

SEISMIC VELOCITY MODEL IN THE VICINITY OF EGER RIFT FROM DISPERSION OF SURFACE WAVES

Internal Start Project of the Grant Agency of the Academy of Sciences of the Czech Republic
No. I039 / No. Z3046908

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ABSTRACT

We have studied the uppermost crust seismic velocities in the western Bohemia region. Surface wave records were analyzed, dispersion curves were estimated and compared with the theoretical curves computed for average regional models. We made an inversion of the estimated dispersions for 1D velocity models for several tens of surface wave paths. The lateral heterogeneity of the region was discussed and more data were analyzed to prepare surface wave tomography inversion. Several computer programs were developed and joined in the SVAL program package. It can be used in other regions to provide the surface wave analysis and inversion.

KEYWORDS: surface waves, frequency-time analysis, group velocity, dispersion, isometric method, Western Bohemia

INTRODUCTION

The Western Bohemia region attracts the interest of geoscientists mostly because of complicated geological structure and the occurrence of seismic swarms. Despite the long-term survey conducted in this region the problem of seismic velocities has not been accurately solved yet. Body waves were used to invert the travel times and to obtain the crust structure in the recent years. Surface wave analysis is a new contribution to the survey of the region.

PROJECT OBJECTIVES

The aim of the project was to estimate the seismic velocity model of the region. This study should complement geological and geophysical information about the crust structure. Analyzing and inverting dispersion curves of surface waves enables to specify the seismic velocity distribution of uppermost crust. Using only one record, it is possible to obtain 1D average velocity distribution along the blast-station path. Using many such records of surface waves, estimation of lateral variations of seismic velocity is possible by using surface wave tomography method.

METHODOLOGY

Frequency-time analysis techniques are used to estimate the group velocity of seismic surface waves. We prepared a new SVAL program for the surface wave studies. It is based on classical frequency-time analysis. It uses the Fourier transform-based multi-channel filtering (Dziewonski et al., 1969). We have

implemented Gaussian filtering with constant relative resolution and optimal filter widths, Kolínský, 2004. The program was joined with other programs for forward modeling (Proskuryakova et al, 1981) and for inversion problem computing (Málek et al., 2005). The method, which the program package uses, is described in Kolínský and Brokešová, 2005. We obtained a powerful instrument for surface wave analysis and inversion. Besides the uppermost crust estimation, the SVAL program itself is a useful result of the project.

MEASUREMENT

We did not need to make any new measurements since all the data were already available. The records were acquired during the seismic refraction experiment SUDETES 2003 which was part of the SLICE (Seismic Lithospheric Investigation of Central Europe) international experiment.

RESULTS

THE SVAL PROGRAM

The SVAL program is an instrument for frequency-time analysis of seismic records. It is possible to estimate the dispersion curve of selected mode and to make an inversion for 1D layered velocity and density model. We provide the program version which can invert both Love wave dispersion for 1D shear velocity and density model and also Rayleigh wave dispersion for 1D longitudinal and shear velocity and density model. As the program uses graphical interface, it is possible to check all the

computational steps both in time and frequency domain. It is possible to control the parameters of analysis and inversion to obtain the reliable results. The multi-channel filtering technique is used for frequency-time analysis (Kolínský 2003, 2004), the isometric algorithm for inversion (Málek et al. 2005) and the matrix method for forward modeling (Proskuryakova 1981). As the SVAL program computation is divided into separated blocks, it is possible to go through only a part of the task. It is possible for example to make only the analysis of the record or to make only the inversion of the previously estimated dispersion curves.

The source code is written in PASCAL using Delphi environment (version 7.0). It uses only standard components implemented in the environment and one freeware component. The code consists of four units, which contain tens of procedures. The PASCAL code emerges as a result of translating of older codes from FORTRAN language (Kolínský 2004). Then it was compiled together with code written in Delphi (Málek 2005). One FORTRAN subroutine from Numerical Recipes (Press et al. 1992) translated to PASCAL is also used. The SVAL program is distributed as a single *.exe file (3 MB). No installation is necessary.

