Using cross-validation to improve depth conversion – a West Africa example

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Introduction

An accurate Top Reservoir depth structure map is an essential ingredient in well planning, reservoir volumetrics and economic analysis. The process of depth conversion is still something of an art, with different practitioners having their own favorite methods of velocity model building (see Etris et. al (2001)).

In this study, we investigate the use of cross-validation to provide an objective method of choosing between these different methods. Cross-validation is a technique well known in the field of geostatistics (e.g. Todorov and Stewart (1997); Logel and Holroyd (2000)), but deserves to be more widely applied. When applied in depth conversion studies, the process of cross-validation involves systematically dropping out each well in turn, and predicting its depth using the remaining wells. When this is done for all wells for a range of different velocity models, the relative merits of the different models can be assessed.

Dataset

The dataset used is from offshore West Africa. The Top Reservoir time map, with inlines through two of the wells, is shown in Figure 1:

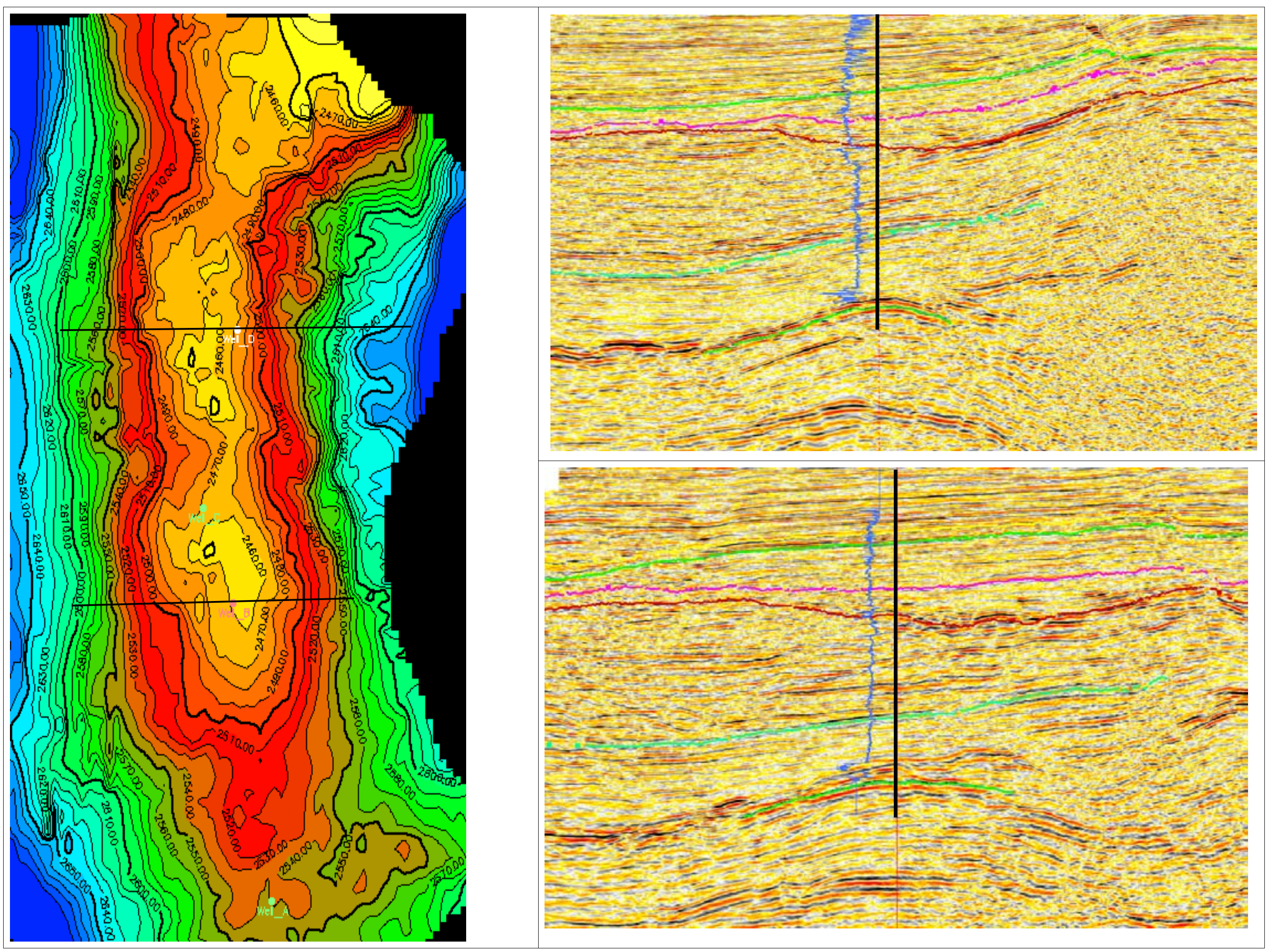

Figure 1: Top reservoir time structure, with inlines through two of the wells

The structure is a four-way dip closure, elongated in a North-South direction. Four wells have been drilled on the structure; two have full log suites and checkshots, one has logs only, and the fourth has only basic drilling data. The velocity-depth plots from the two wells that have checkshots are shown in Figure 2, along with one of the velocity models used

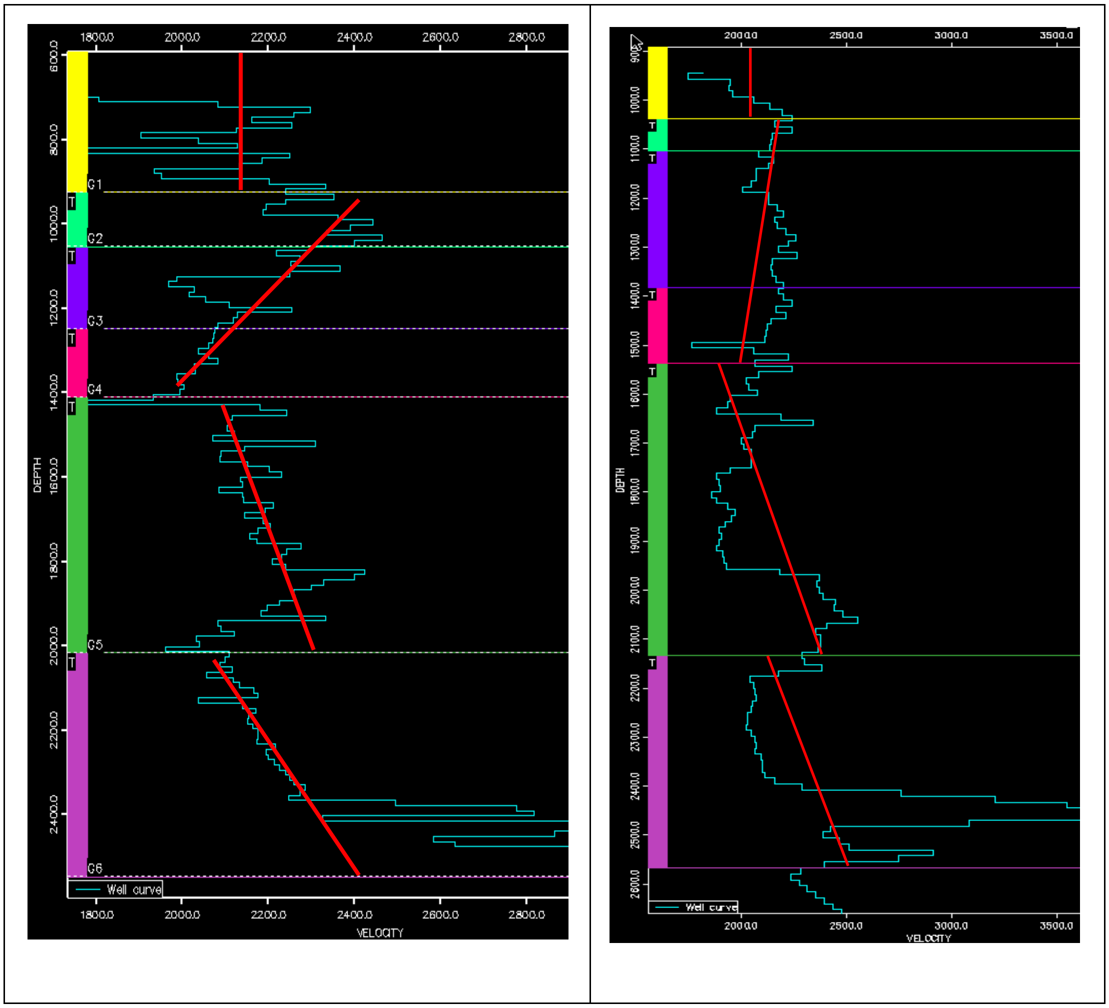

Figure 2: Velocity-depth curves for the two wells which have checkshot data.

