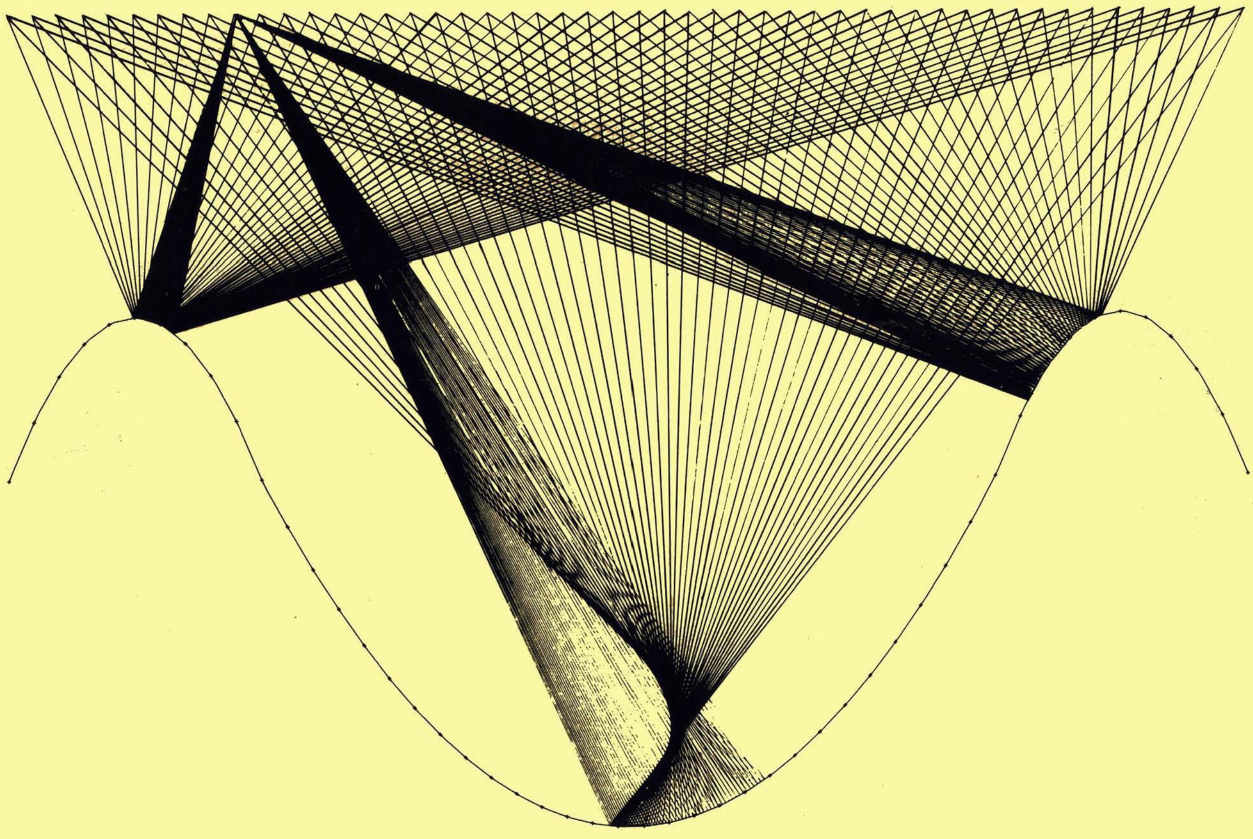
PRAKLA-SEISMOS INFORMATION No.16

2-D Modelling



2-D Modelling

Aim of modelling is the derivation of synthetic seismic traces from hypothetical geological and geophysical data or from survey data (typical: the so-called synthetic seismograms). The application of modelling becomes more and more important for the following purposes:

Field Technique: Derivation of field parameters for a given structural model

Application to the solution of static correction problems

Processing: Confirmation of effectivity of chosen processing parameters

Applications in the research and development of seismic processing techniques

Interpretation: Iterative adjustment of pre-given geological models to surveyed data

Special studies: Investigation of stratigraphic, lithological and structural parameters

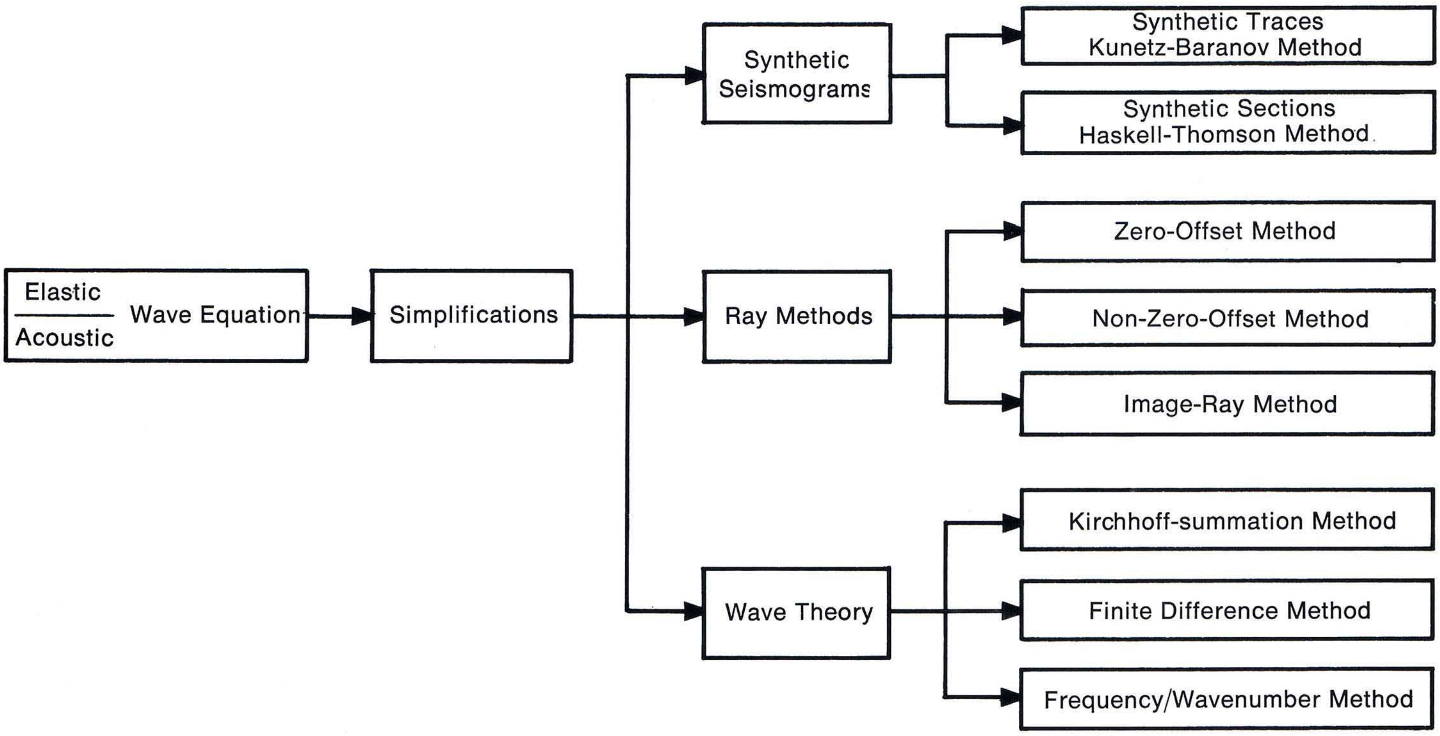
Investigation of multiples, diffractions and noise

