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Sketch-based modelling with flow diagnostics: Prototyping geomodels for better resource modelling decisions

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Summary

Sketch-based modelling with flow diagnostics provides a prototyping approach to quickly build geomodels and generate quantitative results to evaluate volumetrics and flow behaviour. This approach allows users to rapidly test the sensitivity of model outputs to different geological concepts and uncertain parameters, and informs selection of geological concepts, scales and resolutions to be investigated in more detailed models.

Rapid Reservoir Modelling (RRM) is a sketch-based modelling tool with an intuitive interface that allows users to rapidly sketch geological models in 3D. Geological models that capture the essence of heterogeneity of interest and related uncertainty can be created within minutes. Flow diagnostics then instantly computes key indicators of predicted flow and storage behaviour within seconds.

Here we apply the prototyping approach to three aspects of geoenergy modelling: (1) scenario screening to identify heterogeneities with the most impact; (2) use of mini-models and hierarchical models to derive effective properties; and (3) training of geoscientists and engineers to investigate the impact of geological interpretations on storage volumes and connectivity. Geomodels addressing all three aspects are constructed and analysed quickly, using simple, geologically intuitive workflows that do not require prior geomodelling expertise.

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Introduction

Most subsurface geoenergy applications (e.g. CCS; H_2 & gas storage; geothermal; …) use geomodelling as part of the workflow to calculate volumetrics, to plan for production and/or injection of fluids, and to minimise and mitigate risk due to geological uncertainty. Modelling workflows are often too time-consuming and computationally expensive to capture the full extent of the uncertainty space and scale. Sketch-based modelling (Olsen et al, 2009) with flow diagnostics provides a prototyping approach to quickly build geomodels and generate quantitative results to evaluate volumetrics and flow behaviour. This approach allows users to rapidly test the sensitivity of model outputs to different geological concepts and uncertain parameters, and informs selection of geological concepts, scales and resolutions to be investigated in more detailed models.
Rapid Reservoir Modelling (RRM) is a sketch-based modelling tool with an intuitive interface that allows users to rapidly sketch geological models in 3D (Jacquemyn et al., 2021; Jackson et al. 2015). Geological models that capture the essence of heterogeneity of interest and related uncertainty can be created within minutes. Flow diagnostics (Petrovskyy et al., 2022, preprint) then instantly computes key indicators of predicted flow and storage behaviour within seconds.
Here we apply the prototyping approach to three aspects of geoenergy modelling: (1) scenario screening to identify heterogeneities with the most impact; (2) use of mini-models and hierarchical models to derive effective properties; and (3) training of geoscientists and engineers to investigate the impact of geological interpretations on storage volumes and connectivity. Geomodels addressing all three aspects are constructed and analysed quickly, using simple, geologically intuitive workflows that do not require prior geomodelling expertise.

