Modeling of seismic data using tools of free software SEISMIC UNIX

Andrei Gromyko Oliveira Soares and Rosangela Corrêa Maciel - Universidade Federal do Rio Grande do Norte-UFRN.

This paper was prepared for presentation at the Twelfth International Congress of the Brazilian Geophysical Society, held in Rio de Janeiro, Brazil, August 15-18, 2011.

Abstract

Seismic methods have become the most powerful tool for hydrocarbon exploration in the lucrative industry of Oil. The success of this method can be mainly attributed to the constant improvement of techniques for seismic data processing. The modeling is no less important, because we can produce synthetic seismic data using a geological model"a priori"aimed at several important goals, such as (a) planning of field surveys and (b) analysis of the inversion results for confrontation with the procedures used with real data, to assess the outcome of the inversion and increase the knowledge of the area. In this work, the study was conducted in two 2D geological models, which have potential for hydrocarbon accumulation, then generating their seismograms with the Seismic Unix (SU) software package which is free and maintained by the Center for Wave Phenomena (CWP) of the Colorado School of Mines, more precisely the set of Demos "Cshot" Folder. The first model is based on an acquisition Maritime, end-on, whose main target of sub-surface geology is a salt dome, which is responsible for the vast majority of known hydrocarbon reservoirs. The second model presents an acquisition geometry split-spread, on land, characterized by domal structures, which are always subject to exploratory research, for presenting great potential for accumulation in most basins in the world. The main objective of this work is to familiarize yourself and compare synthetic seismic responses (simple as it is) in two dimensions created by direct modeling with real models of geology obtained by inverse modeling, and increasingly expanding the knowledge modeling and Seismic Unix in seismic processing.

Introduction

Currently, all oil which surfaced or that it was shallow surface has already been extracted or is in final phase extraction (mature fields). For this reason, new techniques for mapping the subsurface are being studied, for the discovery of new reservoirs, determine points of drilling wells and to estimate the hydrocarbon reserves. To reach depths such as the Brazilian pre-salt, large reserves of oil and natural gas at depths that exceed 5,000 meters below the sea level with water depth and a layer of salt that can exceed 2,000 meters of thickness was required, among other factors, increased robustness of the algorithms used in processing seismic reflection data. It can be seen thus the extreme importance scientific and consequently commercial of the study and implementation of new techniques to increase the resolution of subsurface seismic illumination.

As the geophysics in general is a science based on models of the geology of interest, imaging algorithms were developed based on simple models that reasonably approached the real geological models. But when they have complex geological structures, the assumptions contained in the traditional methods do not provide a good image of the subsurface, thus promoting the intensity of scientific papers in the area.

The package of software Seismic Unix (SU) operates under the operating system UNIX / LINUX. It is a software widespread in the academic world, constantly updated, informative and without requiring a large computational apparatus. Today, the SU allows you to perform much processing as modeling of seismic data, and for be open source, they can be used in the development of increasingly complex applications.

The models developed in this study were based on simple geological structures that have potential for hydrocarbon accumulation. After a preliminary study of these structures has been started to create models of the SU package, following the set of Cshot Demos folder. These Demos are easy to understand and demonstrate step by step how to create a geological model followed by rays tracing and therefore the corresponding seismograms.

Modeling with “SU”

An important aspect of seismic exploration and research, are the programs to create synthetic data. A processing program that does not work in a idealized model data probably will not work in real seismic data.

The SU has some variety of programs for the creation of synthetic models. The program CSHOT of the Seismic Unix, used to generate the models of this work is useful when it comes to model synthetic data that can be based on real geology of a reservoir. Interestingly observe the ray graphic showing didactically the scope of energy, and consequently the seismograms obtained in common shot. However the ability to model does not go beyond this, because the program traces rays, depending on the angle of incidence, the velocities in the layers that form the interface (in which the ray falls) and always will be normal to the wavefront, ie this is not a dynamic ray tracing and Gaussian beam (not resembles the finite difference method), “ rays are actually limited ”. Therefore, it is not suitable for creating models of greater complexity, especially those where there is an intersection of interfaces, because the CSHOT not accept this type of operation, but is very good for the simulation of primary reflection events, direct wave, reverberations, peg-legs and multiples in general.

