The Oquirrh basin contains Pennsylvanian and Early Permian sedimentary rocks as much as 26,000 feet thick; the area of maximum sedimentation was in west-central Utah. Three principal units are recognized: a lower unit of cyclically bedded bioclastic limestone and sandy limestone, a middle unit of interbedded limestone and quartzite, and an upper unit of quartzite. The lower and middle units were mostly deposited in an offshore shallow water environment; the upper unit in offshore moderately deep water; these grade laterally both eastward and westward into shallow nearshore facies.

The Middle Permian Phosphoria basin was partly coextensive with the Oquirrh basin, but the area of maximum sedimentation was in northeastern Nevada and southern Idaho, where locally 3,500 feet of shale, cherty shale, chert, dolomite, and limestone accumulated. This facies was deposited in an offshore deep-water environment, favoring formation of thick sponge-spicule chert and cherty shale units; these grade southward and eastward into carbonates and shales that were deposited in shallow nearshore environment.

In Cretaceous time the Paleozoic and early Mesozoic rocks of northeastern Nevada and western Utah moved eastward on great thrust plates that extended from southern Utah into Idaho. Movement took place on the Willard-Charleston-Nebo thrust belt in the Wasatch Mountains. Westward continuations of these thrusts crop out in northwestern Utah and eastern Nevada. Imbricate thrusts and tear faults within the upper plate have resulted in complex distribution of late Paleozoic facies.

17. J. G. C. M. FULLER, Amerada Petroleum Corporation, Calgary, Alberta

INDUSTRIAL BASIS OF STRATIGRAPHICAL GEOLOGY

An unprecedented need for a new source of mechanical power in 18th century England, capable of functioning at rates beyond horse-power capacity, was met by coal-fuelled atmospheric engines. They propelled the country into an industrial revolution. Economic force-exerted by big population changes greatly altered husbandry, industry, and transportation. Acts of Parliament relating to surveying and draining of lands, mines, and construction of roads and canals multiplied six-fold in the second half of the century.

A land drainer and mineral surveyor, in the course of canal-building in the east Somersetshire coal-field, discovered and then exploited the stratigraphical principle of natural order and regularity in fossil occurrence—each Class assigned to its peculiar Stratum (William Smith, 1796). He had employed the prime stratigraphical principle of order and regularity among the strata (drawing on colliers' lore and probably a published record), during underground surveys of the mines (1791–93). Seventy-two years earlier a wide-ranging account of the same coal-field had illustrated a definitive succession, strike, dip, subcrop, outcrop, concealed faulting and unconformity (John Strachey, 1719), and established by direct measurement underground that "the *Strata* lye shelving and regular, and observe a regular course." It codified the colliers' tradition. A century later this knowledge, unchanged in principle but enlarged in scope, achieved generality in the academic realm.

18. FRANK E. KOTTLOWSKI, New Mexico Bureau of Mines, Socorro, New Mexico

SEDIMENTARY BASINS OF CENTRAL AND SOUTHWESTERN NEW MEXICO

Major sedimentary basins in this, the eastern part of the Basin and Range province, are the Orogrande and Pedregosa basins of Mississippian, Pennsylvanian, and Wolfcampian age, the San Mateo-Lucero and Estancia basins of Pennsylvanian age, the Carrizozo and Quemado-Cuchillo (Foster, 1957) evaporite basins of Leonardian age, the Early Cretaceous basin near the Hatchet Mountains, and the continental basins of vols canic piles of Late Cretaceous age near Elephant Butte and Steeple Rock. Numerous Cenozoic intermontane graben basins dot the region, with the southern part of a long north-south string of interconnected grabens now followed by the Rio Grande and called the Rio Grande structural depression. Sediments filling the Cenozoic basins are mainly of Late Miocene. Pliocene, and Pleistocene in age.

Pre-Mississippian Paleozoic rocks remain only south of about 33°45′ N. Lat. The basal Paleozoic unit, the Cambrian-Ordovician Bliss Sandstone, thickens depositionally southward and southwestward. The Early Ordovician El Paso Limestone thins northward due to intra-Ordovician erosion whereas the Middle and Late Ordovician Montoya Dolomite is relatively uniform in thickness where overlain by Silurian rocks. The Silurian Fusselman Dolomite thins northward partly due to erosion during Late Silurian and Early Devonian time. The Devonian shaly strata are relatively uniform in thickness, although marking the first large scale influx of clay and silt; as with all older Paleozoic rocks they appear to have been deposited in shallow epicontinental seas.

