Evergreen workflows that capture uncertainty – the benefits of an unlocked structure

Ingrid Aarnes[1*], Knut Midtveit[1] and Arne Skorstad[1] **look at new approaches to the reservoir modelling process and how new tools are supporting operators to set up a repeatable and automated workflow that is easy to update and where uncertainties can be added at any level.**

Uncertainty in the reservoir's geological structure is the reservoir modelling profession's version of the 'elephant in the room'. Its significance is well known to most practitioners, but often overlooked due to time constraints.

Structural uncertainty is, however, one of the most important factors when determining both in-place and recoverable hydrocarbons, and it tends to remain substantial throughout the E&P lifecycle (Figure 1). One of the key challenges is to avoid locking the structural model early on in the reservoir modelling lifecycle. This is unfortunately a natural consequence if the available tools are not designed for revisiting these early assumptions.

The locking of geological structure can be attributed to two key factors: 1) The fact that the logical process of building a reservoir model in a sequential workflow chain starts with defining the structure, and 2) the limitations in common reservoir simulation practices, where changing the geometry of the simulation grid is comparable to starting from scratch.

In many applications of best practice, the revisiting of assumptions made early in the modelling process, such as the choice of a velocity model, is usually not prioritised because the traditional model update is manually-based, resource demanding, and takes too much calendar time.

The same arguments apply for adding uncertainty to the structure at a later decision gate. Hence, after the structural modelling job is finished, exploring uncertainties in static and dynamic volumes tend to be limited to parameters that do not affect the grid layout. Changing faults and horizons are not among those.

The higher risk of geological inconsistencies emerging in the simulation model(s) is a consequence of this sequential approach, where flow simulation is seen as 'the last step' and where there is a lack of iteration back to the starting point.

