RESERVOIR CHARACTERIZATION OF THE UPPER DEVONIAN ELK SANDS IN THE APPALACHIAN BASIN

BOTTOM LINE

Successful gas production established from Elk sands at Council Run field in Cener County, Pennsylvania, has great potential for being duplicated using modern technologies from Elk-sand-equivalent facies in similar Appalachian Basin settings, several of which have been tested in the past and rejected based on the technologies then available for establishing production.

PROBLEM ADDRESSED

Lack of detailed knowledge of the factors that are responsible for production at the Council Run gas field, coupled with a lack of familiarity with depositionally-equivalent rocks in other Appalachian Basin locations, has led to under-exploration for similar reservoirs. This workshop addressed both aspects of the problem, reviewing the Council Run field in great detail and documenting promising historical exploration efforts and regional studies performed on the equivalent rocks.

KEY WORDS:

Completion techniques
Log interpretation
Upper Devonian Elk Sands

TECHNOLOGY OVERVIEW

The Council Run gas field in north-central Center County, Pennsylvania, produces from the first, third, fourth, fifth and sixth Elk sands of the Upper Devonian. Estimated ultimate recoveries (EURs) of over 90% of the 550 wells exceed 450 Mmcf. EUR's of some wells exceed 1.0 Bcf. Reserves are estimated as 50 to 400 Mmcf in the first Elk sand, 30 to 100 Mmcf in the third, 50 to 700 Mmcf in the fourth, 50 to 1700 Mmcf in the fifth, and 30 to 150 Mmcf in the sixth. Reservoir sands have porosities up to 16% with gas saturations up to 83%. The stacking pattern of sands defines lowstand, transgressive and highstand systems tracts. The fifth Elk sand is the most prolific and consists of multiple coarsening-upward sequences deposited in nearshore and deltaic environments of the lowstand systems tract.

Diagenesis played a critical role in formation of the Elk sand reservoirs through a general reduction of primary intergranular pore space through cementation and a fabric-selective enhancement of secondary porosity. Principal trapping mechanisms are stratigraphic. Source rocks are Devonian black shales of the Burket Member of the Middle Devonian Harrell and Marcellus formations. Burial modeling predicts that petroleum generation and emplacement was early at about 320-290 million years before the present. This early hydrocarbon emplacement played a large part in preservation of primary porosity. Isotopic analysis confirms that the gas is primarily oil-associated, derived by thermal cracking due to subsequent increased burial depth and temperature.

The workshop included the results of an extensive (1,662 well, 90 quadrangle) study of the equivalent stratigraphic intervals in northern West Virginia. The study encompassed not only the Benson Sand, the equivalent of the historically dominant Elk sands, but also the stratigrapic intervals above and below the Benson. Depositional environments from basin plain to delta front were encountered. Upper Benson (Facies "b") sands occupy five major submarine channel systems that sporadically transported sediment into deeper water settings.

In Garrett Co., Maryland, and Somerset Co., Pennsylvania, the sixth Elk sand (a thick 40 to 60 foot sandstone of shoreline origin at the base of the Foreknobs Formation) continues to be pursued as a gas target in spite of elusive commercial success. Six wildcats have been drilled in the Accident anticline area along the depositional trend of this sandstone in pursuit of success comparable to that obtained at the Council Run field.

In eastern Pennsylvania, 150 miles east of Council Run field and four miles west of anthracite coal beds of the Lackawanna syncline, gas has been produced at the Harvey Lake field since 1956.

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Now a gas storage field, production was primarily from fractured siltstones of the Devonian Chemung Group. At least one of the wells in this field, however, had gas shows and some commercial production from a sandstone unit believed to be correlative to the Elk group sands. Modern logging and stimulation techniques, coupled with the options now available for deviated, horizontal and slimhole drilling, are keeping interest in these potential reservoirs alive, but the equivalent interval, though present, has not yet been tested in New Jersey or New York.

Recommended logging programs for the Elk sands in the West Virginia, Maryland, and Pennsylvania area include conventional determination of pay thickness, effective porosity, and water saturation, accompanied by caliper logging, calibration to production to determine permeability, and determination of mineralogy using PE, GR, and density logs. Use of dipmeters and seismic might be expected to further improve results and the benefits of detailed modern core analysis cannot be overemphasized.

Stimulation of Elk sands must include consideration of geology and geometry of the reservoir as well as the fracture fluid type and the effectiveness of perforations. Open-hole completions have success using water as a fracturing fluid, but cased-hole completions require higher viscosity fracturing fluids. High viscosity fluids (40 lb cross-linked gels and foams) have the advantage of good sand transport combined with low leakoff, but are higher in cost and higher in residue. Lower viscosity gels (linear gels and friction reducers) are marginal in terms of sand transport and are characterized by higher leakoff, but are lower in cost and have less associated residue. Primary considerations should include designing the cement job with geology in mind to minimize leakoff, attempting to open all perforations, designing the fluid type to place sand across all permeability zones and promoting a multidisciplinary approach.

LESSONS LEARNED

Review of historical exploration and production data, when combined with modern regional stratigraphic studies, can point to missed exploration or even missed development opportunities. Modern logging and completion technologies have the potential for quickly turning marginally exciting past evaluations into commercially productive reservoirs.

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