HGS Dinner—Poster 1

Importance of depositional facies, early diagenesis and unconformity karst in Arbuckle reservoirs from Central Kansas

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Arbuckle strata account for about 40% of the produced oil and known reserves in Kansas. Much past production has come from the upper 25 feet of the Arbuckle in areas with structural highs and regional uplifts related to basement structural elements that were enhanced by karstic processes related to the overlying unconformity. A detailed analysis of facies and reservoir characteristics of the Arbuckle has not been performed. Results from our study of more than a dozen cores from several regions in central Kansas suggest that Arbuckle reservoir characteristics are strongly related to depositional facies, early diagenesis, and dolomitization. Development of brecciation, fracturing and dissolution related to the post-Arbuckle unconformity is variable and alternately created or destroyed porosity.

Five main depositional facies account for more than 85% of the cored intervals described from eleven cores. Listed in order of decreasing relative abundance, these include (1) clotted algal boundstone, (2) laminite algal boundstone, (3) peloidal packstone-grainstone, (4) packstone-grainstone, and (5) wackestone-mudstone. Intraclastic conglomerate and breccia, cave fill shale, depositional shale, and chert account for the remaining 15% of the total rock. Matrix and grain size are the controlling petrophysical properties of the facies at the core plug scale. All lithologies exhibit increasing permeability with increasing porosity and can be

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characterized as lying along the same general porosity-permeability trend. Clotted algal boundstones, pelodial packstone-grainstone, wackestones, mudstones, and shale generally have porosities of less than 10%. Absolute permeabilities are generally below 0.1 md and frequently below 0.01 md. The facies also exhibit high to very high irreducible water saturations (Swi), and effective hydrocarbon permeabilities at Swi are one to several orders of magnitude less than the absolute permeability values.

In contrast, laminated algal boundstones with abundant grains have porosities ranging from 10% to 30% and absolute permeablities ranging generally from 0.1 md to 1,500 md. Irreducible water saturations in these facies are related to permeability but are generally low. Effective hydrocarbon permeabilities range between 30% and 100% of absolute permeabilities. Early chert replacement, early and late dolomitization, and early to late brecciation and fracturing have variously created and destroyed porosity. These processes, in conjunction with depositional facies, have created a vertical herogeneity resulting in complex compartmentalization of Arbuckle Group strata.

While much attention has been directed previously at karst features, results from this study indicate that matrix properties also play an important and even dominant role in some reservoirs. Arbuckle strata have experienced pervasive but mostly non-fabric destructive dolomitization(s), allowing inference of depositional facies and the paragenetic sequence of events that affected these strata. The striking feature in the cores is the abundance (>50%) of matrix porosity (intercrystalline, moldic, fenestral, vuggy) throughout the length of the cores related to depositional facies, early diagenesis, and dolomitization, unrelated to the upper post-Sauk subaerial exposure surface.

The facies and paragenentic sequence of events described here are characteristic of most Arbuckle strata in Kansas. Although production strategies typically have been based on karst-controlled models associated with the post-Sauk unconformity, study of a dozen cores and reconnaissance of others in Kansas indicate that matrix properties unrelated to the unconformity are significant and may be the dominant control on reservoir properties and architecture. The relative lack of karst-associated fracture, breccia, and dissolution porosity in the cores was surprising, especially considering that the cores come from the flanks or tops of structural highs where karst processes would likely have been most extensive.

Arbuckle strata in Kansas comprise original shallow water subtidal to peritidal carbonate facies that have been overprinted by pervasive, but mostly non-fabric destructive dolomitization(s) and late diagenesis. Much of the matrix porosity (intercystalline, moldic, fenestral, vuggy) is associated with coarse-grained, laminated to bedded facies that are differentially cemented or with algal (stromatolitic) intervals that show differential porosity development likely due to differences in original texture (e.g., mud content) and early diagenesis (e.g., development of fenestral and vuggy porosity during early subaerial exposure). As evidenced by oil stains and (in many cases) a prolific production history, the intervals apparently are significant in their potential as reservoirs.

The regional stratigraphic and sedimentological framework of Arbuckle strata is providing an understanding of the relative importance of depositional facies, diagenesis, and unconformity-related karst processes for controlling reservoir architecture and properties in various structural settings. Integrated with quantitative petrophysical data for individual depositional facies and diagenetic features, the comprehensive framework will provide: (1) a predictive capability for identifying favorable reservoir facies that intersect the post-Sauk unconformity on structural highs; (2) improved ability to identify additional horizons deeper in the Arbuckle that have favorable reservoir potential; (3) quantitative data that can guide production strategies and determine if zones are best produced with vertical, horizontal, or target infill drilling; and (4) quantitative data that can be used in reservoir simulations to aid in determining production strategies.

Biographical Sketches

Mark Steinhauff holds BS degrees in anthropology and geology, and MS and PhD degrees in geology. He completed internships with the California Division of Mines and Geology, Shell USA, and Exxon USA and gained more than six years of experience in the environmental industry before and after completing his dissertation at the University of Tennessee. During his tenure in the environmental industry he was employed as a hydrogeologist and later as risk assessment team leader at the Oak Ridge National Laboratory, responsible for managing risk assessments for the Portsmouth Gaseous Diffusion Plant in Ohio, and as an instructor with the University of Tennessee Evening School. He spent one year as carbonate sedimentologist at the Kansas Geological Survey before joining Exxon Exploration Company in 1998 where he has worked on regional stratigraphy in the Gulf of Mexico. His publications and presentations include topics on Miocene marine microfossils from Antarctica, stratigraphy and diagenesis of Paleozoic strata, and environmental risk analysis.

Evan Franseen received his BS, MS and PhD in geology from the University of Wisconsin-Madison. Since 1989 he has worked at the Kansas Geological Survey, University of Kansas, where currently he is an Associate Scientist in the Petroleum Research section. His research interests are in carbonate sedimentology, diagenesis and sequence stratigraphy and integration of seismic, ground-penetrating radar, geochemistry and modeling techniques to understand controls on sedimentary systems and reservoir character.

Alan Byrnes received his BS in geology from the University of Illinois at Chicago and his MS in geophysical sciences from the University of Chicago. He has been a research geologist at the Institute of Gas Technology, Marathon Oil Company Research Center, Core Laboratories, and Tetra Tech. He owned and operated GeoCore, a special core analysis laboratory, prior to joining the Kansas Geological Survey as a research geologist-petrophysicist in 1997. He presently does applied research in lithologic controls on petrophysical properties with emphasis on CO_2-enhanced oil recovery, formation evaluation, reservoir characterization and modeling.

Jason Cansler received his BS in geology from Kansas State University in 1997, and is currently working on his MS in geology at the University of Kansas. While attending KU he also works as a Graduate Research Assistant in the Petroleum Research section at the Kansas Geological Survey. His specific research interests are in examining the paleogeomorphology of the pre-Pennsylvanian surface over the Central Kansas uplift. □