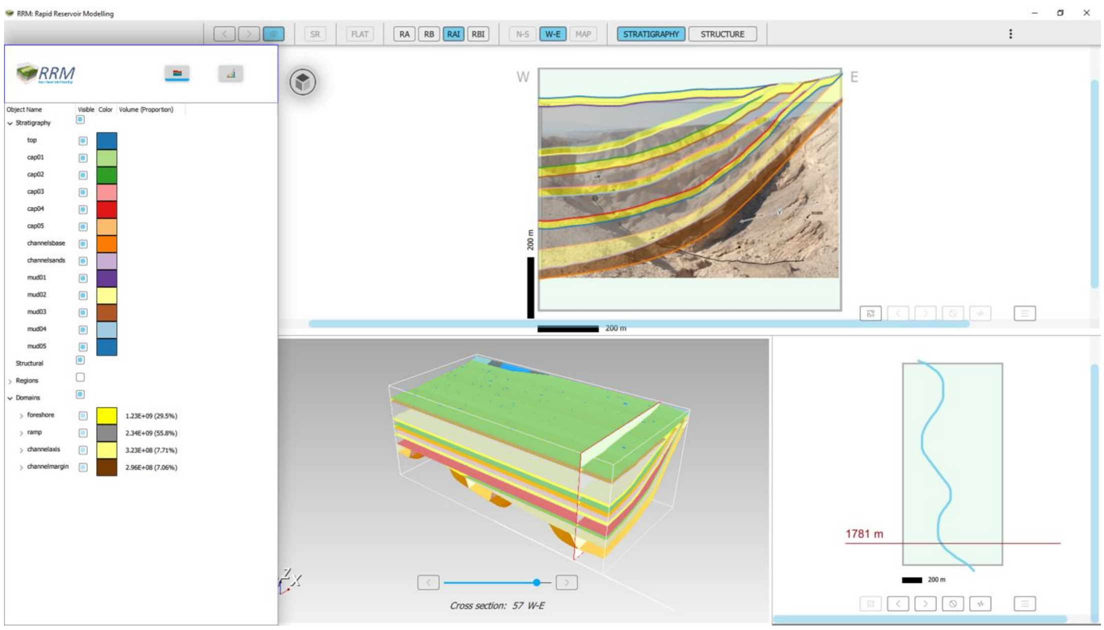

Figure 1 *Screenshot of the sketch-based interface of RRM, showing the cross section sketching canvas (top right), map view sketching canvas (bottom right), 3D perspective view (bottom centre) and (left) stratigraphic panel of sketched surfaces and domains. The sketched model corresponds to foreshore, ramp and channelised deposits deformed by a growth fold (based on Lewis et al., 2015).*

Methods

Sketches drawn on one or more 2D vertical cross sections and horizontal slices are combined into 3D surfaces (Figure 1). Geological operators ensure correct truncation relationships between these 3D surfaces by the modelling engine. The flow diagnostics module (Figure 2) allows users to assign petrophysical properties to geological domains and place wells intuitively and on-the-fly, and provide metrics to assess how the sketched geological heterogeneity impacts flow patterns (Petrovskyy et al, 2022, preprint). Metrics include pressure and time-of-flight distribution, gravity number, production or injection profile, well partitioning and others.

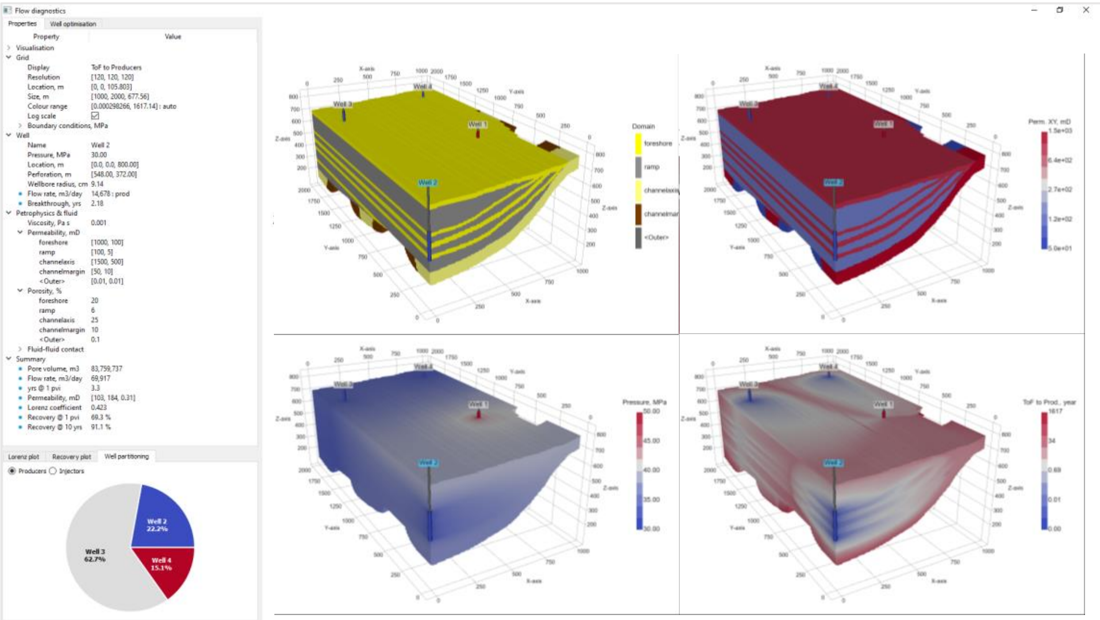

Figure 2 *Screenshot of the flow diagnostics of RRM, showing parameters and results (left) and four 3D visualisations (right) of geological domains, permeability distribution, pressure distribution and time-of-flight for user-defined well distribution.*

