AAPG

27 - 29 May 2024
Westin Abu Dhabi Golf Resort and Spa

2ND EDITION: AAPG GEOSCIENCES TECHNOLOGY WORKSHOP
GEOLOGICAL PROCESS-BASED FORWARD MODELING

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WORKSHOP OUTLINE

In order to support the energy transition, optimizing exploration and production from complex stratigraphic-diagenetic conventional and unconventional plays remains highly important. At the same time, Carbon Capture and Storage (CCS) poses new technological challenges that will impact both the industry and academia for decades to come. Both areas require a robust approach to the prediction and risking of reservoir heterogeneity and seal integrity. Currently, prediction and risking rely primarily on stochastic geostatistical approaches, which have seen an impressive development over the last few decades. However, exploration and production from complex plays as well as CO_2 storage in depleted reservoirs and saline aquifers have revealed higher levels of uncertainty in geostatistical reservoir models.

Reasons include:
- 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 geological studies (analogues) have proven highly pronounced rock heterogeneity
- Multiple, concurrent processes with various feedback mechanisms control reservoir quality
- Physical-chemical properties of CO_2 in its various states differ from hydrocarbons

In order to meet the current and future challenges associated with subsurface exploration, production and storage, the industry needs to develop new, additional approaches for modelling reservoir, seal, and source rocks. The key requirement for reducing uncertainty and risk is a rigorous understanding and quantification of geological processes and controls.

Fundamental research in geological process-based forward numerical modeling started in the 1980s in academia and industry. However, industry has only recently started to more widely utilize process-based 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 machine learning, fuzzy logic, cellular automata and various other reduced-complexity modeling approaches that produce output information on petrofacies, depositional environment, and textural porosity. Forward modelling is also being applied to diagenetic processes using reaction-transport modeling (RTM) or reduced complexity proxy rules. Geomechanical modeling relies on finite element or discrete fracture network modeling based on post-burial mechanical stratigraphy and local/regional stress patterns. Geological process-based forward modeling has shown highly promising results for reservoir quality, seal integrity and sweet spot prediction in complex play and initially also storage settings.

Many challenges persist, including:
- Calibration of numerical input parameters specific to age, climate and structural settings
- The effective use of physical experiments and outcrop-reservoir analogue studies for model verification
- Automated input parameter optimization
- Multi-scale process-based models from basin to play and intra-well scale
- Linking and integrating modeling approaches for depositional, diagenetic and structural modeling
- Integrating textural, diagenetic and fault/fracture-related poroperm models
- Sensitivity analysis and quantitative risk assessment of multiple modeling realizations
- Effective implementation of process-based model results in standard and future industry workflows
- Data conditioning

The 2nd edition of the workshop builds on the results of the 1st edition, which was held on May 23-25, 2022 in Abu Dhabi. It is expected to review and discuss technology developments in geological process-based forward modeling achieved during the last 2 years. Perspectives for future technology developments and implementation in industry workflows will be updated and or adapted as deemed necessary. The additional focus on CO_2 storage and other sustainability-related application for geological process-based forward modeling will considerably extend the scope of the 2nd edition of the workshop.

The workshop will bring together invited experts and interested researchers from both industry and academia. We will concentrate on all technical aspects related to geological process-based forward modeling. Six sessions spread over a period of 3 days will be dedicated to key challenges, finishing with a concluding session to define the best practical way forward.

WORKSHOP GUIDELINES

FORMAT
The workshop will be 3 days, consisting of oral presentations, poster presentations and breakout sessions where participants can discuss and investigate a specific theme that is of mutual interest. The first day will feature an inaugural keynote speech by a high-profile professional from the industry.

ATTENDANCE
Registrations are invited from all relevant disciplines with experience and/or knowledge of the subject areas being addressed in the workshop. Registrations will be accepted on a first-come, first-served basis.

CALL FOR ABSTRACTS
You are invited to prepare a poster for presentation at the workshop. If you are interested in participating, please send a short abstract to cnavarro@aapg.org by 29 April 2024. All posters will be produced as pull-up banners and delivered by AAPG. There will not be any other format available for poster display.

REGISTRATION TYPES & FEES
Fees are inclusive of onsite documentation, coffee breaks and luncheons.

$1,850 AAPG Non-Member Fee
$1,850 Join and Save
$1,650 AAPG Member Fee
$1,550 Committee/Presenter
$850 AAPG Young Professional Non-Member Fee
$750 AAPG Young Professional Member Fee
$500 Academia Fee
$350 AAPG Student Non-Member (Masters)
$250 AAPG Student Member (Masters)

*Please be advised that fees are non-inclusive of 5% VAT.
**To avail a Member rate you must be an active member of AAPG.
***To register as a Young Professional you must be under the age of 35 with less than 10 years of work experience.

