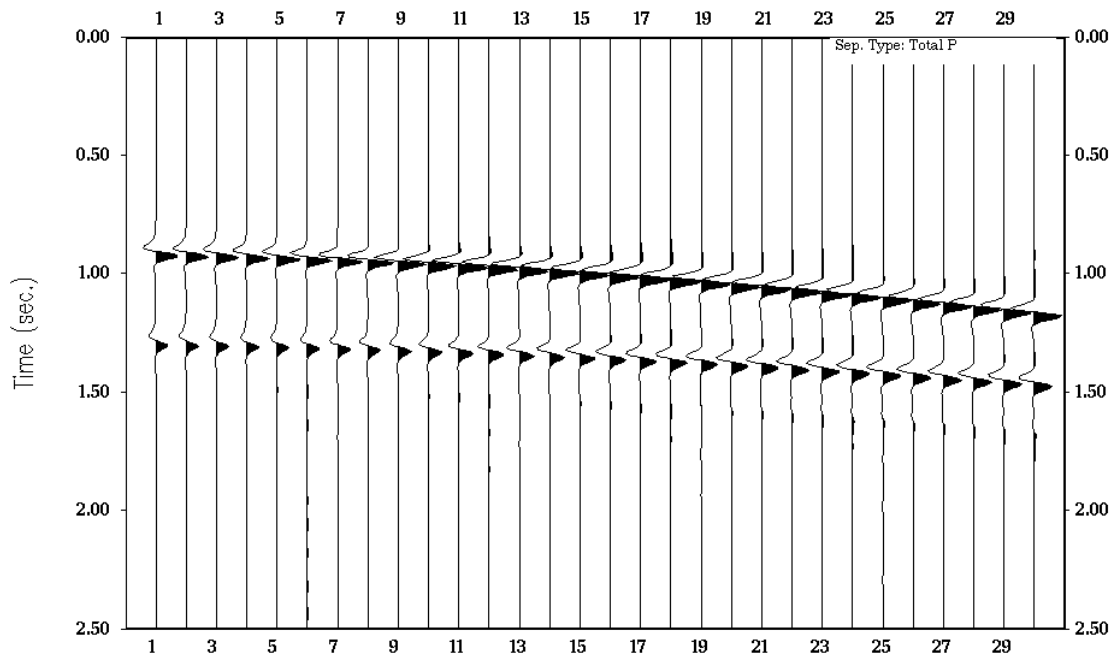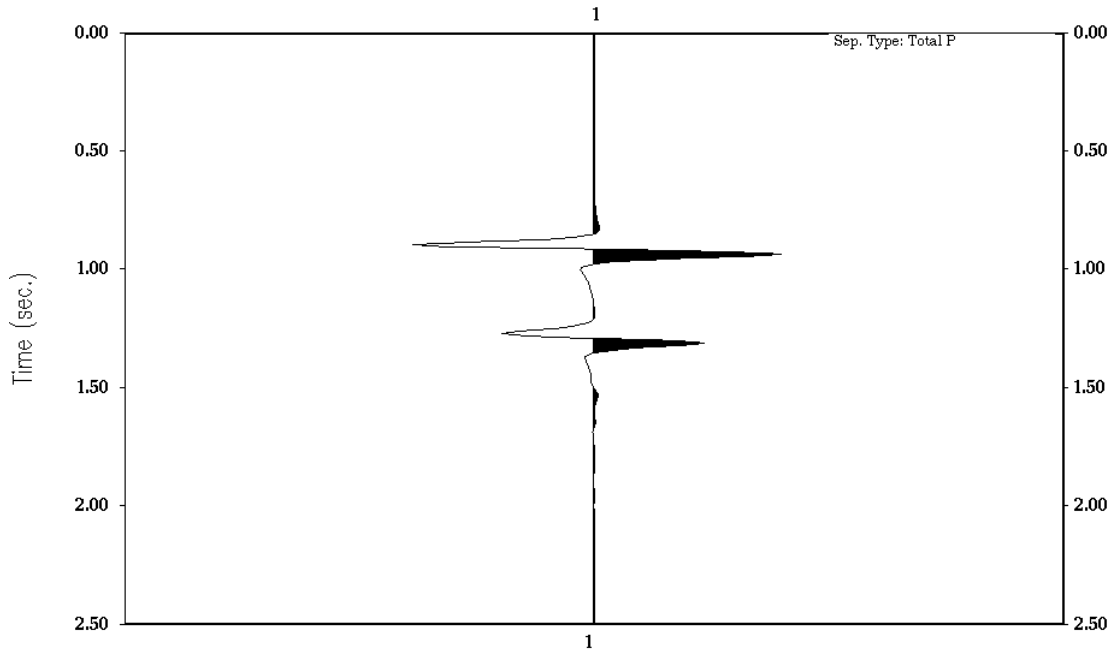

Figure (11). The total P wave field for case A (TI)

