Controls on Reservoir Quality of Sandstones, Cotton Valley Group (Upper Jurassic), East Texas Basin, Texas

Sandstones in the Cotton Valley Group are poor-quality gas reservoirs that require massive hydraulic fracturing for economic production. Burial diagenesis of these rocks has resulted in extensive cementation and grain replacement that, with few exceptions, has reduced porosity to less than 10% and permeability to less than 0.1 md. Major diagenetic minerals are quartz and carbonates (calcite, ankerite-dolomite) with clay minerals, albite, and anhydrite present in subordinate amounts. The abundance of cement is related in part to initial sandstone composition. Cotton Valley sandstones are very fine to fine-grained, moderately to well-sorted quartzarenites and subarkoses. In quartzose sandstones, pore-filling cements average between 15 and 20% of the rock volume, whereas in feldspathic sandstones cements usually comprise over 20% of the rock volume. These cements eliminate most of the primary intergranular porosity leaving a series of nearly isolated voids connected by submicron-size pore throats. Although blockage of pore throats by authigenic clay minerals locally contributes to low permeability, quartz and carbonate cements usually line pores and appear to more effectively block pore throats.

Porosity preserved in the Cotton Valley consists of primary intergranular and secondary dissolution voids. Most secondary porosity results from dissolution of feldspar and chert; a sparse amount of secondary voids originate from dissolution of shell fragments and possibly calcite cement. Dissolution porosity is locally the most abundant type of porosity, particularly in feldspathic sandstones, but is usually associated with inadequate permeability to improve reservoir quality. Secondary voids are not interconnected because their distribution depends on the presence of soluble grains, which are dispersed in the sandstones. Highest permeability is present where primary intergranular porosity forms over 50% of the total porosity.

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Computer-Aided Offshore Reservoir Delineation

Delineation of discrete reservoirs is essential in the development of a petroleum field. This may be especially complex in offshore situations where numerous wells deviate from one or more platforms. An offshore field in southern California is an example where reservoir delineation was needed prior to designing a secondary flooding program.

A data base, containing directional survey data and measured depths of stratigraphic horizons, was used to generate structural cross sections at user-defined planes. These cross sections aided in the structural interpretation by outlining the plunging anticline, identifying faults, and revealing the variability in zone thicknesses.

Digital well-log data were used by the Stacked Curves System to assist in the stratigraphic interpretation. Color stratigraphic cross sections were generated on a zone-by-zone basis to compensate for the changing locations of the deviated boreholes. Lithology and porosity variations were easily determined from the color cross sections.

Merging the information obtained from structural and stratigraphic cross sections provided a detailed geologic picture of the field allowing the strategic location for injection wells.

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Sedimentology and Petroleum Geology, Spirit River Formation (Lower Cretaceous), Deep Basin, Alberta

The Spirit River Formation is subdivided into three members in northwest Alberta. The basal Wilrich Member consists of two 50 to 100-m thick upward-coarsening cycles of marine shales, siltstones, and sandstones. The Falher Member consists of nonmarine clastics and coals in the southern part of the area. Around the Elmworth gas fields, it is composed of five transgressive and regressive cycles in which marine and nonmarine conditions alternated. Each cycle can be traced northward into a laterally extensive upward-coarsening marine cycle.

The gas reservoirs are complexly interbedded fine conglomerates and sandstones. Conglomerates interpreted as fluvial deposits have sharp bases, moderate to poor sorting, some cross-bedding, and variable amounts of sandy matrix. Those interpreted as beach deposits are moderate to well-sorted, horizontally bedded, and may lack matrix entirely. A complete gradation exists between the types, which are closely interbedded. Shoreface and beach sandstones are fine grained, well sorted, burrowed, and have near horizontal laminations and truncation surfaces. On a large scale, this shore-zone complex is best considered a wave-dominated delta. The Notikewin Member is the final seaward progradation of this system.

Most sandstones in the Falher have less than 6% porosity and 1 md permeability whereas the reservoirs may have 20% porosity, much of which is secondary, and several darcys permeability. Early cementation, then formation of secondary porosity in the delta complex followed by deep gas generation have created a combined stratigraphic-diagenetic trap.

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Depositional Environments in Lower Cretaceous Gates Member, Northeastern British Columbia

The Lower Cretaceous Gates Member, which outcrops in the Rocky Mountain Foothills of northeastern British Columbia, consists of approximately 300 m of marine and nonmarine clastic sediments. The lower unit consists of several coarsening-upward marine cycles, which thicken and increase to the north. Thin coal seams at the top of some of these cycles thicken to the south and pinch out northward. Sediments in the middle unit of the Gates were deposited in a nonmarine environment and include several thick coal seams which are economically important. Fluvial sandstones and conglomerates in this interval were deposited in rivers which flowed in general to the north, subparallel to the tectonic strike and into a paleocoastline which was trending approximately east-west. Three major fluvial conglomerates are recognized and are interpreted as indicating three pulses of tectonic activity in the source area to the southwest. During the deposition of the upper unit of the Gates, a marine transgression occurred which reworked part of the underlying section and deposited locally a thin marine lag conglomerate. The overlying marine sandstones were deposited in a marine shelf and tidally influenced coastal environment. Coastal sand bodies include fining-up subaqueous channel deposits which grade laterally into coarsening-up sandstone units interpreted as marine shoals. The orientation of these sand bodies is at right angles to the paleocoastline.

