NORSAR Seismic Modelling

Newsletter, June 1999

NORSAR-3D, New version 2.1!

The first commercial version of the seismic modelling package NORSAR-3D was released in January 1997. The package combines a flexible model representation (the *Open Model* concept) based on triangular interfaces with the unique *Wavefront Construction* ray-modelling method developed by researchers at NORSAR from the beginning of the nineties. For the first time, it is possible to do bulk simulation of large surveys in realistic models in a workstation environment. Below, you'll see an example of synthetic seismic acquisition of several thousands of shots and the generation of illumination maps.

The new version 2.1 has several improvements and extensions:

- Import/Export of freepoint XYZ time, depth or interval velocity grids for model building
- Import of SPS land surveys
- Integration to the petrophysical package VelRock developed by **UniGEO *a.s.*** marketed by NORSAR
- Up to 40% reduction of CPU time in the modelling
- Improvements in parallel processing on several machines
- Export of SEG-Y files with synthetic seismics
- Export of modelling data such as traveltimes, amplitudes, reflection points, reflection angles and much more on various ASCII formats

General features of NORSAR-3D

- Import/Export of many grid formats
- Import/Export of GOCAD$_{TM}$ triangulated interfaces
- Time- to-depth or depth-to-time mapping by image rays
- Model representation with the possibilities of:
  - * Overhangs, faults, and pinch-outs
  - * General three dimensional velocity and density variations
  - * Holes or missing parts of the interfaces (the *Open Model* concept)
  - * Free surfaces
  - * Water layers and elastic layers
- Shot modelling and zero-offset modelling
- Modelling by *Wavefront Construction* with:
  - * P-S mode conversion at the interfaces
  - * Angle dependent reflection/transmission coefficients at the interfaces
  - * Full elastic amplitude calculation
  - * Free surfaces and liquid/solid interfaces
  - * 3D geometrical spreading
  - * Phase-shifts at caustics (i.e. focal points) and at over-critical reflections
  - * Parallel processing of large surveys on all available machines in the network
- Generation of synthetic seismograms and SEG-Y files from the modelling
- Source code toolkits and example programs for creation of special surveys and for the generation of illumination maps

Platform: UNIX/XII/Motif
Architectures: Sun Sparc, IBM RISC 6000, Silicon Graphics

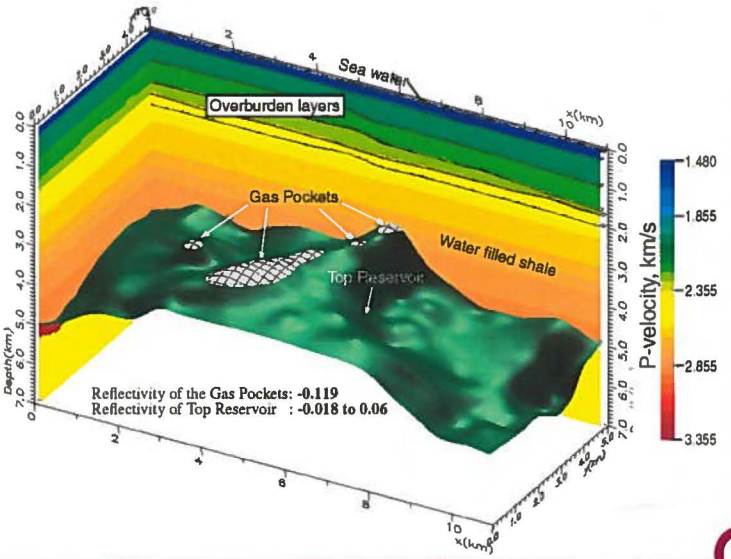
Modelling Example: The effect of gas pockets on seismic amplitudes

Trapped gas is generally assumed to have a substantial effect on the seismic amplitudes. So called "bright-spots" on the seismic sections are often taken as subsurface gas. Using NORSAR-3D, we want to check whether such an assumption holds in a model with interfaces taken from Charisma$_{TM}$ interpretation of real seismics. In addition, we want to use ray modelling by NORSAR-3D to create a "correction map" in order to retrieve the true reflectivity of a selected reflector in the model.

The Gas Model

8 depth grids from interpretation of seismics are imported. To simulate a realistic reservoir, 4 pockets of gas-filled sand/shale (porosity 25%) is trapped within a reservoir layer with a rough surface topography. Just below the gas pockets the pores of the sand/shale are filled with 100% oil. The content of oil drops linearly with depth and is replaced by water. Above the reservoir is impermeable shale with up to 30% water. A plot of the model is shown to the right.

The seismic velocities and densities are estimated by the petrophysical package VelRock developed by **UniGEO *a.s.*** and marketed by NORSAR.