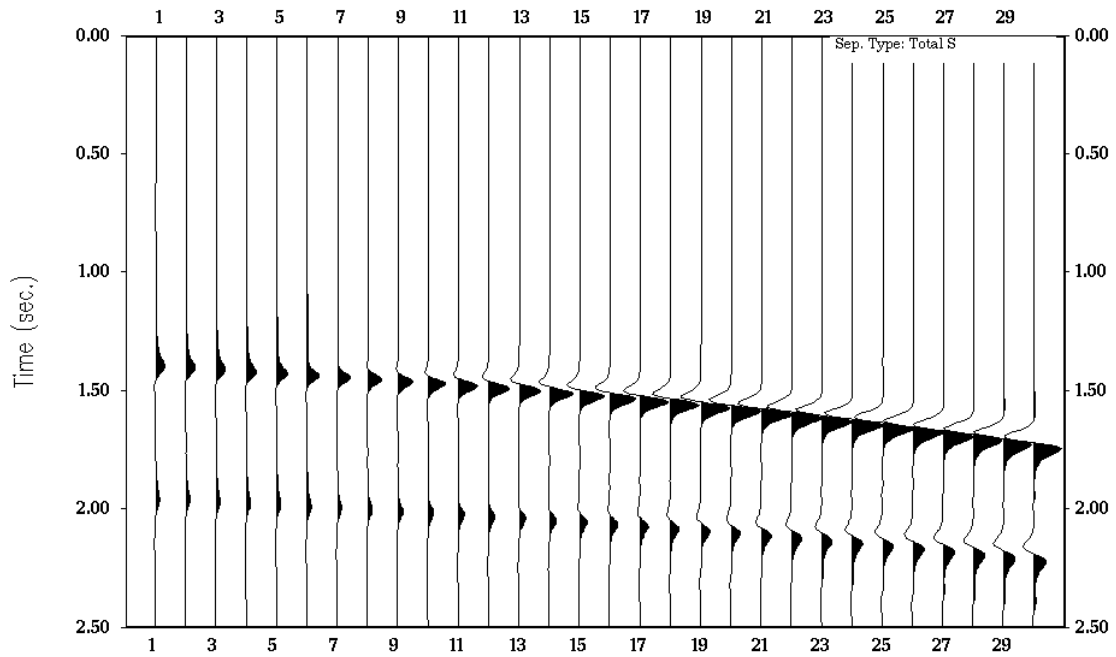Figure (12). Stacked trace of reflected P wave for case A (TI)

