KERR, S. DUFF, Kerr & Assocs., Denver, CO

Paleotectonic Controls on Carbonate Reservoir Development in Central Williston Basin

The Williston basin has been portrayed as the archetype intracratonic basin, wherein tectonics have played only a minor role in geologic history. This may be demonstrated in the subtle manner in which tectonics have controlled the locus and development of most of the producing reservoirs in the Paleozoic sedimentary sequence.

The pattern of the initial sedimentary sequence covering the crystalline basement is that of a westerly to southwesterly thickening wedge. Limited penetration of the Deadwood sequence has restricted full understanding of its hydrocarbon potential. However, it forms the foundation for overlying Upper Ordovician Red River production focussed along the North Dakota–Montana border. The structural features on which most Red River production occurs show near classic effects of active structural development during deposition of the reservoir beds. Peritidal facies represent minute variations in depositional topography and, therefore, respond to the smallest increments of uplift. This causes sharp variations in distribution of reservoir and nonreservoir facies within a given structural feature.

Major unconformities mark tectonic episodes at the close of the Silurian and near the close of the Devonian. Each of these events is marked by uplift and leveling around the periphery of the basin and significant shifts in depositional patterns within the basin. Late Ordovician through Silurian sedimentation is reflected in basin-centered patterns of thickening. Facies patterns, including the distribution of reservoirs and seals, reflect this. The Devonian onlaps across an unconformable surface and has formed a wedge with significant northward thickening. Facies patterns of both Middle and Upper Devonian units reflect a tectonic and sedimentary connection into the Alberta basin.

Mississippian seas flooded across the late Devonian unconformity and deposited thick sequences of carbonates and evaporites again in a predominantly basin-centered pattern. Rapid subsidence and rapid sedimentation caused a filling of the basin, and a strong regressive pattern of facies developed. Peritidal sedimentary facies dominate in development of reservoir and seal. Traps are thus influenced by very subtle tectonic-topographic variations throughout the basin.

Late Paleozoic to early Mesozoic uplift, tilting, and erosion, followed by deposition of early Mesozoic seals has had a profound effect on the distribution of hydrocarbons in the previously developed traps. A more complete understanding of this final episode and its relation to source rock maturation and migration holds the key to much of the future development of the basin.

KOELMEL, MARK, Chevron U.S.A., Inc., Denver, CO

Paleotectonic, Stratigraphic, and Diagenetic History of Rangely Area, Colorado

Rangely field is located in Rio Blanco County, Colorado, on a Laramide doubly plunging anticline asymmetrical to the southwest. The Pennsylvanian Weber Sandstone is the primary producing horizon, with cumulative production exceeding 650,000,000 bbl. The Weber is a subarkosic arenite deposited in an eolian regime. It interfingers with the alluvial Maroon Formation in the southern and southeastern portions of Rangely field. Lower Pennsylvanian stratigraphy suggests a paleotectonic high in the Rangely area. Hydrocarbon migration into the Rangely area probably occurred prior to the Laramide with stratigraphic entrapment at the Weber-Maroon transition. The subsequent Laramide structure localized the hydrocarbon accumulation.

Diagenetic history of the Weber Formation differs between the Uinta and Piceance basins. Weber diagenesis in the Uinta basin is dominated by silica precipitation; porosity appears to be residual primary. Weber diagenesis in the Piceance basin includes dissolution of matrix material and precipitation of a complex sequence of carbonate cements. Weber porosity in the Piceance basin appears to be secondary. The boundary between these two diagenetic regimes seemingly coincides with the present Douglas Creek arch.

A diagenetic model is proposed for the Rangely area. The model assumes a paleotectonic high in the Rangely area or early expression of the Douglass Creek arch. Silica precipitation commenced after Weber deposition throughout the Rangely area. Pre-Laramide expression of the Grand Hogback may have caused sufficient faulting to permit fluid communication between the Eagle Valley Evaporites and the Weber Formation. Saline solutions from the Eagle Valley Evaporites had sufficient head or diffusion drive to replace the Weber Formation fluid in the Piceance basin. The saline solutions halted silica precipitation in the Piceance basin and initiated precipitation of the carbonate cements. Precipitation of silica continued in the Uinta basin. Development of secondary porosity in the Piceance basin occurred prior to or simultaneously with oil migration.

KVALE, ERIK P., and CARL F. VONDRA, Iowa State Univ., Ames, IA

Stratigraphy of Upper Jurassic Morrison and Lower Cretaceous Cloverly Formations of Big Horn Basin, Northern Wyoming

The Morrison and Cloverly Formations in the Big Horn basin of northern Wyoming and southern Montana are part of a distal edge of a westward-thickening clastic wedge of sediments deposited in an elongate intracontinental basin in the western North American craton. These formations reflect orogenic and volcanic activity in the western Cordillera during Late Jurassic and the subsequent eastward migration of volcanic centers during Early Cretaceous.

