Ray tracing computations in the smoothed SEG/EAGE Salt Model

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Summary

Ray tracing computations need smooth seismic models. The paper shows utilization of SW3D software to compute rays and synthetic seismograms of refracted and reflected P-waves in the smoothed SEG/EAGE Salt Model.

Keywords

Velocity model, ray tracing, seismic waves, synthetic seismograms

1 Introduction

The original 3-D SEG/EAGE Salt Model (Aminzadeh *et al.* 1997) is very complex model and cannot be used for ray tracing. Is the smoothed SEG/EAGE Salt Model (Bulant 2001, 2002, 2003) suitable for two-point ray tracing computations performed by the SW3D software? This question stimulated all the work that is described in this paper.

The greatest advantages of ray tracing in comparison with precise methods, e.g., finite differences, finite elements, are the speed of computation, the small memory requirements and the possibility to separate elementary seismic waves. The memory requirements of individual programs used for calculation of rays, generation of synthetic seismograms and VRML or GOCAD files do not exceed 16MB. All computations were performed on PC equipped with Athlon XP 1700+ processor and with Linux operating system.

Files referred in this paper and used for computation are included on compact disk SW3D-CD-7 (Bucha & Bulant (eds.) 2003) in packages CRT, MODEL, FORMS and DATA. GOCAD program was used for visualization of the 3-D smoothed Salt Model with shot, receivers and computed rays. The figures in the paper are GOCAD screen snapshots of limited resolution, and their quality is thus not very high.

2 Smoothed SEG/EAGE Salt Model

The Salt Model selected for ray tracing computations was smoothed by Bulant (2001, 2002, 2003). It is the best model obtained as a result of many test smoothing computations. The model was smoothed using the Sobolev scalar products on a sparser grids than the original SEG/EAGE Salt Model 20 x 20 x 20m spacing due to the computer limitations. There are two versions of the smoothed model, with and without the most important interfaces. Ray tracing in this paper is performed on the version with the most important interfaces that are characterized by the highest discontinuities in the velocity field. These interfaces are the ocean bottom, the interfaces limiting the salt body, the geopressure horizon and the bottom flat interface (see Figure 1). The data for smoothed Salt Model are in file `sal-mod2.dat`.

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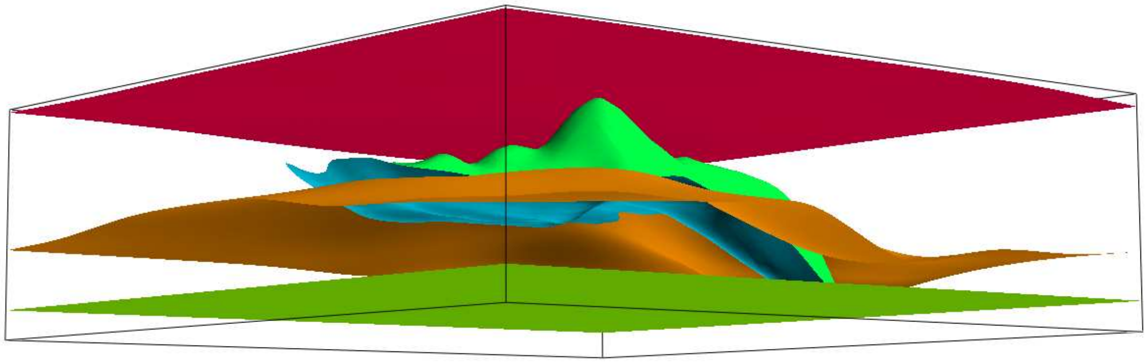

Figure 1. Smoothed Salt Model with the most important interfaces. Interfaces are coloured according to the indices of surfaces.

2 Shot and receivers

Only one shot in the depth of 20m at the centre of the square of 21 x 21 receivers was used in this paper (see Figure 2). The receivers are located in the depth of 0m. The position of the shot above the salt crest is similar to the original Phase A Acquisition

