Water Flood vs Velocity Profile in Ultra Deep Water Model Building

Bruno Silva, Fernanda Souza and Ernesto Lemos, PGS Brazil

This paper was prepared for presentation during the 12th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 15-18, 2011.

Abstract

The water flood technique, which is the use of a constant velocity to the water column, has been widely used in velocity model building with great success. With the advance of surveys in deep and ultra deep water, the assumption of a constant value to water column, can input in the first step of the model building an error, mainly when there is significant topographic variation on the water bottom. The present article describes an attempt to overcome the problem with the use of velocity profiles, collected during the seismic acquisition, in comparison with the traditional water velocity scan & water flood approach. The study aims at showing how much the constant velocity assumption can jeopardize the correct position of events.

Introduction

The first step of a velocity model building process is the water velocity scan, commonly with values floating around 1500m/s (Huang et al, 2009). With the most suitable velocity found, the shallow part is migrated to produce the stack data over which the water bottom will be picked. It is the horizon that will separate the initial sediment model (the best pre-migration RMS velocities converted to depth), from the chosen water flood.

This technique is very well succeeded when the water column is not close to the ultra deep water threshold of 5000 ft (~ 1500m). In this area the dominant variable to the water velocity is purely pressure. The water velocity can then easily reach much higher values than the standard 1500 m/s, what can create a mismatch between what the water flood provides to the shallowest events and the deepest.

Also factors other than vertical pressure may influence water velocity, such as temperature (Figure 1). To those commonly encountered, the rate of change of water velocity is approximately 4 m/s/℃ (Sheriff, 1991). For a water depth of 1500 m, using a 1500 m/s water velocity, the vertical two-way travel time is 2.000 s. By decreasing the water temperature of 3℃ would decrease the wat er velocity to 1488 m/s, hence increasing the travel time to

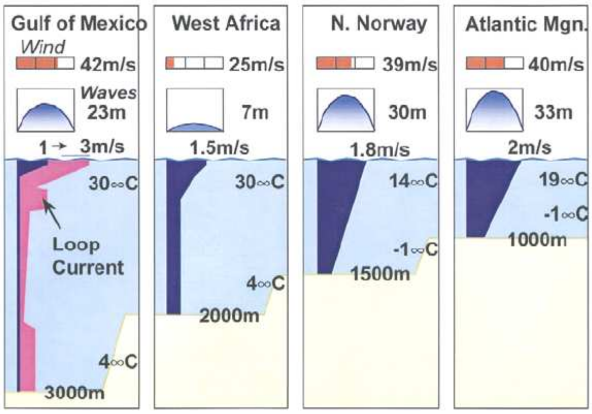

Figure 1 – Different temperature vs depth profiles in famous exploration areas all over the world, showing how heterogonous can be this behavior depending on the weather (Adapted from Barley, 1999).

2.016 s (Fried & MacKay, 2001). Then, two questions come up:

1) In the model building, can we discard the influence of temperature from a period of time to another, since an acquisition campaign can take several months?

2) Is it possible to describe a global behavior to the water column velocities all over to the planet?

The answer to the both questions is: yes. During the pre-processing, the water columns statics (WCS) application suppose to correct all the possible time variations found amongst the acquisition sequences. Variations due to: temperature, salinity, tide, etc (MacKay &Fried, 2002) are dully treated by the WCS solution. In relation to a global behavior, we can find our question in an important oceanographic concept: **the thermoclines**. They are defined as being zones which divide the water column by the dominion of the chemical and physical factors: salinity, temperature and pressure (Medwin & Clay, 1997).

The Thermocline I (Figure 2) refers to the shallowest layers and is dominated by pressure, having temperature and salinity considered approximately constant. The Thermocline II has as dominant factors, temperature and salinity. Is the layer of the great world currents (Afonso, 1996).

Finally, around 1000, 1100 m (very close to the threshold of deep and ultra deep water) these two factors are not anymore influent, remaining only pressure the dominant factor. We are now in the Thermocline III, the most important to the velocity model building in deep water.