The Morrison Formation (Upper Jurassic) conformably overlies the Jurassic marine Sundance Formation and consists of light olive-green, lenticular, calcareous siltstones and mudstones interbedded with white to buff or yellowish green, massive and cross laminated, calcareous quartzarenites. The olive-green mudstones in the upper portion of the formation alternate with red-brown calcareous mudstones or shales producing red banding. A lenticular bed of siliceous accretionary lapilli is present in the upper portion of the formation along the west flank of Sheep Mountain anticline, north of Greybull, suggesting a closer proximity to volcanic vents than previously hypothesized.

The Cloverly Formation (Lower Cretaceous) consists of three members: the Pryor Conglomerate, the Little Sheep Mudstone, and the Himes; it overlies the Morrison Formation both conformably and unconformably. Its basal contact is sometimes marked by a lenticular, cross-bedded, conglomeratic quartzarenite or a pebble conglomerate consisting of clasts of black chert (Pryor Conglomerate) derived from uplifted Paleozoic deposits to the west and deposited as channel lag. The Little Sheep Mudstone Member is composed of variegated mudstones which are generally noncalcareous bentonitic, and laced with abundant chalcedony and barite concretions and veinlets. The Himes Member also contains a stacked sequence of devitrified tuffs interbedded with bentonitic mudstones, which locally may be several meters thick. The individual tuffs, however, are generally less than 1 m (3 ft) thick and are very fine grained, buff to white, and massive. Also, relatively thin lenticular lithic wackes occur in the Himes Member. These are anomalous to the quartzarenites of the rest of the Morrison and Cloverly. A thick lenticular, trough-cross-bedded, quartzarenite caps the formation.

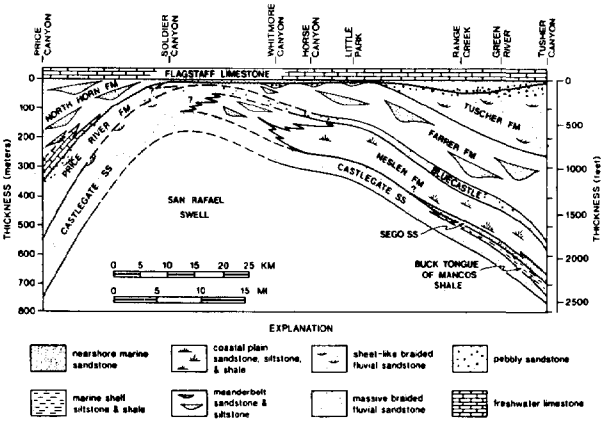
Both the Morrison and Cloverly Formations are characterized by high ratios of overbank fines relative to coarse channel sands. It has been assumed, but not documented by detailed sedimentologic study, that the deposits were part of an aggrading alluvial flood plain complex dotted by seasonal lakes and swamps and crossed by braided rivers. This model deviates from most modern braided systems which are characterized by rapid lateral mobility and the lack of fine-grained overbank material. The large ratio of fine-grained siltstones and mudstones to coarser grained sandstones can be explained by a number of processes, the most probable being rapid overbank aggradation as a result of a large influx of wind-blown volcanic material from vents to the west. However, this ratio could also be obtained in a rapidly subsiding basin whose river systems are characterized by long periods between avulsion, which is common in an arid to semiarid environment.

LAWTON, TIMOTHY F., Sohio Petroleum Co., San Francisco, CA

Late Cretaceous Fluvial Systems and Inferred Tectonic History, Central Utah

Upper Campanian nonmarine sedimentary rocks exposed between the Wasatch Plateau and the Green River in central Utah record a tectonic

transition from thin-skinned deformation in the thrust belt to basement-cored uplift in the foreland region. Thick sections of the Mesaverde Group in the Wasatch Plateau on the west and the Book Cliffs on the east are separated by the San Rafael swell, a basement uplift across which the group is erosionally thinned. Strata in the west (Castlegate Sandstone and Price River Formation) were deposited by east to northeast-flowing braided rivers. Time-equivalent eastern sections comprise a lower sequence of mixed braided fluvial deposits (Castlegate Sandstone and Bluecastle Tongue of Castlegate), coastal swamp and meander-belt deposits (Neslen Formation), and nearshore marine deposits (Buck Tongue of Mancos Shale and Sego Sandstone), and an upper sequence that coarsens upward from meander-belt deposits (Farrer Formation) into pebbly braided river deposits (Tuscher Formation). Paleocurrent data indicate that rivers of the lower sequence flowed east, while those of the upper sequence flowed northeast.