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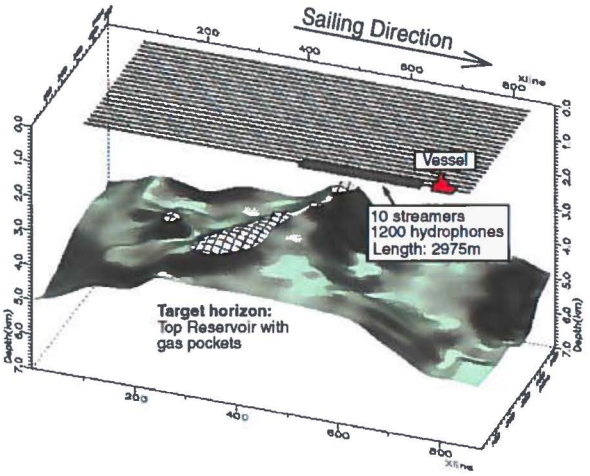
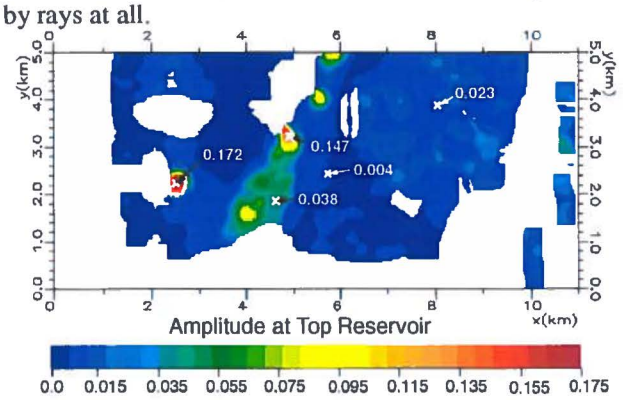
The seismic survey

A marine seismic survey with a total of 4011 shots is simulated in the Gas Model. The 21 shot lines, the 10 streamer cables behind the vessel, and the Top Reservoir are shown below. This survey gives a 30 fold coverage in a rectangular area of 34 km^2.



Parallel modelling of the survey

Primary PP reflections from the target horizon were chosen. The entire job was done simultaneously on 10 workstations. The whole modelling took about 15 hours, with an average of about 2 minutes per shot. A total of 24 million reflection points with corresponding traveltimes and amplitudes were found. The amplitude map at the target horizon (Top Reservoir) is shown below. The white areas on the map are not hit by rays at all.



Retrieval of the true reflectivity

The amplitude at Top Reservoir shows large deviations from the true reflectivity (Reflectivity= $\frac{\alpha_2\rho_2 - \alpha_1\rho_1}{\alpha_2\rho_2 + \alpha_1\rho_1}$).

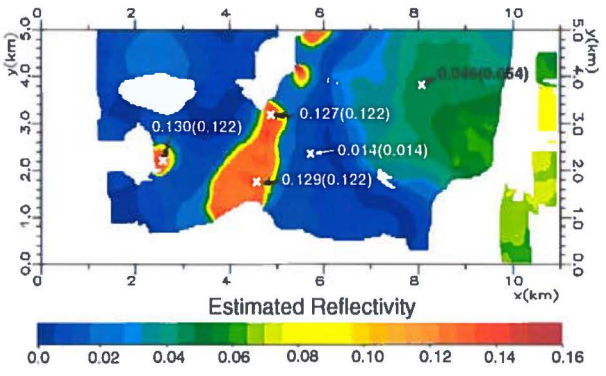
The variation in amplitude across the largest of the gas pockets (at x=4 km, y=2 km) varies with an order of magnitude. In addition, the amplitudes in the Top Reservoir away from the gas underestimate the reflectivity considerably. There are several reasons for the deviations between "recorded" amplitudes and the true, subsurface reflectivity:

- Geometrical spreading in the overburden
- Geometrical spreading caused by the Top Reservoir
- The survey parameters (Number of shots and receivers and their location)

In order to correct for these factors, a *Reference Model* is created. It is a blueprint of the Gas Model, but with one exception: the reflectivity of the Top Reservoir is set to 1.0 everywhere.

Modelling of all the 4011 shots in the marine survey is repeated in the Reference Model, and an amplitude map at the Top Reservoir is created in the same way as for the Gas Model.

It can be shown that by combining the amplitude map from the Gas Model with the map from the Reference Model, the absolute value of the true reflectivity is (approximately) retrieved as shown on the map below. On this map, the deviations between estimated reflectivity and true reflectivity (in parenthesis) are within a few percent. This remarkable result shows that NORSAR-3D may be used also for amplitude correction in order to estimate the reflectivity of target horizons.



About NORSAR

NORSAR is a research company specializing within the fields of seismic exploration and seismology. NORSAR develops and markets commercial software packages (NORSAR-2D and NORSAR-3D) for seismic modelling. NORSAR's R&D within exploration technology is mainly connected with seismic modelling. The company's record comprises research projects, consulting services and software development for the petroleum industry over the last 20 years. Key projects have been: 2D and 3D seismic modelling and wavefield simulation; seismic velocity inversion and tomography; ray theoretical depth conversion and depth migration; seismic survey planning and seismic noise studies.

Join us for a computer demo or informal discussions at booth D 19 at the EAGE Conference & Technical Exhibition, Helsinki, Finland, 7-11 June

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