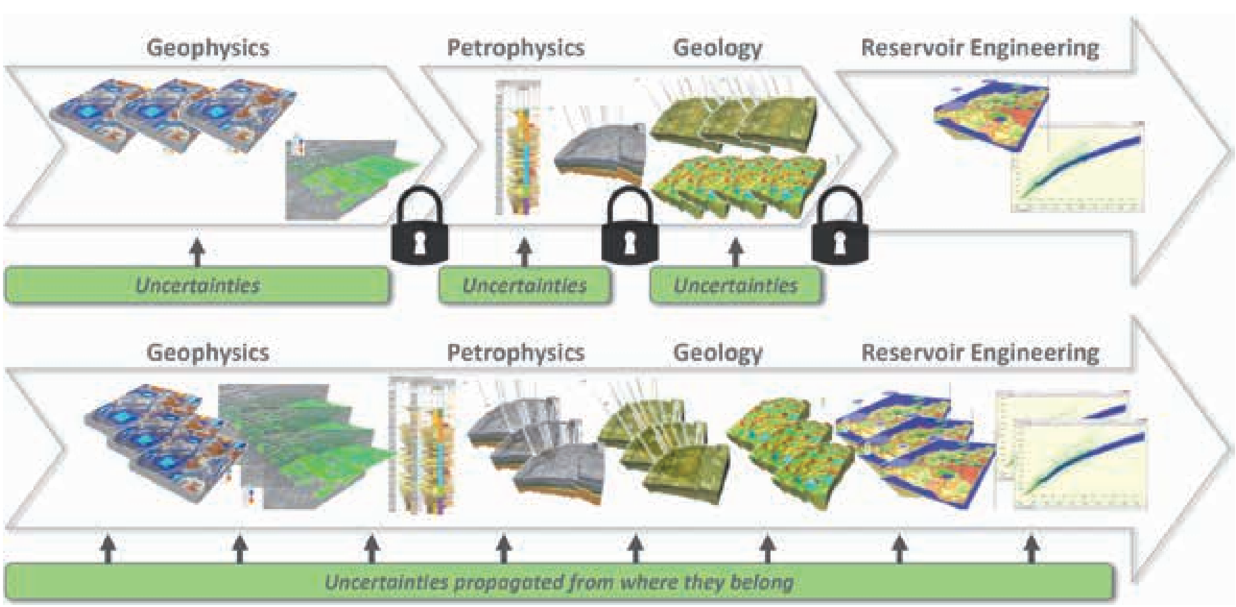

Figure 1 *It is difficult to evaluate uncertainties with the traditional approach due to specific choices of model and data, and gaps between each domain. Uncertainties tend to be reduced without support from data. Anchoring decisions without knowing the uncertainties increases the risk. A better alternative is an ensemble workflow spanning from seismic to simulation, which allows for propagating uncertainties from where they belong to where they matter through the use of multiple runs and realisations.*

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More subtle but equally critical risks are that: 1) uncertainties are not captured and propagated through the workflow from where they apply; 2) that there is deficient alignment that does not utilise the full potential of synergy between domains; and 3) that excessive time and resource demands are spent on costly model updates and model refinements. The latter is a natural consequence of each profession ensuring that their domain's delivery is as correct as possible since revisiting earlier assumptions is unlikely.

Improvements to this practice require a change in modelling philosophy and how the operator and asset approaches the reservoir modelling process.

We will look at how new tools are supporting operators in meeting these challenges through the ability to set up a repeatable and automated workflow that is easy to update and where uncertainties can be added at any stage.

The evergreen workflow – easy to update with new data

Reservoir modelling comes with high resource and time demands, which are increased by costly model updates and excessive model refinement. Updating the structure to include new well data is particularly expensive due to the manual steps involved. When the changes are major, it could for example require rebuilding the whole model (Figure 2a and c).

Recent technology advances provide efficient model updates of the reservoir structure (e.g. Stenerud et al., 2012). The key outcome is a robust and integrated update of the velocity and structural model, reusing the existing workflow (see Figure 2 b and d). This novel conditioning technique combined with the existing consistent modelling framework allows us to support evergreen workflows consistent with all the latest information. Adapting this technology as an integrated part of a 'best practice' workflow will help E&P companies save both time and money.

Velocity modelling and depth conversion come with large uncertainties, mainly because there is a lack of data to condition to, particularly for estimating anisotropy or directional dependencies of seismic velocity. Data collection comes at a cost and at the stages of drilling production and injection wells, velocity information might not necessarily be prioritised.

Yet, these new wells still provide a lot of depth data, often with good lateral coverage of the reservoir. In velocity modelling methods, there is no straightforward way to incorporate depth data without associated velocity measurements.

Even though this can be overcome through the process of calculating pseudo-well velocities, there is the additional challenge of producer-wells being horizontal and often geosteered into one specific zone. In this setting, the pseudo- well velocity method doesn't work as there are no vertical time-depth pairs available.

A solution to this challenge is a Bayesian geostatistical approach to depth conversion (e.g. Abrahamsen et al., 1991; Abrahamsen, 2005). The Bayesian approach adds value to existing velocity modelling practices by allowing for fast and robust updates of the prior velocity model with the arrival of new data.

The Bayesian approach combines information on time interpretation, depth observations, thicknesses, surface correlations, velocity and associated uncertainties in order to make geostatistical predictions of the velocity model in the process (Figure 3). Creating probabilistic subsurface depth maps to cover the structural uncertainty is a matter of choosing between a deterministic or probabilistic approach. The result of the latter will be multiple equi-probable realisations reusing the same workflow.