Results

Fast evaluation of impact of sedimentological heterogeneity on CO_2 storage

Sketch-based modelling is applied to assess the impact of sedimentological heterogeneity on static and dynamic reservoir parameters on CO_2 migration and storage in fluvial (Sherwood and Bunter Sandstones, UK; Alshakri et al., 2023) and shallow marine (Johansen Formation, Norway; Jackson et al, 2022) reservoirs. For each case, using experimental design on 8 uncertain factors of heterogeneity, a series of 32 models is needed to explore the uncertainty space. Capturing uncertainty in numerical variables is straightforward and just requires changing the value used in different models. Capturing uncertainty in geological concepts cannot be achieved by changing a numerical variable but can be varied easily by sketching the different concepts (Figure 3), such as lateral connectivity, continuity and geometry of geological heterogeneities that act as flow barriers and pathways. Capturing multiple different concepts in conventional modelling approaches is time-consuming and in practice not often carried out.

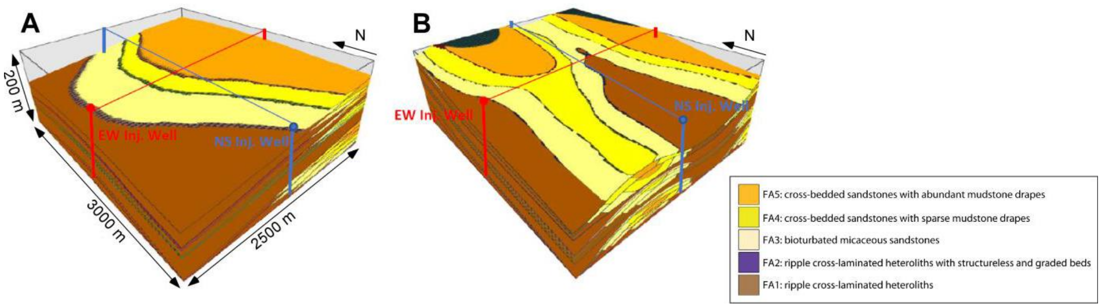

Figure 3 *Screenshot of two different concepts of delta geometry in the Johansen Fm. (Jackson et al, 2022), showing an arcuate (left) and elongate (right) planform delta geometry sketched in RRM.*

Calculation of effective properties in nested minimodels

Heterogeneity at different scales can affect flow and storage behaviour. Using a nested hierarchy of models, effective properties of models at a smaller scale can be computed and embedded in larger scales. Creating multiple models at each scale of interest is difficult and often requires different approaches to modelling depending on scale and data types at different scales. Core description linked with outcrop analogues at m-scale and 100m-scale are used to understand and quantify the impact on flow and storage of CO_2 in the Sherwood and Bunter Sandstones at reservoir scale (Hossain et al, 2023). Outcrop photographs of different facies are used as sketching backgrounds to construct 3D models that are realistic representations for each facies. These are then combined into facies association and geobody models sketched from larger scale outcrops. Sketching a 3D model takes 10's of minutes, and thus multiple models can be generated and analysesd quickly.

Sketch-based modelling as a tool in geo-energy training

As part of geoscience and engineering training, hands-on experience with geological modelling is essential to understand the impact of geology on subsurface applications. However, using conventional modelling packages, the learning curve to create or adapt a geological model is steep and long and can distract from training objectives. Using intuitive sketch-based approach the entry point to creating a geological model is much more accessible while still maintaining the key learning, i.e. impact of geology on subsurface applications. We applied sketch-based modelling on a CO_2 storage project in a Rotliegend Group sandstone reservoir for a classroom of 25 students. In a 1-day lecture and practical, students were taught how to sketch 3D models and subsequently each built several models capturing different geological concepts and well correlations and evaluated the impacts of their interpretation (Figure 4). Similar learning would not have been possible using conventional modelling packages without extensive software-specific training.