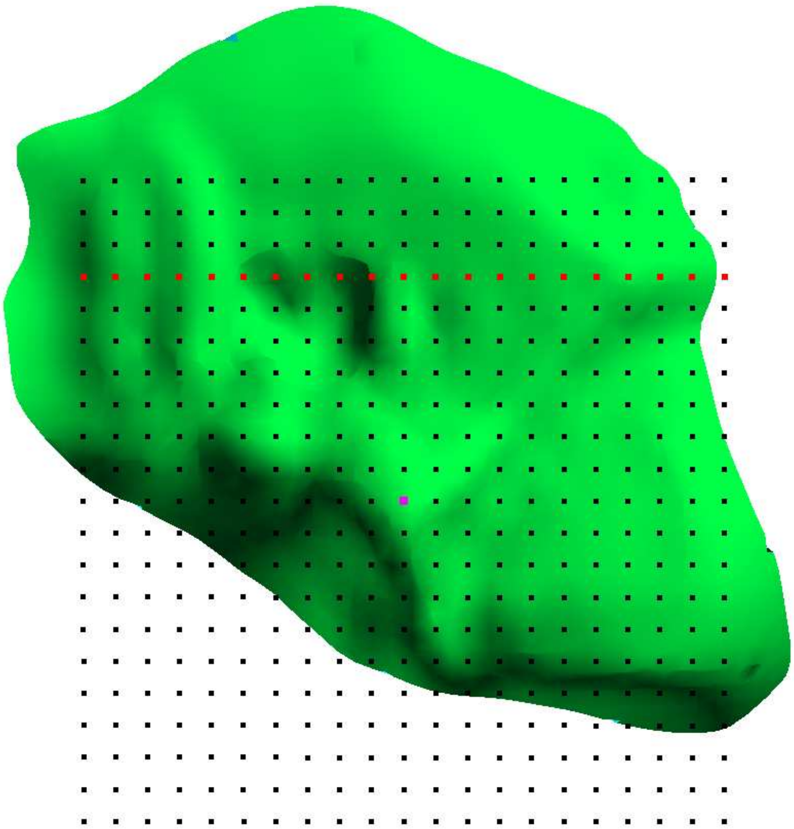

Figure 2. Top view of the shot, receivers and salt body. Violet point in the centre of configuration is source. Red point profile is used for synthetic seismogram computation.

SEG/EAGE where this point is the intersection of two 3-D shot lines (Aminzadeh *et al.* 1997). The receiver grid step is 320m, that seems to be reasonable for computation and visualization. The receiver grid step in Phase A Acquisition was 20m. An attempt to compute one elementary wave for 329x329 grid of receivers with step 20m was performed successfully but the sizes of output files make the computation on a PC very slow, and the visualization of the model with rays crashed the GOCAD program. The names and coordinates of the shot and receivers are in files `sal-src1.dat` and `sal-rec1.dat`. The red point profile (see Figure 2) was selected for generation of synthetic seismograms. Receivers of this profile are defined in file `sal-rec1.plt`.

3 Ray tracing computations

History file `sal-ray1.h` manages the computations of rays, seismograms, and generates VRML or GOCAD files. The history file contains both the data and the information how to execute the programs. Detailed description of the use of history files can be found in older report papers, e.g., Bulant & Klimeš (1998), Bucha (2001). In this paper only short description of the computation steps will be presented.

Two-point rays of one refracted and three reflected P-waves are computed in the first step of the computation running program `crt.for`. Two-parametric shooting method is used for two-point ray tracing. Salt model is a complex model and the intersection of geopressure interface with the salt body caused a necessity to use several codes of elementary waves in computation of elementary waves reflected from the top and bottom of the salt body and from the bottom interface. The codes of elementary waves are defined in `sal-cod1.dat` file. Program `crtray.for` converts the unformatted output of program `crt.for` into formatted files with rays suitable for plotting. Program `linwrl.for` adds rays of computed waves into VRML or GOCAD files. Program `ptswrl.for` does the same for shot and receivers. Figures 3, 4, 5 and 6 show rays of computed waves. The figures are screen snapshots of several GOCAD camera positions with limited resolution. Some of the interfaces are partially transparent.