Resolution of seismic data

etc.

Starting point for the calculation of synthetic seismic traces is the elastic or the acoustic wave equation. At present the solution of these equations for arbitrary models, taking into account all seismic phenomena which are important in exploration work, is not possible. However, a series of numerical methods has been developed, permitting partial solutions or solutions for simplified models. Therefore, the choice of method to be applied depends on the problems involved.

In particular, model calculations can be carried out as follows:



Calculation of Synthetic Seismograms

Synthetics Traces

The calculation of synthetic traces according to the **Kunetz-Baranov-Method** has been carried out by PRAKLA-SEISMOS for many years. The basis of calculation is the data of velocity logs obtained from well surveys. Density logs should always be included, if the logs of both surveys show deviations. Seismic well velocity surveys are applied for the correction of the logs.

Reflection coefficients of primary events, of free-surface and/or interbed multiples are calculated from the calibrated logs. The spikes, obtained in this way, can be filtered arbitrarily.

Quite recently this method gained importance due to its application in Wavelet Processing (see PRAKLA-SEISMOS Information No. 8) and in Vertical Seismic Profiling.

Given a shot-receiver-geometry, dynamically uncorrected seismograms can be produced, which, however, only present a rough approximation of the "real" conditions; an essential improvement is presented by the method for the production of synthetic sections, which is described in the following paragraph.

