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

(Meramecian) in age and therefore had no influence on the earlier deposition of Mississippian sediments. The Mississippian system in this region is represented by the Madison, Leadville, Redwall, Humbug, and Manning Canyon formations. The Humbug and Manning Canyon formations are present only in the northwestern part of the area, due to erosion of the Humbug and the fact that the Manning Canyon was deposited only in the area of the Oquirrh basin of central Utah. At the close of Humbug time, strata of the Mississippian system formed the eastern shelf of the Cordilleran miogeosyncline, and was exposed over the positive area of the Southern Colorado Plateau, now known as the Paradox, Black Mesa, and San Juan basins.

The possibilities of finding oil and gas accumulations in the thick, commonly porous, carbonate sediments of Mississippian age are favorable along the Cordilleran shelf, or hinge area. Both stratigraphic and structural conditions are favorable in this area. The only Mississippian oil production in Utah is in the Paradox basin at the Big Flat unit, discovered in 1957 by the Pure Oil Company. The complex, subsurface, structural conditions of the Mississippian strata, in the Paradox basin, imply excellent possibilities for oil accumulation in structural traps.

It is concluded that there is a Cordilleran shelf or hinge area in south-central Utah and that the Mississippian formations can probably be correlated throughout the Four Corners region.

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Dakota Stratigraphy in San Juan Basin

Subsurface stratigraphic study of the Dakota formation in the San Juan baisn area of northwestern New Mexico and southwestern Colorado has been facilitated by (1) published stratigraphic sections along its outcrop, (2) good distribution and density of well control, and (3) presence of a persistent, superjacent marker—the Greenhorn limestone (zone of *Inoceramus labiatus*).

The Dakota formation is the basal sandstone of an early Late Cretaceous transgression that probably reached its maximum extent in this area during latest Greenhorn time. It overlies a rather even erosion surface developed on the Morrison and Burro Canyon formations.

The Dakota may be divided into three units in the San Juan basin area. The lower unit is predominantly non-marine and generally consists of a basal conglomeratic sandstone overlain by carbonaceous shales that commonly contain thin coal beds and lenticular sandstones.

Overlying the basal Dakota and grading upward into the Graneros shale is a 30–100-foot-thick transgressive middle unit, predominantly sandstone, that becomes progressively younger from east to west. These middle Dakota sandstones probably were deposited as nearshore sands along the westward margin of the advancing Cretaceous sea during Belle Fourche and early Greenhorn time. Careful correlation in the subsurface and between the subsurface and outcrop sections shows the interval between the base of the Greenhorn and the top of the middle unit to be more than 200 feet in thickness in the southeast part of the basin, about 150 feet in the southwest and northeast part, about 100 feet in the west-central part, and less than 50 feet along the west and northwest margins. These and other relationships suggest that regionally middle Dakota strand lines, unlike those of succeeding Upper Cretaceous strata, trend northeast-southwest in the southern part of the basin and north-south in the northern part.

The sandstones of the upper unit of the Dakota intertongue with the Graneros shale and are developed in one or more correlative intervals below the Greenhorn limestone. They commonly occur as lenses, are early Greenhorn in age, and have been referred to as "Tres Hermanos sandstone" in outcrop sections along the southern border of the basin and as "Graneros sands" in the subsurface. These sandstone tongues probably represent minor regressive phases resulting from local increase in sand supply during the major Dakota transgression. The uppermost interval of widespread sandstone development occurs about 30 feet below the base of the Greenhorn and locally is more than 50 feet thick in the southwest part of the basin. Its distribution and northeast pinch-out suggest the source of the sand was at the southwest and that by the time of its deposition regional northwest-southeast "trends" had been established.

Present Dakota production is largely from stratigraphic accumulations in the San Juan basin and from structural accumulations in the platform area along its northwest margin. The variations in shoreline trend during Dakota deposition suggest diverse orientation of trends for new Dakota discoveries.

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Marine Redbeds in Central Colorado Basin

Considerable, difference of opinion is reflected in geologic literature concerning the environment of deposition of redbeds. Many geologists apparently assume that red coloration (hematite) in sediments can be preserved only under conditions of subaerial deposition, and they therefore assume that all redbeds are continental sediments. These assumptions are not valid. If an adequate source of hematite is available, redbeds can originate in any environment, continental or marine, in which