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Water Breakthrough Signatures in Fractured Carbonates – Where Reservoir Architecture meets Agile Well Reservoir Management

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Summary

Fluid pathways in deformed carbonates can be the result of multi-fold combinations between inherent primary and secondary matrix pore networks and a variety of fault and fracture configurations. This translates into a diverse flow ecosystem with pronounced lateral and vertical permeability contrasts that govern connected volume and sweep.
Assessing the dynamic character of flow paths through space and time requires continuous adjustment of conceptual geological models as drilling campaigns deliver additional calibration points of static and dynamic character of critical geological denominators that define the inherent reservoir architecture.
Streamlined data feedback analysis between reservoir surveillance campaigns and the static geo-parameter characterization is the foundation for adopting an agile and proactive reservoir management across all subsurface disciplines that allows adjustment of field development strategies in response to the dynamic shift from initial oil production through the onset of water breakthrough.
The iterative development of a catalogue representing the dynamic ranges of flow-relevant geo-parameter (e.g. fracture corridors vs. vuggy fracture cluster) was attempted for assessing and classifying the degree of flow partitioning between each geo-parameter.

The objective of interactive and agile well reservoir management is:

A. Transformation of water breakthrough from a production threat into a managed variable through integrated monitoring.

B. De-risking of development decisions with high-confidence data on fluid fronts, zonal contributions, and reservoir connectivity.

C. Extension of well and economic field performance by delaying water breakthrough and optimizing production profiles.

Workflow

This study discusses 5 horizontal and slanted wells that were selectively completed in a naturally fractured carbonate oil reservoir. All wells were equipped with electrical submersible pumps and downhole pressure gauges with upstream and downhole installations. Patterns in bottomhole flowing pressure profiles in response to water encroachment were examined to identify characteristic signatures of early indication of inflow anomalies for water onset facilitated by the inherent fluid pathway architecture of the reservoir showcase.

The distinctive range in bottomhole flowing pressure profiles resembles their response to the permeability contrasts, their distance to primary and secondary faults, general fault spacing and width of damage zone drainage, presence of fracture corridors, matrix potential and relative distance to initial water-oil-contact.
Pro-active reservoir management was tailored well-specific and based on a multi-layered surveillance strategy integrating real-time (downhole gauges), periodic (PLT, logs), and diagnostic (tracers, MDT) tools to capture the indicative character change of bottom hole pressure and Periodic Production Logging Tool responses in response to the corresponding fluid pathways in action.

Collectively, the proposed suite of surveillance activities summarized in Table 1 enabled better characterization of fracture-matrix interactions, fine-tune drawdown strategies, and manage water production risks, thereby sustaining well performance, maximizing oil recovery and determine operative adjustments.

Category	Data Type / Tool	Purpose	Timing / Frequency
Static characterization	Image Logs (FMI, UBI)	Identify open fractures, orientation, density	All wells
	Core Acquisition + Analysis	Fracture properties, matrix porosity/permeability, capillary pressure	Selected wells
Post-Completion / Production	PLT / Array PLT	Inflow profiling, water entry detection	Baseline post-startup, then contingent
	Wellhead Surveillance (WHP, Rate, GOR, WC, Temp)	Performance and water cut monitoring	Hourly to daily (SCADA)
Pressure Monitoring	Permanent Downhole Gauges (PDG)	Reservoir depletion, aquifer movement	Continuous
	Interference / Pulse Tests	Fracture connectivity and permeability tensor	Periodically (after new well drilling)
	MDT / RFT	Pressure and mobility profiling	In pilot/infill wells
PVT & Fluids	PVT Sampling and Study	Bubble point, viscosity, Bo, Rs, compressibility	Selected wells at initial conditions
Water Management	Tracer Tests (optional)	Identify water source (aquifer vs fractures)	If water source uncertain
	RST / Pulsed Neutron (cased hole saturation logs)	Monitor water saturation trends	Every 1–2 years

Table 1: Surveillance Campaign Recommended for Wells in Naturally Fractured Reservoirs with Active Bottom Aquifer

Conclusions

A detailed characterization of fault and fracture systems and other associated flow-enhancing geological features by combining wireline logs, fieldwork and field analogues, seismic interpretation and dynamic parameters has proven to be essential for understanding and predicting well behaviour patterns in the fractured carbonate field case.
The effectiveness of this multi-disciplinary flow pathway assessment relies on flexibility and adaptability to instantly incorporate new dynamic information and conclusions from each evaluation stage in this continuous and retro-fed workflow.
The following main conclusions form this evaluation are:

1. Complex reservoir architecture requires re-visiting and re-learning the reservoir understanding, including the geological elements that will act as fluid pathways and their dynamic behavior over time

2. Continuous dynamic monitoring and integrated, seamless alignment between Geoscientists and Reservoir and Production Engineers is crucial to achieve the most refined understanding of flow paths and their reservoir model manifestations throughout the maturation stages of the reservoir to optimize decision making

3. Water influx from bottom aquifers requires considerable energy to reach the wellbore. Its approach can be identified by a noticeable decline in flowing bottomhole pressure which becomes steeper as the waterfront nears the well

4. Water production in gravity-controlled systems can be controlled with changes in the drawdown pressure Early intervention through well and reservoir management can significantly influence well performance and prolong productive life

5. Segmented completions and selective stimulations are essential for achieving a more balanced productivity index across all perforated intervals

6. The team needs to be able to incorporate learnings and take prompt necessary actions and independently from what direct model observations indicate as models may not be able to capture relevant details or do not undergo frequent updates to reflect correctly the current reservoir state

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