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Ultimate Recovery from Hydraulic Fracturing

After approximately eight years of use by the oil industry, hydraulic fracturing of formations has been generally accepted as a means of production stimulation. The experience of one major company in the Mid-Continent area shows that this fracturing increases the ultimate recovery of oil. This study is based on reconditioning treatments of wells in semi-depleted reservoirs where ultimate recovery can be accurately evaluated from production decline curves, and examples are given.

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Differential Entrapment of Oil and Gas in Arbuckle Dolomite in Central Kansas

In central Kansas thousands of wells produce oil from the Arbuckle dolomite of Cambro-Ordovician age at depths from 3,200 to 4,400 feet. A few hundred wells produce gas. Reservoir porosity consists of intergranular space between dolomite rhombs, of irregular pin-point to cavernous voids, and of vertical fractures. This porosity was formed, or improved, by solution in early Pennsylvanian time when the dolomite beds cropped out on a low relief land surface. Ground water moved downward through joints, then laterally along bedding planes in the soluble dolomite, continuing down dip under Ordovician Simpson shale cover on the flanks of the Central Kansas uplift. The gently tilted, truncated, solution-riddled, porous, and permeable Arbuckle beds were buried under Pennsylvanian shales and limestones which provide an impervious seal. Oil and gas are trapped at the top of the Arbuckle on structural highs, whether anticlinal folds, buried hills, or traps formed by barriers such as clay-filled solution valleys. Dips are half of one degree or less.

The lowest Arbuckle traps such as the Shady and Zook fields of Pawnee County produce sour gas from depths near 2,000 feet below sea-level. In the Sweeney, Ash Creek, and Pawnee Rock fields of Pawnee County gas is produced from the Arbuckle near 1,800, 1,750, and 1,650 feet subsea, respectively, with a thin oil column present in each field. Both oil and gas are produced from the Otis-Albert field of Rush and Barton counties where the gas-oil contact is 1,600 feet subsea. Oil, and only oil, is trapped in the major Arbuckle fields of Rice, Barton, Russell, Ellis, Rooks and Graham counties at subsea depths of 1,600–1,400 feet. In the Kraft-Prusa field of Barton County the oil-water contact is 1,465 feet subsea. The critical closure of the Arbuckle anticline is also 1,465 feet, indicating that the reservoir is exactly filled with oil. In Ellsworth County, a large anticline with porous Arbuckle as high as 1,350 feet subsea contains only salt water.

This pattern of differential entrapment of gas and oil accords closely with the theoretical distribution described by Gussow in his "Differential Entrapment Principle." It is concluded that oil and gas migrated out of the Anadarko basin of Oklahoma northward through the Arbuckle for several hundred miles due to regional tilting, and spilled upward under an impervious roof of Ordovician Simpson shale and Pennsylvanian shale until trapped in central Kansas. Time of tilting, hence migration, was post-Permian; important migration appears to have occurred in Cretaceous time.

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Some Features Common to Sand Bars on Modern Coasts and in Geologic Column

Sand bars which have features and distribution similar to sand bars on modern coast lines are being recognized as oil reservoirs in many parts of the geologic column, and their occurrence is in many widely spaced areas. A knowledge of modern sand bars, therefore, should aid the discovery and development of oil fields in ancient sand bars.

Systems of sand bars are common features of many coasts of the world. They are particularly well developed on the Atlantic and Gulf coasts of the United States. Except for an attachment, commonly at one end, the bars are separated from the mainland by lagoons or marshes, many of which range from ½ to 5 miles in width. The width of some lagoons, however, is 30 miles or more. The length of many bars on the Atlantic Coast ranges from 4 to 8 miles, others from 15 to 30 miles, and on the Gulf Coast from a few to more than 100 miles. The individual bars are separated by narrow water channels called tidal inlets, which connect the ocean with the lagoons. The inlets are kept open by tidal currents which surge in and out through the inlets twice daily.

Longshore currents, which are produced by waves striking the coast at an angle, operate on the seaward side of the bars. They transport sand along the shore, and lengthen the bars at one end. At the same time the tidal currents at the inlets tend to limit the extension of the bars. The result is that the end of an individual bar is extended along shore beyond the end of the next bar on the coast, but slightly seaward of it; thus producing an en echelon arrangement of the bars. Offset features are particularly well developed on the south shore of Long Island, where a westward longshore current has extended the western end of each bar westward beyond the adjacent bar.

