TuPG13

Successful Reconstruction of the Fluvial Conceptual Model on Gullfaks Sør with Object Modelling

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Summary

We show that object models are able to handle real world data complexity by applying a recently published object model to a North Sea reservoir. The reservoir used is the Statfjord formation of Gullfaks Sør, which has rich alluvial-fluvial sandstone deposits. For this reservoir, object modelling of channel objects and crevasse splays is preferred as it provides better geometric control of the channels and crevasses than indicator/data-driven models. However, earlier object models have had problems with conditioning to the amount of well data here. With this new approach, we can condition perfectly on well data, while also reducing the run time compared to previous models. The article addresses the improvements of the well conditioning which is central as it enhances the possibilities of doing automatic modelling of multiple realizations without any subjective modifications by the field geologists around wells. The improvements implicate that the necessary manual time for the geologists to create a good model can be reduced, which again implicates both cost-saving and a more robust automatable model. Our results demonstrate that object models have a vital role to play even in the current data-driven market of our industry.

Introduction

To obtain support for making better decisions in reservoir management, workflows covering the entire geosciences and reservoir engineering domains are customary set up. Facies modelling is an important part of such workflows, as it defines the main flow pattern in the reservoir and represents the geological understanding of the depositional environment. Automatic generation of multiple realizations is used to obtain quantified risk estimates for many reservoir management decisions (Zachariassen et al., 2011). This means that manual edits to change facies realizations that have not properly conditioned on all data destroys the reproducibility, which is key. Moreover, manual edits may introduce local effects becoming bull's-eyes, which reduces the predictive power of the model. A correct well conditioning on all well data is therefore a mandatory element in such workflows. We use the fluvial reservoir of Gullfaks Sør as a case study to evaluate the recent object-based facies model for channel systems presented in Hauge et al. (2017). The model will be assessed based on well conditioning success, geological sensibility in the results as well as performance of the model compared to the existing facies model for the reservoir, including "time to model".

The Gullfaks Sør field is situated in the western part of the Viking Graben on a west dipping fault block in the southern part of the Tampen Spur area. We focus on the facies modelling of the alternating alluvial-fluvial sandstone and shale in the Upper Triassic to Lower Jurassic Statfjord Group (Gp.). The wellbores through the Statfjord Gp. are drilled unbiased by not aiming for a specific channel belt. The wells are cutting horizontally through much of the stratigraphy, giving a good indication of the actual facies distribution.

The Statfjord Gp. is subdivided into the Raude-, Eiriksson- and Nansen Fm. (Vollset and Doré, 1984). The sediment deposition consists of fluvial channels, interfluvial floodplains and shallow marine sediments with single- and multi-storey fluvial channels, with a cyclic alternation of the sandstone-rich channel belts and the mudstone-rich intra-channel intervals (Ryseth, 2001). The Statfjord Gp. conceptual model in the Gullfaks Sør area shown in Figure 1 is based on an analogue study of the Lourinhã Formation in Portugal (Keogh et al., 2014). The facies model consists of channels, crevasses, and intra-channel barriers, with floodplain as a background. To simplify the modelling, the lateral- and downstream accretion channels are combined into one channel type.

Model and algorithm

The facies-modelling algorithm for channel systems used in this study is described in Hauge et al. (2017). This follows a long tradition of object modelling for fluvial reservoirs, as described in Keogh et al. (2007). Its core idea is to generate cross sections of the channel sequentially in such a manner that it is consistent with local well observations, including those observations that are slightly ahead of the current location. By including this information, we get a very efficient conditioning algorithm.

The channels are parameterised around an infinite straight line giving the main direction. The local horizontal centre and width of the channel is given by two independent 1D Gaussian fields. Crevasses are made in a similar manner but differs from channels in having a backbone consisting of two finite connected lines. The first is connected to the edge in an outer bend of the channel and gives the breakout direction. The second line gives the final splay direction. These lines are used to build a local coordinate system, as described in Syversveen et al. (2011**)**. The cross-sectional shapes of the objects are given by a trend, modified by 2D Gaussian fields added to the top and base. These Gaussian fields give the flexibility needed for well conditioning.