Method

Four different techniques were applied to assess the uncertainty in the depth structure, and hence the Gross Rock Volume:

1. Choice of velocity model

For each of the layering schemes chosen, at least two different velocity models were defined, following the method described by Crabtree et. al. (2001). The velocity models chosen vary from layer to layer depending on the geology, but in general, one of the methods chosen was a contoured interval velocity, and another was a compaction-based relationship.

2. Choice of geostatistical parameters

Most of the velocity models chosen for this study involve some element of gridding or contouring. Kriging was chosen for this task. With only four wells, direct variogram modeling was not possible, so a variety of different kriging parameters were examined.

3. Choice of layering scheme

In the above figure, it appears that some of the intermediate layers (G2 and G3) may not be necessary for depth conversion / velocity modeling purposes. In addition, it is a common practice to use a single layer to Top Reservoir when depth converting. The various different possible layering schemes that were examined are shown in Figure 3:

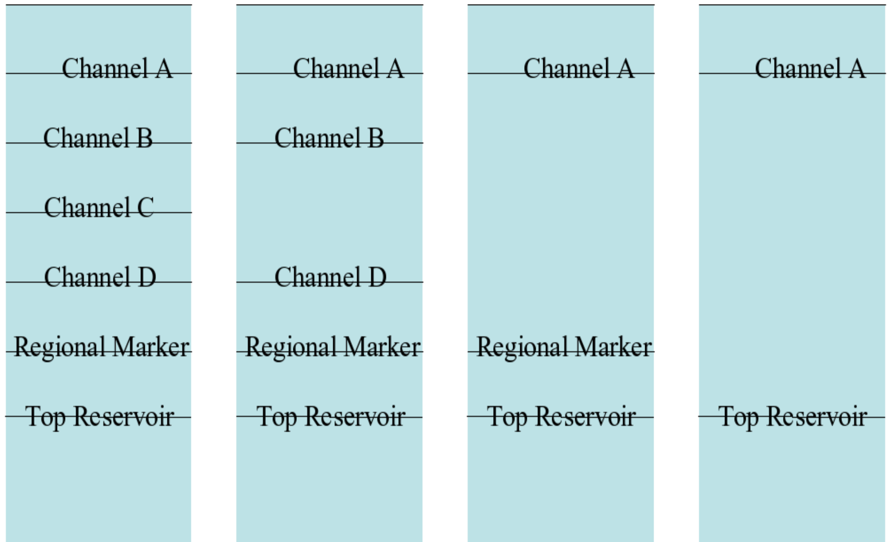

Figure 3: The different layering schemes that were used in the depth conversion

4. Cross Validation

For each depth conversion defined by a combination of the above three methods, four further depth conversions were performed, each omitting one well. The ignored well was completely dropped from all processes, including linear regression calculations, and was essentially treated as if it had not been drilled. This is an extension of the usual geostatistical use of cross-validation, where the interpolation parameters are not re-estimated in the absence of each well. The complete automation of this process is one of the unique features of this work.

Results

Initially, the results of the first three methods were assessed to determine the level of depth conversion uncertainty. The mean and standard deviation of the top reservoir depth structure is shown in Figure 4. It should be emphasized that each of the individual realizations is one which could have been chosen by somebody who was manually depth converting this structure. As is expected, the uncertainty in the depth structure increases both with depth, and with distance away from the wells. The depth structure shows a much more pronounced dip to the North than the time structure; this is due to the variation in velocities in the shallower layers.

Following the initial run, the cross-validation calculations were performed, using a fully automated process. The results from the cross-validation were surprising. (It should be emphasized that these results only pertain to this particular dataset, and are not a general rule).

Firstly, the use of an error correction step after the depth conversion (to force the depth map to tie the wells) actually made the cross-validation results worse. The uncorrected depth maps were more predictive of well data not included in the analysis.

Secondly, the number of layers used directly affected the cross-validation results; using more layers improved the predictability of the results. This is surprising because adding additional layers, particularly in the relatively thin channel sequences, could introduce further uncertainties into the process. In this case, the uncertainties are outweighed by the improved predictive power of the multi-layer model.

The use of different kriging parameters had no significant impact on the cross-validation results. Although the interpolation between wells is uncertain, the variability of this was masked by the above effects.

