B035 The 2004 BP Velocity Benchmark

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Abstract

In 2004, BP conducted a 2D velocity model estimation benchmark study. The study was open to all interested parties, and was constructed as a blind test of available velocity model estimation/building techniques. The test was based on a 2D synthetic (finite-difference) dataset generated by BP, which was made available to the interested parties. After receiving the data, the participating groups were offered to present their results at the 2004 EAGE workshop and/or provide the results to BP to partake in the overall evaluation.

In this paper, we will present the model used for the benchmark and comment on the results received by BP before the solution was displayed at the 2004 EAGE conference in Paris. The model was designed to cover several issues encountered when estimating migration velocity models in geophysically challenging areas around the world. The model provides velocity estimation problems ranging from a gradient estimation to difficult sub-salt velocity anomaly detection.

Introduction

During the summer of 2003, the EAGE and the SEG co-sponsored a research workshop on velocity model estimation in Trieste (see Jones, 2004). During the workshop it became clear that the current test datasets, such as the Marmousi (*IFP*), Sigsbee (*SMAART JV*) and SEG/EAGE 3D models, should be supplemented by a new benchmark/test dataset more suitable for velocity analysis.

During the workshop, several good results were shown from applying a variety of velocity estimation methods to field data, but without knowledge of the true model, it is hard to properly evaluate methods side-by-side. Other results were presented using the classical models mentioned above, but with a known answer, these tests cannot be viewed as unbiased and fully objective. In general it remains hard to fully validate methods without a challenging synthetic dataset where the true solution is known, but kept secret during the testing period. Follow-up discussions confirmed that it was desirable to offer a new dataset that could be used in a blind test to properly validate and test new velocity estimation methods.
The co-organizers of the EAGE 2004 workshop W8 - Estimation of Accurate Velocity Macro Models in Complex Structures - Gilles Lambaré (*Ecole des Mines de Paris)*, Paul Sexton (*Total),* and Frédéric Billette (*BP)* kindly offered the workshop as a venue to present the first results of the benchmark. The announcement and invitation to participate in the benchmark was posted on the EAGE web-page in February, and the synthetic dataset was made available for download at the same time. Of the participants, nine groups presented their results publicly during the workshop and twelve sent their derived model to BP by the deadline set on June 6th, 2004.

This paper will discuss how the model was constructed and what geophysical challenges that motivated the design. We will also review the internal testing procedure and show how we conducted a comparison test of the results. We will focus on the particular challenges included in the model and show how the various velocity estimation methods handle the different tasks. The study will be presented without revealing the author/group associated with each model.

Model building

The velocity model is 67km long and 12km deep, and was built on a 6.25m x 6.25m grid (see Figure 1). We used a model building technique presented by O'Brien et al. (1999), where the reflectivity is taken from field data and adapted to a smooth background velocity model. The model building steps are:

1. generate a water layer with a constant velocity of 1486m/s,
2. build a compaction-driven layer-based sediment background and smooth the sediment interfaces,
3. build two salt index masks and insert salt in the model with a constant velocity of 4510m/s for the left salt body and 4790 m/s for the right salt body,
4. manually define a set of anomalies and insert them "smoothly" into the background velocity field. This way, we maintain a highly variable, but smooth velocity field,
5. construct the reflectivity from "real data" stacks and apply it as a scaling/perturbation to the density model, hence introducing the realistic looking reflectivity (see Figure 2).

The model can be divided into three distinctive parts, each focusing on a specific challenge for velocity estimation methods. The left part consists of a simple background (compaction trend) with a complex rugose multi-valued salt body. An added challenge here comes from the sub-salt slow velocity anomalies that are meant to represent over-pressured zones. This part of the model is representative of geology we find in the deep water Gulf of Mexico. The main challenges in this area are related to obtaining a precise delineation of the salt and recover information on the sub-salt velocity variations. Immediately to the right of this salt body, a fast velocity anomaly was inserted to test tomography tools in a simple velocity regime.

The center part of the model is built around a deeply rooted salt body. Salt delineation is the main challenge here, since steep dips are difficult to image and the water-bottom multiple could be interpreted as base salt. Channels are located adjacent to the salt. Some of these introduce velocity variations, while others are only present in the density (reflectivity) field. This part of the model is also representative for the Gulf of Mexico and West Africa.