Sandstones within the section consist of two distinct compositional suites, a lower quartzose petrofacies and an upper lithic petrofacies. The compositional boundary occurs at the top of the Bluecastle Tongue and can be correlated across the San Rafael swell. The quartzose suite contains mostly compositional quartzarenites and sublitharenites; the lithic suite is composed of litharenites and feldspathic litharenites. Lithic grain populations of the upper petrofacies are dominated by sedimentary fragments in sections of the Wasatch Plateau and volcanic fragments in sections near the Green River. The sedimentary lithic grains were transported generally eastward from miogeoclinal strata uplifted within the thrust belt. The volcanic lithic grains of the Farrer and Tuscher Formations were derived from more distal arc sources to the southwest, and transported through the thrust belt somewhere west of the Kaiparowits region, where time-equivalent sedimentary rocks are also rich in volcanic lithic fragments. Disappearance of volcanic lithics and appearance of pebbles at the top of the Tuscher Formation is interpreted to reflect a latest Campanian reorganization of drainage patterns that marked initial growth of the San Rafael swell and similar basement uplifts to the south of the swell. Contemporaneous fluvial systems that deposited the uppermost part of the Price River Formation in the Wasatch Plateau were apparently unaffected by the uplift and continued to flow northeast. Depositional patterns thus indicate that initial growth of the San Rafael swell was probably concurrent with late deformation in the thrust belt. Depositional onlap across the Mesaverde Group by a largely post-tectonic assemblage of fluvial and lacustrine strata (North Horn Formation) indicates a minimum late Paleocene age for growth of the San Rafael swell and deformation within the thrust belt.

LEFEVER, JULIE A., and SIDNEY B. ANDERSON, North Dakota Geol. Survey, Grand Forks, ND, and RICHARD D. LEFEVER, Univ. North Dakota, Grand Forks, ND

"Spearfish Water Sand": An Overlooked Play?

The Waskada-Pierson plays in the Amaranth Formation in southern Manitoba have prompted a study of similar units in Bottineau County, north-central North Dakota. The pay zone in the Waskada field is a sequence of sandstones and siltstones trapping oil which has migrated from the underlying Mississippian strata. The Triassic Spearfish Formation of North Dakota, correlative with the Amaranth Formation of Manitoba, consists of a similar sequence of interbedded sandstones and siltstones which unconformably overlie carbonate and anhydrite rocks of the Madison Group. Log characteristics show the sandstones and siltstones of this sequence to be laterally continuous over the study area.

Except for one well, production in the Bottineau area of North Dakota has been confined to either a portion of the Madison Group or a basal Spearfish sand. This basal sand is overlain by a 20 to 25-ft (6 to 7-m) thick impermeable siltstone which acts as a vertical seal for the Newburg/South Westhope pay. Above this siltstone is a unit locally known as the Spearfish "water sand," a water-bearing sandstone in the Newburg/South Westhope fields.

The one exception to basal Spearfish production is located in Sec. 6, T163N, R78W, where the Cardinal Petroleum 1 Oscar Aftem well has been producing from the Spearfish water sand since December 1961, indicating that the water sand may have potential for more production in the area.

LINDHOLM, ROSANNE, Univ. North Dakota, Grand Forks, ND

Bivalve Associations of Cannonball Formation (Paleocene, Danian) of North Dakota

The Paleocene Cannonball Formation, cropping out primarily in southwest-central North Dakota, is a marine deposit with variable lithologic characteristics ranging from medium to dark-gray-weathering mudstone to fine-grained, well-sorted, brownish-yellow-weathering sandstone. Also, two distinct tongues of the formation, exposed in southwestern North Dakota, are comprised of organic-rich siltstones and claystones.

There are 30 known species of bivalves in the Cannonball. Because bivalves are abundant and well known, and because their morphology and life habits are highly reflective of environmental demands, they are used to more accurately define depositional environments of the Cannonball sea. Based on Q-mode and R-mode cluster analysis, five bivalve associations are defined: *Ostrea-Corbicula, Crassostrea-Corbula, Isognomon, Crassatella-Nucula,* and *Glycymeris-Arctica* associations.

The *Ostrea-Corbicula* association, in the lower Cannonball tongue, and the *Crassostrea-Corbula* association, in the upper tongue, suggest that the Cannonball sediments in southwestern North Dakota were deposited in lagoonal or estuarine environments.

Where present, *Isognomon* occurs in abundance. However, it is found at only a few known localities in southwest-central North Dakota, and it has not been found in association with any other macrofossils. *Isognomon*, found in organic-rich sands, appears to have lived attached to vegetation in shallow-water environments.

The *Crassatella-Nucula* and *Glycymeris-Arctica* associations, common throughout southwest-central North Dakota, are most characteristic of the Cannonball. The *Crassatella-Nucula* association occurs in silty, clayey sand with moderately high organic content. It is dominated by both deposit and suspension-feeding bivalves, and has a high species diversity. It appears to have been deposited in a low energy environment with moderately high turbidity. In contrast, the *Glycymeris-Arctica* association is found in fine-grained, well-sorted sandstone with low organic content. It is dominated by infaunal suspension-feeding bivalves that indicate both a higher energy environment and low turbidity. Crabs and *Ophiomorpha* commonly occur stratigraphically above this association. These two associations most likely represent foreshore, shoreface, and/or shelflike environments.

The distribution of these bivalve associations, along with lithologic characteristics, suggest that the Cannonball Formation was primarily deposited in a barrier island complex and included lagoonal, beach, and offshore environments.

LINDQUIST, PAUL E., and PATRICIA I. HAGAR, ARCO Exploration Co., Denver, CO

Exploration Significance of a Possible Subsurface Meteorite Impact Feature in Garfield County, Montana