There is one basic and two auxiliary windows to be displayed at the monitor while the program is running, see Fig. 1. The basic one is used for setting all parameters and for checking results in the time domain and in the group velocity-period plane. The result of inversion is also displayed in this window. One of the auxiliary windows allows displaying of the filtration in frequency domain and the other displays information about the inversion problem progression. The program is set to be able to process the record of length up to $2^{14} = 16384$ samples.

Program inputs

files:

- seismogram or velocigram record (1 component)
- the previously estimated dispersion curve file
- file containing the depths of layers which will be used for structure estimation

earthquake (blast) parameters (from keyboard):

- epicentral distance (km)

record parameters (from keyboard):

- sampling frequency (Hz)
- time interval between origin time and beginning of the record
- instrument characteristics selection (Lenartz 3D/5s, STS2 120s, Guralp 30s)

filtration parameters (from keyboard):

- minimal and maximal group velocity (km/s)
- minimal and maximal period (s)
- maximal number of filters

- length of smoothing window for the record edges (num. of samples)
- coefficient α (width of filters) (dimensionless), intercept point and slope of the linear dependence
- default value of α coefficient
- scale factor of filtered seismogram amplitude (percents, options)

dispersion curve (from keyboard):

- two options which determine how to compile the dispersion curve from the local dispersion points: "A" from the absolute maximum of whole spectrogram, "L" from the last filter
- option for making FFT only

inversion (from keyboard):

- minimal and maximal period to be inverted (options)
- group velocity starting value for the forward problem computing (km/s), it is possible to change this value but it is not necessary
- approximate shear wave velocity at the surface (km/s)
- approximate v_p / v_s ratio and its variability range
- maximal step of velocities in the next layer (km/s)
- approximate density value at the surface (g/cm^3)
- approximate step of density in the next layer (g/cm^3)
- Love or Rayleigh wave inversion (option)

There are also other buttons and edit windows for zooming and changing the views of displayed results in the program.

Program outputs

files:

- separate channels: file columns containing following values are saved:
 - time measured from origin time (s)
 - instantaneous period of nearly monochromatic signal (s)
 - amplitude of the nearly monochromatic signal
 - envelope of the nearly monochromatic signal
 - amplitude of the truncated nearly monochromatic signal
 - envelope of the truncated nearly monochromatic signal
 It is possible to save this file for each separate channel.
- seismograms or velocigrams: file columns containing following values are saved:
 - time measured from origin time (s)
 - original record

