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Depositional and Diagenetic Models for Devonian Birdbear (Nisku) Reservoirs, Northeastern Montana

Carbonates comprising the approximately correlative Upper Devonian Birdbear and Nisku Formations were deposited over an immensely broad, shallow shelf that extended from eastern North Dakota over an immensely broad, shallow shelf that extended from eastern North Dakota to central Alberta. Major oil production is concentrated in Nisku pinnacle reefs bordering the central Alberta basin and Birdbear stromatoporoid banks and biostromes bordering the Williston basin in northeastern Montana. Birdbear fields are located on structures coincident with favorable reservoir facies. Birdbear porosity, formed upon dolomitization, is dominated by interconnected intercrystalline and microvugular voids, skeletal molds, and leaching-enhanced intraskeletal voids. Fractures and vugs are relatively unimportant. Diagenesis and the distribution of reservoir facies, in turn, were controlled by the sequence and local geography of depositional settings and early burial conditions. Accordingly, depositional and diagenetic models are fundamental to geological exploration for Birdbear reservoirs.

Depositional models over the region are varied, but all have in common early marine inundation of a nearly featureless shelf and coastal plain, followed by universal gradual shoaling by vertical sediment accretion culminating in an extremely restricted depositional setting. Mud-rich depositional textures and contained fossil assemblages demonstrate the predominance of low-energy, shallow subtidal to supratidal waters of more or less elevated salinities. Normal marine shelf conditions were exceptional. Depositional models are constructed as vertical facies sequences, each subject to local and regional facies changes. One such model sequence, from the base upward, progresses from restricted intertidal mud flats (commonly brecciated mudstone), semirestricted *Amphipora* banks (wackestone and current-bedded packstone), normal marine lagoons (nodular-bedded mudstone and wackestone), semirestricted stromatoporoid biostromes (in-situ laminar and tabular stromatoporoid boundstone), restricted intertidal mudflats (laminated, stromatolitic mudstone), to supratidal flats and evaporitc ponds (nodular-mosaic anhydrite and mudstone). *Amphipora* bank and stromatoporoid biostrome facies, which bear the highest porosity values, are especially prone to lateral facies change.

Principal events of a generalized Birdbear diagenetic model include desiccation, brecciation, and caliche development in mudstone; displacive growth of nodular and nodular-mosaic gypsum; and lithification by pervasive dolomitization. These early events were accompanied throughout by physical compaction and loss of nearly all primary porosity. Development of most secondary porosity occurred during dolomitization. Deep-burial diagenesis encompassed fracturing; gypsum-to-anhydrite transformation accompanied by fracture and pore filling and replacement by anhydrite; hydrocarbon generation and migration; and pressure-solution formation of stylolites and microstylolites. These latter events are characterized by chemical compaction, cementation, and reduction of secondary porosity. Any specific diagenetic model and resultant reservoir characteristics, however, are valid only for that particular set of rock fabrics and burial settings embodied in any given depositional model.

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Poncho Field—Cretaceous "J" Sandstone Stratigraphic Traps—Denver Basin, Colorado

Distributary channel and delta destructional sandstones of Early Cretaceous age are important reservoirs for stratigraphic traps in the "J" sandstone at Poncho field, Adams and Arapahoe Counties, Colorado.

Cores and logs from the field area reveal a lowermost, nonproductive, northeast-trending delta front sandstone (J-3); a middle complex of southeast- and east-trending, productive distributary channel sandstones (J-2) that grade into tightly cemented delta fringe marine sediments to the southeast and northeast; and an upper, northeast trending, productive delta destructional sandstone (J-1). Vertical and lateral sequences of sedimentary structures, textures, trace fossil assemblages, and geometry and trend of sandstone bodies suggest that these units were part of a wave-dominated delta complex that prograded to the east and southeast from the area of Lonetree field.

Thin section and SEM analyses reveal that the principal cements in both reservoir sandstones are quartz overgrowths, kaolinite, and chlorite, and that the bulk of the porosity is secondary and related to dissolution of carbonate cement and feldspar grains. Porosities and permeabilities are most variable and lowest in the nonproductive delta front sandstones, averaging 15% and 7 md; variable and intermediate in the productive distributary channel sandstones, averaging 16% and 28 md; and most uniform and highest in the overlying delta destructional sandstones, averaging 21% and 88 md.

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Application of Geological Studies to Overburden Collapse at Underground Coal Gasification Experiments

Detailed geologic and mineralogic studies were conducted on the Hanna, Wyoming, and Hoe Creek, Wyoming, underground coal gasification sites. These studies demonstrate the importance geologic factors have on controlling overburden collapse into the reactor cavity during and after coal gasification and on subsequent environmental problems. Parameters that control the collapse of overburden material into the reactor cavity include: duration of the burn; maximum span of unsupported roof rock; lateral and vertical homogeneity, permeability and rock strength; and thickness of overburden materials. The duration of the burn, maximum span of unsupported roof rock, and total thickness of overburden rock are, in large part, determined by the technical engineering aspects of the burn. The remaining parameters are determined by geological factors including original composition, depositional environment, diagenesis, and structural deformation.

The coals and overburden units at both sites are Eocene in age and are virtually flat lying. The three burn cavities studied at the Hoe Creek site are directly overlain by laterally discontinuous, poorly indurated, kaolinite-cemented sandstones, siltstones, and mudstones of channel and overbank origin. At the Hoe Creek I experiment, a small reactor cavity and a correspondingly short maximum span of unsupported roof rock consisting of fine-grained, low permeability overbank deposits resulted in minimal collapse. At the Hoe Creek II experiment, a significant amount of collapse occurred due to an increased span of unsupported roof rock comprised of poorly consolidated, more permeable channel sandstones and a limited amount of overburden mudstones and siltstones. Roof rock collapse extended to the surface at the Hoe Creek III experiment where the maximum span of unsupported roof rock was largest and where the roof rock consisted of highly permeable, poorly consolidated channel sandstones.

The unit comprising the reactor cavity roof rock at the Hanna II experimental site is a laterally continuous lacustrine delta deposit, which primarily consists of sandstones with lesser amounts of interbedded siltstones and claystones. The overall strength, specifically the bridging capacity, of this unit is enhanced by abundant calcite cement. This cement reduced permeability and interstitial waters which probably kept spalling of the roof rock to a minimum. Consequently, roof rock collapse at the Hanna II experiment was much less extensive than at the Hoe Creek II and III experiments.

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Potentiometric Surface and Quality of the Water of Madison Group, Montana

The potentiometric surface map of the Madison Group of Mississippian age in Montana indicates that water in this aquifer generally moves northward. The principal recharge areas of the Madison are the Little Belt and Big Snowy Mountains of central Montana, the Pryor and Bighorn Mountains of south-central Montana and northern Wyoming, and the Black Hills uplift of Wyoming and South Dakota. The dissolved-solids concentration of the water ranges from a few hundred milligrams per liter near mountainous recharge areas to about 300,000 mg/L in the