The Pedregosa basin was autogeosynclinal, receiving thick deposits of Middle Mississippian crinoidal limestones, Late Mississippian arenaceous calcarenites, Pennsylvanian limestones, and Wolfcampian interbeds of limestone, black shale, and redbeds. The Orogrande basin began as a poorly defined autogeosyncline in which siliceous Middle Mississippian limestones and Late Mississippian arenaceous calcarenites were deposited, then became zeugogeosynclinal during Late Pennsylvanian time as detritus was swept westward from the Pedernal landmass, and during Wolfcampian time was filled by limestones and shales that grade northward into redbeds. The Estancia basin was a small Pennsylvanian zeugogeosyncline, and the San Mateo-Lucero basins were autogeosynclines connecting the Pennsylvanian seas northward toward the San Juan and Paradox basins.

19. JOHN EMERY ADAMS, Consultant, Midland, Texas

STRATIGRAPHIC-TECTONIC DEVELOPMENT OF DELAWARE BASIN

The Delaware basin of west Texas and southeast New Mexico is the most negative structural unit of the southern Permian basin. It occupies an upper Paleozoic intermontane trough between the Central Basin Platform Mountains and the Ancestral Rockies. Before the development of these ranges, this area formed part of the broad Tabosa sag which accumulated shelf deposits from Lower Ordovician through Mississippian. These sediments consisted largely of carbonates and shallow water shales. The Delaware basin, as a structural and stratigraphic unit, began developing in Early Pennsylvanian. Extensive subsidence coupled with compressive faulting converted the axial portion of the Tabosa sag into the Central Basin Platform Mountains and raised the Diablo arch to the west. An east dipping half graben, the Delaware basin, developed between these uplifts. Water depths in the southern and eastern portions of this basin probably exceeded 2,000 feet throughout the Pennsylvanian. The deep areas are characterized by starved shale sections. Pennsylvanian shelf limestones cover the shallows along the north and northwest margins. Permian tectonism deepened the basin and elevated the marginal mountains. Fault displacements along the western edge of the Central Basin platform exceeded 12,000 feet. Shelf limestones were deposited on the marginal shallows, but turbidites and flysch poured in to practically fill the basin during the Wolfcampian. Subsidence continued during the Leonardian, which is characterized by bedded sands, dark limestones and dark shales. In the Guadalupian, the reef-bordered marginal limestone shelves began encroaching on the semi-starved sand and shale floored basinal area. This fore-stepping was checked when reef growths sealed off the seaward opening to the basin. Upper Permian, Ochoan, evaporites furnished the final filling for the structurally negative Delaware basin. Overlying Triassic terrestrials and Cretaceous shelf limestones show no evidence of a buried deep basin in the area.

20. JOHN C. OSMOND, Consulting Geologist, Salt Lake City, Utah

GEOLOGIC HISTORY OF SITE OF UINTA BASIN, UTAH

The Uinta basin in northeastern Utah includes an area of 9,300 square miles. The differential vertical movements which created the basin and its rim began in Paleocene or Eocene time, during the deposition of the Wasatch Formation. The synclinal axis of the basin trends easterly and is slightly convex northward. The basin is asymmetric with a broad gently-dipping south flank and a north flank which is up to 10 miles wide with beds near vertical and locally overthrust.

The configuration of the Uinta basin is controlled in part by pre-existing structures and geologic trends, but much of the present rim is the result of Tertiary tectonics.

The dominant tectonic factor in the development of the basin is the rise of the Uinta Mountains block and the simultaneous subsidence of the synclinal axis of the basin. This major flexure in the crust probably conforms to the edge of the late Precambrian trough in which the rocks of the Uinta Mountains block were deposited. This belt of Precambrian rocks was essentially dormant until Eocene when it began to rise from depths of about 16,000 feet below sea level to elevations of 7,000 to 13,000 feet above sea level.

