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How Well Do We Predict Depth?

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SUMMARY

With more than 3000 hydrocarbon wells drilled, the Netherlands ranks as a highly mature petroleum province. Virtually all well planning relies on 3D seismic which is often of high quality. Velocity model building and time-depth conversion is a key step in all depth predictions. EBN, the Dutch state oil company, conducted an extensive review of the technical performance of the different operators in the country. Interesting observations can be made in the area of predicting reservoir depth. The analysis of 253 recent wells disclosed that at least one third of those wells with disappointing results (i.e. lower well rates, smaller volumes proven) suffer from poor depth prognosis. The depth errors at reservoir level range from -219 m to +130m. The standard deviation amounts to 38 m which equals 1.2% of the (average) depth. Interestingly, there is a clear bias of 10 m in the depth errors towards being deep to prognosis. The number of wells being deep (64%) is almost double the number of wells (36%) being shallow to prognosis.
A possible explanation for the bias is given by a mechanism that can be referred to as selection bias. It is important to realize that we do not have a precise knowledge of the subsurface. Our evaluations, including the depth maps, are the result of seismic interpretation and velocity assumptions which do contain noise. If we would conduct random drilling on these maps and compare actuals versus prognosis, -most likely- no bias would show up. However, in reality we do not drill randomly, moreover we put a lot of effort in selecting our targets carefully. In many cases an important selection criterion is structural height. In those cases where modest hydrocarbon columns are probable (or where the contact is already pinned down) often the planned well is aiming for a crestal position. The depth map available, with its inherent uncertainty, is a key factor in guiding the location picking. Due to the uncertainty, the crestal areas, as expressed on the depth map, are partly genuine highs, partly spurious highs. Selection bias acts equivalent to Darwin's principle. The ranking of the drillable targets in a portfolio is analogous to the survival of the fittest. Whether the selected location was really crestal (fit) or only perceived crestal; that will show only after drilling. This effect will show up as a statistical bias in the depth prognosis errors.

Introduction

With more than 3000 hydrocarbon wells drilled, the Netherlands ranks as a highly mature petroleum province. Virtually all well planning relies on 3D seismic which is often of high quality. Velocity model building and time-depth conversion is a key step in all depth predictions. The Dutch state oil company EBN is participating in most upstream activity and has access to the well results. As such it is possible to conduct extensive reviews of the performance of the different operators in the country. This allows for a compilation of statistics on exploration success ratios, volume predictions and project costs. Interesting observations can be made in the area of predicting reservoir depth. From all the subsurface parameters being prognosed pre-drilling, few can be tied down so unambiguously as the reservoir depth. The well look-backs disclosed that at least one third of the wells with poor results (i.e. lower well rates, smaller volumes proven) suffer from poor depth prognosis. In those cases typically wells came in deeper than anticipated and often show reduced hydrocarbon columns compared to the prognosis.

Analysis

Assessing the quality and precision of depth conversion workflows requires a substantial dataset to be statistically meaningful. For this purpose 253 petroleum wells recently drilled in the Netherlands have been analyzed and the depth prognosis as described in the well proposal was compared with the depth of key markers actually found. Also the methology used for the depth conversion was tracked. It appears that most mapping, being the basis for the depth prognosis, follows a workflow of *layer-cake* time-depth conversion using 3D PreSDM data. Velocities for these layers are being derived from well data and/or pro-velocities and are parameterized in various ways. Interval velocity maps, velocity functions (Vo,K) and 3D gridded velocities are being used frequently. In most cases the depth prognosis for key overburden horizons was also available. The depth outcome was not only compared with prognosed depth but also with the reported uncertainty range where available. Often the uncertainty range is specified as plus/minus 2 sigma. Assuming a normal distribution, this implies that around 95% of the predictions are supposed to fall within this range.
An example of the *actual versus prognosis* comparison for one specific well is given in figure 1.

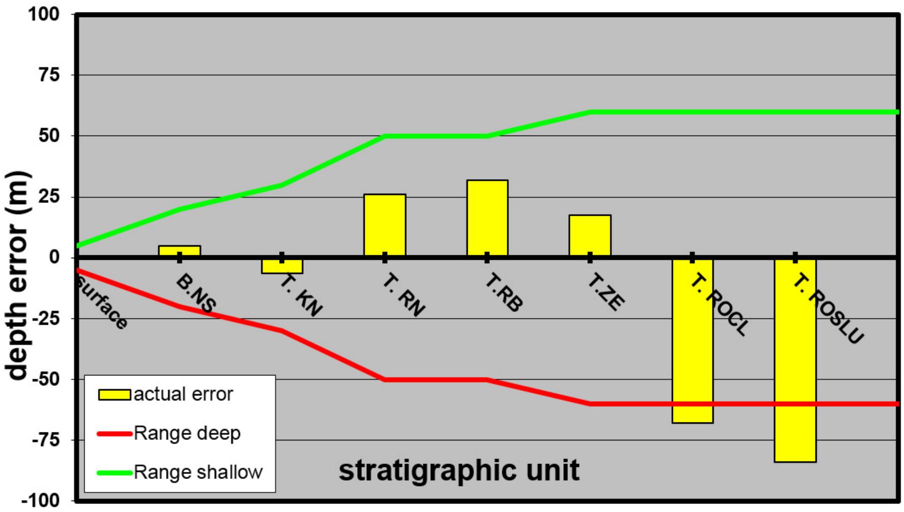

Figure 1 *Depth prognosis errors for a single well: reservoir (ROSLU) and key overburden markers. Pre-drill uncertainty ranges (2 sigma) for reference.*

