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

Mountain system, and includes an almost continuous belt of granitic batholiths and a chain of active and recently active volcanoes. Though numerous, granitic intrusive masses between the Alaska and Brooks ranges are small, except a few in the southeastern part of the Yukon-Tanana upland. Relatively few igneous rocks are known within and north of the Brooks Range.

The Paleozoic and much of the Mesozoic tectonic history of Alaska, involving a broad geosynclinal tract that lay between the Pacific Ocean on the south and west and a stable platform region on the north and east, can be considered conveniently in three major stages: Cambrian through Silurian, Middle Devonian through Permian, and Triassic through early Cretaceous. The mobile belt encroached northward at the expense of the stable region, until by mid-Mesozoic time eugeosynclinal conditions extended over most of Alaska. In mid-Jurassic time in southern Alaska, and in early Cretaceous time in central and northern Alaska, Alaska became differentiated into positive and negative tracts of erosion and deposition that were maintained through the rest of the Mesozoic era. Basins of known Tertiary marine deposition are limited to the northern and southern borders of Alaska. Inland, Tertiary basins were sites of accumulation of continental sediments.

35. General Geology and Hydrocarbons of Cook Inlet Basin, Alaska: THOMAS E. KELLY, Halbouty Alaska Oil Company, Anchorage, Alaska

The Cook Inlet basin of south-central Alaska is an intermontane structural basin approximately 14,000 square miles in area, encompassing almost 80,000 cubic miles of sedimentary rocks ranging in age from upper Triassic to Recent. The basin coincides with most of the northern part of the Matanuska geosyncline, an arcuate Mesozoic trough located at the northwestern end of the Pacific Cordilleran mobile belt.

The Cook Inlet sedimentary trough, in contrast to the structural basin, is defined as a Paleozoic-early Mesozoic eugeosyncline that received sediments from emergent volcanic islands which were part of the volcanic archipelago belt bordering the Pacific Coast of North America. Middle Jurassic epeirogeny transformed southern Alaska into arcuate geanticlinal and geosynclinal belts with the Cook Inlet basin beginning as a half-graben created by complex faulting on the east flank of the Talkeetna geanticline.

The Mesozoic embayment that collected marine sediments and occasional non-marine wedges abutting cratonic source areas was semi-enclosed or silled as the Kenai and Chugach ranges began to emerge following the early stages of the Laramide orogeny. During the early Tertiary, an abundant supply of non-marine clastic sediments and carbonaceous material was widely distributed in the subsiding intermontane basin.

The structural grain of the major tectonic elements describing the basin architecture is preserved in trends of local structure throughout the basin. Intense folding and faulting are exhibited on the north, east, and west flanks of the basin. Several major buried anticlinal trends extend in a northeasterly direction through the interior of the basin.

Mesozoic hydrocarbon accumulations associated with anticlinal traps are found on the western side of the basin. Minor quantities of oil, gas, and condensate have been produced from sandstones of the middle Jurassic Tuxedni formation. The oil is believed to be indigenous to Jurassic beds, the exact age and position of which are questionable on the basis of present-day stratigraphic relations.

Oil and gas accumulations in Tertiary beds will determine the significance of the Cook Inlet basin as an oil and gas province. Present oil production comes from the Hemlock zone, a distinct sandstone and conglomerate unit near the base of the Tertiary Kenai formation. Entrapment has been influenced by folding and faulting along trend of an interior basin high which lies adjacent to and parallel with an early Tertiary hinge belt. The Tertiary crudes were probably derived from Eocene marginal marine strata or from upper Cretaceous marine shales which are unconformably overlain by the Tertiary sediments.

Significant quantities of gas, predominantly methane, are present in the loosely consolidated sands of the upper Kenai formation. The two conditions necessary for gas accumulation anywhere in the basin are (1) abundance of lignite or coal beds in the section to serve as source rocks, and (2) a suitable trap.

The Cook Inlet basin is in its earliest stage of exploration and development. It is anticipated that many new oil and gas fields will be discovered. Regional isopach maps of the interval between the Mesozoic beds and the base of the Hemlock zone are suggested as a basic approach to delineating old basin highs that may be sound Hemlock prospects. The Cook Inlet basin should become a major gas basin regardless of its future as an oil province.

36. Tectonic Summary of Backbone of Americas: CAREY C. CRONEIS, The Rice University, Houston, Texas

Thursday Afternoon, April 27

Presiding: ORLO E. CHILDS, DANIEL S. TURNER

37. Challenge of Exploration for Natural Gas: B. W. BEEBE, Consultant, Boulder, Colorado

During the year 1959, more than 11.44 trillion cubic feet of natural gas was marketed in the United States. This is equivalent in energy on a British Thermal basis to approximately 5,300,000 barrels of oil daily. More than six times as much natural gas will be delivered to consumers in 1960 than was delivered in 1935. The current oil production in the United States is approximately 6,800,000 barrels daily. The impact of this tremendous growth of natural-gas consumption on the market for crude oil is obvious.

The American Association of Petroleum Geologists published a symposium, "Geology of Natural Gas," in 1935. During the 25 intervening years, gas transmission systems have been constructed to all of the heavily populated areas in the United States. Consumers have recognized natural gas as a premium source of energy, not only because of its ease of handling and its cleanliness, but because natural gas is so grossly underpriced when compared with other sources of energy. The executive committee of A.A.P.G., recognizing the importance of natural gas, has authorized a new multi-volume symposium, "Natural Gases of North America," now in preparation. This massive authoritative work will be by far the most comprehensive documentation of all of the facets of the natural-gas industry which has ever been attempted.

The greatest source of natural gas in the past has been the so-called Appalachian geosyncline province. For the immediate future, Tertiary rocks of the Gulf Coast embayment will continue to be major sources of natural gas. However, as the reserves of the Permian basin of West Texas and the immense Hugoton-Panhandle field of Kansas, Oklahoma, and Texas are depleted, it appears that the huge intermountain basins of the Rocky Mountain area will become increasingly important as sources of natural gas. Recent discoveries in Tertiary and upper Cretaceous strata in this immense, relatively