8. WILLIAM R. KEEFER, U. S. Geological Survey, Denver, Colorado

GEOLOGIC HISTORY OF WIND RIVER BASIN, CENTRAL WYOMING

The Wind River basin was part of the stable shelf region that lay east of the Cordilleran geosyncline during Paleozoic and much of Mesozoic time. Rocks representing all systems except possibly the Silurian were deposited across the area during repeated transgression and regression of the epicontinental seas. Most formations are thicker and more complete in the western part of the basin than in the eastern part, and some units disappear eastward owing to truncation or nondeposition. Depositional environments, generally marine, were often influenced locally by slight fluctuations in sea level or by tectonic movements. The latter were limited to broad upwarping and downwarping along trends which, with few exceptions, show little direct relation to structural trends developed later during Laramide deformation.

Near the close of the Jurassic, highlands began to form in the geosynclinal area west of Wyoming, and the major sites of deposition shifted eastward. During Late Cretaceous time the seaways lay in eastern Wyoming, and a thick sequence of alternating transgressive, regressive, and nonmarine deposits accumulated across the Wind River basin area. The latest marine invasion (represented by the Lewis Shale) covered only the eastern part of the basin.

Laramide deformation began in latest Cretaceous time with downwarping of the basin trough and broad doming of parts of the peripheral areas. The intensity of movement increased through the Paleocene, and culminated in earliest Eocene time in high mountains that were uplifted along reverse faults. A complete record of orogenic events is preserved in the more than 20,000 feet of fluviatile, paludal, and lacustrine strata that accumulated in the areas of greatest subsidence during this period.

Basin subsidence and mountain uplift had virtually ceased by the end of Early Eocene time. Clastic debris eroded from the mountains, augmented by volcanic debris, continued to fill the basin during the later stages of Tertiary time. Near the end of the period the entire region was elevated several thousand feet above its previous level, and the present cycle of erosion was initiated. Normal faulting, perhaps concomitant with regional uplift, locally modified the older structural features.

9. ELMER H. BALTZ, U. S. Geological Survey, Albuquerque, New Mexico

TECTONIC AND SEDIMENTARY HISTORY OF RATON BASIN AND NOTES ON SAN LUIS BASIN

RATON BASIN

The Raton basin of northeastern New Mexico and southeastern Colorado is a Laramide structural basin bounded on the west by the Sangre de Cristo uplift, on the north by the Wet Mountains uplift and Apishapa arch and on the east by the Sierra Grande and Las Animas arches. The basin is strongly asymmetrical and the northerly-trending axis is near the Sangre de Cristo uplift. The intrabasinal Cimarron arch separates the structurally deeper northern part of the Raton basin from the shallower, southern, Las Vegas subbasin.

During most of Paleozoic time the Raton basin and its bounding uplifts were part of the relatively stable "Continental backbone." The oldest known sedimentary rocks in the basin are Devonian (?). In Early Pennsylvanian the Rowe-Mora basin was formed in the area of the present Sangre de Cristo uplift and the western half of the present Raton basin. The Rowe-Mora basin was bounded on the west by the intermittently rising San Luis uplift and on the east and north by the ancestral Sierra Grande Apishapa and Wet Mountains uplifts. An unstable-shelf facies of the Magdalena Group of Pennsylvanian age in the southern part of the Rowe-Mora basin is 1,500–2,500 feet thick. These rocks grade abruptly northward into a geosynclinal facies which is as much as 6,000 feet thick in the Las Vegas subbasin. The Magdalena Group is absent from the Cimarron arch, but it probably is present in the western half of the northern part of the Raton basin where it may be 4,000 feet thick. Orogenic debris of the Sangre de Cristo Formation of Pennsylvanian and Early Permian age was derived mainly from the San Luis uplift, filled the Rowe-Mora basin, and lapped into Precambrian rocks of the other bounding uplifts. The Sangre de Cristo Formation is 700–3,500 feet thick at the south, and 6,000–10,000 feet thick at the north.

