Ray tracing computations in the smoothed SEG/EAGE Salt Model. Part 2: Sources in the well

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Summary

Two-point rays of refracted and reflected P-waves in the smoothed SEG/EAGE Salt Model are computed for two sources situated in a well. The source-receiver configuration is derived from the original SEG/EAGE Phase A Acquisition. One profile is used for generation of the ray-theory seismograms.

Keywords

Velocity model, ray tracing, seismic waves, synthetic seismograms, well

1 Introduction

This paper continues the analogous SW3D Report 13 paper by Bucha (2003). The main difference is the location of the sources. Two-point rays and synthetic seismograms are calculated for two shots located in a well, one shot above the salt body and the other shot below the salt body. The smoothed SEG/EAGE Salt Model (Bulant 2001, 2002, 2003) with the most important interfaces (ocean bottom, interfaces limiting the salt body, geopressure horizon, bottom flat interface) and the position of receivers are the same as in the first paper. For short description of the model see the first paper (Bucha 2003). All computations were performed on a 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-8 (Bucha & Bulant 2004) in packages CRT, MODEL, FORMS and DATA. The GOCAD program was used for visualization of the 3-D smoothed Salt Model with shots, receivers and computed rays. The figures in the paper are GOCAD screen snapshots of limited resolution.

2 Shots and receivers

Figure 1 shows the location of the well (yellow diamond) near the centre of the square of 21 x 21 receivers. Two shots are located in the well, one shot above the salt body in the depth of 900m and the other shot below the salt body in the depth of 2300m. The names and coordinates of the shots are in files `sal-src2.dat` and `sal-src3.dat`. The receivers are located in the depth of 0m and the grid step is 320m. The names and coordinates of the receivers are in file `sal-rec1.dat`. The red point profile (see Figure 1) was selected for generation of synthetic seismograms. Receivers of this profile are defined in file `sal-rec1.plt`. The position of the shots and receivers is derived from the original Phase A Acquisition SEG/EAGE (Aminzadeh *et al.* 1997).

In: Seismic Waves in Complex 3-D Structures, Report 14 (Department of Geophysics, Charles University, Prague, 2004), pp. 27–34