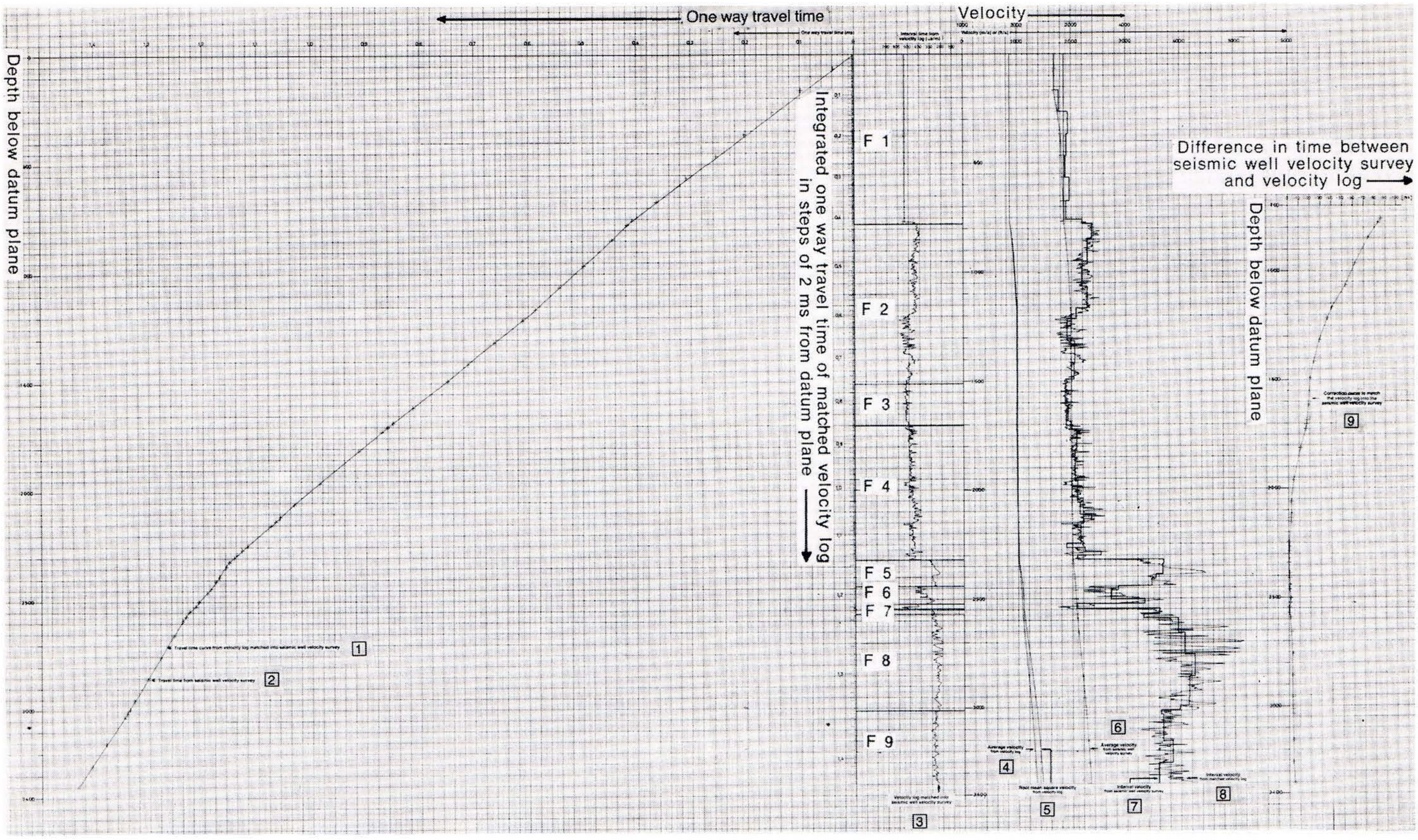
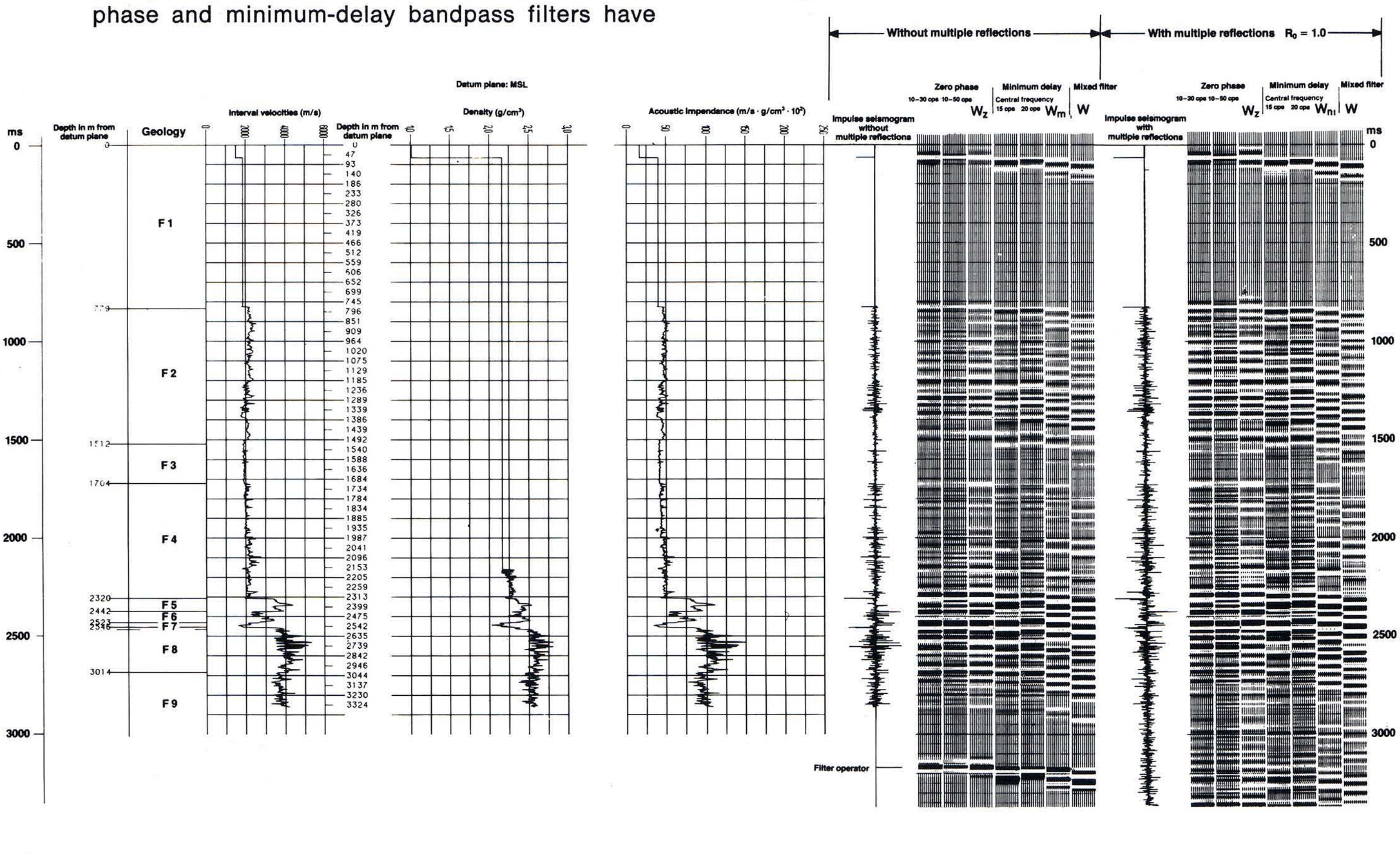


Fig. 1: Presentation of results of a seismic well velocity survey in the usual PRAKLA-SEISMOS form

- 1: Travel time curve from velocity log matched into seismic well velocity survey
- 2: Travel time from seismic well velocity survey
- 3: Velocity log matched into seismic well velocity survey
- 4: Average velocity from velocity log
- 5: Root mean square velocity from velocity log
- 6: Average velocity from seismic well velocity survey
- 7: Interval velocity from seismic well velocity survey
- 8: Interval velocity from matched velocity log
- 9: Correction curve to match the velocity log into the seismic well velocity survey

Fig. 2: Presentation of synthetic traces in the usual PRAKLA-SEISMOS form. Here velocities, densities, transmission losses, interbed and free-surface multiples have been taken into account. Zero-phase and minimum-delay bandpass filters have been applied as well as the mixed delay wavelet "W", derived from wavelet processing, its zero-phase correspondent W_z and its minimum-delay-correspondent W_m



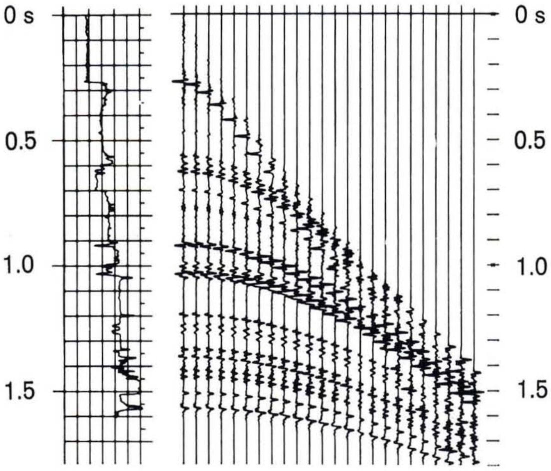


Fig. 3: Velocity log and corresponding synthetic traces constructed assuming increasing source-receiver-distances.