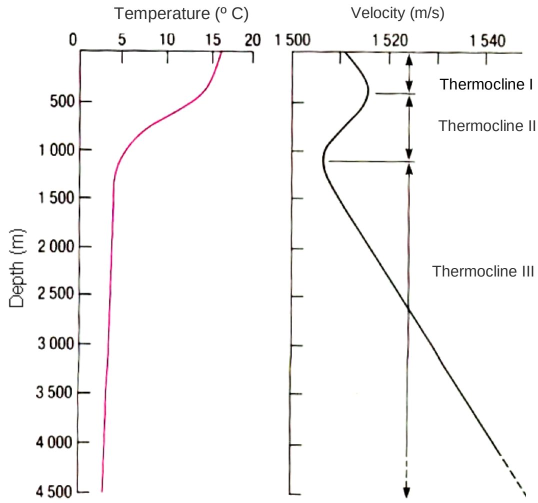

Figure 2 – The left graph shows the temperature curve in the 3 thermoclines and in the right graph the velocity curve, with the discrimination of each one of them (Adapted from Mansur & Silva, 2008).

For these reasons, the use of a real velocity profile can overcome the problem of mismatch, since this dynamic difference between the shallow and the deep zone are better solved with its use. It will be also discussed if the use of a mean curve, fitted through all the profiles available, would be also a good solution, since the mean values of an areal distribution is normally a more reliable solution.

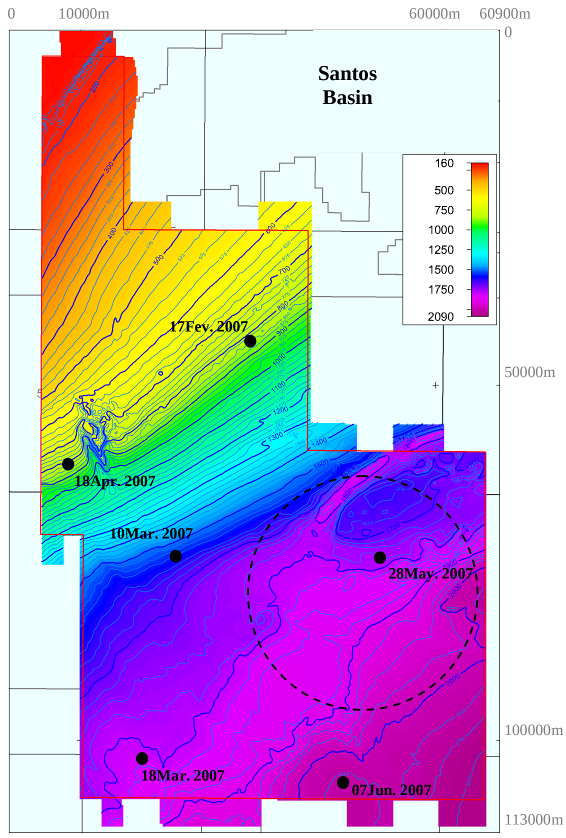

Figure 3 – Water column map. The black dots show where the profiles were acquired with their respective date. In this specific test, two profiles were discarded due to short length of information (17th February and 7th July). The black circle points out the test area.

This would show, if good results were obtained, that the differences (due to salinity, temperature, tide, etc) in the profiles acquired in different days are small enough to a lower number of profiles be acquired in all survey.

The Acquisition Area

The test area is in Santos Basin that has become one of the hottest areas in the world after Petrobras announces 5-8 billion BOE of recoverable oil in Tupi (2007), besides other discoveries later on as Jupiter and Pão de Açúcar. Most of these important fields are in areas where water column can reach depths way far than the ultra deep water threshold. In the survey were collected 6 profiles, but only 4 were used. Two profiles were discarded since only shallow data was available. The area in the southeast was the chosen one to the tests (Figure 3).