Given the large number of wells available it was possible to derive statistics on the quality of the depth prognosis. For example, now it is possible to investigate whether certain areas are more challenging to predict depth for. Also the quality of the predictions can be linked to certain workflows or to specific operators. An interesting observation can be made by looking at all the 253 depth predictions of the main objective reservoir tops. The depth errors range from - 219 m to +130m. Whilst the average top reservoir depth in the wells amounts to 3010 m (TVDmsl) the depth errors show a standard deviation of 38 m. In line with expectation, exploration wells typically show larger depth errors than development wells. Looking at all wells (fig. 2), it turns out that there is a clear bias

(10 m) in the depth errors towards being *deep to prognosis*. In the well population studied, the number of wells being *deep* is almost double the number of wells being *shallow* to prognosis.

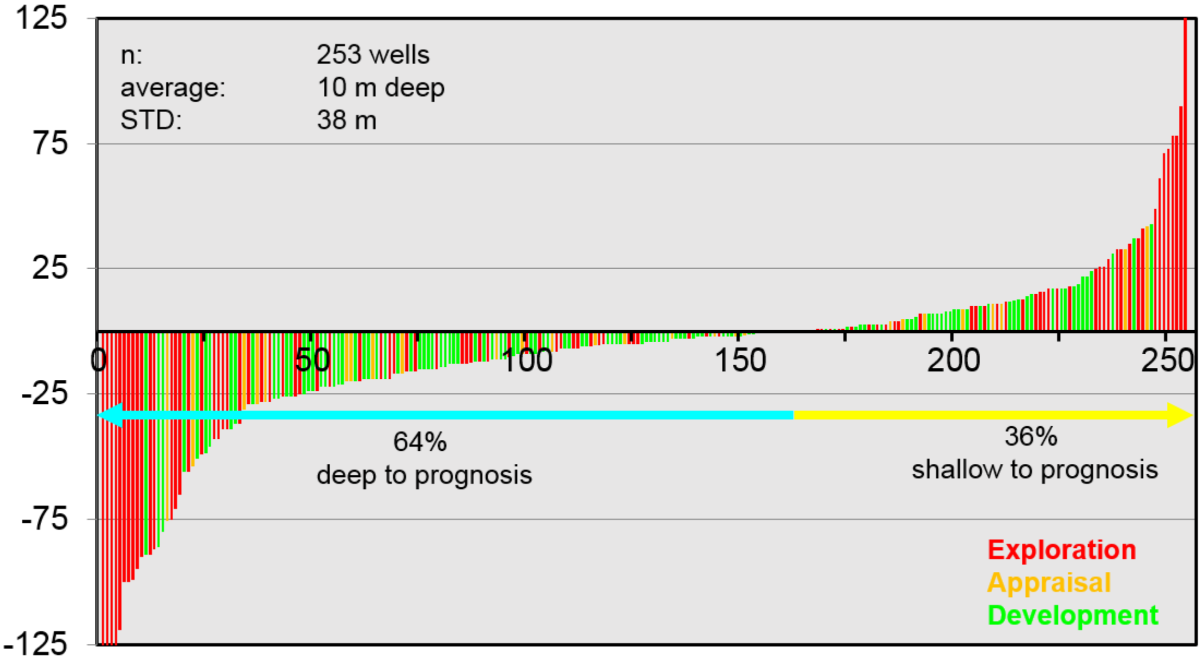

Figure 2 *Depth prognosis errors (in m) for 253 wells: sorted from deep to shallow with respect to prognosed depth. Well type is color-coded as per legend.*

Why biased depth estimates?

A possible explanation for the bias in the depth estimates is given by a mechanism that can be referred to as *selection bias*. It is important to realize that we do not have a precise knowledge of the subsurface. Our evaluations, including the depth maps, are the result of seismic interpretation and velocity assumptions which do contain noise. If we would conduct random drilling on these maps and compare actuals versus prognosis, -most likely- no bias would show up. However, in reality we do not drill randomly, moreover we put a lot of effort in selecting our targets carefully. In many cases an important selection criterion is structural height. In those cases where modest hydrocarbon columns are probable (or where the contact is already pinned down) often the planned well is aiming for a crestal position. The depth map available, with its inherent uncertainty, is a key factor in guiding the location picking. Due to the uncertainty, the crestal areas, as expressed on the depthmap, are partly *genuine highs*, partly *spurious highs*. *Selection bias* acts equivalent to Darwin's principle. The ranking of the drillable targets in a portfolio is analogous to the survival of the fittest. Whether the selected location was really crestal (*fit*) or only perceived crestal; that will show only after drilling.

Conclusions

A lookback at the quality of reservoir depth predictions in the Southern North Sea area (253 wells) shows that the uncertainty amounts to 38 m (1 sigma) which equals 1.2% of the (average) depth. Intriguingly, a bias of 10 m (*deep to prognosis*) is observed in the dataset. A possible explanation is given by the mechanism of *selection bias*. Crestal areas, genuine or spurious, are more likely to be selected in the portfolio ranking process.

References

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Al-Chalabi, M. [2014] *Principles of Seismic Velocities and Time-to-Depth Conversion*. ISBN Number:9789073834873.