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Diagenetic Patterns and Rock Properties of the Natih Formation in a Carbonate Oil Field, North Oman

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SUMMARY

Rock properties of the Natih Formation in Field F were strongly modified as a result of diagenesis. The paragenetic sequence is well defined, and typical for a carbonate field from this geographic location and time period. It exhibits an interplay between early diagenetic processes, faulting and the tectonically controlled circulation of deep burial fluids. Conclusions are supported by detailed petrographic and geochemical data including isotopes, fluid inclusions and elemental compositions.

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The earliest paragenetic phase was dominated by localized meteoric processes at paleoexposure surfaces, including both cementation at some depositional cycle tops and third-order sequence boundaries. Both meteoric cementation and leaching were muted by the apparent lack of chemical reactivity of the predominantly (low magnesium) calcitic chemistry that is typical for this time period. This lack of reactivity helped preserve a range of primary depositional pore types into the burial realm.

The lengthy paragenetic phase during early to intermediate burial was dominated by competing processes of burial leaching and burial compaction/cementation. These processes accentuated depositional reservoir heterogeneity. In particular, long-lived, selective burial leaching caused significant enhancement of pore throats and thus increased permeability in more hydrologically open intervals. Compaction and burial cementation also occurred repeatedly over a long period of time, producing intervals with lower porosity and permeability – particularly those associated with more closed hydrological intervals and/or increased admixtures of clastics.

Brines derived from the Ediacaran – Early cambrian Ara Group evaporites reached the reservoir via deep-rooted and reactivated fault systems repeatedly from the onset of early burial diagenesis (middle Late Cretaceous – First Alpine Event) causing both cementation as well as leaching.

The final phase of calcite cementation is coeval with a first phase of hydrocarbon migration, with precipitation at temperatures of at least 70–80oC. The final paragenetic stage was dominated by at least one episode of leaching, creating matrix porosities exceeding 35%. Porosity creations was focused upon but not limited to solution-enhancement of micro-porosity in micrite . Based on petrographic evidence, leaching clearly post-dated pressure-dissolution and is interpreted to be related to extensive mixing of undersaturated mildly acidic hypersaline brines with evolved connate waters. Organically-derived CO2 and organic acids released during source rock maturation and pre-charge fluid circulation maintained the acidic conditions over a time period that allowed significant matrix dissolution. Finally, hydrocarbons moved into the structure and retarded further diagenetic processes in the oil leg.

Our fluid evolution model proposes the circulation of burial fluids upwards along faults and upon hitting a sealing trap soaking the adjacent matrix rock above a structural spill point. It explains a general trend of increased reservoir heterogeneity associated with preferential leaching up-dip in the structure. Key to this preferential leaching is the bounding fault to the field, along which carbonate-undersaturated fluids were introduced to the structure. A progressive increase in carbonate saturation, through rock:water interaction, away from this fault would have resulted in decreased volumes of leaching down-dip.