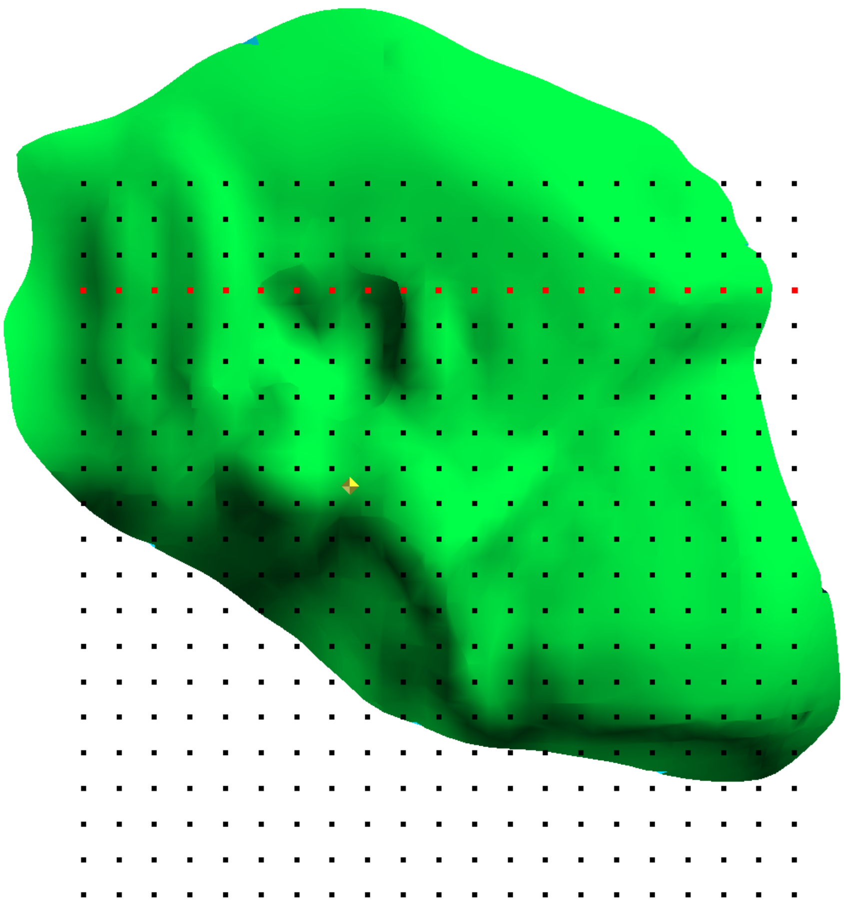

Figure 1. Top view of the well, receivers and salt body. Yellow diamond represents the well with two shots in depths of 900m and 2300m. Red point profile is used for synthetic seismogram computation.

3 Ray tracing computations

History files `sal-rwe1.h` and `sal-rwe2.h` manage the computations of rays, seismograms, and generate GOCAD files. The possibility to generate also VRML files is not used because known VRML browsers cannot switch on and off displayed objects, especially computed rays and the visualization of all rays at once is not very reasonable. The history files contain 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.

History file `sal-rwe1.h` computes two-point rays of one refracted and three reflected P-waves for the source above the salt in the depth of 900m. Reflections are calculated from the top and bottom of the salt body and from the bottom flat interface. Eight codes of elementary waves are defined in the file `sal-cod2.dat`.

History file `sal-rwe2.h` computes two-point rays of one refracted and four reflected P-waves (three of them are multiply reflected) for the source below the salt body in the depth of 2300m. Single reflection is from the bottom interface. Multiple reflections are from the top and bottom of the salt body, from the bottom of the salt and bottom flat interface, from the top of the salt and bottom flat interface. Twelve codes of elementary waves are defined in the file `sal-cod3.dat`.