Synthetics Sections

The calculation of synthetic seismograms is generalized to the case of horizontal layers for separated source- and receiver-positions, by employing a procedure based on the **Haskell-Thomson-Method,** taking into account all converted elastic waves, including head waves, and frequency-dependent absorption. This method determines the complete solution of the elastic wave equation for horizontal layers, and is especially suitable for the investigation of thin layered strata and for absorption studies.

In addition to the parameters necessary for the calculation of synthetic traces, the following can be considered:

Source- and receiver-coordinates
Absorption coefficients
Velocities of shear waves

The figures below show two sections, processed using this method, with and without consideration of absorption.

Fig. 4: Synthetic section without consideration of absorption

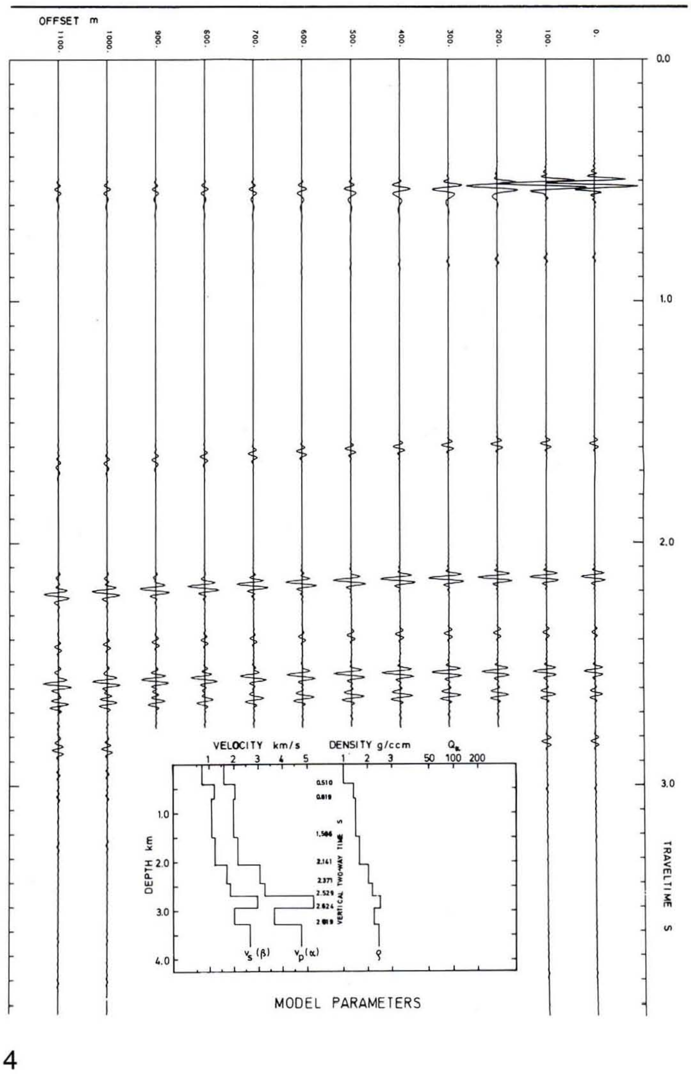
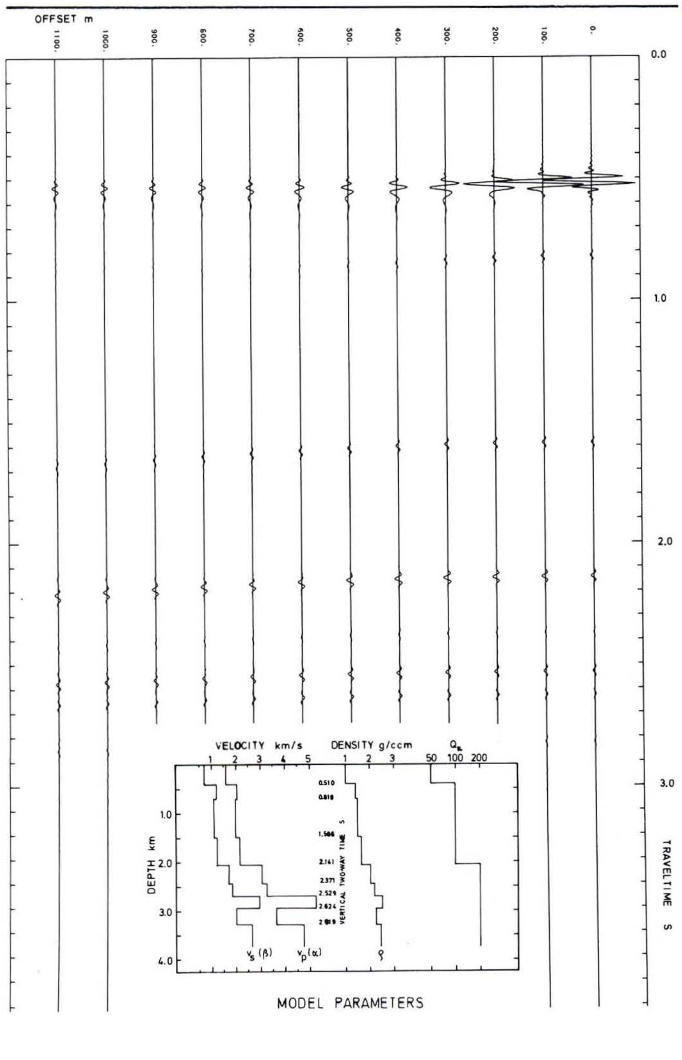


Fig. 5: Synthetic section with consideration of absorption taken into account: velocities, densities, reflection- and transmission losses, spherical divergence, correct consideration of the angle of incidence



Wave Equation Methods

Solutions of the acoustic wave equation are produced by employing **Kirchhoff's integral formulation** or certain **finite difference schemes** for the solution of partial differential equations.