Geological models

In this work two geological models were chosen in order to investigate targets commonly mapped by seismic exploration for hydrocarbons. The first model is a salt dome, in which we seek to simulate a marine geology and performing a data acquisition geometry end-on. The second model is a domal structure around a simulated terrestrial geology on which we made the acquisition of data using split spread geometry. The layers of each model are characterized to be homogeneous and isotropic and its dimensions are 20,100 meters in the horizontal direction and 5,500 meters of deep into the earth model and 6,000 meters to the ocean model.

Marine model - salt dome

This model attempts to reproduce local deformations (folds) caused by the presence of a diapiric salt with the top at a depth of 3,000 meters. Due to the movement of salt bodies, a wide variety of oil traps are generated. In the model we have two types of geological trapping: the structural trapping (traps folded) just above the salt dome, and diapiric traps on the sides of the dome caused by the flow due to the density contrast between the sandstone (clastic) and salt. Alleged stratigraphies concerning the velocities this model are: water (1,500m/s), Limestone (4,000m/s), Sandstone (2,600m/s), shale (3,800m/s), Sandstone (3,000m/s) and Salt (5,500/s), as shown in Figure 1.

Terrestrial model - domal structure

The structural traps (anticlines) are most apparent in the mapping of surface and the more easily found subsurface. The structure generally extends vertically through a considerable thickness, resulting reservoir traps in all affected by it. This type of geological setting has a high potential to accumulate hydrocarbons. A single well in these conditions usually have high productivity. This is the case of Camp Yates (USA), where a single well can produce oil with a flow of 260,681 barrels per day (the average of all Brazilian basins in 2,000 was 1,260,000 barrels / day). A folding trap is seldom free from faulting, but this model does not consider the faults by limiting the program Cshot. Then we have the supposed stratigraphic sequence: Limestone (3,800m/s), shale (3,400m/s), Sandstone (2,500m/s), shale (3,600m/s), Sandstone (3,200m/s), shale (3,900m/s) Limestone (5,000m/s) and Sandy (3,700m/s), shown in Figure 2.

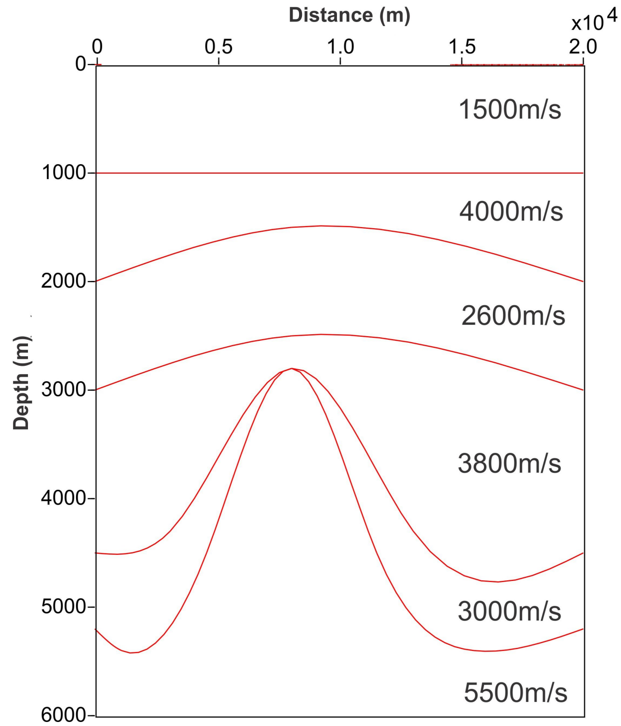

Figure 1: Marine model - salt dome.