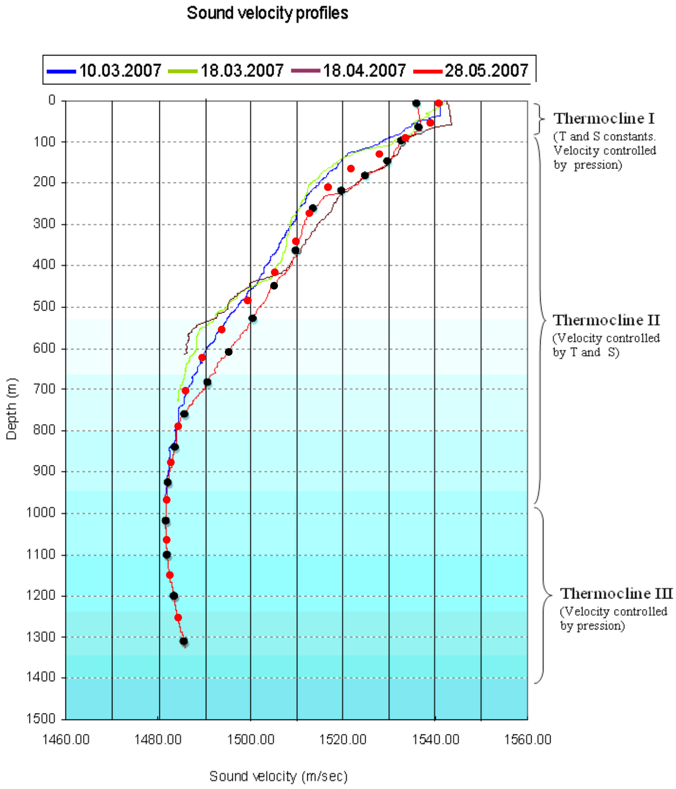

Figure 4 – The water velocity profiles. The black dots show the curve of 28th May that is exactly on the tested area. The red dots the mean curve fitted using the 4 curves available. There were no records after 1300m but the water depth in the tested area reached 2200m. So an empiric gradient of 20m/s/km was used, based on the expected behavior to that zone.

The map of the Figure 3 shows the water depth distribution in the test area. Plotted on the map are black dots, representing the profiles collection points with the respective date when they occurred, and a black circle pointing out the test area. In Figure 4 is observed the plot of the 4 velocities profiles used. The idea would be initially using only the profile closest to the analyzed area but to test the use of a mean curve, taking account the 4 profiles used.

Methodology

For the water flood tests 4 values were used: 1480, 1490, 1495 and 1500. A sequence of shallow events, each one migrated with their respective constant model, are shown in Figure 5. All events belong to the ultra deep water zone. It is noticeable that none of them is flat in all extension of the area. The best result obtained was using 1500, clearly still to fast to the deepest events. The difference in depth measured in the event comparing 1480m/s to 1500m/s is about 30m (1860m to 1890m, as shown by the yellow arrows on Figure 5.a and 5.d). This is a delta of about 1.5%, value expected only to subsalt areas. It illustrates the amount of depth error on the ocean floor the use of bad values to the water flood can cause.

It was decided to create two different approaches: to test the curve closest to the test area and, in parallel, the mean values amongst the 4 curves. This fitted curve is plotted in red dots in the graph of Figure 4. It brings the discrimination of the 3 thermoclines. It is noticeable that there is only a few values to Thermocline III. The deepest measured was until 1300m.

However, its well behaved shape makes easy to extrapolate the velocity based on the gradient of the portion of data acquired. It was calculated a gradient of 20m/s/km. This value was used to produce the model shown on the Figure 6. The results presented on Figure 7, show that the use of the mean values (fitted from all