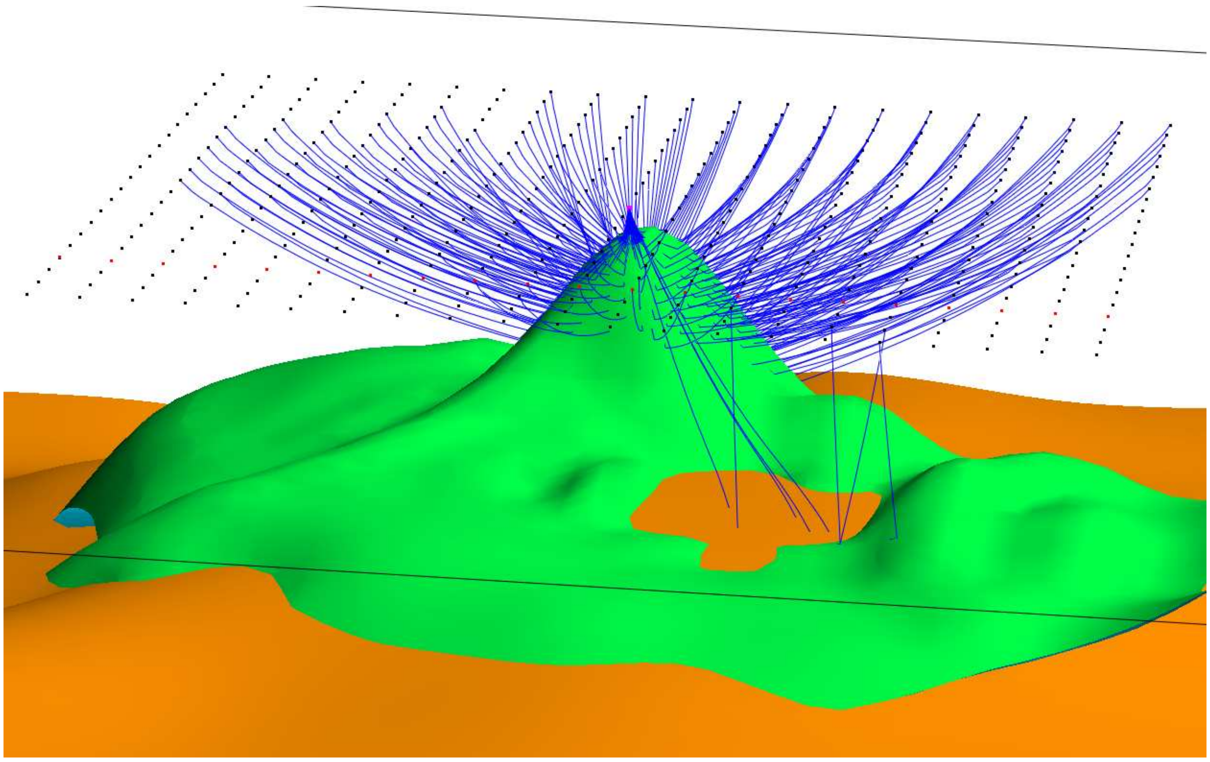

Figure 3. Rays of the refracted P-wave.