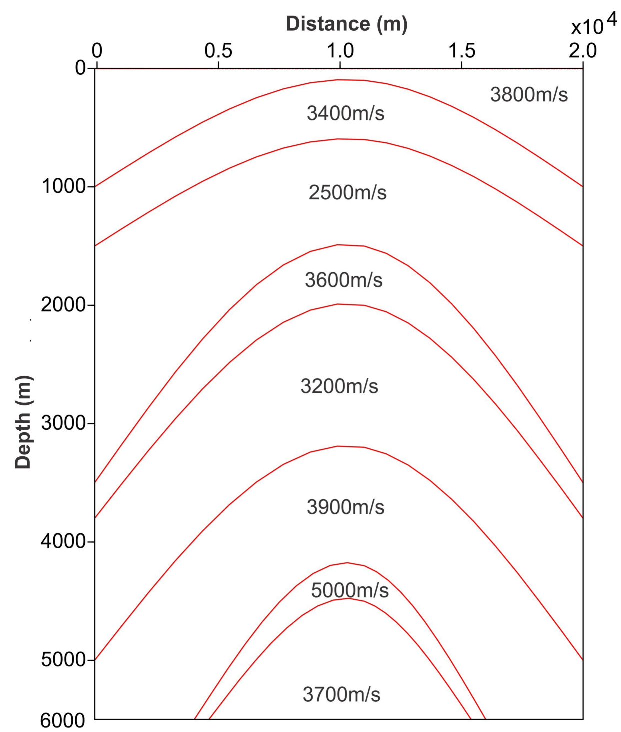

Figure 2: Terrestrial model - domal structure.

Synthetic seismic data acquisition

The acquisition parameters are described in Table 1, which describes the parameters of marine survey (end-on geometry) and ground survey (split-spread geometry). On the marine survey hydrophones are placed at 5 meters below sea level. In the ground survey the geophones are positioned on the surface of the ground. The reference station (N^{o} 1) is located at position "0m".

Table 1: Acquisition parameters.

DESCRIPTION OF PARAMETERS	PARAMETERS UTILIZEDS
Number of shots	485
Distance between shots	30 (m)
Number of channels	180
Distance between receivers	30 (m)
Minimum Offset	60 (m)
Maximum offset (end-on)	5430(m)
Maximum Offset (split-spred)	2730(m)
Recording time	6(s)
Number of samples per trace	1501

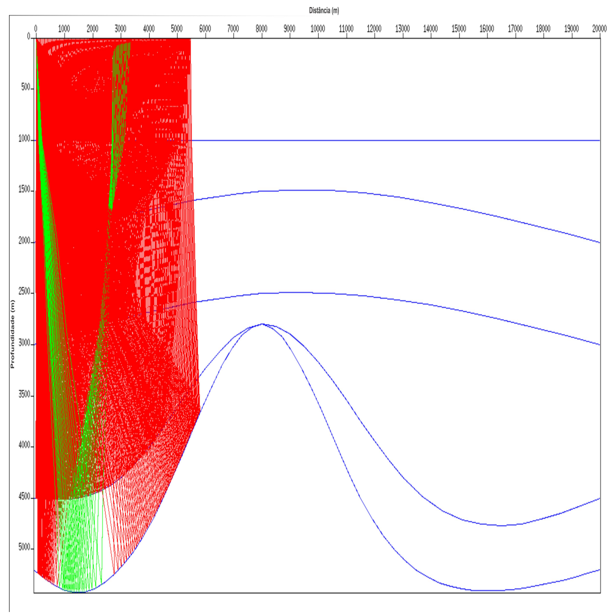

Figure 3: Ray tracing - marine model: for the first shot in station 1 (0m); The rays in green represent the typical event of synclines (caustic).

It is important to view the tracing of rays because they show how geological events didactically behave with the passage of a seismic wave, and thus can be compared with the responses in the seismograms. For the first shot of the marine model, for example, we noticed a family of rays (shown in green) that cross before reaching the geophones, which we associate them with synclines (Figure 3). Figure 4 is shown the ray tracing for the terrestrial model, corresponding the primary and direct waves, which presents no special feature.The family of rays equally distributed on both sides of the source is related to the acquisition arrangement symmetrical split spread, when the source is at the station 191, ie, in the position 5,700m .