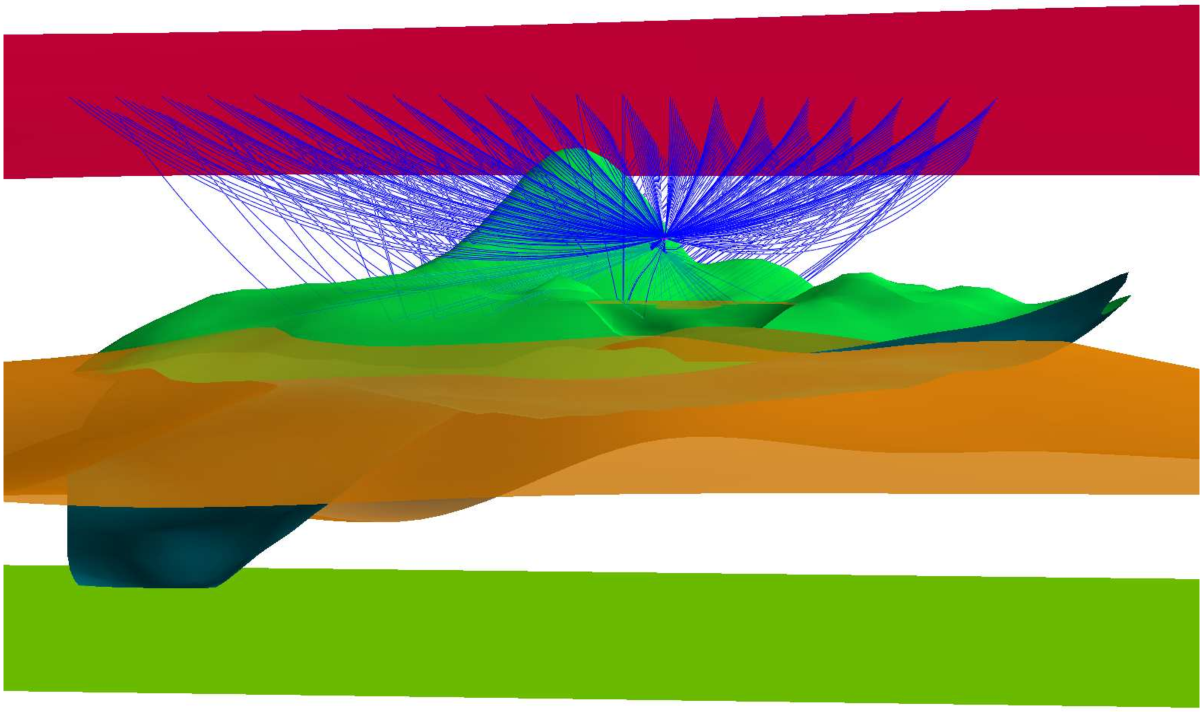

Figure 2. Rays of the refracted P-wave. Shot is located in the well above the salt in the depth of 900m. The salt top interface and the geopressure horizon are partially transparent. The most important interfaces of the smoothed Salt Model are coloured according to the indices of surfaces (ocean bottom, interfaces limiting the salt body, geopressure horizon, bottom flat interface).

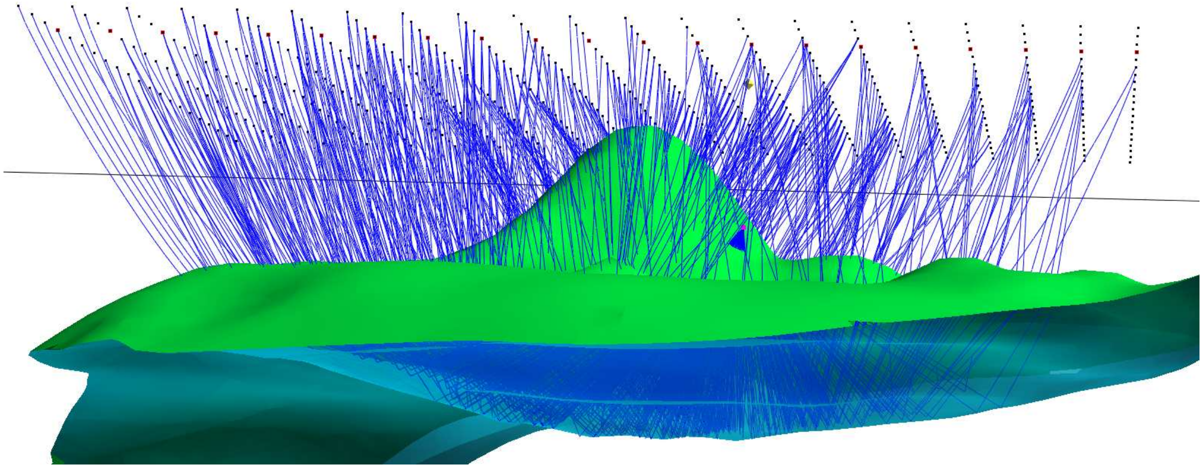

Figure 3. Rays of P-wave reflected from the salt bottom interface. Shot is located in the well above the salt in the depth of 900m. The salt bottom interface is partially transparent.

These are the main differences between the computation managed by two history files `sal-rwe1.h` and `sal-rwe2.h`. Following calculation steps are similar for both history files.

Two-parametric shooting method is used for two-point ray tracing. Salt model is a complex model and the intersection of the geopressure interface with the salt body caused a necessity to use several codes of elementary waves in computation of elementary

