cycles that significant reserves of oil and gas have been discovered. In the Upper Cretaceous, a major transgression joined the northern and southern seas into a large seaway crossing the downwarping basin, and lapping against the uplifted Front Range. This Laramide tectonic activity reached its peak during the Eocene with the basin acquiring its present configuration.

22. LEONARD E. THOMAS, Marathon Oil Company, Casper, Wyoming

GENERALIZED HISTORY OF SEDIMENTATION AND STRUCTURAL DEVELOPMENT OF BIG HORN BASIN

The Big Horn basin of northwest Wyoming is primarily a Laramide structural basin. The area has been a portion of larger sedimentary basins throughout most of geologic history.

The basin is located on the eastern shelf of the Cordilleran geosyncline, east of the hinge line separating the shelf from the former deep parts of the syncline.

Local structural deformation on the sites of several Laramide anticlines in the basin is suggested by slight thinning noticeable in strata of Ordovician age. Local structural influence upon the present-day basin, however, is not evident until at least as late as the beginning of Upper Cretaceous.

During the pre-Laramide eras, periods of regional movements indicate a "see-saw" action with repeated northerly tilting, deposition, emergence and erosion which resulted in truncation of the Ordovician, Devonian and Mississippian sediments from north to south. There is a complete absence of Silurian sediments.

During Pennsylvanian, Permian and Triassic, the area of the present-day basin underwent southerly tilting, deposition, erosion and truncation that resulted in the formations thinning from south to north.

Jurassic and Lower Cretaceous formations show an increase in thickness from south to north. They also show the development of a low-relief structural arch that appears to be the buried, northwest-plunging nose of the Casper arch and Laramide Range in south and central Wyoming.

By the beginning of Upper Cretaceous time the embryo of a structural basin may have been present which affected some of the basal sands of the Frontier Formation.

Later transgressions and regressions of the Upper Cretaceous seas continued until the Laramide Orogeny came into strong evidence at the beginning of Fort Union time. The period of intense movement continued into Eocene with thrust faulting followed by deposition and partial erosion of volcanics on the western margin of the basin.

This movement resulted in peripheral mountain building, pronounced unconformities at the margins of the basin, the development of conglomerates in the Tertiary beds, and the development of the intense anticlinal folds preserved today.

23. BERNARD E. WEICHMAN, Superior Oil Company, Casper, Wyoming

GEOLOGICAL HISTORY OF THE POWDER RIVER BASIN, WYOMING

Precambrian igneous and metamorphic rocks underlie the Powder River basin. Their distribution is uncertain because of lack of subsurface control.

For the purpose of this paper the geologic section is divided into eight rock units. Some of these rock units cross time boundaries between periods.

Rock Unit 1 includes Cambrian and Lower Ordovician sediments deposited by a sea that began transgressing eastward during Middle Cambrian time and regressed at the close of Lower Ordovician time. Following this regression all sediments in Rock Unit I were eroded from the extreme southeastern part of the Powder River basin.

Rock Unit 2 is bounded by the "St. Peters Break" of post-Lower Ordovician time at the base and the Upper Silurian unconformity at the top. The sea in which these beds were deposited transgressed southward from the Williston basin. Sediments of this unit thin southward due to Upper Silurian erosion.

Rock Unit 3 includes the predominantly carbonate rocks of Devonian and Mississippian age. Four unconformities can be mapped within this unit; one at the top of the Devonian, one between the Lower and Middle Mississippian, one between the Middle and Upper Mississippian and one at the top of the Mississippian. Widespread karst topography characterizes the upper surface of the unit at the top of the Mississippian.

Rock Unit 4 includes the Pennsylvanian and Lower Permian rocks. Lower Permian tectonics and erosion breached folds subsequently buried under Unit 5.

Rock Unit 5 includes the Permian and Triassic redbeds and associated carbonates and evaporites. Large-scale uplift and erosion prior to Jurassic formed an unconformity at the top of this unit.