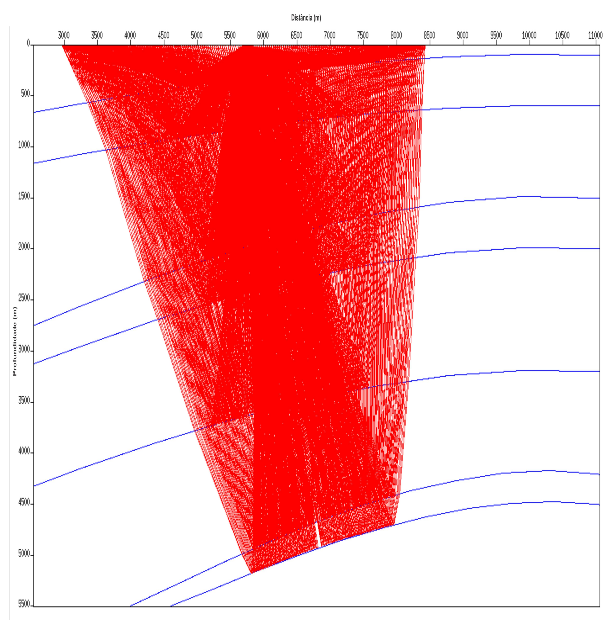

Figure 4: Ray tracing - terrestrial model: relating the primary and direct waves with the shot in position 5700m.

Seismograms

We selected the clearance section for the two models, with the intention of having a vision of the subsurface geology of each model. In each seismogram was not used any kind of noise because there is the initial goal to have an idea of how the program would respond to changes in interfaces with the velocity variation.

Looking at the clearance section obtained for the marine model (Figure 5), we can see first the direct waves in time 0s, and then the primary waves referring the interface which divides layer of water (1,500m/s) of limestone (4,000m/s). The velocity difference between these two bodies and the proximity of the interface with tha surface where are located the arrangement of the acquisition, reflected in a strong response in the seismogram around 1.4S. Then the waves are curved interface (limestone/sandstone and sandstone/shale) which is also mapped. From there it has been a considerable loss of energy caused by geometrical spreading. It is important to note the difficulty of visualizing the syncline region and a small portion of the top salt model (due to contact between the interfaces).

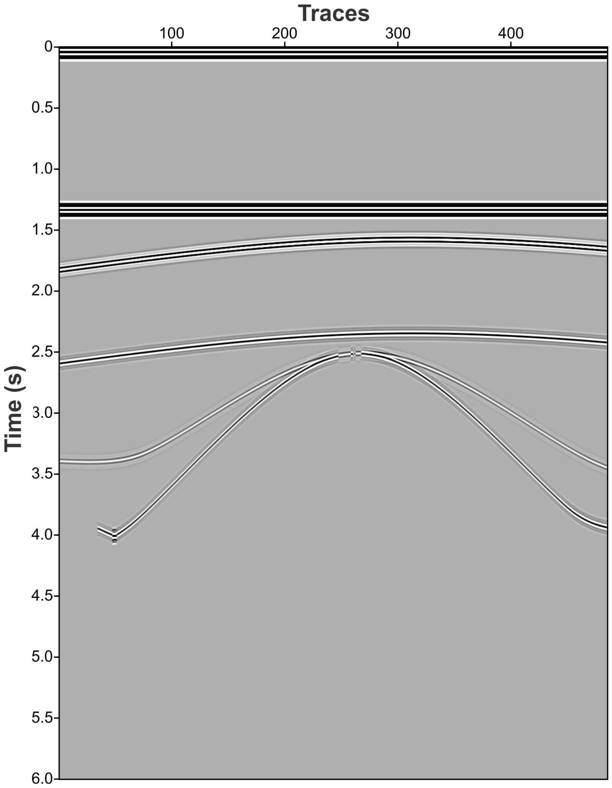

Figure 5: Minimum offset section for marine data.