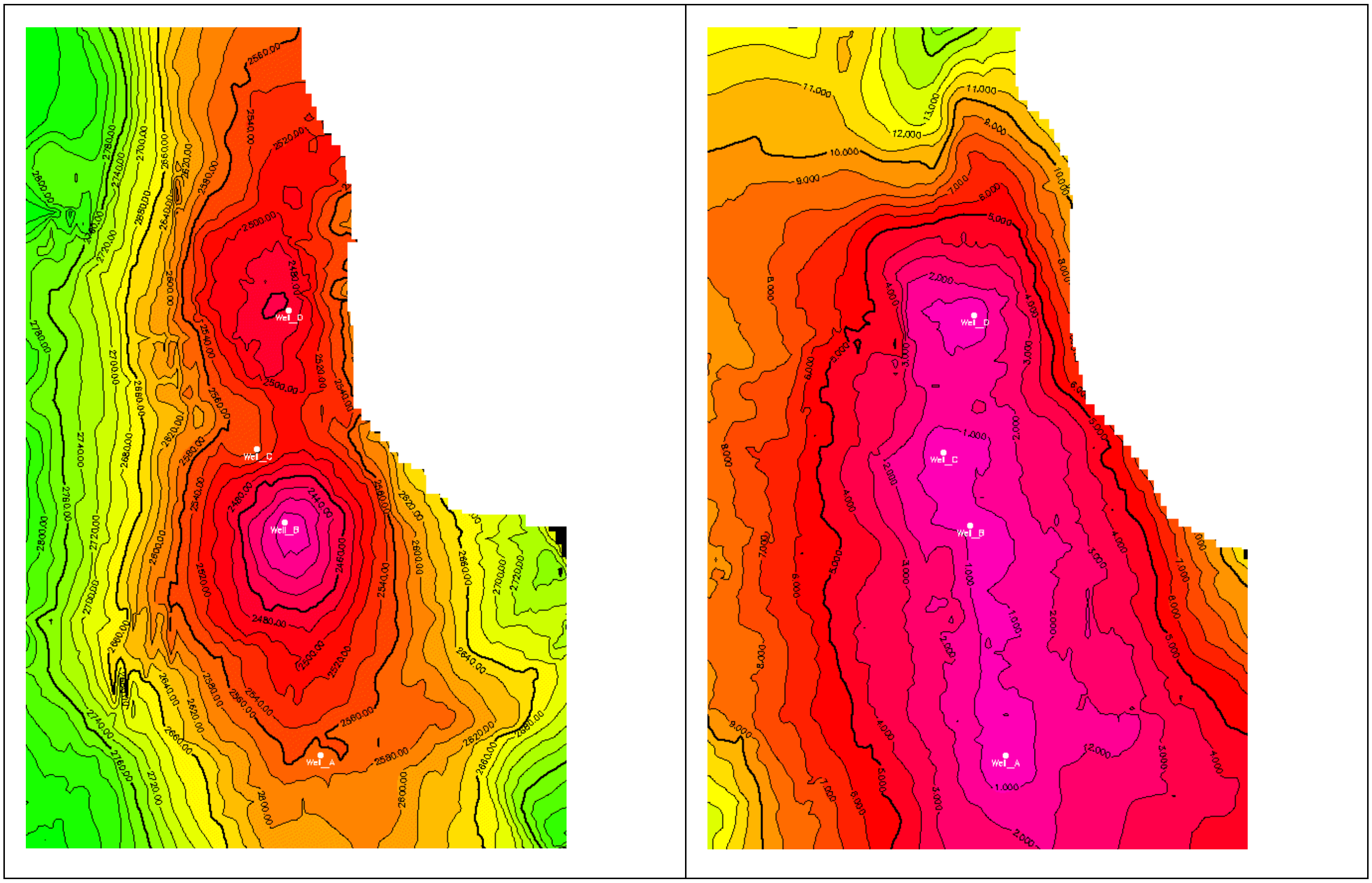

Figure 4: Mean (left) and standard deviation (right) of the Top Reservoir depth structure.

Conclusions

Cross-validation is a powerful tool for assessing which of the variables in a depth conversion study are significant. In this particular dataset, it has been shown that the choice of geostatistical parameters, and the choice of velocity models, is less important than the layering scheme chosen, and whether to perform error correction to force the depth maps to tie to the wells.

References

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