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SinFusion-based Geological Model Augmentation and Well Data Integration

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Stratigraphic forward modeling (SFM) is a geological modeling framework that simulates depositional processes in sedimentary systems (e.g., deep water, fluvial, delta), enabling the generation of stratigraphic architectures and reservoir property distributions. This approach is particularly effective in reproducing the realistic non-stationarity and geological heterogeneity of deep-water reservoirs, which are difficult to capture using conventional geostatistical methods such as two-point and multipoint statistics. However, SFM results are highly sensitive to small variations in initial geological input parameters, making the integration of observational data such as well logs and seismic data challenging and thereby limiting its application at an industrial scale.

In this study, we propose a novel geological model characterization framework that combines SFM with a generative artificial intelligence approach capable of achieving both high generation efficiency and robust geological realism (Fig. 1). First, an SFM-based geological model is constructed and then preprocessed to make it suitable for neural network training. A single-image diffusion model, SinFusion, is then applied to learn the geometric and property distributions of the geological model and to enable multiple equivalent generations. Furthermore, a well data integration strategy is developed using the aforementioned trained SinFusion. By infusing well data during the reverse diffusion process, the proposed method allows seamless conditioning on well data regardless of the number or spatial locations of wells. This enables immediate model updates when new well data become available in the field with no further need for costly model retraining, ensuring high flexibility.

The validity of the proposed method is evaluated through quantitative comparisons of spatial continuity, property distributions, and geometric pattern similarity with the original SFM model. The results demonstrate that the proposed method can efficiently generate multiple geological realizations and is well suited for ensemble-based uncertainty assessment. Moreover, the proposed method has the potential to expand the applicability of SFM toward industrial-scale geological modeling workflows.

Fig. 1. Overview of the SinFusion framework for geological model augmentation and well data integration based on stratigraphic forward modeling

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