Mountain features of this region are the result primarily of Laramide vertical uplifts of oval or irregularly broad shape. They generally lack linear, narrow, or sinuous aspect. Some are conspicuously asymmetrical; others are fairly symmetrical; others approach gentle quaquaversal form. The structural relief ranges from 500 feet (Bowdoin dome) to 40,000 feet (Wind River uplift). Later Tertiary faulting, subsidence, sedimentation, and igneous activity have modified these Laramide uplifts considerably in places.

When the thrust faults are charted, they are found to be for the most part marginal to the uplifts. The uplifts of low and intermediate amplitude generally do not have associated border thrusts, but those in which Precambrian rock is exposed in the core commonly are bordered on one side or both by outwardly displaced thrusts. A firmer tie of uplift to border thrust is found in those where a structural relief of 25,000 feet or more exists.

These relations suggest that vertical uplift was the primary deformation and that thrusting was a secondary lateral deformation caused by gravity sliding and flowing. Since the basins were filled with sediments as the uplifts rose, it appears that thrusting is apt not to be related directly to the structural relief of uplift over adjacent basins, but to absolute relief at any one time as uplift exceeded sedimentation.

Anticlines suitable for oil and gas accumulation seem to be related to the marginal gravity creep from the uplifts. The locale is one of interplay of thrusting and folding of the surficial strata, and of sedimentation.

The Rocky Mountain region of uplifts is essentially the igneous province of alkalic and calc-alkalic rocks. Consideration of the origin of these rocks, of the nature of the uplifts, and of geophysical data lead the writer to postulate that the uplifts are due to megasills or lopoliths deep in the silicic (granitic) layer, perhaps near the boundary of the silicic and basaltic layers. It is expected that model experiments will indicate size, shape, and depth of intrusion to produce the various surface structures, and the nature of the border faults.

27. Laramide Sediments along Wind River Thrust, Wyoming: Robert R. Berg, Embar Oil Company, Denver, Colorado

The Wind River Mountains of west-central Wyoming are bounded on the southwest flank by a thrust fault which dips 20° NE. and has a maximum vertical displacement of 35,000 feet. Seismic data show the magnitude and character of the fault zone. The fault originated from an overturned basement fold which was subsequently broken and thrust toward the southwest. Uplift of the mountains began by folding during the late Cretaceous, continued throughout the Paleocene, and culminated in thrusting at the end of the Paleocene. Non-marine sediments in the Green River basin adjacent to the uplift were deposited without interruption in a dominantly quiet-water environment, but as uplift progressed, increasingly numerous coarse clastics were derived from the mountain flank. After thrusting, early Eocene fluvial sediments from the uplift spread basinward. Gas occurs at Pinedale in tight sandstones of the Paleocene Hoback formation in a basinal facies. Possibilities for both gas and oil exist farther west where cleaner fluvial sandstones interfinger with the basinal shales.

28. Tectonics and Oil Accumulation in Central Montana: John R. Fanshawe, Consultant, Billings, Montana

The east-west structural complex, known as the Big Snowy anticlinorium, is believed to be mid-Miocene in age. It was a stable area during the Laramide orogeny, which terminated during the Eocene. Injection of igneous material accompanied and followed the deformation in central Montana. The then increase of crustal thermal conditions probably aided the structural growth, which was principally vertical in expression rather than arcuate and compressional.

Jurassic formations overlie the Amsden, of Pennsylvanian age, throughout the structural province. Paleozoic structure is at variance with the observable surface geology (involving Paleocene through Jurassic formations). This ancient tectonic control is more significant in areas not affected by the mid-Miocene deformation that formed the big and obvious features like Porcupine dome, the Big Snowy Mountain dome, and Woman's Pocket anticline.

Generation and accumulation of oil and gas occurred under structural conditions that existed before the mid-Miocene tectonic pulsations. The present distribution of petroleum pools is due to traps that were not materially affected by the post-Laramide deformation, or traps that were due to secondary migration into newly formed structures. The latter condition has been subject to severe attrition by the increasing effect of artesian waters. The search for new oil should be guided by the more subtle geologic factors of Jurassic and pre-Jurassic stratigraphy and tectonics.