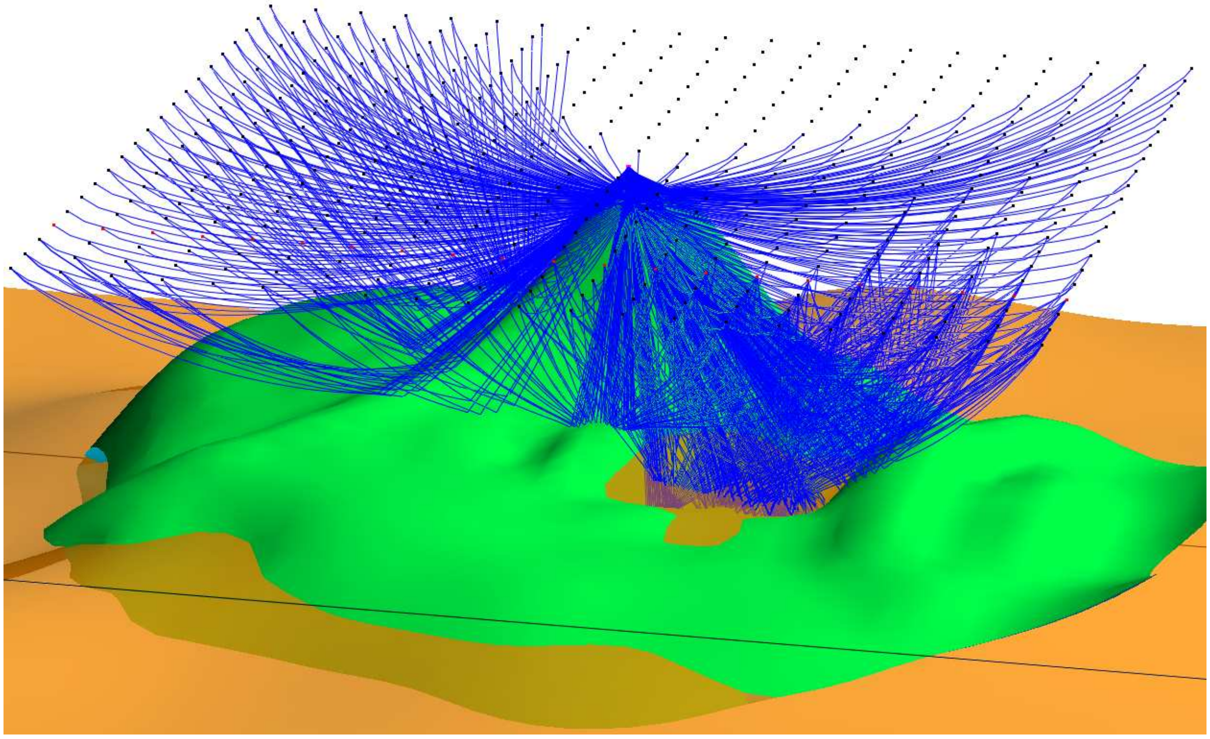

Figure 4. Rays of P-wave reflected from the salt top interface. The geopressure horizon is partially transparent.

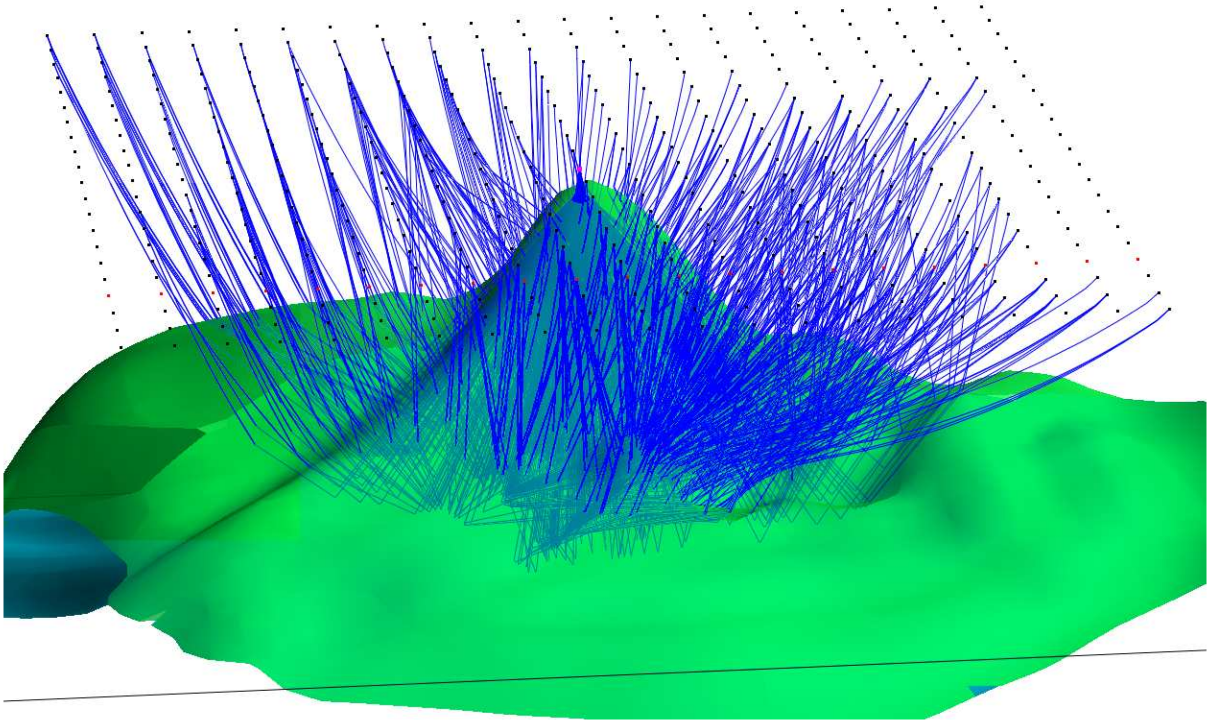

Figure 5. Rays of P-wave reflected from the bottom of the salt body. The top interface is partially transparent.