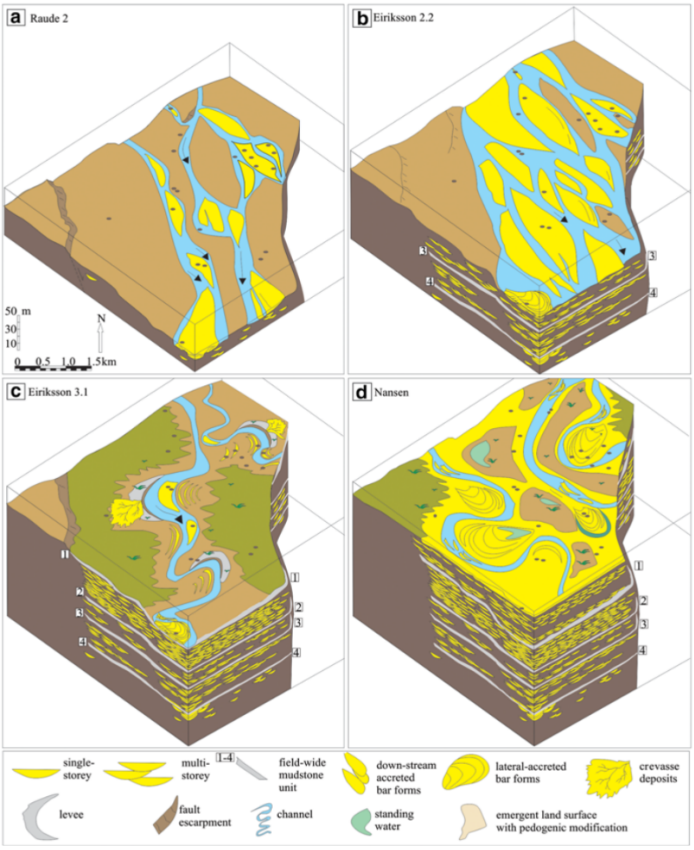

Figure 1 *Depositional environment for the different formations of the Statfjord Gp. on the Gullfaks Sør field. Stratigraphic trends and channel types from oldest (a) to youngest (d). Figure from Keogh et al. (2014).*

Applying the facies model

The established facies modelling workflow for Gullfaks Sør is built around an earlier object-based algorithm, which works by making finite objects according to the specified geometries. The modelled area has more than 40 wells with approximately 5000 facies observations. Statfjord Gp. is here subdivided into eight separate zones modelled individually. The total number of grid cells for the modelled zones are just above 5.2 million cells. Channel and crevasse facies are modelled using the new algorithm (Figure 2a). The barrier facies is first marked as channel facies since these occur within the channel boundaries, and then modelled as intra-channel facies. We use the input values for volume fractions, vertical distribution trends and geometric definitions as established by Equinor in previous work. This allows us to make an algorithmic comparison of the new and previously used facies models.

A challenge with the earlier facies model was conditioning to well data; it would not run through when conditioning to all wells in the Gullfaks Sør reservoir, and some wells would cause the jobs to fail. Which wells failed varied from zone to zone. The process of selecting which well data to omit for each zone is a time-consuming step, and it causes important information to be left out from the model. Moreover, if the model specification should change, different wells may have to be excluded. The new channel algorithm conditioned successfully to all data points in this study, illustrated for one well in Figure 2b.

Another limitation with the previous facies models was that the modelled objects had a finite lateral extent, which produce facies bodies that ends abruptly, and not necessarily connects with another body of the same facies type. This can give rise to unrealistic connection patterns and prohibit the use of intrabody trends, which is one of the major advantages of object-based facies models.

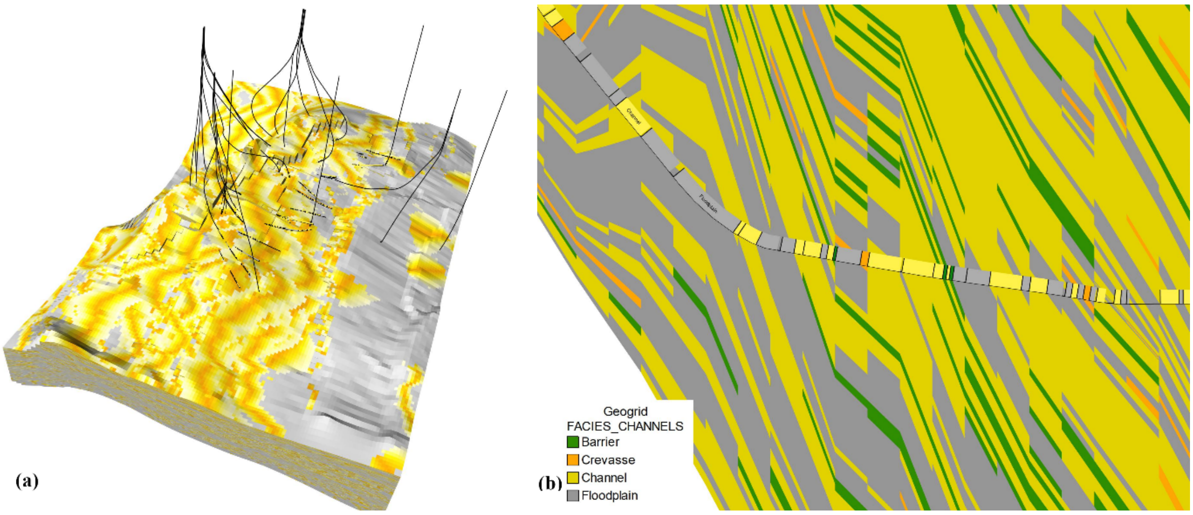

Figure 2 *(a) An overview of the grid model and well pattern. Channel and crevasse facies are displayed with intrabody trends. The orange colours are the channels centres while the lighter yellow are the edges. (b) Reservoir cross-section of the output parameter along a well with its facies log displayed in front of it.*