Rock Unit 6 includes all Jurassic rocks and the transition sediments at the base of the Cretaceous.

Rock Unit 7 begins with the transgression in Early Cretaceous time and the deposition of a dominantly shale sequence subdivided by four economically important regressive cycles. The top of Rock Unit 7 is the top of the Cretaceous, a major and early pulse of the Laramide orogeny.

Rock Unit 8 includes all beds of Tertiary age. The present-day configuration of the Powder River basin and the major structures and fault systems were formed at this time (Laramide orogeny). Tertiary sedimentation was controlled by the present basin outline. Previous sedimentation was related to tectonic features of a much broader area than the Powder River basin.

24. S. B. ANDERSON and C. G. CARLSON, North Dakota Geological Survey, Grand Forks, North Dakota

SEDIMENTARY AND TECTONIC HISTORY OF NORTH DAKOTA PORTION OF WILLISTON BASIN

The Williston basin is a structural and sedimentary basin which covers 51,600 square miles in North Dakota and contains sedimentary rocks of every geologic period from the Cambrian through the Tertiary. The maximum known thickness is 15,128 feet in a well in McKenzie County in Western North Dakota.

The Upper Cambrian to Lower Ordovician Epochs are represented by the Deadwood Formation which represent stable shelf deposits extending eastward from the Cordilleran geosyncline. The Williston structural basin began in Middle Ordovician time with a relatively thin clastic sequence (Winnipeg Group) followed by predominantly carbonate deposition (Red River, Stony Mountain and Stonewall Formations). Carbonate deposition continued through Lower and Middle Silurian (Interlake Formation) followed by a period of erosion marked by a major unconformity.

During the Middle and Upper Devonian Epochs the Williston basin was a part of the larger western Canada basin of deposition which was marked by predominantly carbonate deposition with a thick evaporite in the lower part (Prairie Formation) and cyclical carbonates with some thin clastic and evaporite beds in the upper part

(Duperow, Nisku, Three Forks). Deposition was continuous or nearly continuous into the Mississippian, but the center of the Madison depositional basin was nearly coincident with the present Williston basin. It began with predominantly carbonate deposition with increasing evaporites in the upper part. The evaporites are mostly halite in the central basin area with anhydrite toward the flanks of the basin. Predominantly clastic deposition (Big Snowy Group) followed the evaporites and this was followed by another unconformity.

The Pennsylvanian and Permian periods are represented by clastics with minor carbonates (Minnekahta Formation) and some evaporites. This was a time of slight subsidence with the Williston basin area being part of a larger depositional area extending to the south and west. Similar conditions continued through the Triassic with fine grained clastics and some evaporites being deposited, followed by some non-marine redbeds and another unconformity.

The Williston structural basin had little effect on Jurassic or Cretaceous sedimentation so these periods are represented by eastward extensions of the predominantly fine grained clastics from the Rocky Mountain area seas. The Tertiary Period is represented by a wedge of predominantly non-marine beds which thickens westward toward the Rocky Mountain area.

EXPLORATION AND REVIEW PAPERS 1963–1964, ROCKY MOUNTAIN REGION

IRVIN KRANZLER, Independent Geologist, Billings, Montana

HIGHLIGHTS OF EXPLORATION IN MONTANA, APRIL, 1963–JULY, 1964

Exploration activity in Montana produced significant results in five widely separated areas:

(1) Northwestern Montana (Sweetgrass Hills area)—Oil was discovered in the Cretaceous Sunburst Sandstone in the old Fred and George Creek—Arch Apex gas field area. Also significant was the possible linking of Jurassic Swift Sandstone oil production of Whitlash and Flat Coulee fields.
(2) Northeastern Montana (Williston basin)—Nine new oil discoveries were made in Mississippian Mission Canyon, Devonian Nisku and Duperow, Silurian Interlake, and Ordovician Red River formations.
(3) Central Montana (Big Snowy uplift)—Pennsylvanian Amsden oil was discovered on Pole Creek anticline. Extensions to Keg Coulee field provided new emphasis for Pennsylvanian Tyler Sandstone prospects.
(4) South-central Montana (Big Horn basin)—Pennsylvanian Tensleep oil was discovered below a known gas cap in Northwest Elk basin field.
(5) South-central Montana (Powder River basin)—The first discoveries of Tensleep oil in many years breathed new life into a long dormant part of the basin.