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Depositional Environments of Ratcliffe Interval, Mississippian Madison Group, Williston Basin, North Dakota

The Ratcliffe interval within the Williston basin in North Dakota is included in the Mississippian Madison Group. It is an informal stratigraphic subsurface unit which includes parts of the upper Mission Canyon and lower Charles Formations. Deposition of the Ratcliffe sediments occurred in an open to progressively restricted marine environment along the eastern margin of the basin. Six facies have been recognized in the study area. These are the: (1) brachiopod-bryozoan-echinoderm packstone/wackestone facies; (2) peloid-oolite packstone/wackestone facies; (3) ostracod-foraminifer wackestone facies; (4) laminated mudstone/wackestone facies; (5) anhydrite-dolomite mudstone facies; and the (6) organic quartz siltstone facies. Oil found within the Ratcliffe interval is usually associated with the peloid-oolite packstone facies. Some moldic porosity has developed by solutioning. Dolomitization has increased intercrystalline porosity. Dolomitized areas commonly are capped by less porous facies making good potential stratigraphic traps. Formation of traps and reservoir rock is highly dependent on porosity and permeability and also on the amount of diagenesis, especially secondary anhydrite, associated with the sediments.

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Production Analysis in Exploration: Stettler Field Extension, Alberta

In October 1977, a significant extension to the 50,000,000 bbl Stettler D-3 and D-2 reef oil field was made 28 years after the initial 1949 discovery and 17 years after the field was considered fully delineated by exploratory and development drilling. The Stettler field is among a number of well-documented Upper Devonian reef fields and was seismically and geologically mapped before and after discovery.

The potential of some Alberta reef field extensions became evident with the new oil economic reality following the Arab oil embargo of 1973. Attention was given to the structurally downdip, southwest closing rim of the Stettler dolomitized D-3 atoll during 1977-79 by the drilling of seven successful oil wells beginning with the Geneva Resources 6-17-38-20 W4 test on a prospect created by the speaker.

From November 1977 to January 1, 1981, 122,869 bbl of crude were produced from the 6-17 well at an average rate of 108 bbl oil/day during that period. At least 1,000,000 additional barrels of primary Stettler oil will be produced as a result of these recent extension wells.

The key to this successful prospect was the lead derived from using computer lists and decline curves of production data. By 1977, over 400,000 bbl of oil and less than 20,000 bbl of salt water had been produced from the 1960 Tenneco CPR 12-17-38-20 W4 well. This location was believed by industry in 1960 to have been close to the D-3 reef oil/water contact with an expectation of high water and low oil productivity.

This example of a significant reef extension is a reminder that abundant, economic oil reserves remain to be discovered in other areas by a more realistic use of geology and production information available in existing computer files.

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Progressive Stages of Diagenesis in Early-Middle Eocene Fore-Arc Delta, Shelf, Slope, and Basin Sandstones, Southern Coast Range, Oregon

The Flournoy and Tyee formations (early to middle Eocene) of western Oregon are a model example of pervasive diagenesis in volcanic arenites, which extend over a full range of environments: delta, shelf, slope, and basin. Although younger Eocene units in Oregon prove to be good reservoir rocks, the Flournoy and Tyee lack porosity. This is due to fore-arc basin burial and subsequent mechanical and chemical diagenesis.

Evaluation of the diagenetic phases indicate deep burial and compaction at an early stage. Unstable volcanic rock fragments and plagioclase grains from all environments show alteration to mixed-layer clays and laumontite, making them more susceptible to mechanical plastic deformation.

Cementation and replacement were most common in coarse-grained deltaic and shelf sands, where the depositional porosity was high. An early stage of calcite cementation preserved open framework-supported textures in spherical concretions. A second stage of mixed-layer clays formed cement rims. Clinoptilolite filled remaining pore space. Locally, these two phases are reversed in Flournoy sands. Rare fractures were filled by stilbite. During a late stage, calcite replaced clay rims and zeolites, or filled remaining pores. In other samples, pervasive laumontite, together with minor clays, tightly cemented the coarse-grained sandstones.

Slope and basin sandstones are finer grained and contain more matrix than coarse-grained sandstones. Original composition, grain size, and original porosity (a function of depositional setting) controlled diagenetic development. These deeper water sandstones show some clay and calcite cements, but are generally lacking zeolite cements.

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Mineral Reaction Pathways and Mass Transfer in Sandstone-Shale Sequences, Brazil

The major purpose of this study is to describe and quantify mineral reactions, reaction pathways, and mass transfer accompanying burial of passive margin sandstone-shale sequences, offshore Brazil. Four basins were investigated, encompassing a range of sandstone-shale compositions. Because these basins have similar geologic histories, the effect of original detrital mineralogy on diagenetic products could be ascertained. Standard light microscopy, X-ray diffraction, EM, SEM, and isotopic and chemical analyses provided the basis for interpretation of mineralogy, texture, and diagenetic reactions.

The initial mineral composition of the sediments was a major control of diagenetic products. Arkose and lithic arkose are the dominant sandstone types in these basins. Dioctahedral clay minerals, chlorite, and quartz characterize arkoses, whereas trioctahedral clays (saponite and corrensite) and zeolites are found in lithic sandstones. Dioctahedral smectite-rich shales exhibit the classical smectite/illite to illite burial pattern. However, mafic, trioctahedral clay-rich shales show a burial sequence of saponite to chlorite/saponite mixed-layer, a progressive increase of chlorite-rich phases with increasing burial depth.

The structural change of disordered to ordered interstratification of mixed-layer chlorite/saponite occurs in the temperature range of 60 to 80°C, and at vitrinite reflectance values around 0.7. Increasing substitution of silicon by aluminum in tetrahedral sites is the major chemical change accompanying transformation of saponite to chlorite via corrensite.

Material balance calculations indicate that sandstones lose less than 2% $K^+$, which probably enters interstratified shales, and gain less than 3% $H_2O$, $H^+$, and $CO_2$ during burial diagenesis. Therefore, the burial pathway of Brazilian sandstone