With the rapid economic growth within the GCC, combined with growth in India and China, operating companies within the Middle East are being asked to meet ever increasing local and international demands for oil and gas. The goals set by governments place additional strain on both resources and expertise. To meet their production targets, operating companies are now looking to optimise their existing G&G workflows with focus on EOR techniques.

Paradigm, known as a leading provider of software and consulting services, has been in the Middle East for more than 15 years. Through this experience we will highlight the use of innovative workflows and technology to meet the ever increasing complexity of technical challenges faced by Oil & Gas companies in the GCC.

“Aggressive production goals have been set, which will require innovative technologies to exploit the reserves”

Andrew Sutherland, regional vice president, Paradigm Middle East.

“As custodians of the majority of the world’s hydrocarbon reserves, the National Oil Companies in the Gulf region have a huge responsibility to ensure a continued energy supply,” says Andrew Sutherland, regional vice president for Paradigm, Middle East. “To achieve this, aggressive production goals have been set, which will require clever and innovative technologies and methods to exploit the hydrocarbon reserves,” he adds.

“As an unconflicted supplier of only consultancy and technology, Paradigm is perfectly aligned with energy companies’ business objectives and is able to positively impact exploration success and production efficiency.”

As production targets have been raised, many operators are faced with challenges they had not considered in the past. The production history, in seemingly simple layer-cake reservoirs, may not match the predictive capability of many geological and simulation models currently available to engineers. The limitation with such models can be attributed to many sources. This uncertainty ultimately impacts development strategies used to optimise production efficiency.
Paradigm technology is used by many energy companies throughout each step of their geological and geophysical (G&G) workflows. Only after Paradigm gains an understanding of the unique exploration and production challenges faced by each customer are recommendations made to design specific workflows using a combination of different technologies.

CASE STUDIES: ADVANCED G&G WORKFLOWS

Three example workflows used by clients in the Middle East to enhance their understanding of the subsurface are featured below.

**CONVENTIONAL WORKFLOW**

- Geological Model
- Uncertainty Assessment
- Multiple Realizations
- P10, P50, P90 Geophysical Models
- Upscaling
- Simulation

**ENHANCED WORKFLOW USING STREAMLINES**

- Geological Model
- Uncertainty Assessment
- Multiple Realizations
- Streamline Simulation
- Multiple Realizations
- Uncertainty Assessment
- Streamline Simulation
- Advanced Realizations
- Fine & Coarse Models
- History Matched Model

(Fig 2) Conventional modeling workflows vs. one optimised by using streamline-based flow simulation.

Paradigm has worked with a number of companies that integrate this data in an uncertainty analysis tool, by applying uncertainty on the relationship between the seismic facies and or inversion results to the well log data. In doing so, information derived from seismic can be included in classical geological modeling workflows and easily simulated along with the uncertainty on the positional accuracy of the structure, the physical rock properties $\phi, k, NTG$ and the fluid properties $Sw, FVF$ and fluid contacts.

By combining all geological and seismic inputs with associated uncertainties, the uncertainty analysis tool is able to generate multiple realisations of the reservoir and rank those models using numerous methods which include STOIIP, geobody connectivity and connectivity. In addition, each realization can be sent directly to a streamline simulator to assess the dynamic response of the model at the geological resolution.

**Workflow 1 – Seismically Driven Geological Modeling with Uncertainty Analysis**

Inversion studies and seismic facies analysis are routinely performed by companies, but this data is rarely used to constrain the distribution of properties in geological models. Simulation models therefore carry little of the information derived by the seismic, and the reason for this often lies in the difficulty of calibrating unsupervised seismic facies and acoustic impedance data with well log data and electro-facies. Paradigm technology is used by many energy companies throughout each step of their geological and geophysical (G&G) workflows. Only after Paradigm gains an understanding of the unique exploration and production challenges faced by each customer are recommendations made to design specific workflows using a combination of different technologies.

**Workflow 2 – Use of Streamlines in geological modeling and simulation**

In conventional modeling approaches, the modeler may generate a geological model and apply some form of uncertainty analysis to generate three models, which capture the majority of uncertainty in the output. The P10, P50 and P90 cases are typically upscaled and then exported to a flow simulator for subsequent history match (Figure 2).

Using this approach, the initial dynamic response of the model does not match the production history, which in turn introduces an additional series of iterations between the modeler and engineer to improve the dynamic response of the simulation model. In many cases, this can add months, if not years, to the process of achieving a successful history match, with models often having to be modified due to the mismatch between the simulated geology and the production history.

In part, this breakdown in the workflow can be attributed to the methodology for ranking multiple geological realisations and the process of upscaling. Figure 3 compares a conventional modeling and simulation workflow to one that uses streamline simulation within the uncertainty analysis tool. Streamline-based flow simulation (SL) is an effective and complementary technology to flow based modeling such as finite difference. Streamline-based flow simulation is particularly suited to solving large, geologically complex, fractured and heterogeneous sys-

“To meet their production targets, operating companies are now looking to optimise their existing G&G workflows with focus on EOR techniques”
tems. The increase in computational speed and efficiency of SL is a significant advantage, which allows the uncertainty analysis tool to run dynamic simulation on each geological realisation and automatically load the results back into the Gocad software suite. The uncertainty analysis tool then ranks the geological models based on their dynamic response and not simply on their STOIIP. Having performed production data analysis (PDA) the engineer and geological modeller can choose whether further reservoir data analysis (RDA) needs to be performed, or whether preliminary dynamic match has been achieved with the selected model.

Each of the selected and screened geological models are then upscaled, based on the flow characteristics exhibited in the SL data, and the simulation models are in turn sent to the streamline simulator. The SL results from the upscaled models are compared to those obtained at the geological resolution. If the SL results from the fine and course resolution models are within an acceptable tolerance, the course model can be provided to the reservoir engineer for full finite difference simulation.

By using streamline-based flow simulation in the geological modeling workflow, you can significantly reduce the time needed to achieve a successful history match and increase the confidence in the predictive capability of the final reservoir model.

Figure 3 illustrates the types of data that can be analysed to extract information related to NFS. Information regarding the spatial distribution of NFS is generally derived from seismic and well-bore data, but the ability to extract valuable information from the seismic is largely dependent upon the image quality.

By acquiring multi-azimuth 3D seismic data and performing advanced imaging and analysis of each sector of the workflow 3 – Advanced fracture characterisation solutions (see Figure 3 below)

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SEISMIC WORKFLOWS

data using Common Reflection Angle Migration (CRAM), additional techniques such as Multi-Azimuth AVO (AVOZ) can be used to directly measure the anisotropy. In addition, as fractures perpendicular to the azimuth can be imaged more effectively, this leads to a better estimate of the stress field for direct fracture detection.

Having performed a PSTM of each sector, the volumes are then enhanced in Paradigm’s Coherence Cube. The derived volume based curvature attributes and fracture lineaments are extracted using automatic micro-fault extraction (AFE) in VoxelGeo.

In an exploration case, the direct fracture picks can be used to target appraisal wells to intersect the fracture lineaments. This information can also be used in the production environment as direct input to fracture generators, such as FracMV, for simulating discrete fracture networks (DFN) for output to simulation.

SUMMARY
Paradigm is an unconflicted technology and consulting provider whose objectives are aligned with the needs of energy companies. Our technology is designed to optimise exploration strategies and increase production from drilling fewer wells. Paradigm provides the Middle East oil and gas community with technology, workflows and consulting services, which draw on considerable experience acquired from this unique region.

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