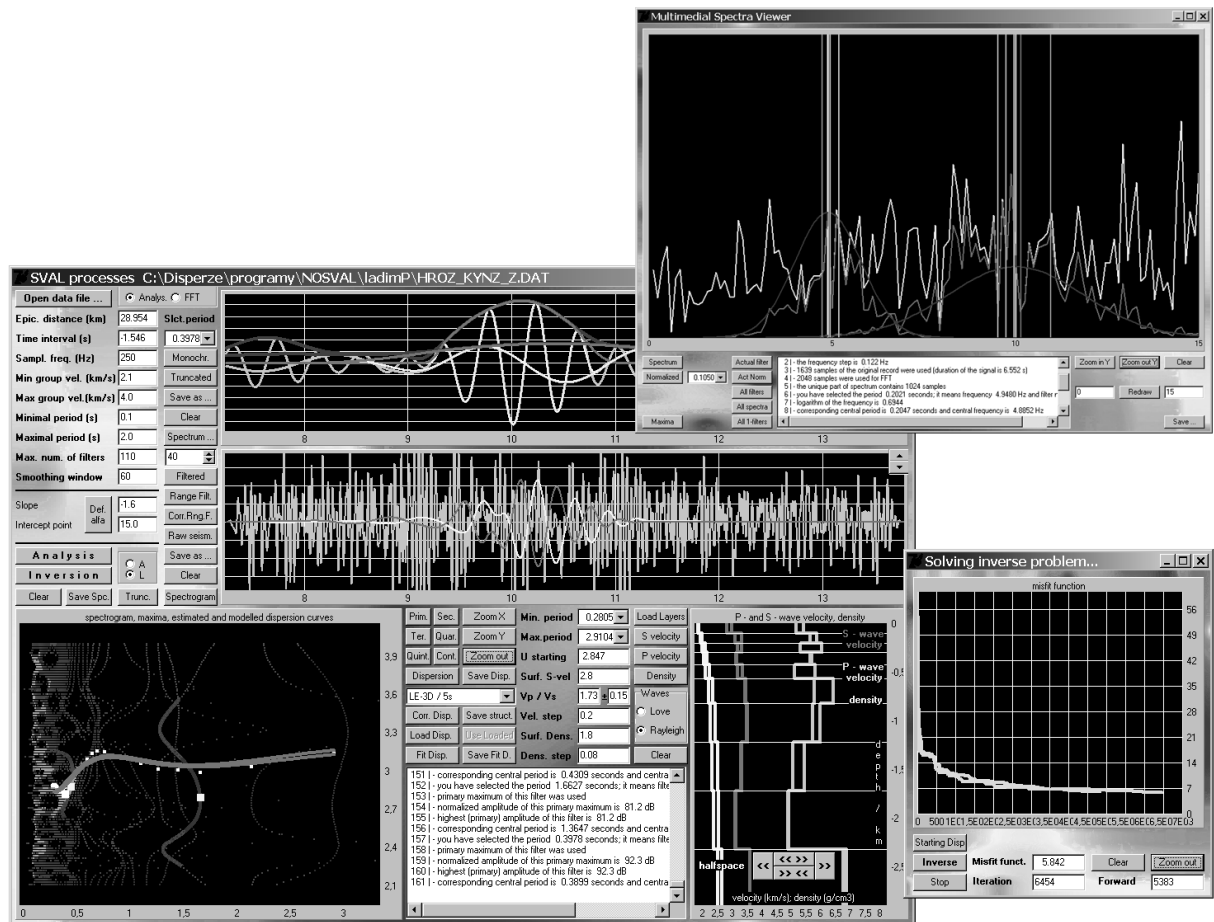


Fig. 1 Main window of the SVAL program and two auxiliary windows.

- filtered seismogram for whole filtered period range or only for the selected narrower period range
 - filtered seismogram or velocigram which is instrument independent (for selected period range only)
- spectrogram: file columns containing following values are saved:
 - period (s)
 - group velocity (km/s)
 - amplitude (normalized into 100 dB scale)

This file is used for imaging the spectrogram as a 3D plane.
- dispersion curve (points): file columns containing following values are saved:
 - period (s)
 - propagation time (s)
 - group velocity (km/s)
 - propagation time corrected with respect to instrument transfer function (s)
 - group velocity corrected in the same way as the propagation time (km/s)
- normalized amplitude of the corresponding dispersion point (the same as in spectrogram) interpolated dispersion curve is also saved into this file:
 - period (s) with the 0.05 s step
 - corrected and interpolated (to the period values) propagation time (s)
 - corrected and interpolated group velocity (km/s)
- velocity model:
 - *.zal file: columns containing following values are saved:
 - thickness of layer (km)
 - P-velocity (km/s)
 - S-velocity (km/s)
 - density (g/cm^3)
 - *.dat file: columns containing following values are saved:
 - depth of top and bottom of the layer (km) (two lines)
 - P-velocity at the layer boundaries (two identical values)

- S-velocity at the layer boundaries (two identical values)
- density at the layer boundaries (two identical values)

This file is used for imaging the structure in 2D plot software.