Higher Permian rocks and Upper Triassic and Upper Jurassic rocks have average aggregate thicknesses ranging from 2,300 feet at the south to 1,100 feet at the north. These deposits blanketed the entire region and buried most of the late Paleozoic uplifts. Cretaceous shales interbedded with some sandstones also blanketed the region. These rocks are about 4,500 feet thick at the north, and remnants in the Las Vegas subbasin are 900–1,000 feet thick.

The latest Cretaceous and early Tertiary rocks, which are about 12,000 feet in aggregate maximum thickness in the northern part of the Raton basin, were derived mainly from the rejuvenated San Luis uplift. During early and middle Tertiary the western part of the Paleozoic Rowe-Mora basin was elevated to form the Sangre de Cristo uplift, and the present Wet Mountains uplift and the Apishapa, Las Animas, and Sierra Grande arches were formed.

SAN LUIS BASIN

In late Tertiary the San Luis uplift was tilted eastward and its eastern part foundered to form the northern part of the complex Rio Grande trough. The San Luis basin in southcentral Colorado is the northeastern part of this tilted and faulted block. The western part of the basin merges into the eastern flank of the San Juan dome. The eastern and northern boundaries are a complex fault zone along the western margin of the Sangre de Cristo uplift which merges, around the northern end of the basin, with the Sawatch and Gunnison uplifts.

Much of the San Luis basin is filled with upper Tertiary and Quaternary sediments and interbedded andesites and basalts that are at least 2,000 feet thick locally. This basin fill rests on lower and middle Tertiary volcanics that are related to the volcanics of the San Juan Mountains. Because the region of the San Luis basin was a part of the Paleozoic and Laramide San Luis uplift, it is doubtful that extensive areas of Paleozoic and Mesozoic rocks are preserved beneath the volcanics.

10. H. R. OHLEN and L. B. McINTYRE, Shell Oil Company, Farmington, New Mexico

STRATIGRAPHY AND TECTONIC FEATURES OF PARADOX BASIN, FOUR CORNERS AREA

The Paradox is a northwest-southeast elongate structural and sedimentary basin, bounded on the east and northeast by the San Juan Mountains and the Uncompahgre Plateau of Colorado, on the south by the Defiance Plateau of Arizona and New Mexico, and on the west by the San Rafael swell of Utah. Approximately 20,000 feet of sediments are preserved within the Permo-Pennsylvanian basin. Surface exposures are mostly sediments of the Mesozoic System, represented by a few thousand feet of clastics. The La Plata, Carrizo, Abajo, and La Sal Mountains are Tertiary intrusives within the Paradox basin.

The thin early Paleozoic sediments transgressed easterly onto the northeast-southwest trending transcontinental arch with the Cambrian sandstones separated from the Devonian-Mississippian shelf carbonates by an Ordo-Silurian hiatus. Exposure of the Mississippian carbonates resulted in a karst-like regolith, the Molas Formation of Atokan and/or earliest Pennsylvanian age. Tectonic influence then gave a northwest-southeast structural grain to the Paradox basin, in which Pennsylvanian cyclic or rhythmic shelf carbonates, sapropelic "black shale" dolomites, evaporites and arkose-redbeds were deposited. Approximately 2,000 feet of shelf carbonates were deposited on edges of the basin where highlands were not present. Evaporites were deposited in the center and distal northwest end of the basin and reach a present thickness of 10,000+ feet as the result of salt flowage in the cores of the intrusive salt anticlines. The many thin sapropelic dolomites are widespread throughout the basin and are the "time-markers" used for correlation. Clastics shed from the Uncompahgre and San Luis uplifts resulted in several thousand feet of arkose and redbeds ("Pennsylvanian" Cutler Formation) being deposited on the northeast and east flanks of the basin. These highlands persisted through Permian time and similar clastic deposition ("Permian" Cutler Formation) continued, depositing a thick wedge of arkose near the Uncompahgre front, which thins to the southwest to 2,000 feet of continental redbeds and eolian and marginal marine sandstones of the Cedar Mesa, Organ Rock, and De Chelly Formations.