REGISTRATION DEADLINE
To guarantee your seat, please make sure to register by 20 May 2024.

CANCELLATION POLICY
AAPG will refund the tuition, less a $100 processing fee, if the request is received no later than 30 days prior to the workshop. Cancellations must be made in writing. The registrar will accept cancellation notices by telephone, but all such notices must be followed up by fax or e-mail. No refund will be made for cancellations received less than 30 days prior to a workshop being given. Nonpayment of tuition does not constitute automatic cancellation. If no cancellation notice is received by 30 days prior to a workshop, participants are liable for full tuition. AAPG reserves the right to cancel a workshop if enrollment is insufficient to ensure proper effectiveness. Substitutions for individuals can be made at any time. A paid enrollment may be transferred one time to a future workshop if the request is received prior to the 30-day cut-off date.

DAY 1: MONDAY, 27 MAY 2024

SESSION 1: CURRENT STATUS, LESSONS LEARNED AND CHALLENGES

Geological Process-Based Modeling is defined by its forward-in-time calculating component. Modeling starts from an initial condition in the geological past and proceeds to subsequent condition in the younger geological past or until present times. While forward models may be inverted, they fundamentally differ from inverse modeling approaches like geostatistical modeling that relies entirely on static realizations.

The foundations for Geological Process-Based Modeling (GPBM) were laid in the 1960s to 1970s but limited to 1D and simple 2D. Since the late 1980s, GPBM has progressed towards advanced 2D and 3D. Key drivers for this development come from both industry and academia. Interest by industry stems primarily from the objective of predicting reservoir quality and of a quantitative understanding of depositional heterogeneity. In recent years, additional interest has come from CO2 storage as part of CCSU (Carbon Capture Storage and Utilization) and geothermal exploration. Interest by academia originated primarily from the objective to develop genetic, quantitative geological models from descriptive or qualitative data. GPBM also serves as an approach to test existing concepts of deposition, transport and erosion. However, GPBM still faces challenges which have limited its application especially in industry, whether as complimentary approach or as a partial replacement for geostatistical approaches.

Existing challenges include, e.g.: i) parameter calibration for the geological past is partly based on empirical approaches, modern analogues or quantitative estimates; ii) individual parameters in the geological past are difficult to separate, e.g. eustatic sea-level vs. subsidence/uplift changes; iii) non-unique result and related uncertainty/risk analysis; iv) integration of the various modeling approaches covering processes of deposition, diagenetic overprint (diagenetic modeling) and mechanical deformation (geomechanical modeling); v) achieving models which best match control and blind testing data; vi) computational expense vs. complexity of mathematical approach vs. temporal-spatial resolution and; vii) implementation in standard workflows in academia and industry.

The intention of this opening session is to set the framework for the workshop by covering developments in GPBM during the last few years, lessons learned from applications in various fields, discussing reasons for success (and failure) until now and by providing a general outlook on challenges existing today.

SESSION 2: MULTI-DISCIPLINARY AND MULTI-SCALE CALIBRATION OF GEOLOGICAL PROCESSES

The benefit of any modeling approach fundamentally depends on the best possible calibration of input parameters. This fundamental requirement is especially valid for geological modeling because of the inherent complexity of sedimentary 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. A simple example is the transfer of thickness maps from well tops or outcrop measurements to volumes and rates of sediment input for large areas of interest or individual source locations over time. This is in marked contrast to parameter calibration in geostatistical modeling, which relies on direct measurements from well locations, seismic data or outcrops.

The workshop intends to cover a wide range of approaches to calibrate parameters for clastic, carbonate, evaporite and mixed environments. Following the fundamental principle of "The present is the key to the Past" modern environments represent an important approach to parameter calibration, e.g. carbonate growth rates for reef-building organisms under specific environmental conditions. Outcrop-subsurface analogues provide reliable parameter calibration for depositional geometries, transport velocities from sedimentary structures, degree of compaction and depositional vs. diagenetic heterogeneities at both high vertical and lateral resolution. The calibration of diagenetic processes and parameters at sample scale predominantly relies on petrographic, cathodo-luminescence, fluid-inclusion, trace element chemistry, δ13C, δ18O and clumped isotope geochemistry data. Core flooding experiments provide additional insights including rates of dolomitization and calcite cementation. 3D stratigraphic architecture in combination with local-regional stress data, burial history and result from experiments (e.g., Linear Variable Differential Transducer) provides direct input to geomechanical modeling.

An assessment of the limitations of modeling results represents an important part of geological parameter calibration. Multiple realizations from parameter sets with minimum/maximum values or serial variations in parameters are one of several approaches to define acceptable levels of calibration in de-risking elements of petroleum, geothermal and CO2 storage systems.