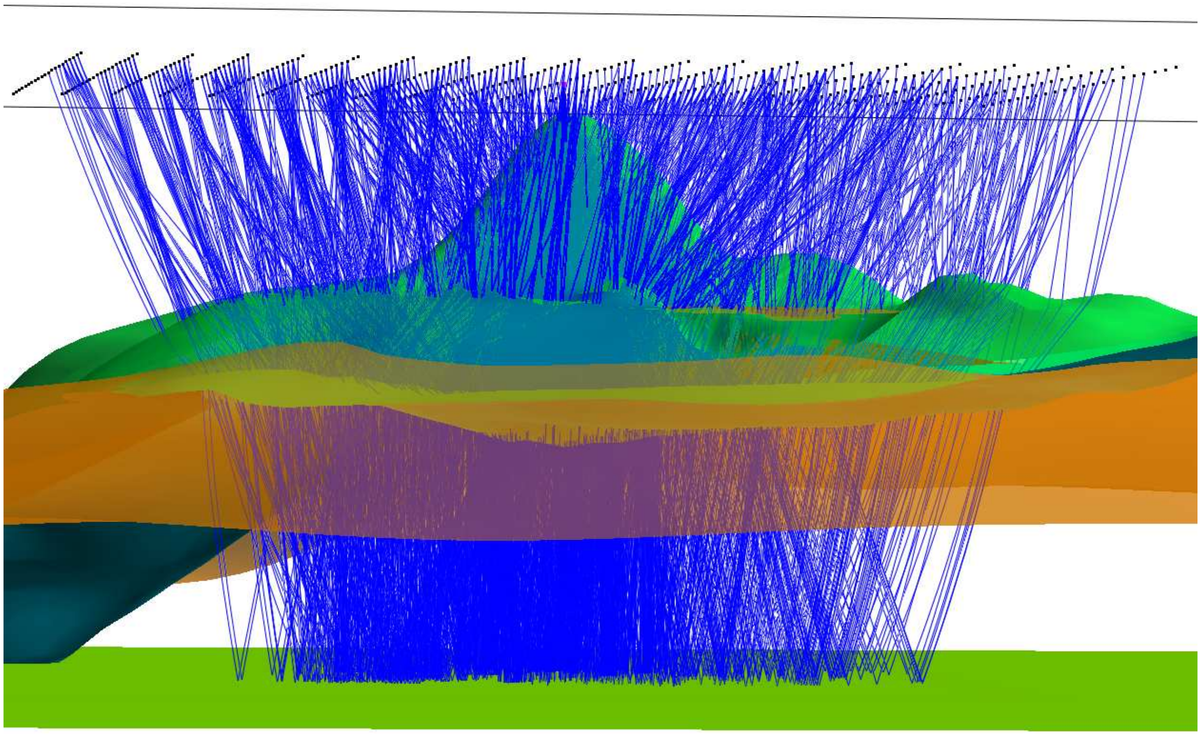

Figure 6. Rays of P-wave reflected from the bottom flat interface. The geopressure horizon and the top of the salt body are partially transparent.

4 Synthetic seismograms

One profile, selected of the 21 x 21 square grid of receivers, was used for generation of the ray-theory seismograms in the frequency domain. The selected profile is marked by red points on Figure 2. The source time function is defined by Gabor signal of prevailing frequency 30Hz. The source is an isotropic explosion. The output of program `crt.for` is converted to the elementary Green functions using program `green.for`. Frequency-domain response function is calculated by program `greenss.for`. The synthetic seismograms are then computed by program `ss.for` and plotted by program `sp.for`.

Figure 7 shows the seismograms generated from all the computed elementary waves: one refracted and three reflected P-waves. The maximum amplitude at each trace is scaled to a given constant. Figure 8 shows traces of individual elementary waves distinguished by colours. The maximum amplitude of each elementary wave is scaled to a given constant. The arrivals of individual waves may be compared with Figure 7, e.g., amplitudes of the reflections from the bottom interface are very small in comparison with other waves and are visible clearly in Figure 8 (*black* colour amplitudes). Simultaneous visualization of the model interfaces, rays, source and receivers helps to interpret the computed seismograms.

The history file `sal-ray1.h` computes the seismograms of individual elementary waves in Figure 8 optionally. It is necessary to uncomment lines in the history file.