Approximately 3,000 feet of Jurassic-Triassic continental shales and eolian sandstones were deposited over the Permo-Pennsylvanian basin and highlands. These sediments are exposed over the western two-thirds of the Paradox basin. Upper Cretaceous marine clastics, exposed at the eastern edge of the basin, are equivalent to a continental facies in western Utah.

The primary structural grain of the Paradox basin is a northwest-southeast lineation paralleling the Uncompahgre uplift of Permo-Pennsylvanian time. This alignment is illustrated best by the several salt anticlines. Laramide tectonics both rejuvenated the older trend and developed new structural lineations such as the north-south striking Monument upwarp. Regional uplift, coupled with the development of peripheral Tertiary basins, has placed the Permo-Pennsylvanian Paradox basin in a high structural and topographic position incised by deep superimposed drainage.

11. M. D. QUIGLEY, Pacific Natural Gas Exploration Company, Los Angeles, California

GEOLOGIC HISTORY OF PICEANCE—EAGLE BASIN

The Piceance and Eagle basins represent the present expression of the Maroon trough or basin that started to develop in Early Pennsylvanian time. It extended across northwest Colorado and was bounded by the positive elements of the Front Range on the northeast and the Uncompahgre on the southwest. The early sediments are clastics, carbonates, and evaporites resulting from cyclic marine transgressions and regressions in the narrow trough. The evaporites are of the basin-center type, according to Sloss, but strongly affected by contemporaneous clastic deposition. The growth of the Front Range in Morrowan time and the uplift of the Uncompahgre in Desmoinesian time contributed large volumes of sediments to the trough during the regressions, which became interbedded with the evaporites.

The coarse clastics from the Front Range and Uncompahgre continued to strongly influence the sedimentary types of the Maroon basin throughout the Triassic and Jurassic deposition, with the predominant type being arkoses and redbeds. In Cretaceous, the area was inundated by the Cretaceous sea where the sedimentation was black shales, marine sands, bars and beach deposits. In Upper Cretaceous the entire basin became a shallow sea with paludal and lagoonal sediments, such as coals, shales, and underclays being interbedded with shoreline sands in response to fluctuations of the sea. Some of the older structural features, such as the Douglas arch, began to influence sedimentation during Upper Cretaceous, as evidenced by thinning in the Mancos Shale over the arch.

After prolonged sedimentation, the Maroon basin was uplifted at the end of Mesozoic time, and folded and faulted by the Laramide orogeny. The Sawatch Range, White River uplift, and the Uinta Mountains came into being in successive stages of the orogeny to separate the Maroon basin into the present tectonic basins; namely, the Piceance basin, the Eagle basin, the Axial basin, the Coyote basin, and the Sand Wash basin. Many of the present-day structural features were formed during the long period of orogeny from Late Cretaceous to early Tertiary time.

Sedimentary types have been most important in determining the reservoirs for the accumulation of oil and gas following the Laramide period of orogeny. Virtually all the oil and gas in the Paleozoic in the Maroon basin has been produced from the Weber Sandstone. It is a lithologic facies having some permeability and effective porosity, that was at the same time sufficiently brittle to fracture. The porosity and permeability alone are insufficient in many of the fields to support commercial rates of production. In addition to the sedimentary type, folding has been all important in establishing substantial reserves with respect to the Paleozoic accumulations.

The same control of the fracturing and sedimentary type applies to Cretaceous and Tertiary reservoirs in the Piceance basin, even though the role of folding is not a prime prerequisite to accumulation. All the important Cretaceous and Tertiary oil and gas fields are related to the local improvement of porosity and permeability above and beyond that normal to the marine shales encasing the reservoirs.

In contrast to the normal relationships of gas, oil, and water found in the Paleozoic reservoirs, many of the same relationships are reversed in the Cretaceous and Tertiary reservoirs. The relationships are similar to those in the San Juan basin and may have a similar explanation. More realistically, the explanation may be the indigenous nature of the oil and gas, where the migration has been limited to reservoirs in juxtaposition with the source beds.

Successful exploratory programs must be cognizant of the fact that the location of the areas of improved porosity and permeability became the primary reason for success. That success can be frustrated by inappropriate drilling and completion methods.