opened in Ordovician time with development of a midgeosyncline hinge (the Manhattan line) which introduced the dual facies aspect. Dark, poorly sorted clastics in the outer belt were derived from tectonic island chains which rose within the belt itself (autocannibalism) while normal carbonates and clean sandstones accumulated in the inner belt. Folding and volcanism commenced in the Klamath Mountain area. Silurian and Devonian tectonic patterns resembled Ordovician.

During the Carboniferous, intensified tectonic activity was expressed as folding and thrusting on the approximate site of the old Manhattan hingeline to produce an uplift (Manhattan geanticline of Eardley) which shed conglomerates into both belts. Folding, volcanism, and deposition of clastics continued in northern California.

Further intensification of tectonic action occurred in the Permian, Triassic, and lower Jurassic periods. Profound subsidence of the outer belt accompanied deposition of autochthonous volcanics of regional extent and extreme thickness. A composite maximum of 70,000 feet (12 miles), centering in the California-Nevada area, dominated the entire outer belt. In addition, (1) strong tangential stresses produced local dynamometamorphism in the Sierra and Mohave areas of California in Permian time, (2) basic plutons were emplaced in central Oregon in Triassic time, and (3) ultrabasic intrusions of lower Jurassic age were injected in the Klamath area. These and earlier tectonic events indicate existence of a so-called Klamath tectogene in Washington, Oregon, and California. During the Mesozoic, midgeosyncline lands crowded the inner belt eastward, finally causing extinction.

Stage III was climactic orogeny involving not only folding and thrusting but regional dynamometamorphism and large-scale batholithic intrusion. Beginning in upper Jurassic time, batholithic emplacement in the Klamath tectogene reached proportions unequalled in North America since the Precambrian. Repeated impulses of folding and thrusting marched eastward during late Jurassic and Cretaceous time to culminate as thrusts of major magnitude (Lewis, Bannock, Strawberry, Muddy) at the Teton-Wasatch line.

Apparent post-orogenic relaxation of Stage IV caused collapse of the orogenic highland in the Great Basin. Extensive block faulting plus actual subsidence produced a Tertiary-Recent depositional basin (comparable with the Triassic of the Appalachian belt) which to-day exhibits internal sediment supply, and which in future may acquire a depositional history of some magnitude. Eventual broad, regional, epeirogenic uplift of the Cordilleran belt with associated erosional planation is predicted.

14. ARMAND J. EARDLEY, University of Utah, Salt Lake City
Thrust Belt of Northern Utah, Southwestern Idaho and Western Wyoming

The thrust belt of western Wyoming and adjacent parts of Idaho and Utah is arcuate eastward with the major thrust sheets having been overthrust toward the east. The northern end is crowded against the Teton—Gros Ventre—Wind River tectonic unit and the southern end against the Uinta Mountains mass. The distance between the buttressing elements is 180 miles. One thrust, the Absaroka has been traced the entire length of the belt; others are fairly long, and most have branch faults. The thrust sheets of the forward or eastern part of the belt are stacked in shingle fashion on each other, and for the most part dip fairly steeply at outcrop, although it is evident from stratigraphic displacements that horizontal movement has been considerable in a number of places. The imbricate thrusts of the eastern part of the belt involve mostly Mesozoic strata at the surface. In the back part of the belt is a master thrust called the Bannock, and it involves both Paleozoic and Mesozoic strata. The original view has recently been questioned that it is a great horizontal shallow thrust sheet that was later folded and eroded through in one place. Instead of one master sheet it may be a complex of several imbricate thrusts.

Sharp anticlines and synclines either in front of, or within, the Bannock thrust sheet have attracted the attention of petroleum geologists, and have been drilled without success. A disturbed belt in front of the thrusts involving Cretaceous and early Tertiary strata has been proved productive of oil and gas in several places. Considerable attention is now being given this belt. South of the La Barge oil field the thrust sheets are extensively covered by the lower Eocene Knight formation, and this renders exploration difficult.

15. HOWARD R. RITZMA, Southern California Petroleum Corporation, Denver
Structural Development of Eastern Uinta Mountains and Vicinity, Colorado, Utah, and Wyoming

During Proterozoic time an east-west trough along the site of the present Uinta Mountains, received 20,000 or more feet of sediments, the source of which was in uplands east and north. These sediments, the Uinta Mountain group, are mainly sandstone and quartzite in the eastern part of the range. They form an homogenous shallow-rooted "pod" imbedded in the earth's crust which has tended to act as a unit in subsequent orogenic events.

