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Along-Strike Structural Control on Lower Silurian Hydrocarbon Reservoirs in the Appalachian Foreland Fold and Thrust Belt, U.S.A.

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Regional trends in reservoir quality and hydrocarbon productivity of Lower Silurian clastic strata in the Appalachian foreland fold-thrust belt are related to structural variations that occur along regional tectonic strike as well as in the dip direction. Based on an extensive subsurface database integrated with outcrop information, the influence of along-strike structural control is interpreted for the following: stratigraphic thickness, sand percentage, depositional facies, unconformity distribution, porosity, permeability, and diagenesis. These along-strike variations are observed between salients and recesses, which are delineated by bulges of the fold-thrust belt into the foreland at salients and by areas at the recesses where the fold-thrust belt does not extend as far into the foreland. The salients and recesses are interpreted as originating in response to collisional tectonism associated with the Taconic orogeny.

Lower Silurian depositional patterns and fluid migration pathways in the Pennsylvania salient are related to backward-rotational subsidence that was caused by thrust loading at the orogen. Rapid subsidence occurred in the proximal part of the salient, which created accommodation for accumulation of thick, aggradational deposits. The rate of sediment supply was high because of uplift along the orogen. As the relative subsidence rate slowed during the late stage of the Taconic orogeny, the proximal accommodation became filled in response to continuing high sediment supply, which led to shoreline progradation cratonward across the foreland ramp. It is possible that flexural uplift and erosion of sedimentary strata in the proximal part of the foreland basin occurred at this time in response to crustal rebound, which may have contributed to the extensive progradational deposits on the distal foreland ramp within the Pennsylvania salient.

The thickness of the Lower Silurian foreland-basin succession is greater in the Pennsylvania salient than in structural recesses to the north and south, whereas the ratio of sandstone to total thickness is greater in the recesses. Regional distribution of the various types of clastic sequences in the succession studied is interpreted as reflecting evolution of the salients and recesses. Deep erosion, common unconformities, and incised valley fills are present in areas of recesses, which is in contrast to the thick, aggradational deposits that accumulated in the salients in response to high rates of relative subsidence and sediment supply. In the succession studied, incised valley deposits are present most commonly in areas of low subsidence rate, where exposure and erosion occurred as the rate of eustatic sea-level change exceeded the rate of change in accommodation due to tectonism. Infilling of the incised topography occurred during subsequent sea-level rise, which produced an orogenward shift in facies. The Lower Silurian valley-fill deposits are present in distal areas of the Appalachian foreland as well as in the areas of structural recesses. Unconformities in the Lower Silurian and adjacent strata are recognized more clearly in areas of the recesses than in the salient.

The incised valley deposits contain sandstones with the highest values of porosity and permeability within the Lower Silurian succession. These deposits consist of cross-bedded, fine- to coarse-grained sandstone that overlies a basal unconformity and fines upward to shale. In contrast to the incised valley deposits of the recesses, reservoir quality of thick aggradational deposits in the proximal part of the Pennsylvania salient is poor because of very low values of porosity and permeability. These coarse-grained aggradational sandstones, which are predominantly estuarine and fluvial in origin, are interpreted as having been buried more deeply than strata of the recesses. Quartz cement is present commonly in sandstones of the salient, even in the distal part, probably in response to the silica-rich pore fluids migrating updip from deeply buried sandstones in the proximal area of the salient. Quartz pressure-solution, evidence for which can be observed in these sandstones, may have provided a local supply of silica to the pore fluids. Deep burial of the Lower Silurian sandstones, along with fluid migration away from the orogen and toward the craton, occurred during the Paleozoic Acadian and Alleghenian orogenies.

The geographic distribution of hydrocarbon production from the Lower Silurian strata generally follows the regional patterns of porosity and permeability as controlled by structurally influenced depositional facies and sandstone diagenesis. From an exploration perspective, the areas with the greatest potential for successful discovery of additional hydrocarbon reserves within the Lower Silurian trend are probably in the structural recesses. Primary porosity is generally greater in the recesses because of the depositional facies present and because the burial depth is likely to have been less than in the salients.

The structural salients and recesses of the Appalachian orogen are well defined by bends in the foreland fold-thrust belt. Previous interpretation for their origin is that they evolved from a series of reentrants and promontories, respectively, along the collisional continental margin associated with the Taconic orogeny (Thomas, 1977, American Journal of Science, v. 277, p. 1233-1278). Boundaries between these regions of differential strain and subsidence within the Appalachian foreland fold-thrust belt may have been transferred toward the distal foreland by displacement along cross-strike discontinuities, which have been mapped previously as structural lineaments. Because regional bends marking salients and recesses occur in many other fold and thrust belts, the influence of along-strike structural control on reservoir development should be examined carefully when exploring in these areas.