Paleogeography and sedimentation of the Lower San Andres in the Northern Midland Basin- from rimmed margin carbonates to basinal turbidites

Xijin (CJ) Liu, Jie Zhang, Lijiang Deng, and Leo Zeng, Surge Energy, LLC

The San Andres Formation, the most prolific producer in the Permian Basin, has cumulatively produced over ten billion bbls of oil, about half of the total conventional hydrocarbon production to date. Most of the hydrocarbons, though, are produced from dolomite reservoirs, formed by the complex interactions of tidal depositional environments during frequent high-order sea-level fluctuations and arid climatic conditions, and near-subaerial diagenesis. The producing reservoirs along the basin margin have been extensively studied and documented. The paleogeography and sediments just before and during the deposition of the Middle San Andres (Brushy Canyon) formation in the basinal settings of the Midland Basin, however, have not been as extensively studied as the overlying hydrocarbon reservoir interval formed in shelfal and tidal environment along the basin margin. This paper will present a new model of San Andres canyon – a progradational wedge system based on a comprehensive integration of multiple data sets, e.g., well data and 3D seismic.

A rimmed-shelf edge, which is believed to be algal carbonate buildup and/or grainstone (e.g., oolite) shoal, formed during a relative highstand of sea level in early Guadalupian (San Andres) time. The rimmed shelf-edge extended from west to east in arc-shaped pattern concave southward in the southeastern corner of Gaines County and the southwestern corner of Dawson County in the northern part of the Midland Basin. The relief of these carbonate buildups above the basinfloor (marked by the toe-of-slope) is in the range of 1500 ft to 2000 ft, estimated from 3D seismic data. A major lowstand of sea level occurred in early Guadalupian time, which led to extensive slope canyon development. The width of these canyons is in the range of a quarter to 1 mile, and the downcutting depth ranges from 30 ft to 100 ft (limited accuracy due to seismic resolution and sufficient well penetration). Inter-Canyon highs are in the range of a half mile to over 1 mile. One interesting observation is that the maximum downcutting depth occur in the middle of the slope setting, instead of upper slope closing to the shelf edge commonly observed from clastic shelf margins. This may be due to the fact that carbonate deposits in the shelf edge and upper slope setting are more resistant to erosion than the time-equivalent deposits in the middle and lower slope setting. In plane view, the canyons are more or less straight, suggesting relatively high slope gradient, and form a fan-shape pattern, radiating from basin to shelf edge (northward), reflecting the concave southward shelf edge geometry. The sandstones filled up the canyons thus smoothed out the topography initially created by the canyons and then spread out across the entire basinfloor.

Directly above the erosional canyon base is the Lower San Andres Brushy Canyon succession, deposited by mass-transport and turbidity current flows. The thickness of the turbidite and mass-transport deposits ranges from less than 10 ft to a few hundred feet, thickening basinward . Two types of canyon-fills can be distinguished/identified: carbonate debris fills and clastic sandy fills. The carbonate debris, derived from erosion of the carbonates deposited on the shelf (including the shelf edge reef buildups), mainly occur in the middle and upper slope, whereas the clastic sands in the lower slope and basinal setting. The distribution of different lithology along the canyon systems could be partly due to bigger grain sizes and slightly higher density of the carbonate debris and therefore shorter transport distance along the slope canyon system as compared to the sands, which, based on site-wall core and mud log description, are very fine-grained with no significant changes in grain sizes and can be carried by gravity flows over a long distance into the basinfloor setting. The sands are believed to be derived from eolian sources, similar to the other sand-rich formations (e.g., Dean, Jo Mill in Lower Spraberry) in the basin. Some carbonate-debris deposits extend further into the lower slope and basinfloor, suggesting larger flow events. Whether the carbonate debris fills and clastic sands were deposited by same gravity flow events is debatable. It is possible that carbonate debris content gradually decreases with increasing clastic sand content from the shelf edge to the basin formed by same gravity flows. It is also possible that the carbonate debris was deposited by separate events.

Previous studies indicate that the Brushy Canyon sands was deposited during a period in the early San Andres time with no co-eval shelfal deposits. Our study, however, demonstrates that the sands were deposited inside a series of progradational packages as the bottomset of seismic-defined clinoforms, synchronously with shelf and upper slope carbonates. In other words, the sands were deposited by multiple gravity-flows that occurred during a relatively longer time period of shelf carbonate progradation.

The turbidite sandstone exhibits excellent reservoir property, with a porosity range of 15% to 25%. Although few hydrocarbon discoveries have been made from the basinal turbidite sandstones in the basin, primarily due to the lack of effective lateral and top seal for formation of traps, it may become an exploration target in areas where hydrocarbon traps occur.