No known important orogenic events disturbed the area from Cambrian through most of Mesozoic time. Commencing during the deposition of the Mesaverde formation in late Cretaceous time and continuing into Paleocene time, a low north-south uplift, the present Douglas Creek arch and south end of the Rock Springs uplift, was folded across the Uinta "pod." In Paleocene and early Eocene time the Uinta arch, roughly coincident with the "pod," was cross-folded normal to the older uplift. The "pod" was forced upward and outward over adjacent basins by depression of these basins located north, northeast, and south of the position of the "pod" in the earth's crust. There was an apparent combination of overthrusting of the mountains and underthrusting of the basins. Further, the "pod" was propelled east by compressive forces pushing from the orogenic belts of southeast Idaho and central Utah. Faulting along the flanks of the Uinta arch occurs in a zone of multiple ruptures and combines faults of normal, reverse, and overthrust types. Where the Uinta arch was folded across the older north-south trend, east-west cross-folds such as Rangely and Salt Wells anticlines resulted.

The Uinta Mountains were greatly reduced from middle Eocene through Miocene time, and the eastern end of the Uinta arch collapsed in late Miocene time into a complex regional graben.

The Rock Springs uplift and probably the Vermilion basin uplift are the result of a still younger episode of cross-folding and upwarping of Pliocene age which has possibly persisted into the Pleistocene in some minor movements.

16. George R. Downs, Consultant, Denver
Oil Producing Structures as Related to Major Tectonic Features in Rocky Mountain Area

The oil and gas producing structures of the Rocky Mountain area may be classified according to their genetic relationship to major tectonic features. Patterns established by this classification may be helpful in searching for unknown structures. Producing anticlines and domes are considered to be subsidiary or secondary structures which were formed by the same forces and created at the same time as the more obvious large features. Based on past experience, favorable environments for new discoveries may be expected: (1) in the zone of adjustment between mountain uplifts and basin blocks; (2) in front of thrust sheets; (3) above basement faults; (4) as "warps" in broad basin areas; (5) at terminal parts of mountain uplifts or arches; (6) above igneous intrusives. It is suggested that by "working backward" from known major tectonic features that subsidiary structures may be found which will be proved effective oil and gas traps.

17. H. H. R. Sharkey, Carter Oil Company, Denver
Structural Control of Oil Fields in Wind River Basin, Wyoming

The Wind River basin of central Wyoming is a typical intermontane tectonic depression. It was formed by the Laramide orogeny at the end of Mesozoic time, and during the early stages of the Tertiary.

Throughout the Paleozoic and Mesozoic eras the stratigraphic record shows that the area of the present basin was a part of the eastern marine shelf of the Cordilleran geosyncline. A conformable sequence of 10,000–12,000 feet of predominantly marine sediment was laid down prior to the period of mountain building.

The Laramide orogeny was manifested by southward and westward compressional forces which developed major overthrust mountain belts. These ranges, the Wind River Mountains west of the basin, the Owl Creek Mountains at the north, the Granite Range at the south, and the Powder River lineament at the east, formed a parallelogram around the Wind River basin.

The orogenic movements were also effective through the basin in forming numerous anticlinal folds. These folds may be classified in four major groups: (1) a series of north-trending anticlinal axes projecting basinward from the Granite Range and including features like Sand Draw; (2) along the east side of the Wind River Mountains, in the westward part of the basin is a series of asymmetric folds caused by crustal shortening; productive structures include Dallas, Derby, and Winkleman; (3) the major overthrusts of the Owl Creek Mountains and of the Powder River lineament have caused the development of major down-buckling along the north and east flanks of the basin; there are a few anticlines in these zones—West Poison Spider is an example; (4) in the northwest quadrant of the parallelogram is a group of anticlines formed under a combination of the stresses outlined in groups 2 and 3, the combination of compressive movements from the Owl Creek Mountains to the north, plus the crustal shortening induced by the uplift of the Wind River Range resulted in a series of folds including Steamboat Butte, Circle Ridge, and others.

Almost all the oil produced in the basin is obtained from structural traps whose origin was the Laramide orogeny. This event developed as the primary significant interruption to the regional continuity of the various marine formations, and therefore it was of primary importance in the localizing and accumulating of oil. Almost all the exploratory test wells in the Wind River basin were drilled on anticlinal structures. This form of exploration has been very successful, and the more obvious anticlines have been drilled.

Future prospecting will undoubtedly consist of geophysical work, to find the more subtle structures, plus subsurface geology to find stratigraphic traps similar to the two most recent discoveries in the Wind River basin.