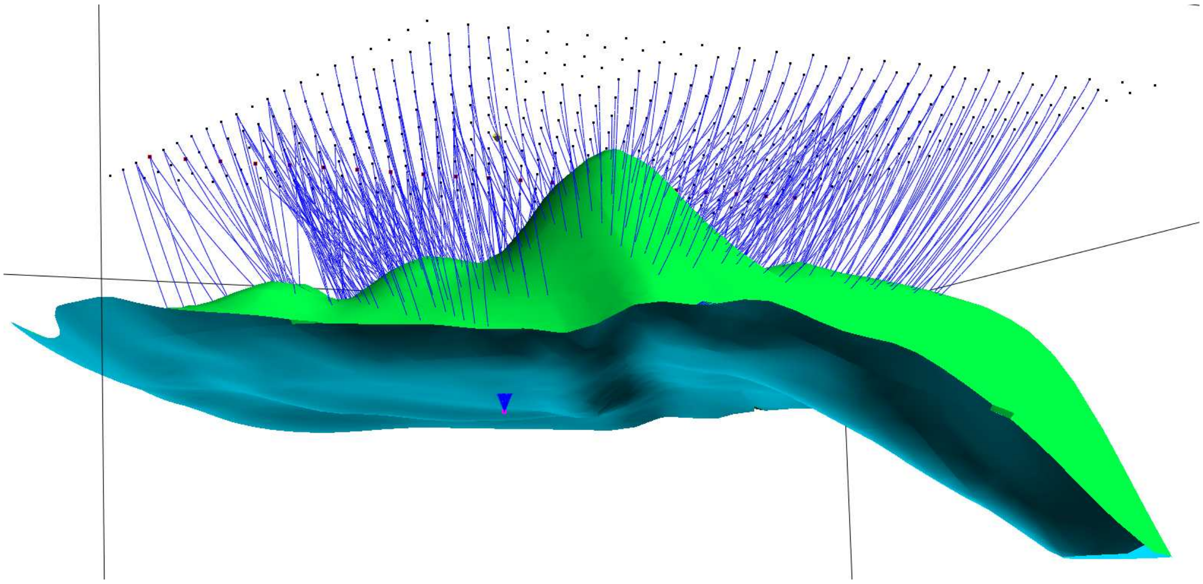

Figure 4. Rays of the refracted P-wave. Shot is located in the well, below the salt, in the depth of 2300m.

waves. Program `crtray.for` converts the unformatted output of program `crt.for` into formatted files with rays suitable for plotting. Program `linwrl.for` writes rays of computed waves into GOCAD files. Program `ptswrl.for` does the same for shots and receivers. Figures 2, 3, 4, 5, 6 and 7 show rays of computed waves. The figures are screen snapshots of several GOCAD camera positions with limited resolution. Some interfaces are partially transparent.