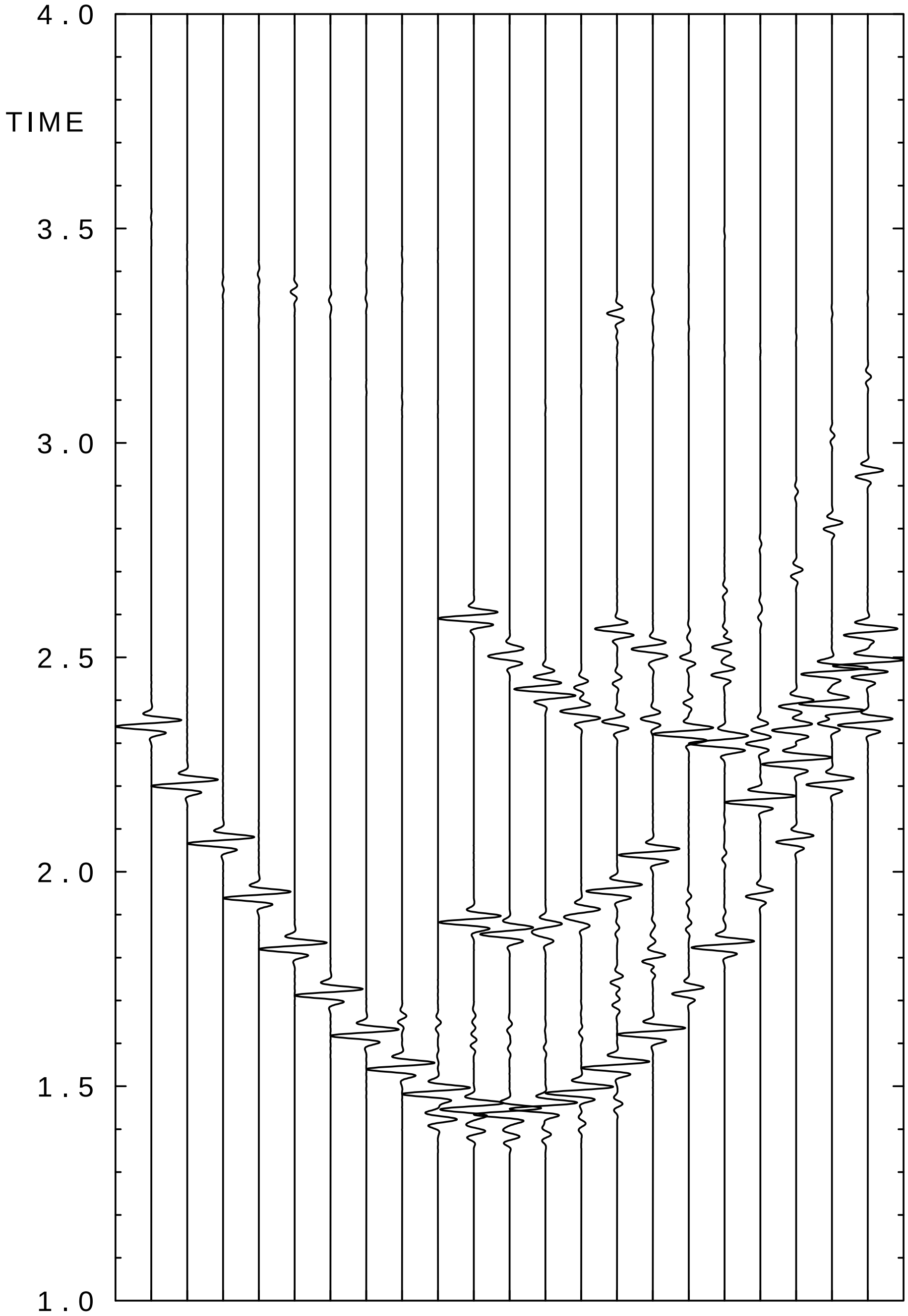

Figure 7. Vertical components of synthetic seismograms of all computed elementary waves along the selected profile. The amplitudes at each trace are scaled according to the maximum amplitude at each trace.

5 Conclusions

Results of two-point ray tracing using SW3D software show that the smoothed Salt Model is suitable for this type of computation. The time of the whole computation including the optional part of the history file `sal-ray1.h` was approximately one hour on PC equipped with processor Athlon XP 1700+. The author hopes that computations for other shot and receiver configurations will be successful. A comparison of similar computations performed with some precise method will be useful. It will be checked in future.