- dispersion curve corresponding to the resultant structure model: file columns containing following values are saved:
 - period (s) with the step according to the forward modeling computation
 - group velocity (km/s)
- frequency domain: file columns containing following values are saved:
 - real part of the spectrum
 - imaginary part of the spectrum

Displayed outputs:

- file name and path of the record file
- or file name and path of the previously estimated dispersion curve
- file name and path of the file containing layer thicknesses
- text box containing information about all important computational steps: input parameters for checking, estimated parameters of filtration, corrected values of minimal and maximal period, number of used filters, information about FFT, list of estimated dispersion points and type of their maxima, information about the inversion parameters, about the period step of forward modeling and about the results of inversion
- option for selecting an instantaneous period of filter (output / input)
- selected nearly monochromatic signals and their envelopes
- selected truncated nearly monochromatic signals and their envelopes
- frequency domain: power spectrum is displayed; also log-log spectrum
- frequency domain: selected Gaussian filters; also in log-log representation
- frequency domain: selected filtered spectra; also in log-log representation
- frequency domain: all Gaussian filters are displayed together (actual or normalized representation); also in log-log representation
- frequency domain: all filtered spectra are displayed together; also in log-log representation
- text information about the frequency domain
- arrival times of 1st to 5th maxima of each filter are marked

- spectrogram contours
- frequency domain: instantaneous frequencies of 1st to 5th maxima are marked
- original raw velocigram (seismogram)
- filtered velocigram for the whole used period range
- filtered velocigram for selected period range
- filtered velocigram for selected period range and with instrumental correction applied
- spectrogram
- truncated spectrogram
- dispersion curve
- dispersion curve with instrumental correction (for selected period range)
- the 1st to 5th maxima of each filtered signal in group velocity-period plane (dispersion ridges)
- information about the inversion progression, current misfit function value and its graphical depiction
- number of forward modelling
- velocity and density structure depiction of the starting model
- velocity and density structure depiction in previously set layers
- dispersion curve for the starting structure
- dispersion curve for final structure (for comparing with the measured dispersion curve)

CRUST VELOCITY MODEL ESTIMATION

During the project many 1D surface wave paths were inverted for S-velocity and density. Six of them, which represent the heterogeneity of Western Bohemia region, are shown in the paper by Kolínský and Brokešová, 2005. These results are also discussed and compared with models estimated by other authors and by means of other method using both body and surface waves.

By forward modelling using matrix method we compute theoretical dispersion curves for previously published models and compare them with the measured dispersions. The total number of estimated dispersion curves in this region is 96. We also prepared programs for surface wave tomography, which will use all the data. The tomography can reveal the 3D distribution of seismic velocities in the western Bohemia region.

ACKNOWLEDGEMENTS

This research was supported by start project No. Z3046908-I039 of the Grant Agency of the Academy of Sciences of the Czech Republic, by grant No. VaV/630/3/02 of the Ministry of Environment of the Czech Republic and by Institute research plan No. A

VOZ30460519. We are grateful to Jiří Málek for providing programs for the isometric method and for consultations about inversion problems. We also thank Oldřich Novotný for programs and consultations concerning matrix method computations.

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MODEL SEISMICKÝCH RYCHLOSTÍ V OBLASTI OHERSKÉHO RIFTU NA ZÁKLADĚ DISPERZE POVRCHOVÝCH VLN

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ABSTRAKT:

Během projektu byla studována svrchní kůra v oblasti Západních Čech. Záznamy povrchových vln byly analyzovány, byly určeny disperzní křivky a ty byly porovnávány s teoretickými křivkami odpovídajícími šíření povrchových vln v průměrných modelech oblasti publikovaných v literatuře. Jelikož rozdíly byly výrazné, byla provedena inverze naměřených disperzních křivek na 1D rychlostní řezy pro několik desítek profilů. Byla diskutována laterální heterogenita regionu a pokračovalo se v analýze dalších dat pro přípravu tomografické úlohy. Bylo vytvořeno několik programů, které byly spojeny do programu SVAL. Ten může být obecně použit pro analýzu a inverzi záznamů povrchových vln i v jiných regionech.