Since both methods are quite intensive on computing time, in general only CDP-sections are produced. Roughly speaking, these methods are preferable to ray methods (encountered in the next paragraph) whenever important seismic parameters change significantly within the order of a typical seismic wave length. In particular, diffraction and propagation phenomena (e.g. buried focus response) are well displayed.

The solution of the acoustic wave equation in the **frequency/wavenumber domain** has recently become possible for seismic data. This method has similar advantages to the Kirchhoff and the finite difference methods described above, but is not as computer intensive. The consideration of lateral velocity changes is, however, a problem.

It should be noted that similar numerical methods are employed in the various migration procedures. Migration schemes, however, produce only simplified solutions of the wave equation, namely those waves which propagate in the upward direction. Wave equation modelling, on the other hand, permits additional solutions of the wave equation such as the calculation of primary and multiple reflections.

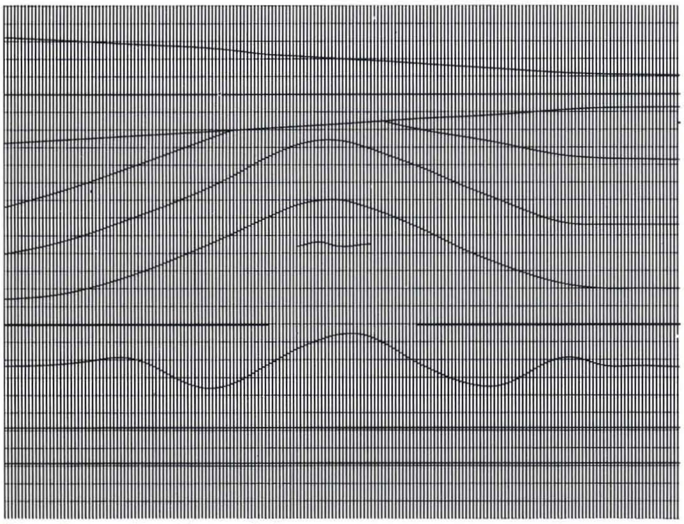


Fig. 6 a: Depth model