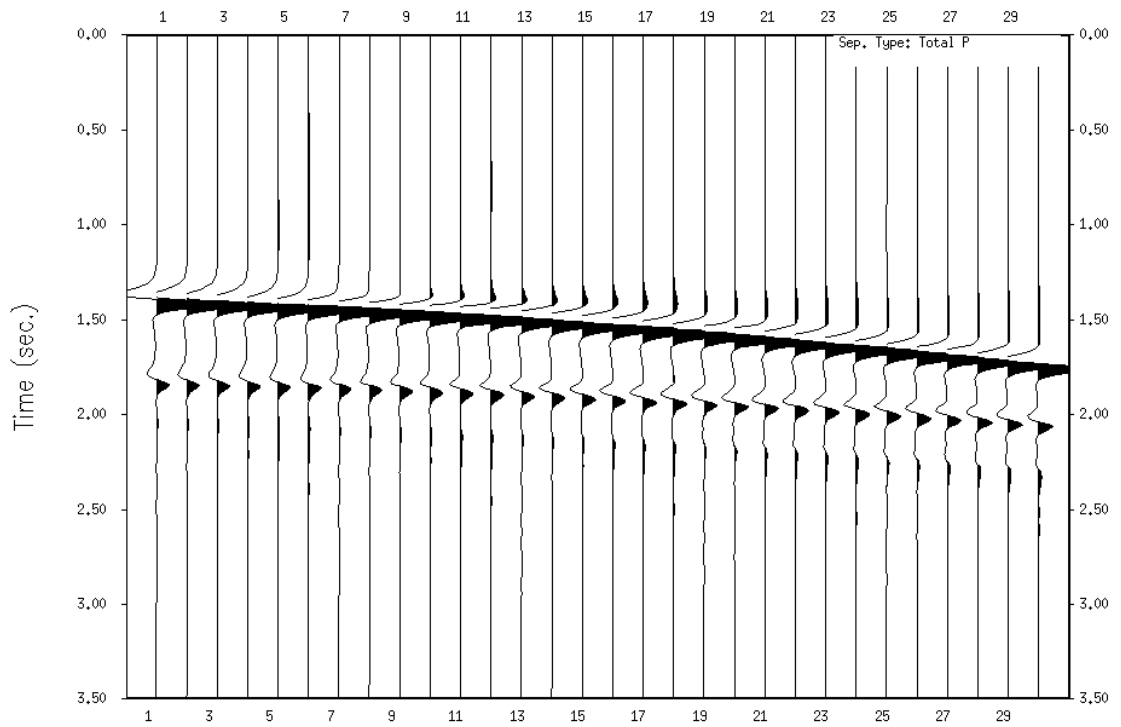Figure (13). The total converted wave field for case A (TI)

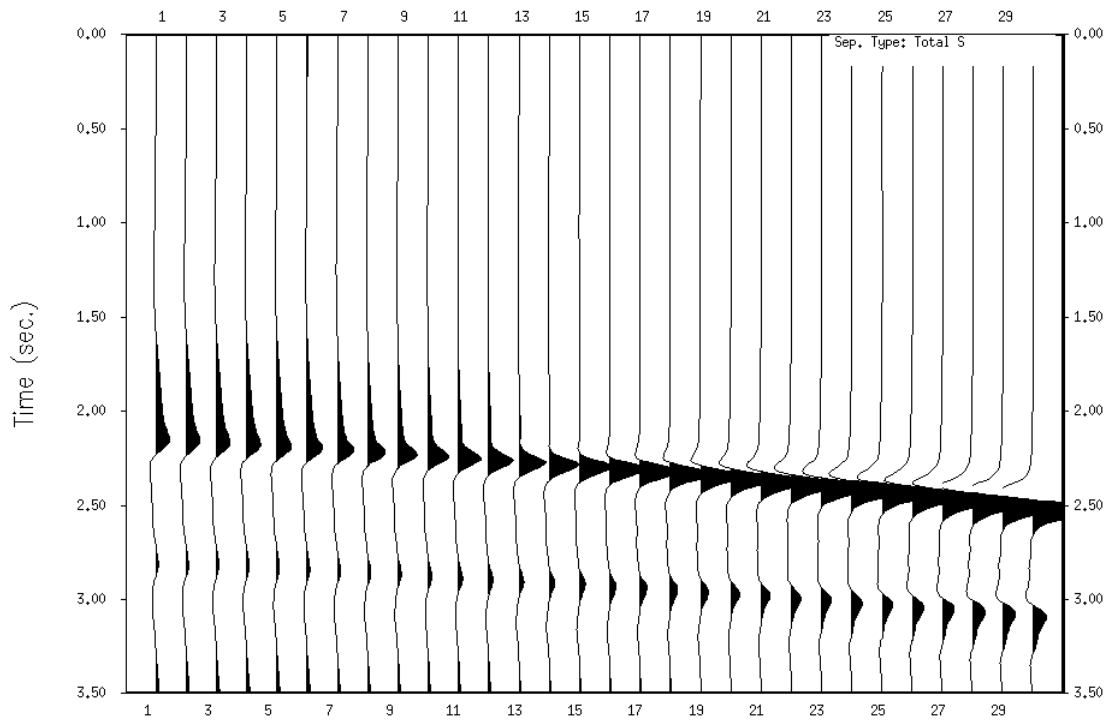Figure (14). The total P wave field for case B (TI)

