# Integrating seismic modeling and basin modeling.

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## Abstract

In this work basin model outputs of an onshore sedimentary sequence were submitted to seismic modeling embodying three different algorithms: Kirchhoff-Helmholtz, Acoustic and Elastic, the last two based on finite difference. The geological model was built using Petromod (IES) basin simulation program. Porosity, density and fluid saturation were exported from Petromod and such data were applied in Willie equation to estimate P velocities. P velocities were used to perform Kirchhoff-Helmholtz and Acoustic finite difference based algorithms. To perform elastic finite difference modeling, shear wave velocity was estimated by Vs/Vp x poisson expected behavior, and density was applied directly from Petromod exported file.

All methods are equally suitable for structural interpretation support. Noise level in Kirchhoff-Helmholtz model is lower than the other two methods. Finite difference methods are indicated, mainly the elastic one, for dynamic studies. Meanwhile, comparison among real seismic section and synthetic seismic ones mainly on onshore surveys are significantly different. It is caused by scale differences between basin scale parametrization and seismic simulation one.

## Introduction

The exploration process is composed of many steps that can be grouped on four phases: Data acquisition, data integration, data interpretation, and finally, the knowledge about basin evolution. Indeed, on the last phase the exploration team has a better idea on tectono-stratigraphic evolution and fluid migration history.

Once seismic survey is the greatest science supporting knowledge on spatial distribution of geological bodies, why not create a seismic model based on information from the own geological model?

In this work output from the basin simulation program, Petromod from IES (Integrated Exploration Solution), was submitted to seismic modeling through three different algorithms: Kirchhoff-Helmholtz, acoustic and elastic, the last tow based on finite difference method.

## Methodology

The outputs of basin modeling program have many parameters need in a seismic simulation (petrphysic parameters). After basin simulation through Petromod, among other exportable variables, we can output: porosity, permeability, density, fluid saturation and if the fluid is hydrocarbon, its API (its density). Cited parameters permit us to estimate P and S velocities and density needed, for instance, for elastic seismic modeling.

In this work P wave velocity was calculated through Willie equation.

$$\frac{1}{V}=\frac{\phi.Sw}{Vw}+\frac{\phi.So}{Vo}+\frac{\phi.Sg}{Vg}+\frac{(1-\phi)}{Vm}$$

Equation 1

$\phi$ - porosity
V = P wave velocity in the rock
Vm = P velocity of the Matrix
Vw = P velocity of water
Vo = P velocity of oil
Vg = P velocity of gas
Sw = water saturation
So = Oil saturation
Sg = Gas saturation

Once Poisson coefficient decreases with depth in clastic basins, AKI (1980), S velocity was estimated through a Vp/Vs ratio that also decreases obeying a quadratic function with depth - figure 1. According to practical observations, it was considered Vp/Vs only between 0,4 a 0,7.

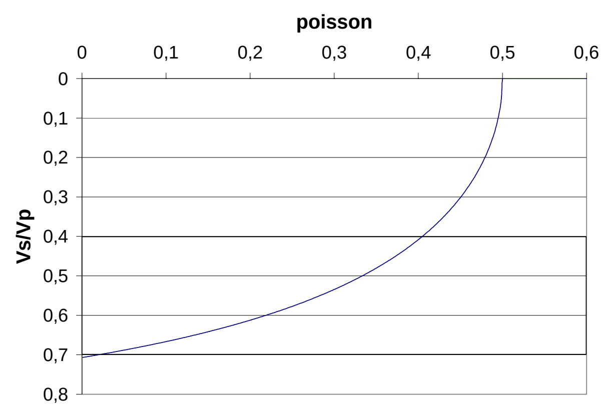


Figure 1: Vs/Vp x Poisson relation obtained from elastic constants relations

Density, extracted from Petromod output, was apllied directly on seismic modeling program.

### Model building for each algorithm

Kirchhoff-Helmholtz modeling, based on Tygel et al (2000) and applied in Santos et al (2004), ask for surfaces that apart each layer with proper fluid saturation and porosity. With those data and with lithological information, obtained during basin modeling process, Willie equation was applied to calculate interval velocities. From interval velocities, RMS velocities were calculated.

For Acoustic modeling based on finite difference algorithm, it was used the same velocities calculated for Kirchhoff-Helmholtz simulation. Nevertheless we should to fill all finite difference mesh with suitable P velocities. We run acoustic routine shooting all the sources together obtaining a zero offset section.

Finally, in elastic modeling based in finite difference algorithm with a $4^{th}$ order approximation in a staggered grid (Levander, 1988), it was used P velocities obtained in acoustic modeling. Shear wave velocities were calculated by relating expected poisson and Vp/Vs behavior with depth. The density file from Petromod was directly applied to perform seismic elastic simulation. In elastic routine we also run by shooting all the sources together obtaining a zero offset section of vertical displacement and another one with horizontal displacement.

## Results

Modeling embodying Kirchhoff-Helmholtz, Acoustic and Elastic methods were applied in basin sector with gentle strucutures. Reached results with three algorithms have shown consistency with known geology. Then, the three methods are equally suitable on supporting structural interpretation. As geological model remove details of real geology, all seismic models are simpler than real seismic.

Noise level of Kirchhoff-Helmholtz is very low. We have obtained only the differences among Vrms – the contacts between different lithologies. In the two other methods, based on finite difference, noise level is greater, but it is not high enough to damage section quality. Their sinal-noise ratio is very high.

Finite difference methods have shown more consistent expected amplitudes. Their errors are systematic and easily identified.

## Conclusion

Qualitative and visual observation of real seismic and modeled section show huge differences. It is a matter of scale. Basin simulation demands an up-scaling level that reduces, let say, the frequency of reflectivity function. Each layer in a basin model, indeed, is an entity which properties is an average of many lithologies. In such case seismic model will be oversimplified.

In a different sense, comparing basin model output in small areas, in reservoir studies, for instance, will furnish better results, as reservoir scale is closer seismic survey one.

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