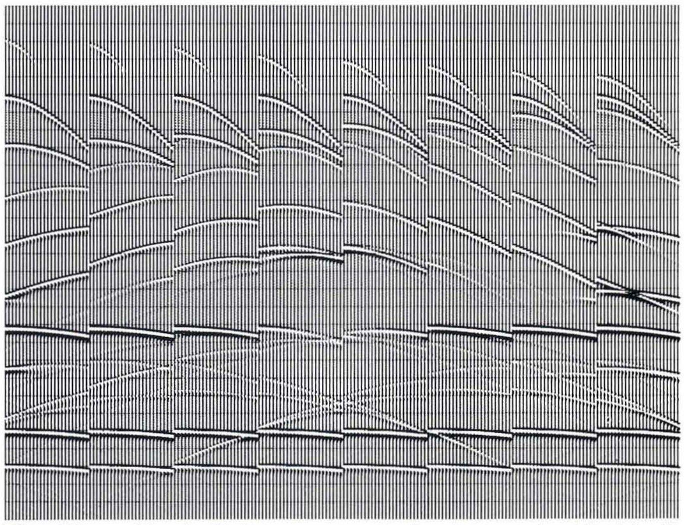


Fig. 6 b: Single Seismograms derived from the Kirchhoff-summation method

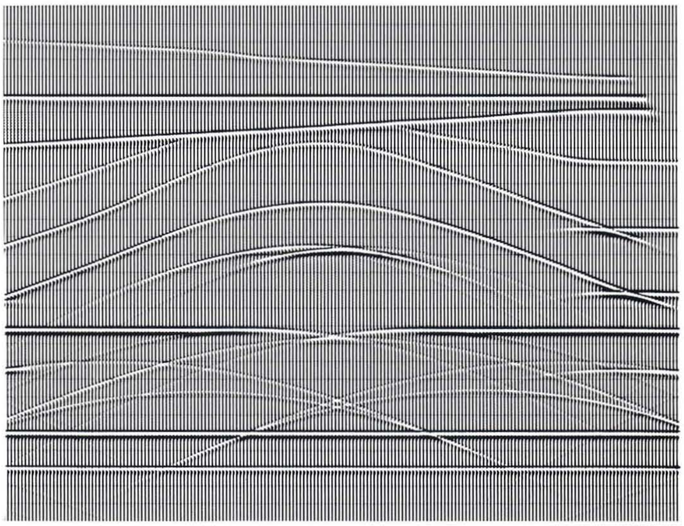


Fig. 6 c: Stack of the single seismograms

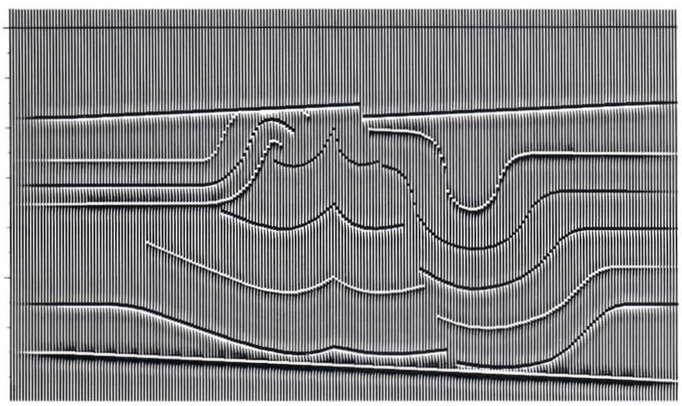


Fig. 7 a: Depth model

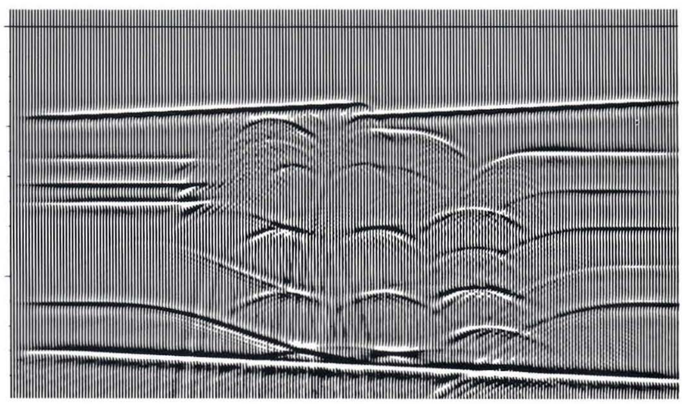


Fig. 7 b: CDP-section derived from the Finite Difference Method

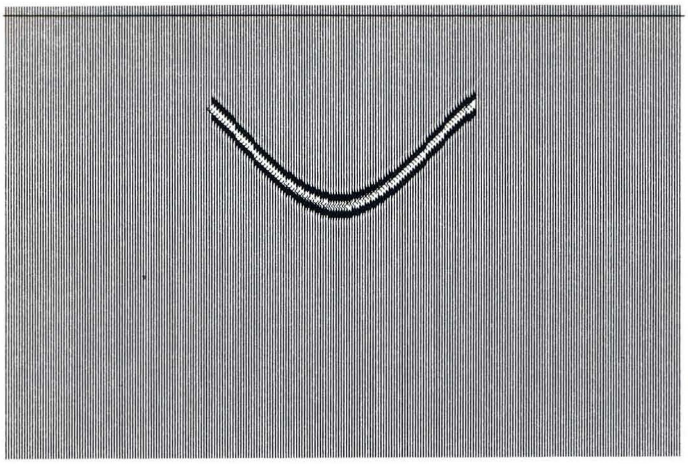


Fig. 8 a: Depth model

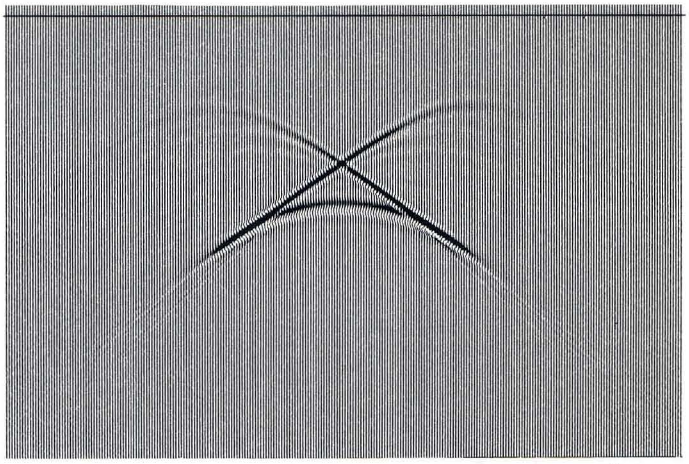


Fig. 8 b: CDP-traces derived from the Frequency/Wave-number method

For those modelling methods using the wave equations, which do not take ray bending due to refraction into account, a corresponding correction can be applied; the result is an "intermediate model" obtained from **P. Hubral's image-ray method,** which is a ray tracing method. Image rays are rays, propagating vertically from the earth's surface, which can be, as in fig. 9a, traced through the depth model; fig. 9b shows the resulting "intermediate model", which is subsequently input for modelling according to the wave equation method.

Fig. 9 a: Depth model with image rays

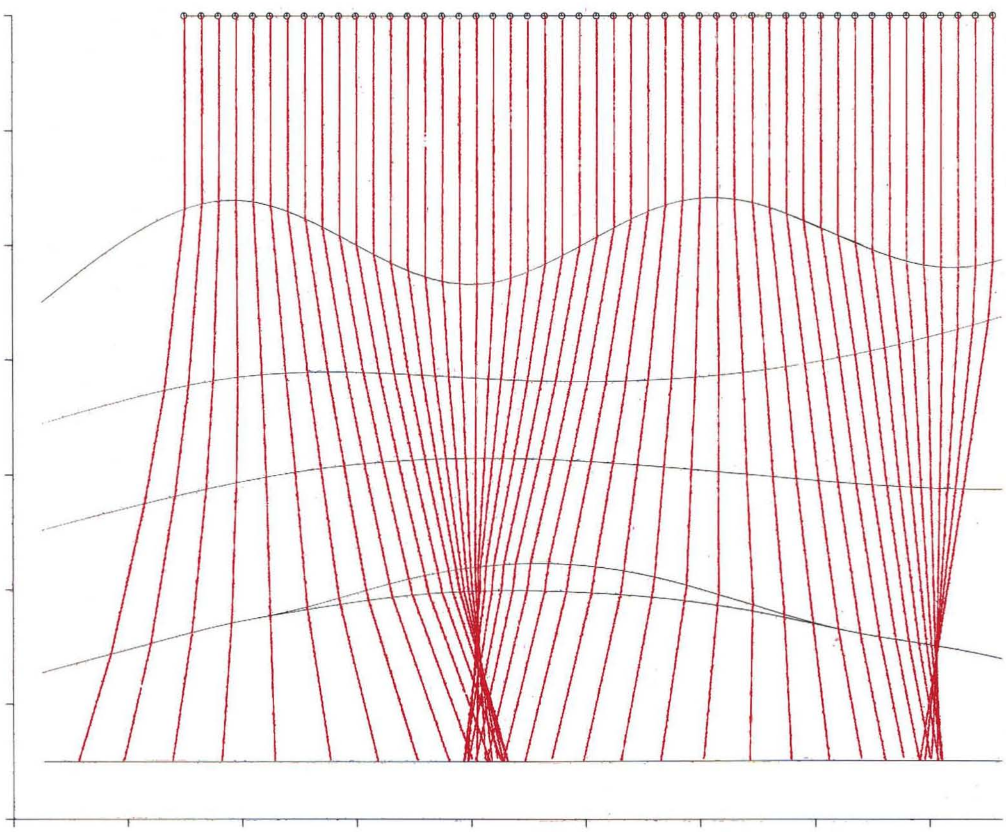
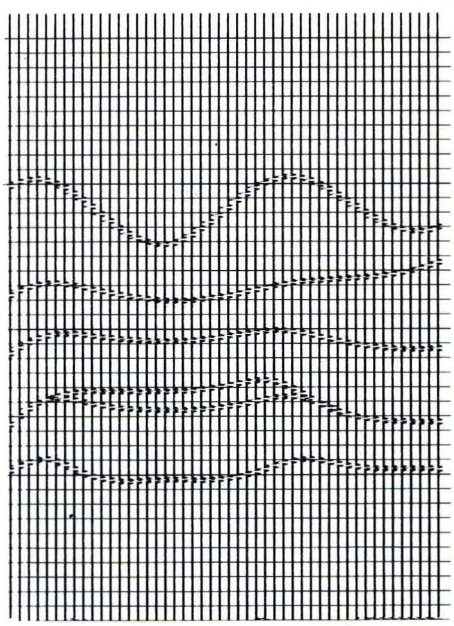