29. Possible Early Devonian Seaway in Northern Rocky Mountain Area: Charles A. Sandberg, Geologist, U. S. Geological Survey, Denver, Colorado

A seaway may have occupied a geosynclinal trough in Washington and Oregon during Early Devonian time. Its existence is postulated from the distribution and sedimentary environment of isolated deposits of Early Devonian and probably Early Devonian age in the northern Rocky Mountains. Regional evidence suggests that the Beartooth Butte formation of Early Devonian age was laid down along the eastern margin of a sea and on the landmass that bordered it in southern and central Montana and northern Wyoming. The Williston basin area in North Dakota was apparently a part of the landmass. The Water Canyon, Maywood, and Ghost River formations which may be in part correlative with the Beartooth Butte were laid down in a nearshore, shallow-water marine environment in northern Utah and southern Idaho, western Montana, and west-central Alberta, respectively. These lie west of the marginal marine deposits of the Beartooth Butte but several hundred miles east of the postulated north-south axis of the seaway.

Discontinuous deposits of the Beartooth Butte formation, which formerly was considered to be a local channel filling at a few localities in northern Wyoming, have now been widely recognized. The formation consists of grayish red and yellowish gray silty dolomite and dolomitic siltstone, sandstone, conglomerate, and breccia. It is generally less than 10 feet but locally as much as 170 feet thick. The continental beds of the Beartooth Butte were laid down on a land surface of generally low relief with karst topography in places. Redbeds filling channels and sinkholes were derived mostly from red soils that had developed on carbonate rocks possibly in a humid, tropical, or subtropical climate. Marginal marine beds of the formation were probably deposited in estuaries, bays, and lagoons along a drowned coast characterized by long, narrow marine embayments.

The Water Canyon formation of Early Devonian age in northern Utah is about 400 feet thick. It is composed of intraformational breccia, silty dolomite, cherty dolomite, and dolomitic sandstone and sandy dolomite containing fish remains. The lower part of the Maywood formation in western Montana is 200 feet thick and may be of Early Devonian age. It is composed of thin-bedded silty dolomite and dolomitic siltstone with imbedded crystals of dolomite pseudomorphous after halite and, like the Water Canyon formation, dolomitic sandstone containing fish remains. The upper part of the Ghost River formation in west-central Alberta is lithologically similar to the lower part of the Maywood and may also be of Early Devonian age. Discontinuous shallow-water, near-shore marine deposits of these three formations were probably laid down at the mouths of bays.

The probable subsurface occurrence of the Beartooth Butte formation and its tentative correlatives provides a hitherto unrecorded and untested stratigraphic trap that might be considered in planning petroleum exploration.

Thursday Morning, April 27

Presiding: B. W. BEEBE, H. W. WOODWARD

30. Upper Cretaceous Delta on Tectonic Foreland, Northern Colorado and Southern Wyoming: ROBERT J. WEIMER, Colorado School of Mines, Golden, Colorado

Recent stratigraphic studies of Upper Cretaceous rocks in southern Wyoming and northern Colorado indicate that a large delta formed along the west margin of the seaway during the Campanian. The delta was deposited on what is now regarded as the tectonic foreland of the Cretaceous geosyncline. The axis of the delta (area of thickest non-marine and transitional deposits) extends from central Moffatt County, Colorado, in a northeast direction passing near Rawlins, Wyoming. The delta is 80–120 miles wide and was built seaward for distances ranging from 100 to 250 miles. Thus, the size of the delta is comparable with the present Mississippi River delta. The deltaic deposits range in thickness from 1,500 to 3,000 feet.

Much of the delta has been removed by erosion but parts are now found in 7 separate structural basins. Formations comprising the delta are as follows: (1) Iles and lower Williams Fork in Sand Wash basin; (2) lower part of Mesaverde in Piceance basin; (3) upper sandstones of Pierre in North Park-Middle Park basin; (4) Mesaverde in Hanna-Laramie basin; (5) Parkman and Teapot in southern Powder River basin; (6) Mesaverde in southeast Wind River basin; (7) Mesaverde (Rock Springs, Ericson, and lower Almond) in Washakie-Great Divide basin.