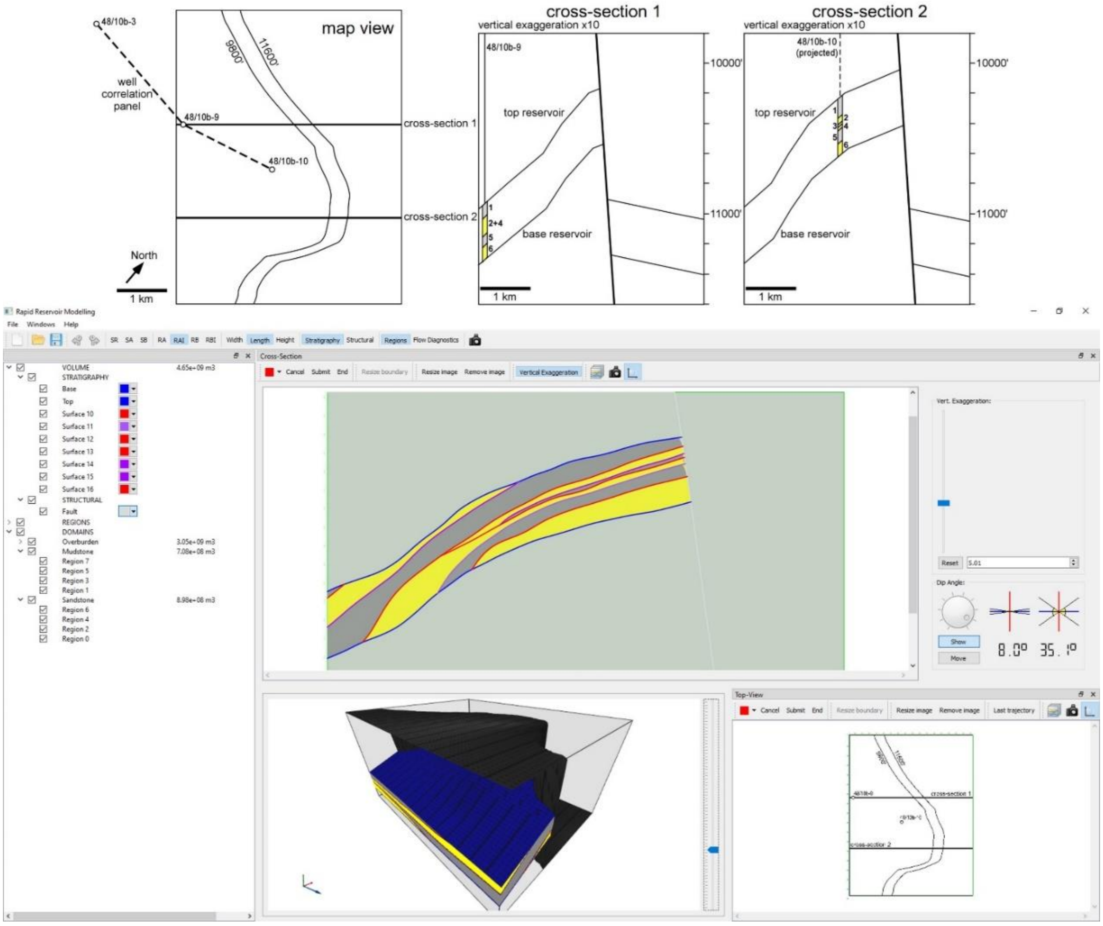

***Figure 4**: Input data (top) and one of many sketched 3D geological models (bottom) of the CO_2 storage project.*

Conclusions

Sketch-based interface and modelling is a modelling approach to generate 3D geological models quickly and intuitively, sketched over data or based on concepts. This allows to assess model sensitivity in a short timeframe and direct which models and uncertainties are useful to investigate further. Models can be sketched at multiple scales, and effective properties of minimodels can be used to inform larger scale models. Because of the intuitive nature of sketching, the entry-point to sketch-based geological modelling is low, and the focus lies on directly linking geological concepts and uncertainties to quantitative static and dynamic properties rather than on software training.

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