Many bars on the Atlantic Coast are characterized by ridges of sand that trend parallel with the shore; the ridges commonly are capped by dunes and are separated by long marsh strips or "slashes." These are growth ridges and are produced by addition of sand to the seaward side of the bars. Growth

ridges are prominent at Cape Henry, Virginia, Bogue Island, Parramore Island, and elsewhere on the Atlantic Coast and at many places on the Gulf Coast.

Beach sands on modern coasts are well sorted within individual beds or laminae. On the other hand, there is considerable range in grain size from laminae to laminae. The beach sands are composed chiefly of grains of quartz but contain minor amounts of a great variety of minerals.

Beach sands on modern coasts are transitory features that are modified by every storm. It is truly remarkable that many similar sand bodies of the geologic past have been so perfectly preserved in the geologic column. A few examples include the so-called shoestring oil sands in the Cherokee shale of Pennsylvanian age in Kansas and Oklahoma. These sand bodies have many features of the modern coastal sands. The length of one system of these sands is 150 miles. Some of the sand bodies in the Cretaceous system in the Denver basin of Colorado and Nebraska, and in the Powder River basin of Wyoming and the somewhat younger Cretaceous sands in the San Juan basin in New Mexico appear to have had a similar origin.

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Facies Changes in Pennsylvanian Rocks along North Flank of Wichita Mountains

The area of investigation in southwestern Oklahoma extends from Cement field, Tps. 5–6 N., Rs. 9–10 W., northwestward along the north flank of the Wichita Mountains to the Oklahoma-Texas boundary. A study of Pennsylvanian sediments in this area reveals conspicuous facies changes both laterally and normal to the mountain flank. In the lateral facies changes show a close relationship to the provenance from which the sediments were derived. Correlation difficulties are increased because of these facies changes. Fusulinids provide reliable age determinations when present. The Pennsylvanian rocks are dominantly clastics. The principal facies near the mountain front is "granite wash," a coarse clastic sediment composed primarily of igneous rock fragments with variable amounts of detrital carbonates and chert. Subordinate facies are arkosic sandstones, arenaceous, silty shales and thin, argillaceous limestones. These continental and transitional facies interfinger basinward with normal marine sandstones, shales, and limestones.

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Facies Patterns and Oil Accumulation in Pennsylvanian of Southern Oklahoma

Analysis of the complex facies patterns expressed by Pennsylvanian strata of southern Oklahoma requires identification of regionally extensive, correlatable, stratigraphic units. The writers have been able to extend a correlation network based on recognition of cyclical units which can be grouped into major operational mapping units separated by regional unconformities. The resulting stratigraphic subdivisions, both major and minor, are not those of the formal stratigraphic nomenclature accepted in the area but they do make possible a classification of trapping conditions related to position in the stratigraphic succession. The types are as follows: (1) blanket sands in which facies trapping components are markedly subordinate to structure; (2) discontinuous sand bodies with traps largely independent of structural axes; differentiation can be made between major sand bodies of greater areal extent than the associated structures, and minor sand bodies significantly smaller than the areas of the structures on which they lie; (3) traps related to unconformities, including channel fills, overlapping strand-line sands associated with marine transgression across major structures, truncation traps sealed by overlying permeability barriers, and secondary accumulations in permeable strata overlying truncated reservoirs; (4) sandstone reservoirs with apparent random distribution and without discernible relationships to facies patterns.

Relationships of the trap types enumerated can be demonstrated in terms of position in the stratigraphic succession, time and geography of structural growth, development and character of major unconformities, and other elements of the regional geologic history.

The regional study raises a number of questions which are not easily resolved but certain tentative conclusions can be drawn from analysis of regional and local facies patterns. Such questions include: (1) vertical homogeneity of areas either rich or poor in number and thickness of sand bodies; (2) relationship of limestone conglomerate to reservoir and sealing components; (3) diagenetic introduction of carbonate cement in relationship to time of oil accumulation; (4) volumetric proportions of sand and marine shale requisite to significant oil accumulation.

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Oil and Gas Possibilities in Central Nebraska Basin

The Central Nebraska basin comprises an area of more than 25,000 square miles bounded on the west by the Chadron-Cambridge arch, on the east by the Table Rock-Nehawka-Richfield arch, on the north by the Sioux uplift, and on the south by the Kansas-Nebraska line. For all practical purposes this basin is a northern extension of the Salina basin of Kansas. The area is extensively mantled with variable thicknesses of Cenozoic rocks resting on Cretaceous, Permian, and Pennsyl-