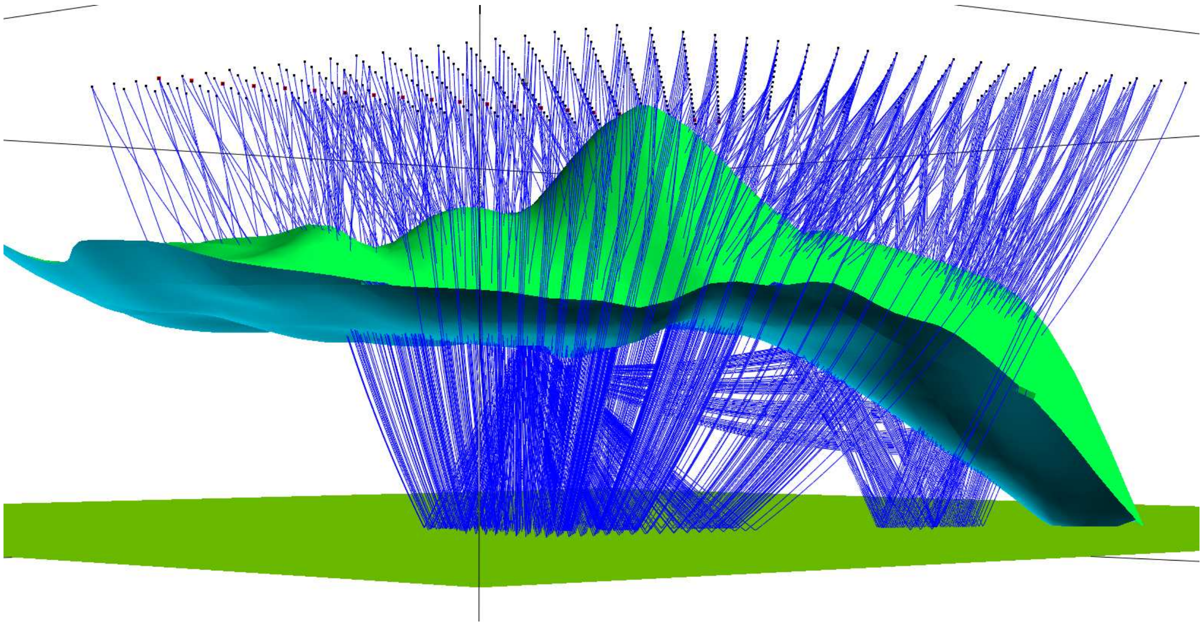

Figure 5. Rays of the P-wave multiply reflected from the bottom of the salt and from the bottom flat interface. The shot is located in the well, below the salt, in the depth of 2300m.

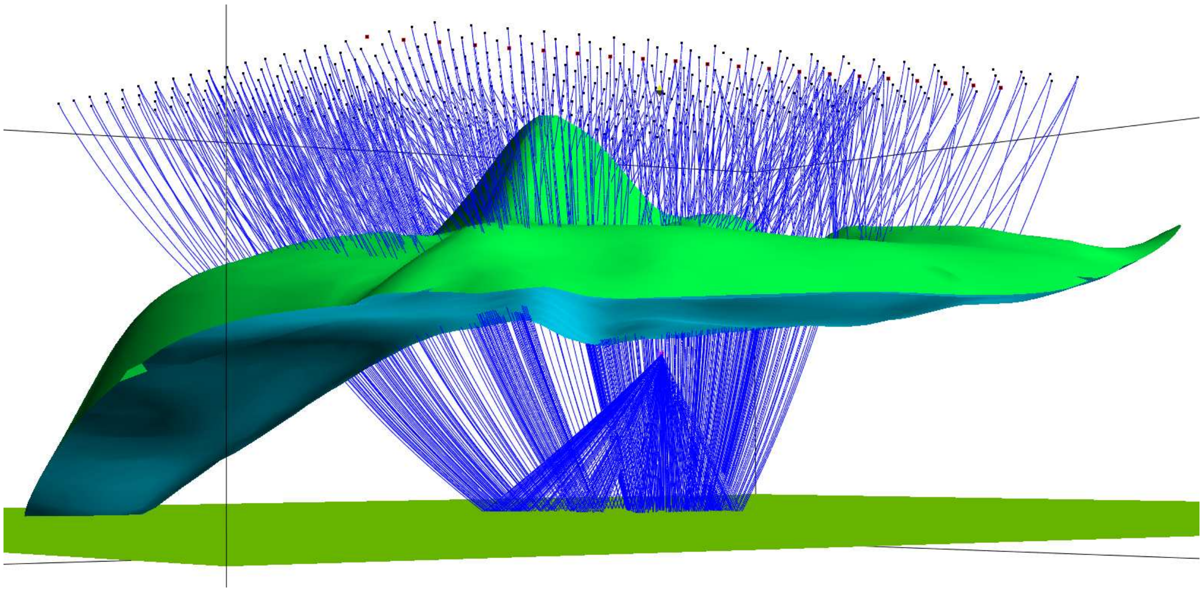

Figure 6. Rays of the P-wave reflected from the bottom flat interface. The shot is located in the well, below the salt, in the depth of 2300m.

