accumulation of 1,250,000 barrels. The true potential of such reservoirs still lies in the minds of the exploration geologists.

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Basin-and-Range Structure Reflects Paleozoic Tectonics and Sedimentation

Upper Paleozoic tectonism and sedimentation are the key factors which influenced the relation between valleys and ranges in northeastern Elko County, Nevada.

The Mississippian orogeny which formed the Manhattan geanticline, a northeast-southwest welt in central Nevada, was also responsible for the formation of an east-west-trending positive feature in northern Elko County, Nevada. This feature, here named the Northeast Nevada high is probably an eastward extension of the Manhattan geanticline. The presence of the Manhattan geanticline divided the Cordilleran geosyncline into an eugeosyncline on the west and an unstable shelf on the east. Acting as a buffer zone for the compressive forces from the west, the shelf was gently folded into a series of essentially north-south-trending synclines and anticlines. Rapid erosion of the Manhattan geanticline and Northeast Nevada high fed coarse clastics east and south, depositing the Tonka and Diamond Peak formations on the shelf which was surfaced by the folded Mississippian Chainman shale. Maximum clastic deposition occurred in a foredeep parallel with the east side of the geanticline, while minor amounts from the Northeast Nevada high were being channeled southward into the folded geosynclinal shale basin. Contemporaneous with the clastic deposition in the synclinal folds, erosion was attacking the adjacent shale-capped anticlinal folds and many of the anticlines were eroded as deeply as the Ordovician Eureka quartzite and equivalents. Filling of the synclines and erosion of the anticlines continued through most of Morrowan time.

By middle to late Morrowan time, erosion had reduced the anticlines to approximately the same level as the clastic-filled synclines. A veneer of chert and quartz gravels and grits remained as pediment deposits over this nearly peneplaned surface. By early Atokan time, the orogeny was limited to spasmodic unrest, supplying minor amounts of chert and quartzite pebbles into the newly formed limestone depositional basin (Moleen, Tomera, and Ely formations). In middle Des Moines time, the entire Great Basin was gently uplifted permitting erosion and non-deposition until at least middle Missourian time. By Virgil-Wolfcampian time, partial relaxation of positive forces in the Great Basin again permitted the seas to invade most of eastern Nevada and adjacent Utah (upper member of Oquirrh formation, and equivalent carbonate formations).

Leonardian time was characterized by quiescence and the deposition of a fusulinid-bearing carbonate formation over approximately 9,000 square miles of northeastern Nevada and adjacent Utah. This heretofore unnamed limestone sequence, dated lower Leonard to lower Guadalupian, is here named the Pequop formation. The Pequop formation is 1,525 feet thick at its type section in Sec. 3, T. 33 N., R. 65 E., Elko County, Nevada. Composed of purplish gray, irregularly bedded, platy, silty limestones with interbedded fusuline coquinas, the lower contact is placed at the red silt member which overlies the massive Wolfcampian limestones (unnamed formation), and the upper contact placed at the base of an unnamed massive dolomite sequence which is overlain by the Phosphoria formation.

Subsidence continued, depositing the Phosphoria and Gerster formations, until uppermost Guadalupian time when once again the rejuvenated Manhattan geanticline and Northeast Nevada high shed minor amounts of limestone, chert, quartzite pebbles and gravel east and south into the western part of the Phosphoria depositional basin in Nevada.

Episodes of tectonic unrest in northeastern Nevada occurred during Jurassic-Cretaceous (Nevadian) and Cretaceous-Tertiary time (Laramide).

Not until post-middle Miocene was the area once again subjected to major compressive forces of the Cascadian (Basin-and-Range) revolution. The north-south-trending anticlines, eroded of their Mississippian, Devonian, Silurian and in some places Ordovician sediments, together with continued compressive forces from the west, acted, as the jaws of a vise on the thicker Paleozoic sedimentary piles within the synclines. Weaker sediments in the synclines were forced topographically higher than the adjacent anticlines with shearing occurring along the flanks of the anticlines. Thus, in northeastern Nevada, present ranges were born from a thick sedimentary section once protected in the synclines, while valleys were developed from eroded anticlines stripped of their lower and middle Paleozoic section.

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Stratigraphic Analysis of Winterburn and Wabamun Groups in Southern Alberta

The units studied have been assigned to two groups, the Winterburn group and the overlying Wabamun group.