The right part of the model is exclusively extra-salt and is meant to represent a geological setting with shallow gas and localized shallow anomalies. However simple by description, this part turned out to be extremely difficult to estimate for tomographic methods. The geology in this part of the model is common in areas such as the Caspian Sea, offshore Trinidad and in the North Sea. The velocity field has significant variations in the long wavelength component and several low velocity anomalies in the shallow section. The size, shape and velocity of the anomalies are variable.

To ensure that the model does not allow for educated guessing and other tricks, the density contours, hence the reflectivity, do not necessarily conform to the velocity contours (see Figure 2). Since the reflectivity is based on field data, the resulting synthetic data has a "real" look to them, further complicating the velocity estimation process, in particular for methods that rely on event picking.

Data generation

The synthetic data were generated using a 2D time-domain, acoustic, finite-difference modeling algorithm. We recorded the data with a free-surface, leaving all free-surface related multiples in the data set. This required a rigorous effort on de-multiple/multiple suppression before migration and velocity analysis could be applied. In hindsight, we see that this caused problems for some of the academic institutions that did not have access to proper de-multiple software. One the other hand, we may see future benefits in this since the dataset could be used in testing of novel de-multiple techniques.

The data were generated with a streamer configuration, using a 15km streamer with 12.5m group interval and a 50m shot interval. Minimum offset in the data is 0m. We recorded 14 seconds of data with a 6ms sampling interval. The dominant frequency is 27Hz and data can be whitened up to 54Hz. The low-cut frequency is 0.5Hz. The wavelength is causal and has not been zero-phased. A total of 1340 shots were generated each with 1201 receivers.

Benchmark results

A total of about thirty parties requested and obtained the data. BP put up a web-site from which the data could be obtained with ftp. We also offered tapes as an alternative. The size of the complete dataset is 14 GB, and it was provided in SEGY format together with a document explaining the experiment and data specifications. Nine groups accepted to present their results publicly during the EAGE workshop: five seismic contractors, two universities as well as two research institutes. All participants were free to choose what part of their results they would show and how to present them. In addition to the workshop presenters, a few additional parties chose to participate in the internal BP benchmark. As a controlled test of the results, we migrated the data using the provided velocity models using a wavefield pre-stack depth migration algorithm with identical parameterization for all runs.

Most contractors used an iterative workflow based on different combinations of some key elements: vertical update, tomography, cascaded salt and sediment flows and eventually velocity-scans for the sub-salt estimate. Most vendor results were produced after close collaboration between R&D and production groups.

Universities and institutes all used quasi-automatic approaches that do not require the interpretation expertise that do not have. Multiple arrivals created a major challenge, particularly for the academic groups that did not have the right tools.

Surprisingly, most contractors were able to obtain a very good salt body on the left size but struggled a lot to understand the right salt body. Very few were able to connect the deep roots. Only three contractors had the time and the capabilities to challenge the sub-salt update with moderate success. Solving this problem seems to require tools beyond today’s technology. The right part of the model has been extremely demanding for everybody. Conventional tomography struggled to back-project the shallow anomalies at the right place, often leading to vertically oscillating solutions.

Conclusions

Unfortunately (or fortunately as some may think), velocity estimation for accurate seismic imaging is still an unsolved problem. Even on a 2D synthetic (acoustic) dataset, with more offsets and frequencies than on most field data, we cannot retrieve a 100% accurate solution, but only approach the true solution. Nevertheless, the industry demonstrated that considerable progresses have been made in the field of velocity estimation in the last few years. Complex salt bodies can be delineated; sub-salt variations can be detected and shallow anomalies can be approximately recovered. We hope that this dataset will also be useful to research groups for their future developments.