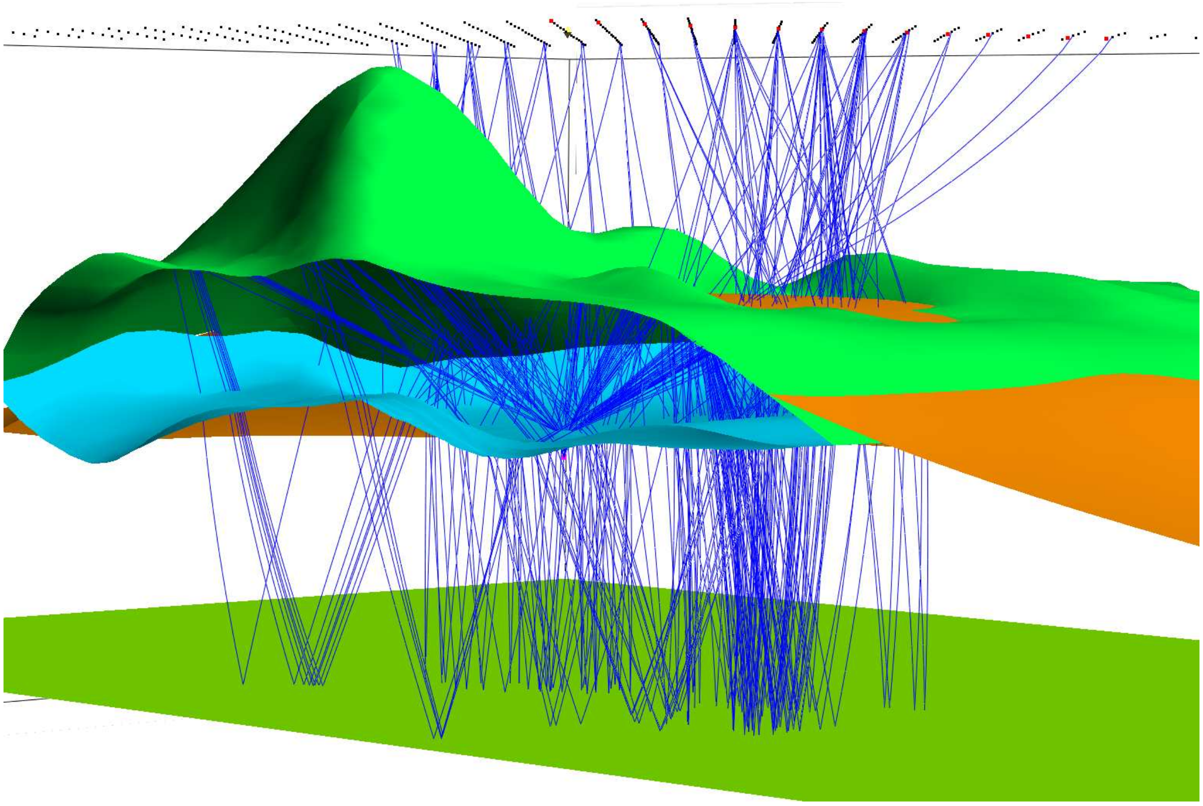

Figure 7. Rays of the P-wave (one elementary wave code) multiply reflected from the top of the salt and from the bottom flat interface. The shot is located in the well, below the salt, in the depth of 2300m. The model is cut by GOCAD slicer.