Fig. 9 b: "Intermediate model" derived from Image Ray Method



Ray Tracing Method

Solutions of the elastic wave equation are obtained from asymptotic series expansions; the resulting modified ray theory allows the calculation of travel times, amplitudes and phases of P and/or S-waves.

For the derivation of time sections the following data are necessary:

- digitized depth horizons
- interval velocities
- source and receiver coordinates
- standard wavelets

Travel times and amplitudes are calculated (under consideration of spherical divergence and reflection coefficients) for primary events and free-surface multiples.

For detailed studies in single seismograms the following additional data can be applied:

- virtually arbitrary velocity distributions
- virtually arbitrary source-receiver-geometry (incl. elevations)
- density distributions
- absorption coefficients
- arbitrary wavelets
- diffraction points

Thus, the following may be considered:

- interbed multiples
- diffraction events
- absorption losses
- focussing and defocussing effects
- reflection- and transmission losses for the layers with regard to the conversion of elastic waves (thus, also phase modification caused by supercritical reflections).

According to this method, the sections can be produced as follows:

Zero-offset Method

Normal incidence rays are calculated, simulating a "normal" stacked seismogram.

Non-zero-offset Method

Single seismograms are calculated from which "real" stacked sections can be produced. This method is recommended in the case of strongly dipping or curved upper horizons, at which the stacking hypothesis is violated.

Using modern computers all ray methods are time-saving and therefore suitable for iterative adjustment to surveyed sections via our **Interactive System.**

Fig. 10 a: Depth model showing ray-paths

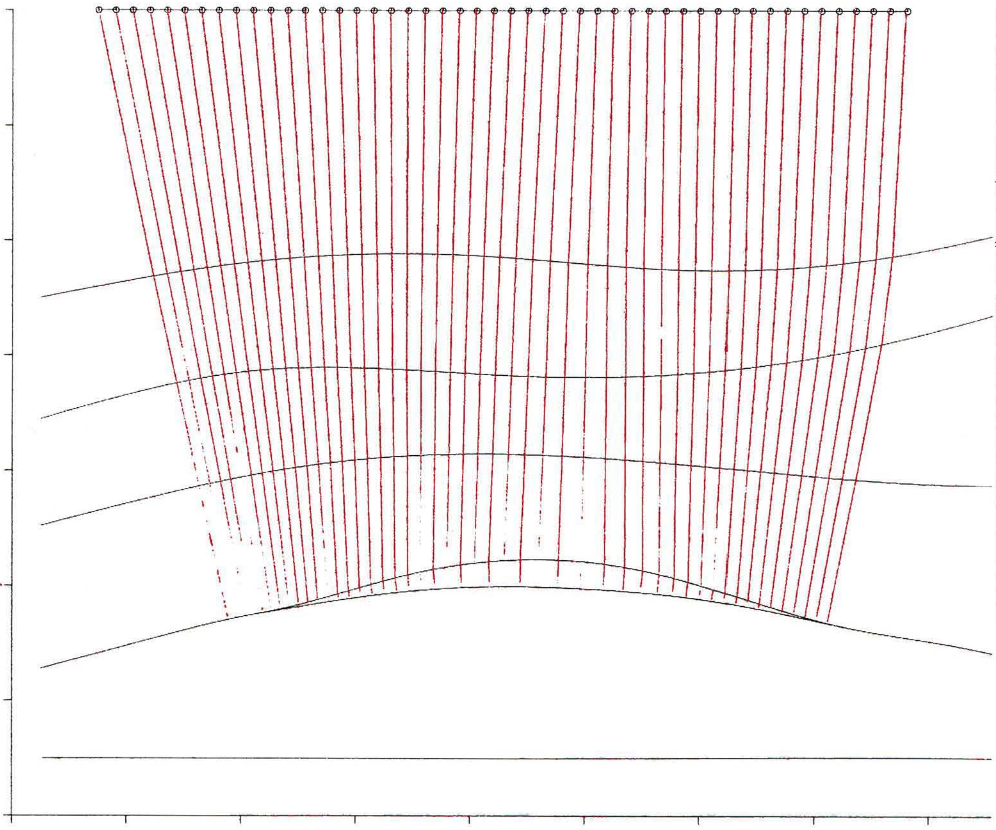
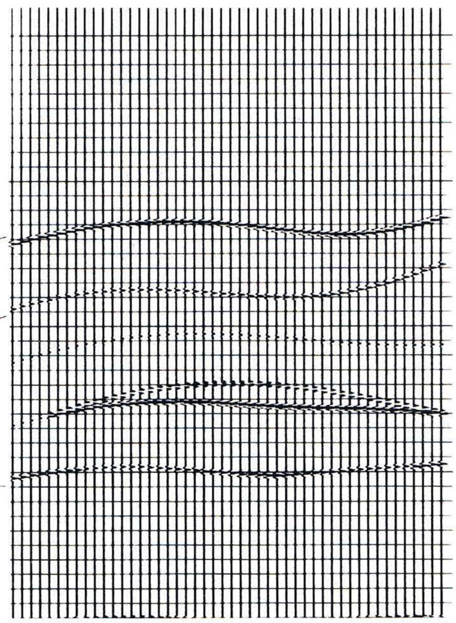


