onstrated by stratigraphic cross sections. By means of the same media it can be shown that the Custer anticline and the Delphia structure were both relatively high in pre-Piper time, because the Amsden at both places is thinner than that in nearby off-structure wells. This gives evidence for postulating that these two Laramide structures had some expression in post-Amsden, pre-Piper time. The same "thins" show up in Amsden isopachous maps.

The Amsden formation in central Montana produces commercial quantities of oil at the Wolf Springs, Delphia, Gage, and Big Wall fields. Stratigraphic studies of the productive intervals at Wolf Springs and Delphia and the surrounding area show that reservoir space in the form of vugs and fractures has been developed in the dense upper dolomite part of the Amsden. Development of such vuggy porosity came about as a result of the dolomite being exposed to a prolonged period of pre-Piper sub-aerial erosion in this general area. Fracturing along pre-Laramide structural highs (later modified by Laramide folding) provided solution channels for ground-water movement. Typically, the Amsden pay is a dense, light-colored dolomite, commonly cherty, vuggy, and fractured. In some places it is breccia-like in appearance and may include chert in the form of irregular inclusions and vug linings. Very little, if any, porosity is intercrystalline.

Subdivision of the Amsden is possible by the use of electric logs. The Amsden can be divided into upper and lower zones stratigraphically on the basis of using a persistent low-resistivity kick as the dividing line. Both zones produce oil. Either can be considered a possible reservoir, depending on whether that part of the section is subjacent to the Piper and hence was exposed at the unconformity surface by erosion.

J. E. Renaud, Consultant, Calgary, Alberta

Provost Gas Field, Alberta, Canada

The Provost gas field is located in east-central Alberta about 172 miles northeast of Calgary, Alberta, Canada. It is typical Upper Cretaceous gas field and one of the most important shallow (2,690 feet) gas accumulations in Alberta.

Gas production is from the sand member of the Viking formation. There are 63 gas wells in the field and ultimately about 394 gas wells will be on production. The proved and probable gas reserves are 926 billion cubic feet and they cover an area of 333,853 acres. The average reservoir pressure is 850 psi. The gas reserve is committed for sale to the Trans-Canada pipeline system and at present 33 million cubic feet per day is being sold. The accumulation of gas in the Provost field is due to updip pinch-out of the Viking sand, in turn overlain by Colorado shales. Other gas fields of similar type, such as the Viking-Kinsella are present in east-central Alberta. Planned wildcat drilling will probably uncover similar accumulations in the prospective east-central Alberta belt.

J. W. Rold, The California Company, Denver, Colorado

New Windsor Oil Field, Dual Stratigraphic Trap

The New Windsor field, on the west flank of the Denver basin 50 miles north of Denver, produces oil from two superposed stratigraphic traps. The shallower is an updip sand pinch-out of the Upper Cretaceous Sussex sand at 4,200 feet. The deeper is an updip permeability barrier in the Permian Lyons sandstone at 9,000 feet.

The discovery of the field provides an illustration of the successful integration of geophysical, stratigraphic, and structural geology. The first well, located on a seismic structure, found the Lyons tight, with an oil show, and encountered no Sussex. A second well, located down the northeast plunge of the structure, encountered porous, permeable Lyons and Sussex sands and proved potential stratigraphic traps. A third well, Calco's Brunner No. 1, which was located between the two, indicated commercial production from both the Sussex and Lyons and was completed for 108 barrels of 41° oil from the Lyons.

Seismic and subsurface data show the New Windsor structure to be a northeast-trending anticline approximately 6 miles long and 2 miles wide. The traps are formed by the nearly coincidental transection of the northeast plunge of the anticline by the Sussex pinch-out and the Lyons permeability barrier.

The Sussex, which is called the second or middle Hygiene along the Front Range and is correlative with the Sussex of the Powder River basin, consists of a series of coalescing bar-like sands 6–12 miles wide from east to west and at least 100 miles long north and south. Five wells are currently producing oil from the updip pinch-out of this "bar."

The Permian Lyons sand is fine-grained, cross-bedded and well cemented by silica and anhydrite. The only apparent stratigraphic change across the field is an abrupt loss of porosity and permeability from east to west. A dry hole east of production cored 62 feet of porous sand with 2,436 millidarcys permeability. A dry hole west of production had a total permeability of only 1.8 millidarcys. Three wells are currently producing oil from the Lyons.

Stratigraphic traps in the Lyons and Sussex sandstones are proved by the small but significant

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

GRANT STEELE, Gulf Oil Corporation, Denver, Colorado

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