Regional Reservoir Characterization of Upper Silurian Lower Acacus Sandstones, Ghadames Basin, Western Libya : A Clue To Improved Reservoir Analysis And Discovery Of New Fields

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ABSTRACT
The Upper Silurian Lower Acacus Sandstone of the Ghadames (Hamada) Basin of Western Libya was studied to assess its regional depositional and diagenetic interrelationships as well as the local transitions associated with those interrelationships as they might have influenced reservoir character, reservoir partitioning and subsequent hydrocarbon entrapment.

Regionally, the unit is a continental fluvial and interfluvial body in the south which is transitional northwestward to a fluvial and coastal complex which passes further northwestard into shales of a marine basin. Fourteen deltaic complexes comprise the Lower Acacus, some derived from the northeast, but most derived from the southeast. Groundwaters of various ages moved through the unit leaving their trace in the regional diagenetic character and chemistries of minerals deposited. Local character and chemistries were the result of modification of the regional relationships.

Regional diagenetic facies consist of the quartz-cemented facies in the southern continental fluvial sediments, a carbonate-cemented facies in the northwesterly coastal and deltaic complexes, and a clay-cemented facies in the northern offshore basin. Preserved primary porosity is most common in the fluvial-channels. Secondary porosity resulted from the dissolution of carbonate cements and unstable minerals in the coastal and deltaic complexes. Microporosity and fractures are the common types in the distal offshore.

Partitioning of the reservoirs occurs at several levels. At the primary level there are the normal clay separations to be expected in the specific depositional environments. At a secondary level there is the diagenetic destruction of porosity and permeability due to the precipitation of either carbonates or clays, to the creation or enhancement of porosity and permeability as a result of dissolution of carbonates and clays, and to the modification or redistribution of porosity and permeability as a result of fines transported in the pore system.

Porosity preservation is the result of a combination of conditions which overlapped in time and space. The maintenance of primary open pathways to permit later fluids to come into contact with sediments in the deeper parts of the

basin also served to redistribute diagenetic fluids which subsequently modified the primary pore systems or created secondary pore systems.

Permeability reduction in the fluvial sandstones is a function of the increase of kaolinite cement basinward and the infiltration of iron oxides and clays into and through the matrix. Clay infiltration generated strong permeability contrasts between channel and overbank sandstones within the same well, and within short distances between adjacent wells. Permeability changes affected fluid movement and thereby the resultant diagenetic character differences between sandstone types. Iron oxides and clay matrix are the dominant diagenetic elements in the overbank-flood plain facies while quartz overgrowths occur in the channel-fill sandstones.

Permeability distribution in the deltaic sandstones is a function of the architecture of the various depositional elements comprising the deltas. Fluvial and coastal environments mixed in the proximal parts of deltas whereas the transition to the offshore occurred over large areas and was more uniform. In the proximal deltaic areas permeabilities vary significantly over short distances normal to the depositional axes and tend to be more readily correlatable parallel to the depositional axes.

Carbonate cement (calcite and dolomite) is characterized by the occurrence of either continuous wide bands in close proximity to shale beds, or scattered occurrences associated with intercalated shale lenses. Between wells in a single correlatable unit there is significant variability in the occurrence of the carbonate lenses. Scattered calcite cemented intervals are most common in the proximal delta front reservoirs. In these areas the sandstone bodies are wedge-shaped and shingle against one another with resultant disruption of continuity by clay intercalations. Where the carbonates are continuous they display a poikilotopic texture in continuous sandstone units which are a function of the primary depositional fabric of the reservoir. Carbonate cement in the offshore thin scattered sandstone lenses has totally occluded any primary porosity, reflecting the primary depositional isolation of these sands.

Grain sizes range from fine to medium sands in the proximal portions of the delta lobes and silty to very fine sands in the distal portions. Kaolinite is present in both areas but had little effect on the permeabilities in the fine to medium-grained sandstones of the proximal delta facies but resulted in significant permeability reduction in the silty to very fine-grained sandstones of the distal deltaic and reworked marine sandstones. The transition is abrupt suggesting that there is a grain-size threshhold for the entrapment or movement of fines within the connected pores.

The best reservoirs of the Lower Acacus sandstones are in the northern portion of the Hamada Basin where proximal deltaic sandstones can be encountered either directly below the Middle Acacus shale, or underlying the intercalated marine transgressive shales of the 14 individual deltaic lobes. Distal deltaic and reworked marine sandstones offshore of the Acacus delta lobes are generally of poor quality due to total porefilling by kaolinite and illite cements. Local improvement of reworked sandstone reservoir potential would be as a result of fractures and related fluid movements to those sands. The fluvial sands encountered to date have been water-wet. Reservoir opportunities in this facies will be the result of stratigraphic pinchouts and lateral facies partitioning associated with fluvial meanders as well as compaction drape over deeper structure.