Wabamun group.	Normal Marine episode
	Evaporite episode

Winterburn group.	Clastic episode
	Biostromal and Evaporite episode
	Evaporite phase
	Biostromal phase

The Winterburn group reflects two sedimentary episodes. The lower of these episodes embraces, in turn, two phases. The initial phase consists of the formation of biostromes in the form of shoals in the more basinal portion of the area. On the south, stratigraphically equivalent deposits on the shelf area are characterized by a series of beaches and bars of bioclastic material. This first phase is governed by the termination of the tectonism which prevailed during deposition of the underlying Woodbend sediments. The overlying deposits, which consist of evaporites and carbonates, form a second phase that marks the initiation of a tectonically and environmentally controlled restriction of sedimentation which remains evident during most of the remainder of Devonian sedimentation.

Clastics in the form of sand, silt, and shale were supplied to the area during the second episode of Winterburn time. The amount of clastic material, diluted to varying degrees with carbonates, and evaporites, is quantitatively not great except in those areas which were presumably nearest to two separated source areas. Evidence is present of a clastic depositional basin marginal and west of the intracratonic evaporite basin.

The evaporite deposits of the basal unit of the Wabamun group constitute by far the greatest thickness of strata studied. Post-depositional solution of the extensive salt and anhydrite deposits make necessary reconstruction of both isopachous and lithofacies maps. The thickness and patterns of sediments in the west suggest a tectonic and environmental history wherein the major factor in the restriction of the evaporite basin is a carbonate buildup which is petrographically and physiographically similar to the Bahama Banks.

The uppermost unit of the Wabamun in the area signals a return to normal marine and unstable shelf conditions—a forerunner for the deposition of the shales of the overlying Mississippian.

Prospective horizons for hydrocarbon accumulation occur at the transition between the Wabamun "Banks" and the evaporite basin, and in the organic deposits of the lower Winterburn.

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Facies Relationships in Mississippian of Williston Basin and Their Effects upon Fluid Migration

A study of available sample longs of the Mississippian Madison carbonates and chemical sediments of the Williston basin reveals a sequence of limestone types which grade from deep, quiet-water limestones through shallow, open-marine shelf-type limestones into a shallow, agitated-water clastic limestone of a barrier shoal facies. These units grade updip into a depositional environment of restricted circulation characterized by evaporites. The three major stratigraphic units are Lodgepole, Mission Canyon, and Charles. Each of these units can be traced through all or part of this sequence. In the center of the basin the individual units generally display this pattern in the following manner: the Lodgepole formation is representative of a fairly quiet, deep-water environment indicated by fine-grained, argillaceous carbonates with rare fossil remains, some chert, and here and there some pyrite. The dominant lithologic character of the Mission Canyon formation consists of finely crystalline to chalky matrix enclosing bioclastic remains and carbonate pellets with some true oölites, indicating deposition under moderately shallow conditions of open-marine environment. The Charles formation is composed of evaporites and fine-grained argillaceous limestones with zones of fossil remains, pellets, and oölites, and is representative of lagoonal, shallow and/or restricted water deposition. No formation is wholly barrier bank lithologically, but characteristic barrier lithologic type consisting of texturally mature bioclastics can be seen locally in all three units. Reservoir characteristics of porosity and permeability within the barrier zone are directly related to the degree of textural maturity, in that primary porosity and permeability are greater in sediments which have undergone better rounding, sorting, and winnowing by wave action.

The fine-grained, argillaceous sediments of the basin deposits though locally porous, have only sub-capillary openings and present considerable resistance to fluid flow because of surface fraction between the carbonate particles and the fluid medium. The shelf-type carbonates, though containing abundant clastic material, show a very low degree of textural maturity, and here also, surface fraction of sub-capillary openings inhibits free movement of fluids. The texturally mature clastic limestone within the barrier-bank facies furnishes the best avenues for fluid movement and also the best reservoir rock. The presence of sparry calcite cement in the texturally mature calcarenites of the barrier indicates a high degree of original porosity and permeability. A potential reservoir cemented with sparry calcite or sparry anhydrite could retain its original porosity in an updip direction if a trap is present. The concepts of mineral cements and of textural maturity previously applied to sandstones should be extended to include clastic limestones.

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Mississippian of Four Corners Region

All of the recognized tectonic features in the Four Corners region appear to be post-Humbug