During lower Paleozoic the Uinta basin area was on a stable crust just east of the Cordilleran geosyncline. In the Pennsylvanian Period the Uncompahgre uplift formed a mountain range part of which now underlies the southeastern part of the present basin. This major tectonic feature had a northwest trend, and several small folds or faults with similar trends developed in the eastern part of the basin. These structures were gradually masked by Mesozoic sediments. Slight Tertiary upwarping and differential compaction allow some of these structures to be reflected as folds plunging into the eastern part of the Uinta basin.

In Cretaceous time the Rocky Mountain geosyncline occupied the region and received clastic sediments from the Cordilleran geanticline in western Utah. In Late Cretaceous time easterly directed compressive forces resulted in folding and over thrusting at the western edge of the Uinta basin area and possibly also caused slight arching of the eastern edge.

During Tertiary time western North America was elevated above sea level. Concurrent with this epeirogeny the mountain ranges and basins of the Rocky Mountain Region were developed by differential uplift. To the west of the Rockies the Basin and Range province was also elevated, and tilted fault-block mountains and valleys were created. This difference between the Rockies and the Basin and Range province reflects the difference in the Paleozoic between the stable block and the geosyncline.

The Uinta basin was outlined in Tertiary time by the central part not being elevated as high as its rim. The northern sector of the rim was the most active in pushing upward. The eastern and southern sectors of the rim were formed by the stable elements supported by the Douglas Creek arch and part of the Uncompahgre block. The southwestern sector of the rim was formed by the San Rafael swell, a Tertiary anticline formed by subsidence of adjacent areas and probably localized by an upper Paleozoic positive trend.

The western sector of the rim of the Uinta basin was created by the interplay of tilting of fault blocks above the eastern margin of the Paleozoic geosyncline and north-trending faults that developed over Mesozoic troughs which, in turn, were superimposed on the margin of the geosyncline.

The structure of the Uinta basin is the result of regional uplift of a heterogeneous area of the crust which incorporated both the sturdy and the weak, or weakened, products of prior deformations. The absence of intrusive igneous rocks is striking.

21. C. A. MARTIN, Continental Oil Company, Durango, Colorado

DENVER BASIN

The Denver basin is one of the largest structural basins in the Rocky Mountain area and extends across portions of Colorado, Nebraska, and Wyoming. The basin is typically asymmetrical with its axis paralleling and close to the Front Range. The deepest portion of the basin lies near Denver, where more than 12,500 feet of sediments are present.

Recently discovered outcrops suggest that during pre-Pennsylvanian time, the Denver basin area was a normal marine shelf receiving sediments from early Paleozoic seas. Post depositional uplift along Siouxia exposed this area to deep erosion removing nearly all the early sediments.

In Early Pennsylvanian time, transgressive seas entered the Denver basin area from the Anadarko basin, depositing a predominantly clastic terrane. Near the end of the Atoka, the first major pulses of the Ancestral Rockies occurred. This uplift reached maximum proportions during the Des Moines. Clastic material eroded from the uplifted mountains was deposited contemporaneously with marine sediments deposited in the expanding seaway. This expansion reached its maximum during the Missourian and was followed by a slight Virgil regression. Continued Permian regression left a full suite of environments and facies ranging from normal marine through an evaporitic sequence to terrestrial deposits. Late Permian and Triassic sediments indicate the Ancestral Rockies were weakly positive and supplied sediments to a shallow hypersaline sea. Non-depositional conditions persisted from Upper Triassic through Lower Jurassic, and into Mid-Jurassic time. During Middle and Upper Jurassic time, transgressive seas fluctuated across the basin from the northwest. As these seas regressed at the close of the Jurassic, a broad inland flood plain developed.

Early Cretaceous seas inundated the area from the north and south reworking earlier sediments and obscuring the Jurassic-Cretaceous boundary. Initial basin-forming movement occurred at this time. Fluviatile material from exposed areas to the east and northeast developed a complex deltaic pattern as it interfingered with marine sediments basinward. Deltaic deposits also extended into the area from the southwest merging with sediments from the east. Another cycle of transgression and regression developed similar depositional patterns. It is within these two Early Cretaceous sedimentary