Today’s oil and gas industry is increasingly turning toward complex stratigraphic-diagenetic and structural plays. Prediction and risk of reservoir heterogeneity, seal integrity and source rock sweet spots are becoming more important than ever before. Currently, prediction and risk rely primarily on stochastic geostatistical approaches, which have seen an impressive development over the last few decades. However, exploration of and production from increasingly complex plays has revealed higher levels of uncertainty in geostatistical reservoir models, because of a combination of factors:

- Statistical models do not fully capitalize on the geological information available
- Prediction and risk assessment usually apply a single statistical approach
- Different geostatistical approaches produce varying predictive models
- Surface geostatistics localized have proven highly pronounced rock heterogeneity
- Multiple, concurrent processes with various feedback mechanisms control reservoir quality

In order to meet current and future challenges of increasingly complex prospect and play types, the industry needs to develop new, additional approaches to reservoir, seal and source rock prediction. The key requirement for reducing uncertainty and risk in exploration and production is a rigorous understanding and quantification of geological processes and controls. Fundamental research in geological process-based forward modeling started in the 1940s to 1970s in academia. However, the exploration industry has only recently started to more widely deploy geological process-based forward modeling. The initial focus has been on depositional modeling using diffusion, Navier-Stokes and hybrid geometric approaches, but more recently a diverse range of approaches is being adopted. They include fuzzy logic, cellular automata and various other reduced-complexity modeling approaches that produce output information on petrophysical, depositional environment, and textural porosity. Forward modeling is also being applied to diagenetic processes using reaction-transport modeling (RTM) or reduced complexity proxy rules simulating chemical processes using finite element or discrete fracture network modeling based on post-burial mechanistic stratigraphy and local/regional stress patterns. Geological process-based forward modeling has shown highly promising results for e.g., reservoir quality, seal integrity and sweet spot prediction in complex play and trap settings but many challenges persist, including:

- Calibration of numerical input parameters specific to age, climate and structural settings
- How to use physical experiments and outcrop/reservoir analogue studies for model verification
- Automated input parameter optimization
- Multi-scale process-based models from basin to prospect, play and inter-well scale
- Linking and integrating approaches for depositional, diagenetic and structural modeling
- Integrating textural, diagenetic and fault/fracture-related properties
- Sensitivity analysis and quantitative risk assessment of multiple modeling realizations
- Computational expense vs. complexity of numerical approach vs. temporal-spatial resolution
- Effective implementation in existing industry workflows.

In recent years, interest in geological process-based forward modeling has extended to the geothermal exploration industry and the CO2 storage industry, which face some comparable challenges in predicting subsurface rock parameters and their spatial distribution. The proposed workshop will include invited experts and interested researchers from both industry and academia. We will concentrate on geological process-based forward modeling rather than on geostatistical modeling, flow simulation, or hydrocarbon systems modeling. Five sessions spread over a period of 2.5 days will be dedicated to key challenges in geological process-based forward modeling, finishing with a concluding session to define a practical way forward.

**Workshop Outline**
SESSION 2: MULTI-SCALE CALIBRATION OF GEOLOGICAL PROCESSES

The benefit of any modeling approach depends on the best possible calibration of input parameters. This fundamental requirement is especially valid for geological models because of the inherent complexity of systems, the number of processes involved and the dependency of input parameters from temporal and spatial scaling. A specific challenge is the requirement for parameter calibration in the geological past, i.e., differentiated by specific time intervals and processed to rates of change. This is in marked contrast to parameter calibration in geological modeling, which relies entirely on direct measurements from well locations, seismic data or outcrops.

The workshop intends to cover a wide range of approaches to calibrate depositional, diagenetic and geomechanical parameters. Modern environments and outcrop-subsurface analogues allow e.g., parameter calibration for depositional geometries, transport velocities from sedimentary structures, the degree of compaction and for depositional vs. diagenetic heterogeneities at both high vertical and lateral resolution. The calibration of diagenetic processes and parameters at sample scale requires knowledge of authigenic mineral precipitation, mineralogy, luminescence, fluid-inclusion, trace element chemistry, δ18O and clumped isotope geochemistry data. Core flooding experiments provide e.g. rates of cementsation and physical compaction. However, they do not reflect current subsurface porosities after diagenetic overprint at shallow to deep burial depths.

The majority of diagenetic overprint in clastic rocks occurs at medium to deep burial depths and is considered significant, porosities may be numerically modeled for a stratigraphic interval at its current burial depth only. However, diagenetic overprint in carbonate rocks starts at deposition (at geologic time scales), tends to peak in shallow burial depths and decreases at deeper burial depths. As a result, any comprehensive numerical modeling approach capable of predicting current subsurface porosities will have to follow a process of sequential depositional, compaction and diagenetic history, i.e., prediction and differentiation of stratigraphic-diagenetic traps, rock physics, geomechanics and fracture/tight reservoirs; ii) porosity and permeability prediction at inter-well to basin scale; iii) prediction of organic matter for conventional and unconventional plays; iv) input to 3D hydrocarbon system and basin models; v) geological evaluation of depleted reservoirs for CO2 storage; vi) geothermal exploration, especially for Enhanced Geothermal Systems (EGS); vii) benchmarking GPFM models for geostatistical predictions in operations and, x) success (and failure) of GPFM models.

Examples for studies with a fundamental or applied research background include but are not limited to: ii) sedimentary basins as archives for depositional, environmental and structural processes; ii) reconstruction of subsidence/uplift, eustatic sea-level, sediment input/production and erosion histories; iii) prediction of future environments due to changes in sea-level, erosion, sediment input, coastal morphology and current dynamics; vi) testing geological observations from surface and subsurface data for controlling processes and advanced sequence stratigraphy concepts.