DAY 2: TUESDAY, 28 MAY 2024

SESSION 3: MODELING APPROACHES AND THEIR INTEGRATION

The workshop intends to address and discuss numerical approaches in GPBM. Current approaches to depositional modeling include diffusion, Navier-Stokes, Fuzzy Logic and geometric/volumetric modeling. Diffusion modeling is based on Fick's Law and has been widely applied because of its balance between complexity and computational expense. Navier-Stokes or hydraulic modeling allows detailed flow and transport modeling at high-resolution although simplifications and approximations are required as equations are non-linear for four independent key variables. Hydraulic modeling approaches are computationally intensive. Fuzzy Logic modeling approaches offer an extension to Boolean logic and are able to handle only partially constrained data and parameters by defining a combined degree of "truth". The advantage is computational efficiency at the cost of resolution and predictive capability. Mixed or Hybrid modeling approaches, such as combining GPBM with geostatistical modeling or Machine Learning/Deep-Learning (e.g., physics-based Machine Learning) represent a recent technology development. Key drivers are assisted parameter calibration, improved resolution of forward models and increased match between models and well data.

Clastic diagenetic modeling follows either a rule-based approach or focuses on burial depth, temperature and rock texture-related parameters to model the cementation kinetics of quartz and illite. The relatively most widespread approaches to carbonate diagenetic modeling are either rule-based modeling or Reaction-Transport Modeling (RTM). However, computational requirements are high and with sufficient resolution areas of interest do not exceed the field to prospect scale. Geomechanical modeling of stress-/strain distribution, fracture and fragmentation most commonly relies on Finite and Discrete Element Modeling.

Current GPBM approaches and studies often focus on individual subgroups of geological processes, such as specific depositional, diagenetic or geomechanical processes. However, the full predictive power of geological process modeling will only be achieved if individual modeling approaches can be integrated or at least linked. Very few existing studies have tried to link different geological processes and modeling approaches, such as combining diffusion-based depositional and RTM-based diagenetic modeling.

The workshop aims to cover various integrated modeling approaches which include a defining forward-in-time calculation component including methodologies for calibration, verification and uncertainty analysis.

DAY 3: WEDNESDAY, 29 MAY 2024

SESSION 4: PROCESS-BASED GEOLOGICAL MODELING FOR CCS

Identification and characterization of potential CO2 storage sites requires high-resolution subsurface data and prediction at inter-well to prospect scale. Seal integrity, porosity and permeability values and their vertical and horizontal heterogeneity are essential properties for the assessment of storage capacity and quality. Geomechanical properties need to be predicted from well and seismic data for the risk evaluation of CO2 storage in depleted hydrocarbon reservoirs and saline aquifers. This can be challenging in many CCS saline aquifer sites where well control can be limited. To fully understand the impacts of injection, CCS models also need to consider a much larger volume than those for hydrocarbon fields, encompassing both the under-and over-burden. Process-based geological models of internal reservoir and aquifer heterogeneity in combination with fluid geochemistry support the development of injection strategies. High-resolution 3D subsurface models with low/er uncertainty inter-well and prospect-scale predictive capability will also support regulatory compliance and public confidence.

So far, few studies have used process-based geological modeling for the assessment of CO2 storage sites and other sustainability-focused applications such as geothermal exploration. The workshop will address existing technical challenges and try to suggest best workflow software development and industry implementation strategies.

SESSION 5: CASE STUDIES OF PROCESS-BASED GEOLOGICAL MODELING

The session envisions a wide range of case studies which focus on or apply process-based geological modeling in academia, consulting and industry.

Example for studies with an industry and consulting background include but are by no means limited to: i) prediction of depositional environments for reservoir, source and seal units; ii) sedimentary architecture and heterogeneity; iii) stratigraphic-diagenetic traps; iv) rock physics; v) geomechanics and fractured/tight reservoirs; vi) porosity and permeability prediction at inter-well to basin scale; vii) prediction of organic matter for conventional and unconventional systems.

Examples for studies with a fundamental or applied research background include but are by no means limited to: i) 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; iv) testing geological observations from surface and subsurface data for controlling processes and advanced sequence stratigraphy concepts; v) geological evaluation of CO2 storage sites and; vi) geothermal exploration, especially for Enhanced Geothermal Systems (EGS).

SESSION 6: PERSPECTIVES AND WAY FORWARD

Advanced development of process-based geological modeling in the geoscience and industry community will be a long-term effort best approached in a step-wise fashion and, as much as possible, in collaboration between academia and industry.

The final session of the workshop will try to: i) summarize learnings and conclusions from the five sessions and related break away meetings; ii) suggest most promising directions in technology development; iii) serve as opportunity to initiate future research and development collaboration between participants.