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Reservoir Geological Controls on Production Behavior in a Lower Cretaceous Rudist Reef, Al Huwaisah Field, North Oman

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The Al Huwaisah Field, discovered in 1969, produces 20,000 bbl/day of light oil (38° API) from the Aptian Shuaiba Formation limestone under primary aquifer drive. The field average watercut is over 92% and many wells are producing at a watercut in excess of 99%. Over 240 million barrels of oil have been recovered to date, which amounts to 9 % of the 1.4 billion barrels of oil-in-place. The ultimate recovery is estimated at 380 million barrels of oil, however the present recovery factor of 26% is considered conservative, and it is believed there is scope to increase the present ultimate recovery by up to 50%. Production behaviour varies dramatically across the field. Well gross liquid production rates range from less than 600 bbl/day to over 18,000 bbl/day. Net oil production rates vary from 0 bbl/day to over 6000 bbl/day. Initial watercut observed in wells varies from 0% to 100% and the time taken to reach 90% watercut varies from several days to several years. Pressure decline is also a major concern, with severe depletion observed in large parts of the field and only minor depletion in others.

Geological, petrophysical and geophysical data have been integrated with drilling and production data to produce a detailed reservoir description of a laterally extensive rudist reef complex. The reef complex formed along the slope of an intra-platform basin by rapid progradation and amalgamation of individual rudist mounds. Dipmeter logs, borehole image logs and cores indicate that the rudist mounds are typically 30m high with steeply dipping flanks inclined from 15 to 40°. In-situ rudist growth is concentrated in the upper 10-20 metres of the slope and rudist talus dominates the lower 10-15 metres. The mounds are elliptical in shape, several hundred metres across by several kilometres long, and are elongated along the strike of the underlying platform slope. Microbial binding of rudist colonies may have helped stabilise the mounds into wave-resistant build-ups. As the mounds spread out and coalesced to form a liner barrier, a high energy fore reef environment formed on the windward side, while low energy back reef and lagoonal environments evolved on the leeward side of the reef complex. Channels formed in the narrow, high-energy restrictions between prograding mounds and are filled with coarse rudist debris. Aquifer support is strongest on the high energy, fore reef side of the field, while little or no aquifer support is provided from the low energy back reef and lagoon. High gross production rates at high watercut are observed in the fore reef area, particularly where permeability is locally enhanced by sub-aerial leaching and the formation of extensive, high permeability, touching vug networks. The back reef areas, particularly adjacent to the lagoon, are characterised by low gross production and a relatively slow increase in watercut. Wells with the highest cumulative oil production are located in the inter-mound channel deposits. The steep depositional dip on the mound slopes, together with the touching vug and fracture networks give enhanced vertical permeability and rapid water breakthrough in wells.

Well planning and completion policies have been modified in response to the reservoir geological model and field oil production has increased by 40% in the 2 to 3 years since work on the new geological model began. Additional applications of the model include: input to dynamic reservoir simulation for field development planning and reserves revisions; planning of Shuaiba near field exploration drilling and seismic acquisition activities; and planning of a waterflood scheme for the severely depleted parts of the field. The integration of a large quantity of varied subsurface data also provides new insights into the depositional environments, internal stacking patterns and the growth and development of rudist reefs.