These events, along with recent renewed interest in previously ignored areas such as the intermontane basins of southwestern Montana, should ensure a high level of exploration activity throughout Montana in the months ahead.

DAN E. HANSEN and JOHN N. KLEMER, North Dakota Geological Survey, Grand Forks, North Dakota and Consulting Geologist, Bismarck, North Dakota

REVIEW OF EXPLORATION AND DEVELOPMENT IN NORTH AND SOUTH DAKOTA; 1963 AND FIRST HALF OF 1964

Development and exploration in North Dakota during 1963 was down from 1962. Exploration activity increased during late 1963. The area which received the most attention was the north-central portion of the state where the pools are chiefly found in stratigraphic traps.

There were 183 wells completed in North Dakota during 1963 and of these, 73 were wildcats. There were 9 discoveries for a wildcat success of 12.3%. Field and outpost wells numbered 110 with 76 producers. Perhaps the most significant discovery of 1963 was the Ordovician Red River production found in the Fryburg-Scoria field of Billings County. The other wildcat discoveries were found in the north-central part of the state.

There were 12 wildcats drilled in western South Dakota during 1963 with no discoveries. A total of five new producers were drilled in the known fields of Custer and Harding Counties. The highlight of activity in the state during 1963 was a widespread lease play.

A considerable increase in exploration activity has taken place in North Dakota during the first six months of 1964. The leading county in number of discoveries is Renville where four wildcats have been found productive. The most significant discovery has been the Mouse River Park field.

Drilling in South Dakota during the early part of 1964 has been confined to the western part of the state with most of the activity centered in Custer and Harding Counties.

RICHARD O. DONLEY, Cities Service Oil Company, Casper, Wyoming

GEOLOGICAL EXPLORATION AND DEVELOPMENT IN WYOMING, 1963–1964

Oil and gas activity in Wyoming in 1963 and so far in 1964 was highlighted by interesting discoveries and developments which could have a far-reaching effect on future exploration in the state. In the way of what might be termed new and startling were: a Cretaceous Lewis Sandstone oil discovery at a rank wildcat in the Hanna basin; stratigraphic Tensleep accumulation discovered on the north side of the Big Horn basin; two widely separated Cretaceous Lakota Sandstone discoveries in the Powder River basin; a flurry of shallow Cretaceous Turner Sandstone drilling, also in the Powder River basin; experimental fire flooding and steam flooding at several places in the state; and two deep wells, Shell's 20,000-foot Madison test at Pavillion in the northwest portion of the Wind River basin and Texaco's 15,000-foot Jurassic Nugget gas well at Table Rock field in the Washakie basin.

The old standbys continued to furnish new reserves—the Minnelusa, Muddy, and Fall River (Dakota) reservoirs in the Powder River basin, and the Tertiary and Late Cretaceous oil and gas sandstones on the Big Piney La Barge platform in the Green River basin. At the Timber Creek field in the Powder River basin, discovered late in 1962, 1.5 million barrels of oil was produced during 1963. At Birch Creek, also discovered in 1962, on the La Barge platform, over 1.1 million barrels of oil was produced in 1963.

ROBERT P. KUNKEL, Consulting Geologist, Salt Lake City, Utah

EXPLORATION ACTIVITY AND OIL AND GAS DEVELOPMENT IN UTAH, NEVADA AND IDAHO SINCE JANUARY 1, 1963

Two significant developments which took place in Utah during the past 20 months are expected to strongly