taining 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 late Precambrian, Caledonian, Hercynian, and Nevadan orogenies has been observed.

The region under study can be divided into two on the basis of structural history and structural type. The southeastern segment comprises the Selwyn, Mackenzie, and Franklin mountains, and adjacent plateaus. Numerous reverse faults characterize the western part of this area. Intrusive bodies are common near the Rocky Mountain trench. Farther east simple folds are the predominant structural type. The eastern margin of the belt is in most parts of the area marked by a high-angle reverse fault. Pre-Cretaceous movements have contributed relatively little to the over-all structure.

The northwestern part of the region is characterized by a complex structural history and a variety of structural types. It comprises the Richardson, Barn, British, Keele, and Ogilvie mountains, and adjacent highlands and basins. Structural belts widely divergent in trend and consisting of structures ranging between simple folds and complex imbricate faults characterize this area.

The principal geologic features distinguishing mountainous regions in the Northwest Territories and Yukon from those making up the Canadian Rockies on the south are the higher degree of structural activity through time, the greater breadth of the mountainous belt, the greater breadth of the region in which thick late Precambrian sedimentary rocks occur, and the presence of intrusive rocks in considerable quantity in the interior ranges.

33. Post-Mississippian Unconformity in Western Canada Basin: JOHN BOKMAN, Western Canadian Venture, A. M. Lloyd, Operator, Calgary, Alberta

One of the most important geological features of the Western Canada basin is the major unconformity of post-Mississippian age. Seventy-eight oil and gas fields in Alberta are situated either overlying or underlying this surface. Detailed knowledge of this fossil topography is obviously important for successful exploration for oil and gas in the basin.

Structurally, the Western Canada basin is a large asymmetrical feature with gentle southwest dips over most of its extent. It is bounded on the east by the Canadian shield and on the west by the thrust belt of the frontal Cordillera. The stratigraphic section consists of a lower, Paleozoic, carbonate portion and an upper, Mesozoic, clastic portion; the two are separated by the post-Mississippian unconformity, the subject of this paper. In the eastern portion of the basin the unconformity is very pronounced; westward it decreases in magnitude and breaks into a series of disconformities and diastems; over the present site of the Rocky Mountains the unconformity probably disappeared entirely, deposition having been continuous throughout late Paleozoic and Mesozoic time. Beneath the unconformity beds ranging in age from upper Mississippian to Precambrian subcrop successively from west to east. Outliers, inliers, and other erosional complexities are present along all the truncated edges. The lithologies, thicknesses, and attitudes of the beds overlying the unconformity are to a considerable extent influenced by the configuration of the surface.

An over-all stream pattern is discernible on the unconformity throughout southern and central Alberta. It consists of three sets of streams, a southwest-flowing consequent set (the master streams), a northwest-southeast-oriented set of subsequent streams, and a poorly developed set of third-order (obsequent and resequent) streams aligned northeast-southwest. This pattern is similar to that described by text writers for streams developing on an emergent coastal plain composed of gently dipping strata. Valley gradients, slopes of the upland surface, and local relief corrected for regional tilt are very low. These facts, plus the existence of numerous flat upland surfaces and streams with broad upper valleys and steep lower valleys, suggest that at least two cycles of erosion are represented on the surface.

Of the 76 oil and gas fields in Alberta at the unconformity, 59% produce gas, 34% oil, and 7% both. Approximately two-thirds of them are Cretaceous and one-third Mississippian. Most of the Cretaceous fields lie over at least some minor nose or closure on the unconformity. However, many similar anomalies have been proved dry or are untested to date. All fields underlying the unconformity are on noses or closures. It is not entirely clear whether any true structural anomalies and (or) textural changes in the carbonates occur where the truncated edges are productive. Oils present in reservoirs at the unconformity have an average gravity of 31° API compared with 38° API for non-unconformity oils. Various observations bear on the problem of time of migration and accumulation of unconformity hydrocarbons.

34. Structure and Tectonic History of Alaska: GEORGE O. GATES and GEORGE GRYC, U. S. Geological Survey, Menlo Park, California, and Washington, D. C.

The major trends of the Cordilleran backbone of North America can be traced through the conterminous United States and Canada into Alaska, where they form a distinctive arcuate pattern bending sharply near the border and flaring out toward the west. The origin and pattern of the dominant tectonic elements of Alaska can be traced back to geanticlines and geosynclines that developed from Middle Jurassic to early Tertiary time. The Brooks Range geanticline forms Alaska's northernmost mountain barrier, a counterpart of the Rocky Mountain system. The range is composed chiefly of Paleozoic limestone, shale, quartzite, slate and schist in faulted folds, and giant plates and nappes, overturned and thrust north over the edge of the west-trending Colville geosyncline. Subsurface data indicate that this geosyncline deepens beneath the arctic foothills and coastal plain to at least 20,000 feet and then rises to within 2,500 feet of the surface near Point Barrow.

South of the Brooks Range and extending to the Alaska Range is an irregular array of low mountains, uplands, and flat lowlands, the Alaska counterpart of the intermontane area between the Rocky Mountain system and the Pacific Mountain system of the conterminous United States. Although several tectonic elements have been traced through this area, some trends are oblique or normal to the major Mesozoic and Cenozoic arcuate pattern. The eastern part of this area is underlain by metamorphic rocks of Precambrian and early Paleozoic age, including what are probably the oldest rocks in Alaska. West interior Alaska is underlain chiefly by folded and faulted marine and continental sedimentary rocks of Cretaceous age and volcanic rocks of Mesozoic age. Bedrock of the Seward Peninsula is mainly schist, gneiss, marble, and metavolcanic rocks cut by granitic intrusive masses. Older structural trends in the metamorphic rocks are chiefly northward on which a younger eastward-trending pattern has been superimposed.

The Pacific Mountain system is extended into Alaska by two major mountain chains divided by a line of depressions that bend in a great arc around the North Pacific Ocean. These mountains consist primarily of great thicknesses of tightly folded graywacke, argillite, conglomerate, and basaltic and andesitic lava flows and tuffs.

The greatest igneous activity has been in the Pacific