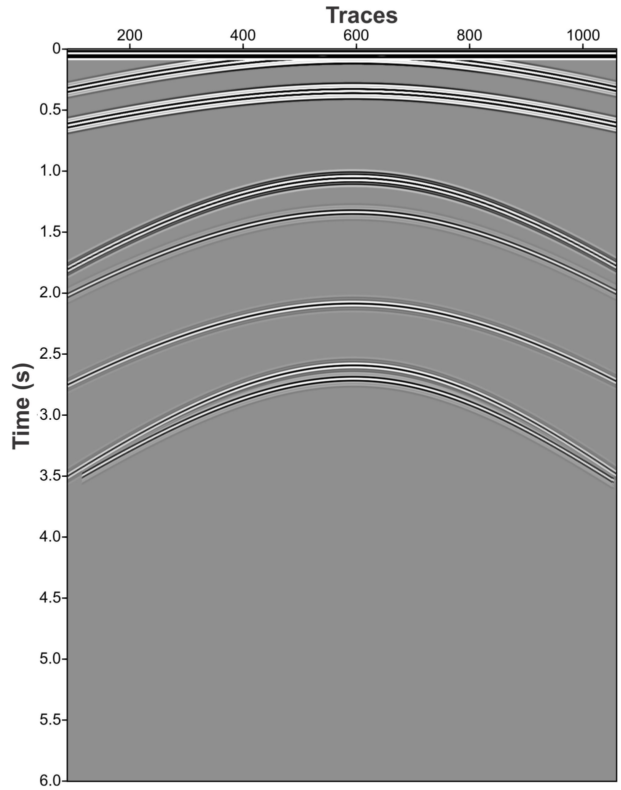

Figure 7: Minimum offset section to terrestrial model.

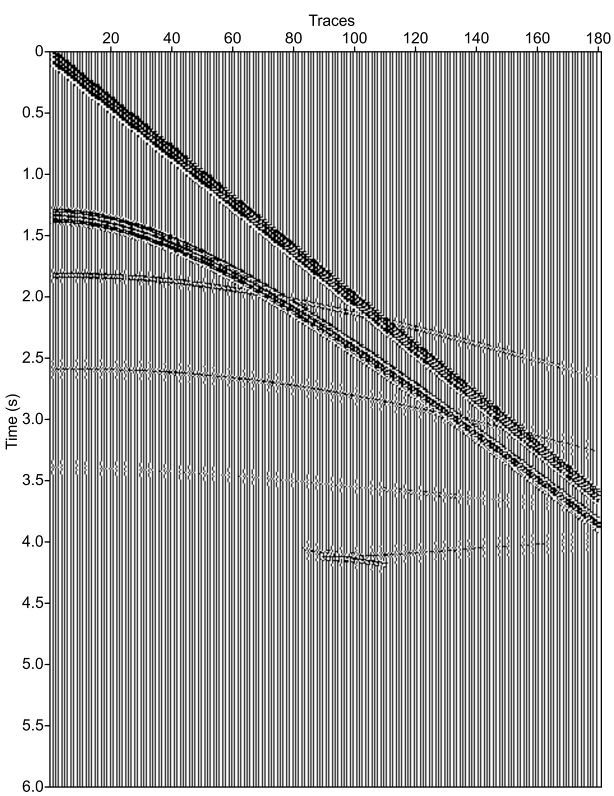

Figure 6: Seismogram for the first shot at the position 0m of marine model, observe the presence of caustic.