The new object model creates channel bodies that runs through the entire modelled area, in accordance with the parametrisation, as can be seen in Figure 2a. This ensures geological sensible result, consistent with the conceptual model. Figure 2b shows how the output has been successfully conditioned to the well data (cf. lower edge of well trajectory). The gaps in the well data are missing data due to grid cell mapping, and the observed dip is structural, and not depositional.

We have specified the channel geometries with a curved bottom shape, for a realistic representation of how channel deposits erode into the floodplain (Figure 3). Note also the distribution of channels differing vertically due to the input trends. Crevasse splays are deposited when a channel wall is broken, producing a body connected to the channel itself. These deposits are often thinner than the channel, and escapes at roughly 90 degrees angles. All crevasse-objects in the facies model are linked to the outer bend of a channel object.

Comparing the runtime for each individual zone, the new facies model runs successfully and condition to all the data ranging from 1 min 30 sec to 7 min and 40 sec. The existing facies model, which does not include all well data, has a runtime ranging from 1 min and 30 sec to 17 min and 30 sec but does not condition to more than 200 well data points. This means that the total runtime has been more than halved if run in parallel using a multi-threaded option. When evaluating the runtimes, we have disregarded the barrier modelling step, as the runtime for this is seconds rather than minutes. However, several factors count when looking at “time to model”. Of key importance is the time it takes to define a model that will run successfully. Being able to condition to all the available data while achieving a geological sensible result, reduces the time significantly. Ten stochastic realisations with varying seed were run in this study, and all completed successfully. Thus, the manual iterations of excluding data are no longer needed, which makes object modelling a solid and efficient method for modelling fluvial channels.

Conclusions

We have demonstrated that the new object model successfully reconstructs the fluvial conceptual model on Gullfaks Sør, by conditioning to a large amount of well data, while keeping the results geological sensible. Conditioning successfully to all well data has two important implications. It reduces time spent on manual work, and it ensures automatability and reproducibility of multi-realization workflows. Together with enhanced performance the “time to model” has been significantly reduced, and the applicability of the object model is widened. This means that object models now are a viable candidate for modelling reservoirs with complex well patterns.

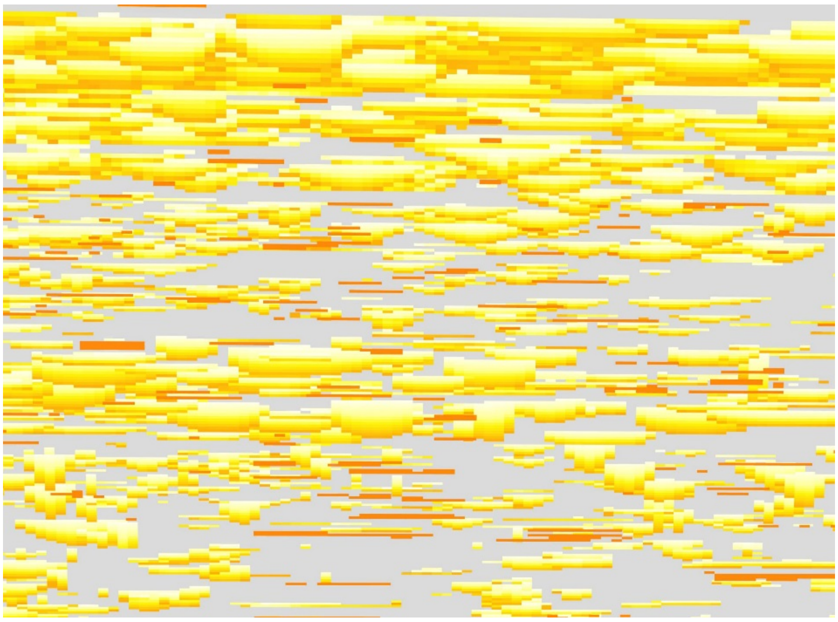

***Figure 3** A cross section showing channel shapes. The channels are displayed with a bottom to top trend highlighting their shapes, and how they have been amalgamized. The crevasses are displayed with orange colour and are emerging from the channel objects.*

Acknowledgements

The authors are grateful to the partners of Gullfaks Sør; Equinor, OMV and Petoro for the permission to use real data in our study, and to publish the results. We also thank our companies, Equinor, Emerson and Norwegian Computing Center for allowing us to work on this collaborative study.

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