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

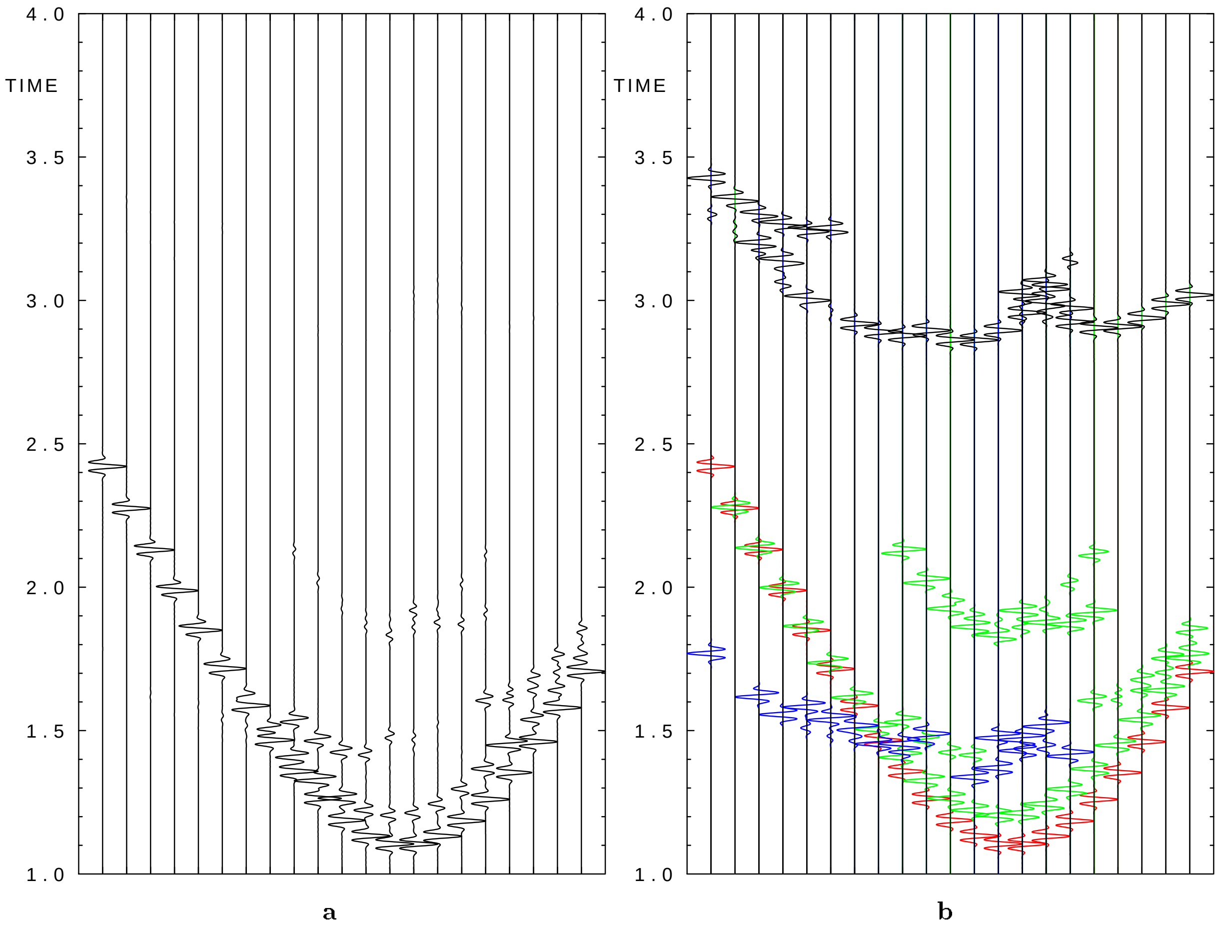

Figure 8. Source located in the well above the salt body in the depth of 900m. a: Vertical components of synthetic seismograms of all computed elementary waves along the selected profile. The amplitudes at each trace are scaled according to the maximum amplitude at each trace. b: Vertical components 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.

by red points in Figure 1. The source time function is defined by the 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`.

Seismograms in Figure 8 are computed for the shot located in the well above the salt body in the depth of 900m. Figure 8a 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 8b shows traces of individual elementary waves distinguished by colours. The maximum amplitude of each elementary wave is scaled to a given constant. The greatest amplitudes are caused by the refracted wave.

Seismograms in Figure 9 are computed for the shot located in the well, below the salt body, in the depth of 2300m. Figure 9a shows the seismograms generated from all