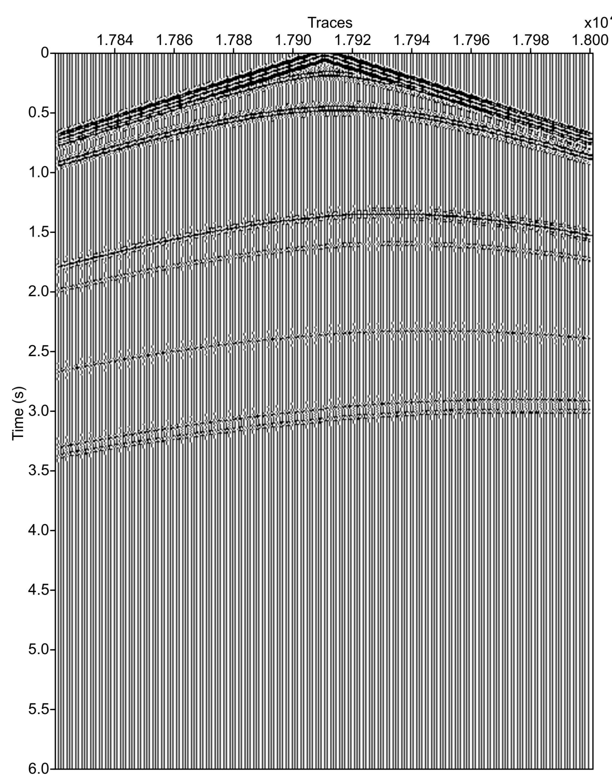

Figure 8: Shot in the position 5700m of the terrestrial model.

In Figure 6 we can observe the seismogram for the first shot, showing the effects caused by the presence of the syncline on the left bank of Salt Dome Therefore we have, the range of 4 to 4.5s the intersection of the reflectors and a higher reflectivity characterizing the syncline.

The seismogram referring to section clearance of the terrestrial model, differently of the marine model, had no difficulties in view of their structures. But some observations can be made. Due to high velocity of the first two layers, we have a decrease in the time of arrival of the first interface, so she gets to be suppressed in the region of the hinge line. Regarding the latter two interfaces which could possibly be a hydrocarbon reservoir, sealed by limestone, it can be noted that these reflectors cut the seismogram (2.7s to 3.5s) completely. Therefore, the visualization of these structures only by the seismogram section of clearance does not provide reliable information of the subsurface geology (Figure 6). In Figure 8 we see the typical response of an acquisition with the split spread shot in the 5,700m position, characterized by the symmetry of the lines on both sides of the source.

Conclusion

In this work we realized the importance of the use of direct modeling to know in practice what happens with the propagation of seismic energy in some simple situations of geology and how they present their answers in the seismograms.

The program CSHOT of the package Seismic Unix (SU), was inadequate for modeling geological structures more complex and very important for hydrocarbon exploration (faults, for example) because it does not allow the crossing of interfaces. But the results for the models studied in this work were satisfactory. Future will be used more sophisticated modeling methods that are part of the package “ SU ”, for example, the method of Delaunay triangulation (TRIMODEL), the dynamic ray tracing (TRIRAY) and the generation of synthetic seismograms based Gaussian beams (GBBEAM), which allow a closer approximation to reality. The models to be simulated will aim to illustrate the geology favorable for hydrocarbon accumulation. A set of seismic data will be generated from these models, which will be processed and will be part of the collection of data to be available for use in other educational activities of the Geophysics Course UFRN.

References

Amaral, Sérgio Estanislau do; Leinz, Viktor. Geologia geral. 11 ed. São Paulo: Companhia Nacional, 1989. 399p., il.

Matta, Milton. Notas de aula da disciplina geologia geral. Departamento de Geologia da Universidade Federal do Pará. http://www3.ufpa.br/larhima/geologiageral.htm

Pennington, W. D; Benz, T. e Forel, D. Seismic Data Processing with Seismic Unix. Society of Exploration Geophysicists-SEG, 2005.

POPP, José Henrique. Geologia geral. 4 ed. São Paulo: Livros Técnicos e Científicos, 1987. 299p., il., 23cm.

Stockwell, J. W.; Cohen, J. K. e Jr., 1998, The new SU User’s Manual: Center for Wava Phenomena, Colorado School of Mines, Version 2.5.

Yilmaz, O. Seismic Data Analysis: Processing, Inversion and Interpretation of Seismic Data, Society of Exploration Geophysics-SEG, Tulsa-Oklahoma, 2001.

Acknowledgment

I would like to thank the Program of Human Resources 22 of the National Petroleum Agency (PRH22-UFRN/ANP) for financial support.

I would like to thank the researcher UFBA (LAGEP-CPGG) Gary C. Aldunante clarification of the modeling programs of the SU.