The implemented algorithm ensures tight integration of the geophysics time/velocity domain and depth domain, strengthening model updates and uncertainty workflows. In

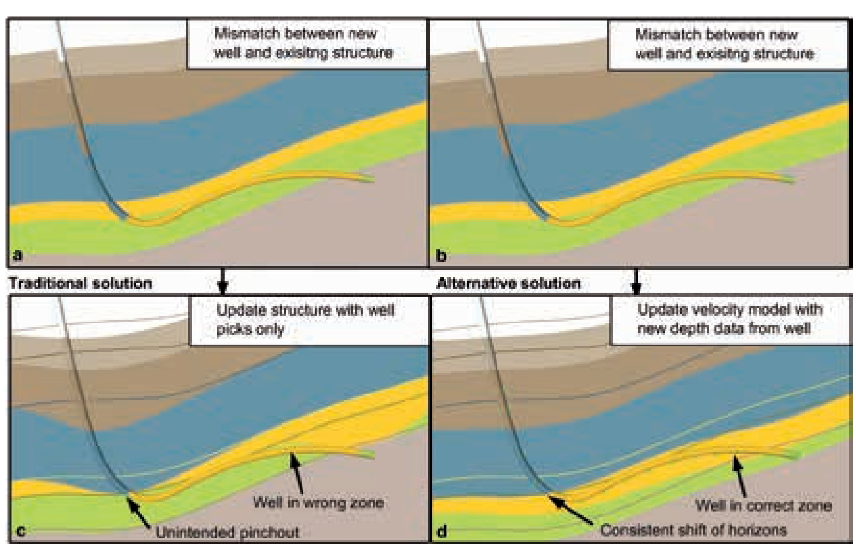

Figure 2 *a) and b) A new well has been drilled and there is a mismatch between the depth information of the well and the existing structure. c) Traditional handling of this problem is to condition the depth surfaces to the new well observations. This can lead to unintended errors, such as zone pinchout and wells ending up in the wrong zone, and overcoming this can be a time-consuming and manual process. d) The alternative solution sees the new data in relation to all the existing information, and predicts which changes are necessary to incorporate the new data in a robust way to ensure consistency. This can, for example, be an update of the velocity model, a local adjustment of the surfaces or a combination of both, depending on the relative uncertainties allowing for the changes. The green points shows that the well is in the correct zone.*

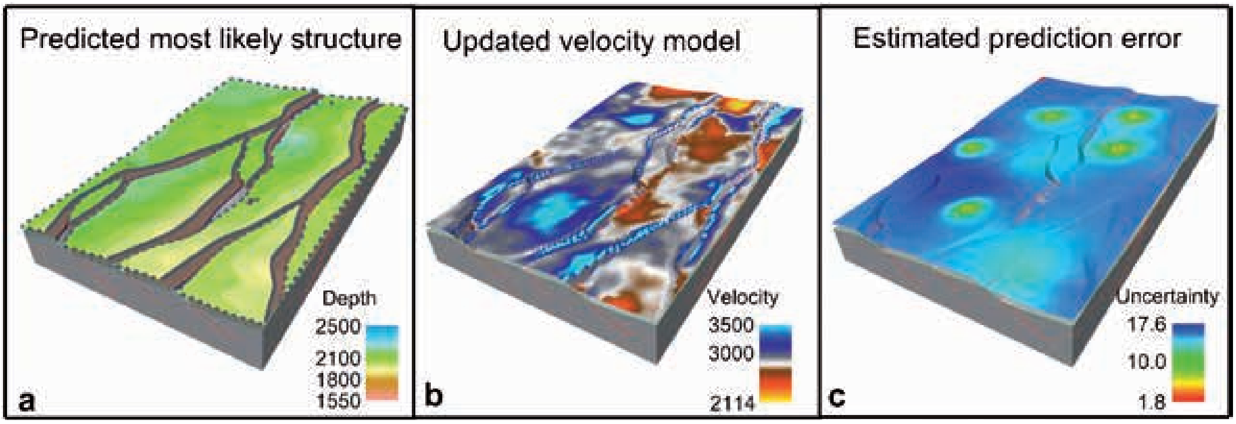

Figure 3 *Geostatistical approaches to depth conversion under uncertainty produces: a) a most likely model, b) an updated velocity model and c) an uncertainty estimate of the prediction, given in one standard deviation. The prediction error (one standard deviation) gives a quantification of how much the horizons can shift and still be consistent with all input data.*

addition, the algorithm allows for the utilisation of depth information along horizontal wells, i.e. conditioning the horizons to specific zones along the wells.