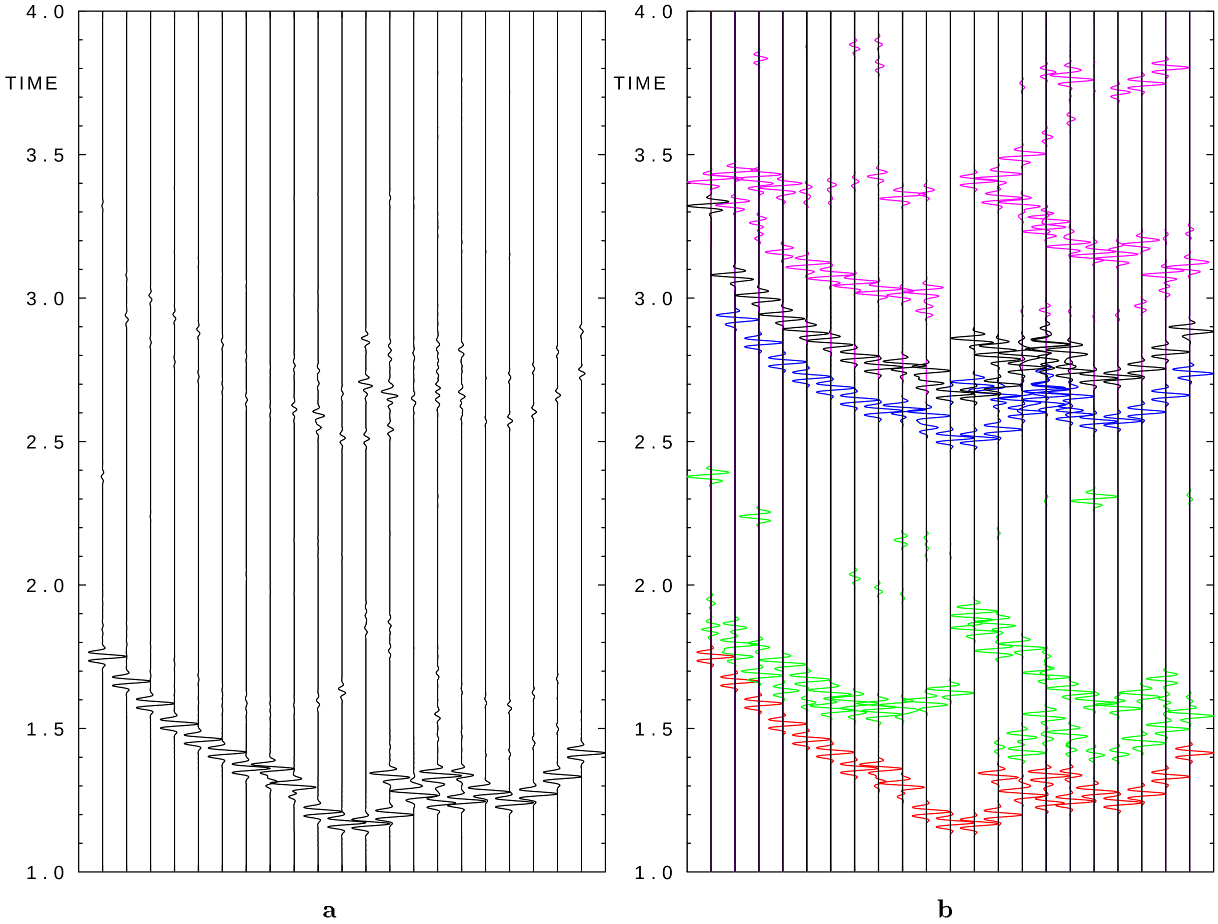

Figure 9. Source located in the well below the salt body in the depth of 2300m. a: Vertical components of synthetic seismograms of all computed elementary waves along the selected profile. The amplitudes at each trace are scaled according to the maximum amplitude at each trace. b: Vertical components 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 multiple reflections from the top and bottom of salt,** *blue* **denotes the reflections from the bottom interface,** *black* **denotes the multiple reflections from the bottom of salt and bottom interface and** *magenta* **denotes the multiple reflections from the top of salt and bottom interface.**

the computed elementary waves: one refracted and four reflected P-waves, three of them multiply reflected. The maximum amplitude at each trace is scaled to a given constant. Figure 9b shows traces of individual elementary waves distinguished by colours. The maximum amplitude of each elementary wave is scaled to a given constant. The greatest amplitudes are caused by the refracted wave. The source is located near to the salt bottom interface. The arrival times of the wave reflected from the bottom flat interface (blue colour amplitudes) and the wave multiply reflected from the bottom salt and the bottom flat interface (black colour amplitudes) are close. This multiply reflected wave is called ghost. Both waves are visible clearly in Figure 9b.

5 Conclusions

Results of this paper demonstrates successful application of the SW3D software to two-point ray tracing and to calculation of ray-theory seismograms in the smoothed Salt Model with interfaces. Computation and visualization of raypaths and seismograms of individual elementary waves is a great advantage of the ray tracing method.

The time of the computation of the history file `sal-rwe1.h` is approximately one hour and of the history file `sal-rwe2.h` is roughly six hours on a PC equipped with processor Athlon XP 1700+.

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