Fig. 10 b: CDP-time section derived from the Zero-offset Method



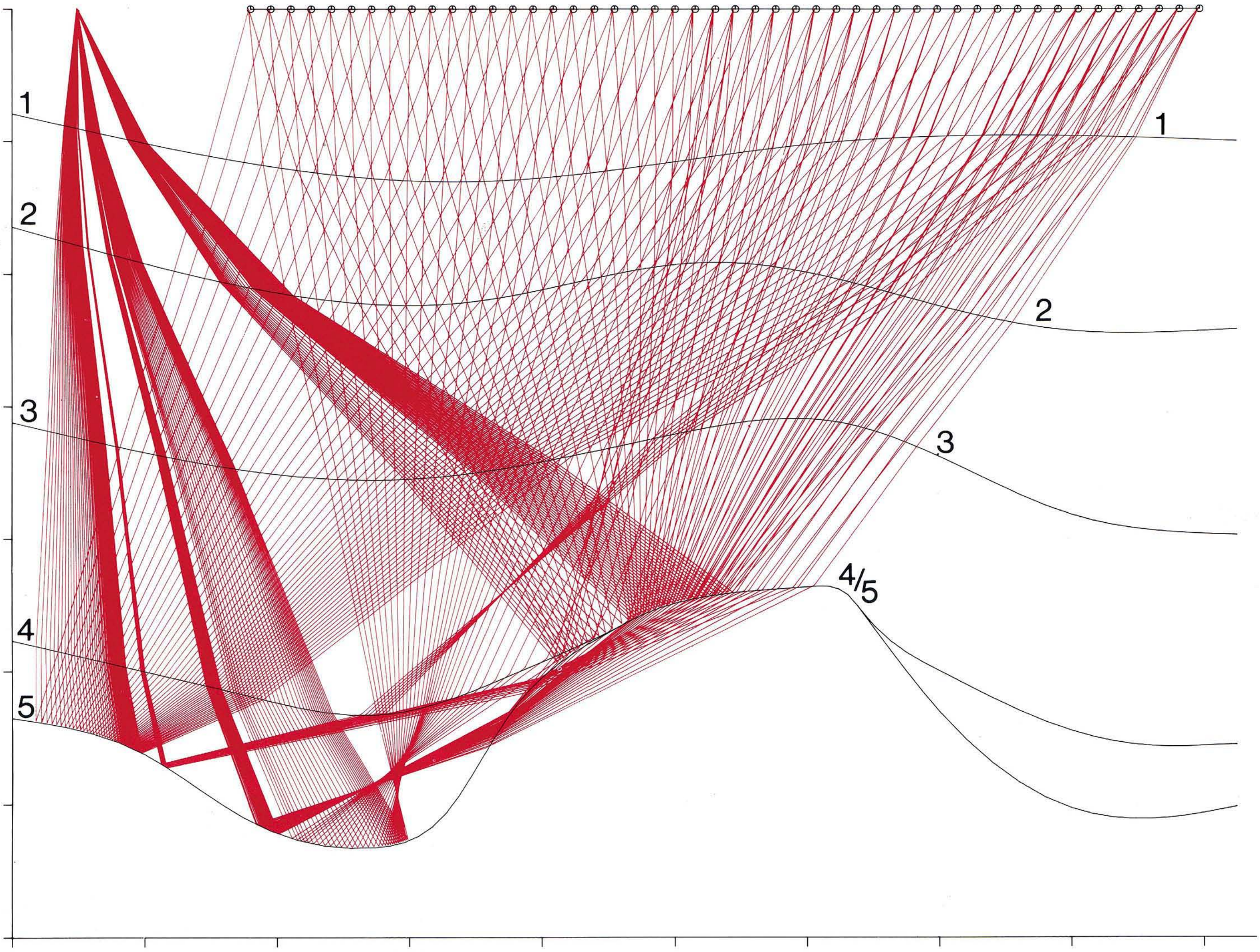


Fig. 11 a: Depth model
(another depth model is presented on the front cover)

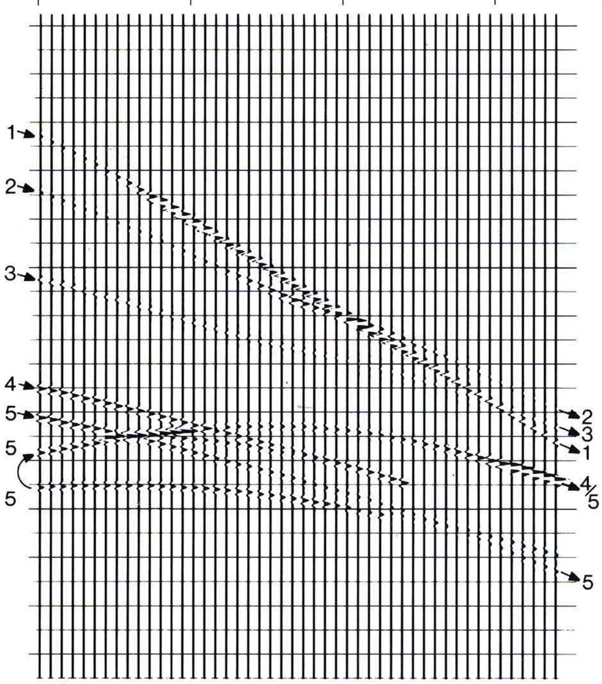


Fig. 11 b: Single seismograms derived from the Non-zero-offset Method

note: 1) the calculated amplitudes are corrected for spherical divergence

note: 2) the effect of supercritical reflections can be seen clearly in the upper horizons

PRAKLA-SEISMOS GMBH · HAARSTRASSE 5 · P.O.B. 4767 · D-3000 HANNOVER 1
PHONE: 8 07 21 · TELEX: 9 22 847 · CABLE: PRAKLA · GERMANY

3500678