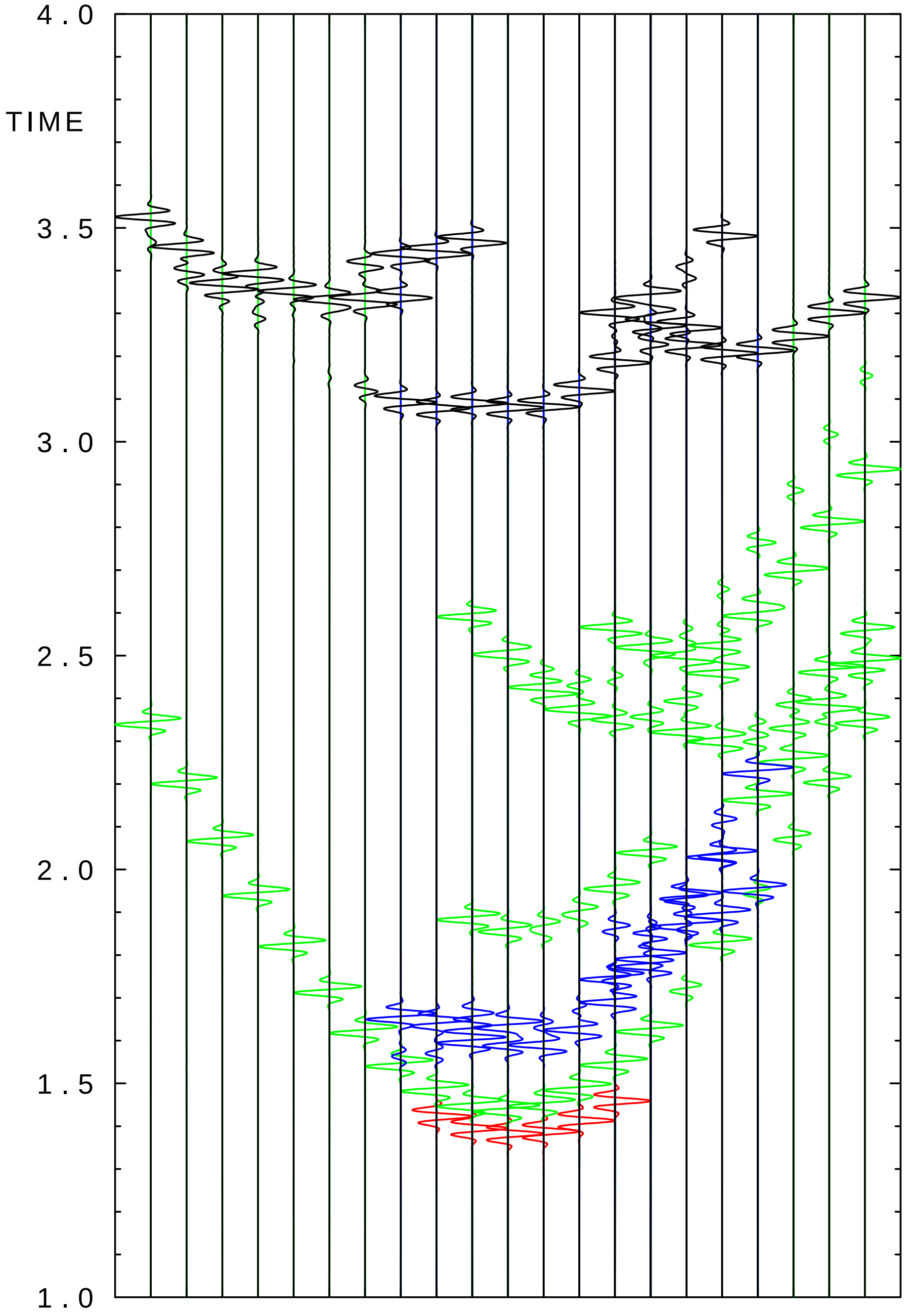

Figure 8. Vertical components of seismograms of individual elementary waves along the selected profile, with maximum amplitude of each elementary wave scaled separately. The *red* **colour denotes the refracted wave,** *green* **denotes the reflections from the top of salt,** *blue* **denotes the reflections from the bottom of salt and** *black* **denotes the reflections from the bottom interface.**

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