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Contribution of Biofacies to Recognize Potential Subdivision of Unconventional Reservoirs: A Case Study from Callovian Carbonates, Saudi Arabia

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ABSTRACT

The Tuwaiq Mountain Formation (TMF) contains world-class hydrocarbon source rocks. These organic-rich carbonates are characterized by mud-dominated deep marine facies that show limited visual variability. Preliminary results from a thin-section micropaleontological study from four wells have led to the recognition and determination of environmentally significant biofacies variations within the carbonate source rock.

Our study recognized four main biofacies ranging from distal to proximal settings and including basinal; distal outer ramp; proximal outer ramp below storm wave base and within storm wave base facies. Basinal biofacies are characterized by wispy laminations comprising suspension fallout biocomponents that accumulated as centimeter-size bundles of densely packed arcuate pelagic bivalve filaments and organic matter streaks of indeterminate origin with rare occurrences of calcispheres and planktonic foraminifera. Distal outer ramp biofacies are predominated by thin laminated layers and are composed of loosely packed long, thin crinoid filaments (Saccocoma spp.) that are oriented parallel to stratification. These filaments are associated with intraclastic aggregates, brown organic rich fecal pellets and amorphous organic carbon. Amorphous organic carbon components are organized into wispy, mineralized aggregate seams. Proximal outer ramp biofacies are characterized by sharp-based, graded, thinly laminated mudstone layers. Individual lamina sets consist of a scoured base comprising silt-size pellets, pyrite and dolomite crystals overlain by continuous intercalated micropellets and Saccocoma filaments in a mud-rich matrix and capped by homogeneous mudstone. This event may represent distally thinned sheets of storm trickle debris flows. These debris flows may be swept down-dip into low-gradient distal outer ramp strata by gravity-driven debris flows below the storm wave base. The last biofacies is predominated by randomly oriented, fragmented Saccocoma filaments in association with sponge spicules (Rhaxelloides sphaerica and monaxon types) and allochthonous shallower forms. This biofacies may suggest a proximal outer ramp setting within the storm wave base.

These biofacies represent a significant contribution toward greater understanding of depositional cyclicity and in further subdividing Callovian unconventional reservoir facies. They also provide additional insights into the relationship between biological processes and TOC concentrations.