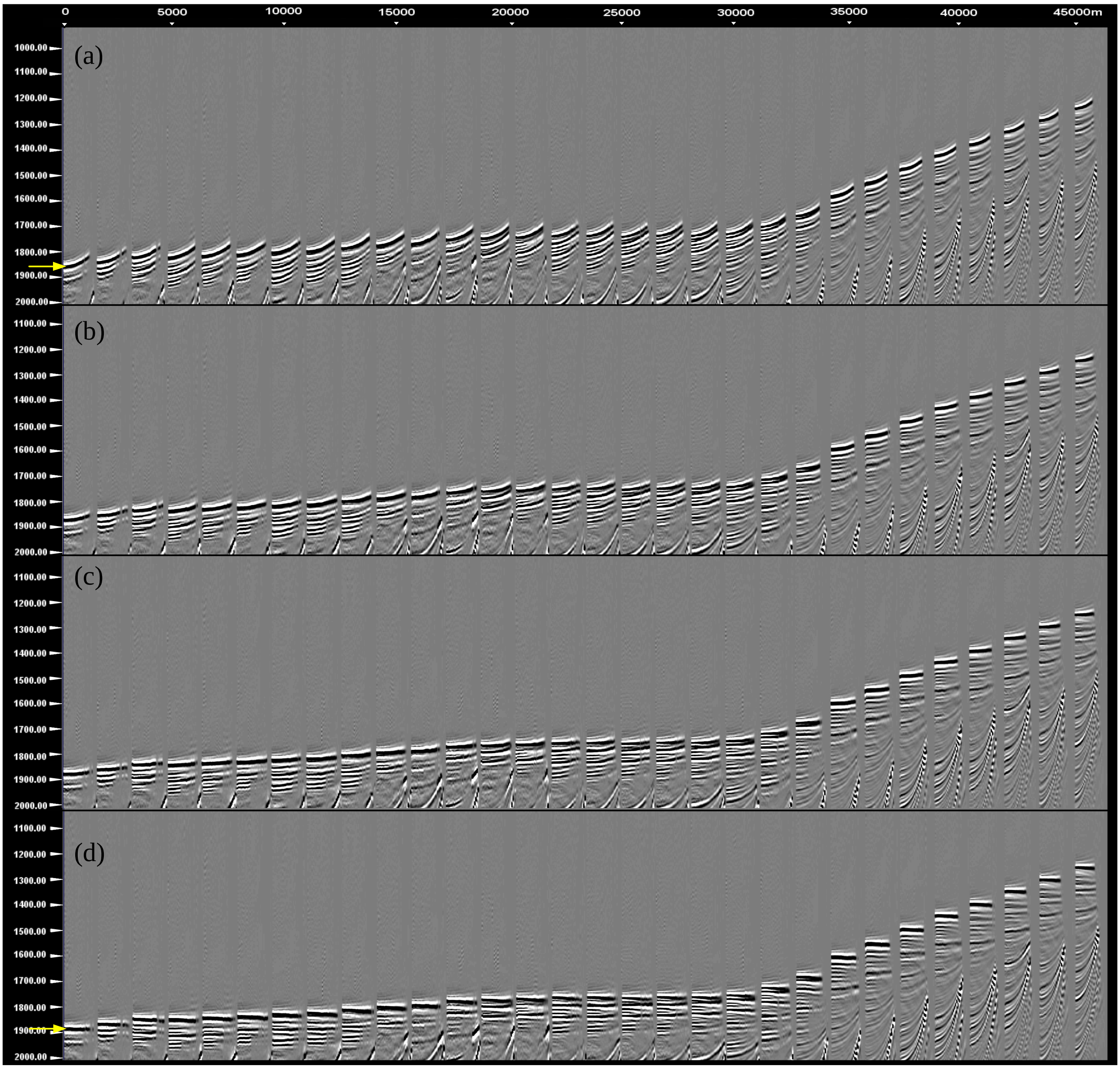

Figure 5 – The images show: the result of the water flood with 1480m/s (a), 1490m/s (b), 1495m/s (c) and 1500m/s (d). It is easy to notice that there is a critical value between 1495 and 1500m/s, that was considered the closest flood of the ideal. Secondary tests with 1497 and 1498m/s shown results very similar to 1495 and 1500m/s, respectively, and for this reason were suppressed from this article.

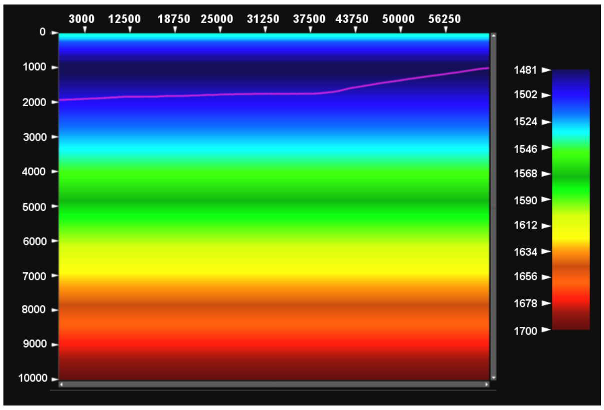

Figure 6 – The velocity model of the water columns until 10km. From 1300m to the end we have a constant gradient of 20m/s/km.

curves available) show results very similar to that obtained using only one curve (the closest to the test area). In comparison with the water flood the deepest zone is lightly best flattened.