There are several reasons for believing that these formations are part of a single delta. Facies trends that can be traced from basin to basin show a large bulge of non-marine beds protruding into the marine basin. A complex association of intertonguing non-marine and marine sediments is present. Shoreline sand trends exhibit rapid changes from one time stratigraphic unit to another. Isopach maps show that the time-stratigraphic unit containing the delta deposits is thicker in the area of the delta than elsewhere along the coast line or in the marine basin. All formations were deposited in a dominantly reducing environment.

The delta theory explains the following anomalous stratigraphic conditions: (1) the northeast shoreline sand trends across the southern Piceance basin which are an exception to the overall north-south trends in the Cretaceous basin of deposition, (2) the marine embayment, west of the delta, in which the Ericson sandstone and associated marine beds were deposited (area of Washakie-Great Divide basin), and (3) the thin nature of the Mesaverde in the Lost Soldier area resulting from the intertonguing of the Mesaverde formation in the southeast with the marine Cody shale in the northwest.

Most of the important gas production from this stratigraphic interval in the area of discussion is associated with the shoreline zone surrounding this delta. Oil production has not been found associated with the deltaic deposits. Oil from the upper Almond in Sweetwater County, Wyoming, is largely from shoreline sandstones deposited along the west margin of the marine embayment that formed immediately after deposition of the delta.

31. Canadian Rockies: Orientation in Time and Space: ERNEST W. SHAW, Imperial Oil Limited, Calgary, Alberta, Canada

The Canadian Rockies are located between the Rocky Mountain trench on the west and the edge of the disturbed belt on the east; toward the north, they plunge out near the Yukon-British Columbia boundary and, toward the south, they extend approximately halfway through Montana. Structurally, and thus scenically, they are unique as compared with the Mackenzie Mountains on the north and the Central and Southern Rockies on the south; this striking difference is principally due to an origin of extreme shortening by means of a series of flat, superimposed thrust faults as opposed to an origin predominated by vertical uplifts in the Central and Southern Rockies.

The age of the Rocky Mountains has been determined as principally Eocene on the basis of very extensive studies of the derived sediments. By comparison, the age of the plutonization of the Western Cordillera is principally Jurassic-Cretaceous transition on the basis of recorded geological relationships or 100 ± 10 m.y. on the basis of extensive radioactive dating.

The Rockies are made up of shelf sediments aggregating 20,000 feet at their eastern edge; by contrast, the Western Cordillera is typified by extensive plutonization of the thick sediments and volcanics of a eugeosyncline.

Shortening in the sediments across the southern part of the Canadian Rockies is somewhere between 100 and 200 miles which has been accomplished by stacking of sediments on a rather uniform system of superimposed thrust faults but without disrupting the underlying shield to any known extent. The restoration of these sediments to their pre-Laramide position implies that the adjacent plutonized complex of the Western Cordillera must also be restored a somewhat similar distance toward the west. Such a restoration sets back the indented western continental margin of Canada and the Alaska panhandle, and puts it into alignment with the western continental margin of the United States. The realization of such differential movement along the western continental margin of North America in the Tertiary and the attendant tensional junctions explains many anomalous conditions in the northwestern states and southern Alaska. The cause of such differential movement in the Tertiary is much more speculative. An acceptable explanation appears to be that the rigid, simatic Pacific plate has underthrust the continental margin of the United States whereas it has pushed the continental margin of Canada ahead of it.

32. Tectonics of Northern Cordillera in Canada: L. J. MARTIN, Consultant, Calgary, Alberta, Canada

Mountains in the Yukon and Northwest Territories within the belt east of the Rocky Mountain trench are principally the product of the Laramide orogeny, but earlier orogenic periods have contributed materially to the structure in a number of areas. Evidence indicating