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References

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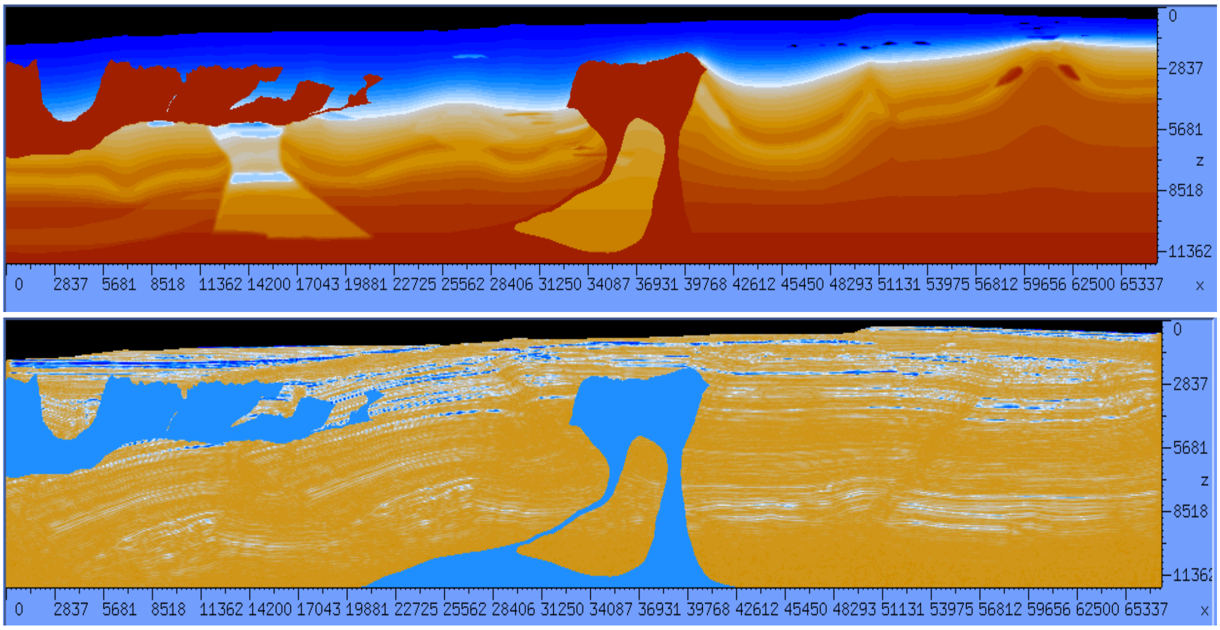

Figure 1: (top) velocity model and (bottom) density model used to generate the dataset.

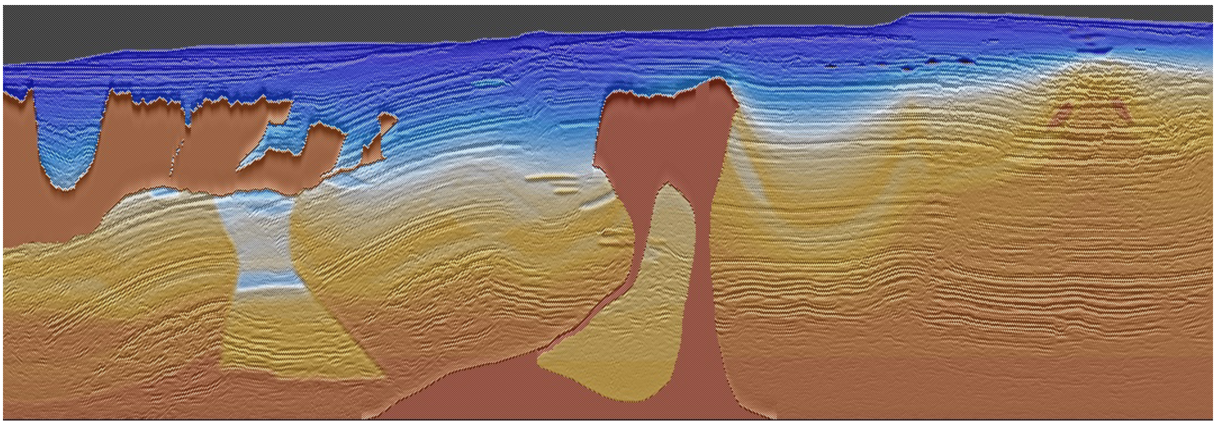

Figure 2: velocity model interleaved with the reflectivity. The vertical scale has been exaggerated twice. We can see the complexity of the signal and notice that velocity and reflectivity have similar trends in some areas only.