Figure (15). The total converted wave field for case B (TI)
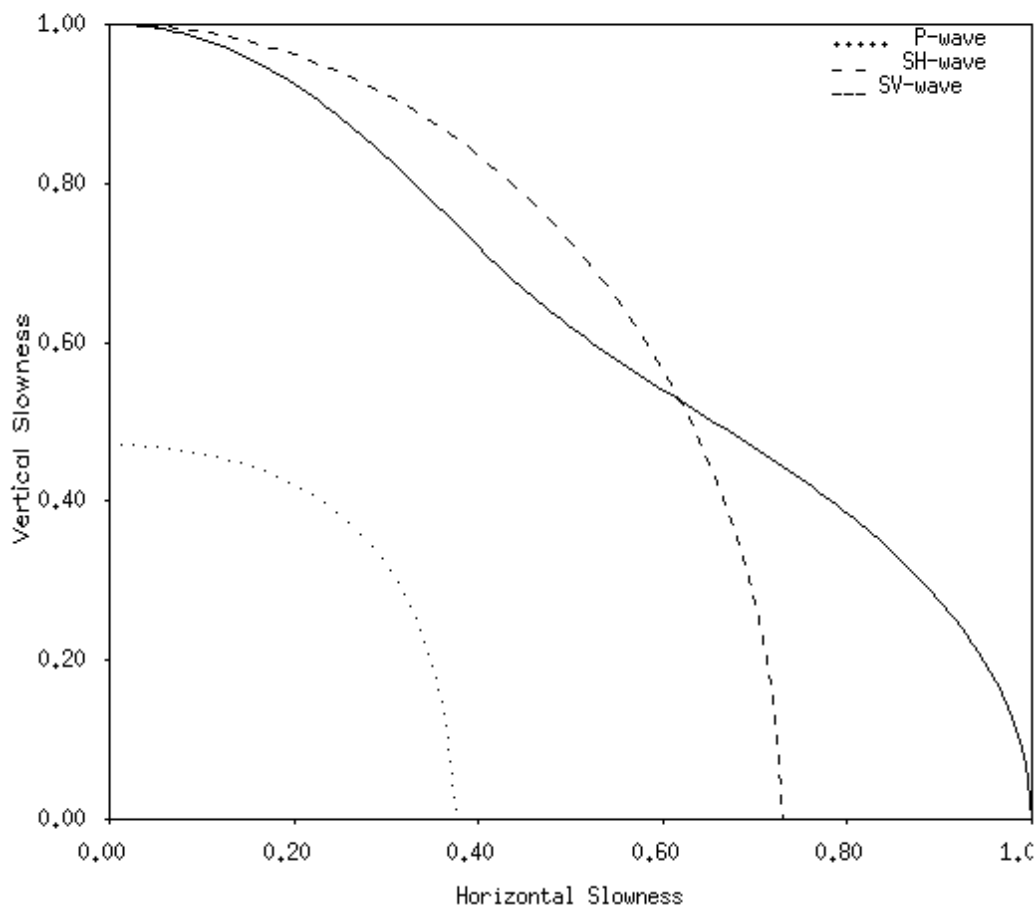
Slowness Surfaces

Figure (16).

Figure (16) shows the slowness surfaces for the first the medium (0 - 1000 m) which consists six sublayers. The program would calculate the average velocities, densities and Q factors for the whole medium according to the volume of each sublayer. It then plots the horizontal and vertical slowness of the medium.

The followings are the velocities of different waves in horizontal and vertical directions:

In horizontal direction   P- wave velocity = 2630 m/s.

                            SH velocity   = 1370 m/s.

                            SV velocity   = 1000 m/s.

In vertical direction   P- wave velocity = 2083 m/s.

                            SH velocity   = 910 m/s

                            SV velocity   = 910 m/s.

CONCLUSIONS

The frequency losses can be due to the low quality factor of the rock for isotropic medium and due to both quality factors of the rock and the thickness of the sublayers in TI medium.

Osiris modeling software is a good tool for modelling different media.

ACKNOWLEDGMENTS

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