It is also worth spending some time on the velocity model updating process. The benefits will be adjusted depth maps and a 3D grid that matches the new well data. This can be done quickly by adjusting the grid to maps, or through a rerun of the whole gridding and property modelling workflows, depending on how much impact the new well is predicted to make.

The automated process makes a most likely velocity model in sync with interpretation in time, depth information and their associated uncertainties. This job can be completed in a matter of seconds, as opposed to what could take weeks of manual work by a geophysicist. Although it is automated, it always leaves the geophysicist in control and the results must still be quality controlled as always.

Somewhat ironically, allowing for uncertainties in the structural data results in a more certain prediction of the reservoir structure. This concept of improved and quantified predictions of subsurface depths can add further value through model updating while drilling for increased predictive power. The value added by applying this technology as an integrated step in the reservoir modelling workflow is clearly recognised (e.g. Pettan and Strømsvik, 2013; Hanea et al., 2015).

The ensemble workflow – automated uncertainty assessment

There is a tendency for domain-specific working methods to be common practice in many E&P companies today, where using the same software is no guarantee of alignment within the assets.

As a consequence, there is a heightened risk of domain-specific goals arising, instead of focusing on the common goals of the modelling project. Moreover, the uncertainties tend to be sustained within each of the domains, instead of aiming for a collective understanding of which parameters and input matters for achieving the end goals of the project.

Our solution to this challenge is to support workflows from the beginning of the relevant input data, such as seismic interpretation, through to the end-goal of the project, such as in-place volumes or production forecasts.

The workflows can be automated, and hence enable the fast generation of an ensemble of models. Each model represents a probable configuration of the reservoir based on the specified uncertainties. The link between the geomodelling workflow and the reservoir simulation can be controlled via Emerson's uncertainty analysis tool Tempest ENABLE, so that all asset members can contribute in the same time frame and as part of the same workflow.

This allows for testing which parameters and processes matter for the end goal. Hence, uncertainties can be added in the domain where they belong (e.g. static), and propagated to where they matter (e.g. production). The key value of facilitating collaboration through an integrated workflow is that it increases the common understanding of the reservoir and results in consistent models being produced (e.g. Pettan and Strømsvik, 2013).

The focus of workflow building should be to remove manual editing processes to ensure a full reproducibility of the workflow. Once the workflow has been set up, it can be run automatically to produce as many realisations and simulation runs as needed. The outcomes from these processes can then be used to understand the sensitivity and interplay of the many parameters involved.

The implementation of a multi-realisation workflow requires the modelling process to be highly automated, while remaining flexible enough to incorporate new data and concepts at any time in the E&P life cycle (e.g. Zachariassen et al., 2011; Skjervheim et al,. 2012; Hanea et al., 2015).

The key benefit of ensemble workflows is that more time can be spent where it really matters, such as analysing input data, testing assumptions for improved understanding, and optimising the field's development strategy.

Final thoughts

This article has described how new technologies in combination with an ensemble philosophy can help to asset teams towards a closer integration of the reservoir modelling workflow – between the classical domains of geophysics, geology and reservoir engineering.

The article shows how Roxar reservoir management software supports a modern ensemble-based approach that automates the workflow and generates multiple realisations where the impact of key uncertainty parameters becomes measurable.

More often than not, the structural uncertainties are of primary importance and should be honoured. The foundation for this approach is an evergreen workflow that can be refined, updated and used to test various assumptions as you move through the different reservoir modelling decision gates.

Geostatistical depth conversion with integrated velocity model updating represents a step-change in available reservoir modelling technology. It supports oil companies in the transition from the current 'best practices' of defining one base case with hand-selected scenarios into combining a statistically most likely case scenario through an ensemble of models with changeable geometries. In this way, structural uncertainties can be captured as seamlessly as any other parameter.

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