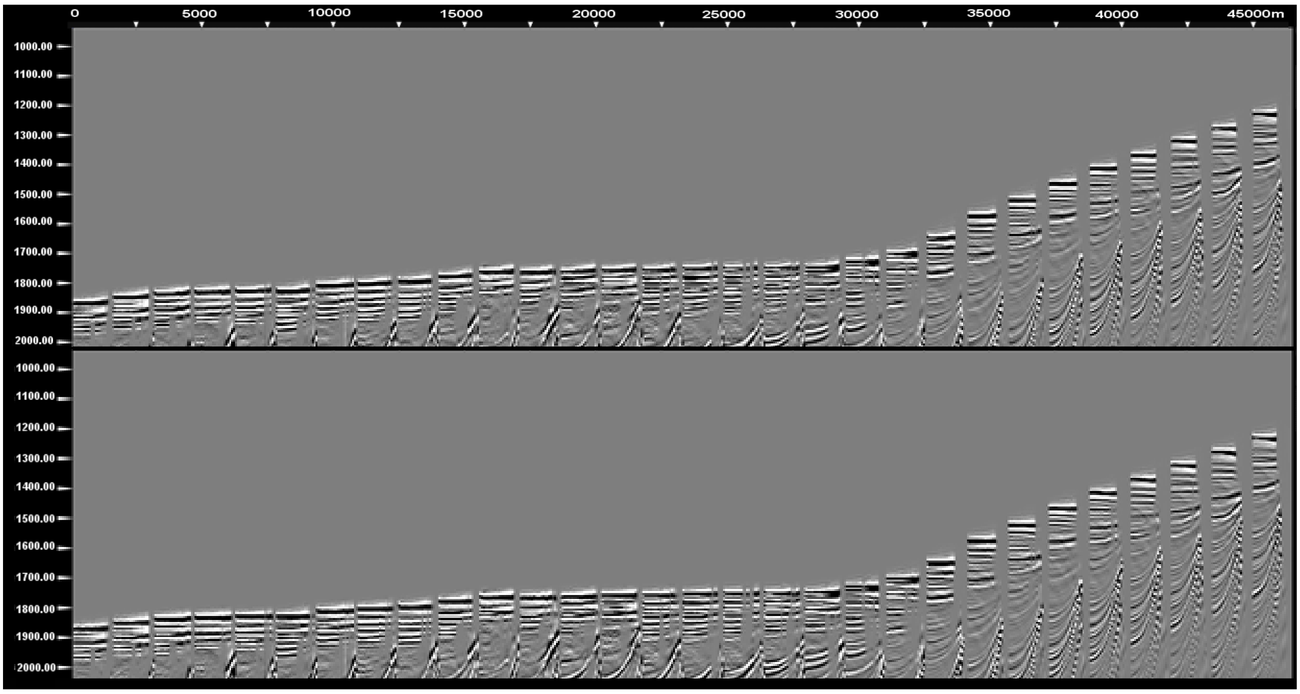

Figure 7 – The images show the result of the water flood with the water column profile using the mean curve (below) and the closest profiles to the test area. They are very close, but it seems there is a light improvement in the moveouts of the shallow zone events using the mean curve.

Conclusions

The use of a real velocity profile in surveys where the ocean bottom reaches the ultra deep zone is highly recommended since water flood can input a mismatch between the solution to shallow and deep area, due mainly to the behavior of the thermocline III, dominated by pressure that is increase linearly with depth.

The test also showed that the methodology of using the mean curve, fitted using all available profiles, produce results very similar to a local acquisition. So in case of a regional velocity model building in the area, those values could be used, being even more reliable than local values.

The errors generated with the use of water flood rarely will pass of 2 or 3 seismic samples (5 to 15 m). However there is no reason to input an error in the beginning of the early stages of the model building once you can adopt an approach that provides a perfect match.

References

Afonso, J. A., 1996, *As correntes Marinhas*, PhD thesis, Coimbra University, Portugal.

Barley, B., 1999, *Deepwater problems around the world*. Leading Edge.

Fried, J. and MacKay, S., 2001*, Dynamic corrections for water velocity variations: a Nova Scotia Case History*, CSEG Recorder

Huang, Y., Lin, D., Bai, B. and Rodriguez, C., 2009., *Pre-salt Depth Imaging of Santos Basin, Brasil*. Expanded Abstract of SEG Houston International Exposition and 79th Annual Meeting.

MacKay, S. and Fried, J., 2002, *Removing distortions caused by water velocity variations: Method for dynamic correction,* SEG Salt Lake City International Exposition and 72nd Annual Meeting.

Mansur, B. V. and Silva, A., 2008, *Heterogeneidades de Velocidade do Sinal Acústico na Coluna D'água de Mar*

Profundo, Oceano Atlântico Sul, III Simpósio Brasileiro de Geofísica, SBGf - Belém.

Medwin, H. and Clay., C. S., 1997, *Fundamentals of Acoustical Oceanography.* Academic Press.

Sheriff, R. E., 1991, *Encyclopedic Dictionary of Exploration Geophysics:* SEG, 324.