The structural grain is north-northeast in the southern part of the Colombian Andes. Toward the north, major alignments are toward the northeast and northwest. The Sautatá arch connects the west Cordillera with the Darien Mountains of Panamá. The Guaviare arch links the Andes and the Guayana Shield.

The syenitic rocks of the Garzón-Guaviare region are the only known Precambrian west of the Guayana Shield. A record of marine Paleozoic sedimentation is preserved in the Eastern Cordillera and Perijá and Macarena mountains. Periods and epochs represented are: Late Cambrian (?), Early and Middle Ordovician, Middle Devonian, Mississippian, Pennsylvanian, and Permian. There is evidence of "Caledonian" orogeny. No Paleozoic marine sediments have been found west of the Central Cordillera.

Interbedded marine and terrestrial sediments and volcanics of Late Triassic and Early Jurassic ages crop out along the west side of the Upper Magdalena Valley, but on the northeast only continental sediments are present. A widespread marine invasion began in latest Jurassic time and affected the Andean region and its eastern foreland during the Cretaceous. The thick marine Cretaceous deposits east of the Central Cordillera and Santa Marta Mountains are a major source of oil. The area of the Bucaramanga massif was not submerged until Aptian time. West of the Central Cordillera, Cretaceous sediments are interdedded with porphyries and diabase flows.

Orogeny began in the Maestrichtian and reached a peak in the middle or late Eocene. Basic and ultrabasic rocks were intruded in the Western Cordillera and Pacific Coast Range regions. Tertiary marine deposition was restricted to regions west and north of the Andes. A thick non-marine Tertiary sequence elsewhere includes reservoirs containing more than 80 per cent of Colombia's proved oil reserves.

There was renewed orogeny at the close of the middle Oligocene, and intrusion of granodiorite batholiths in the Central Cordillera and southern Western Cordillera. A thick section of marine sediments was deposited west and north of the Andes in the late Oligocene and early Miocene. Elsewhere, down-warped and down-faulted belts continued to receive continental deposits.

The most recent orogenic and volcanic activity began in early Miocene and continues today, the orogeny affecting older positive belts and the Tertiary basins of marine deposition.

*Wednesday Morning, April 26*

*Presiding:* MASON L. HILL, VINCENT KELLEY

13. Summary of Tectonic History of Venezuela: ELY MENSCHER, Massachusetts Institute of Technology, Cambridge, Massachusetts

Present-day Venezuela may be divided into the following major structural provinces: Perija Mountains, Goajira-Paraguana arch, Maracaibo basin, Falcon, Venezuelan Andes, Carribbean Mountains (Coast Range and Serrania del Interior), Barinas-Apure basin, Eastern Venezuela basin, and Guayana Shield. With the exception of the shield and possibly the Goajira-Paraguana arch, all these provinces owe their essential development to Late Mesozoic or Tertiary tectonic events.

The pre-Cretaceous history is little known. Mid-Ordovician (?), Late Devonian or Early Carboniferous, and Permian (?) deformations may be postulated, but their trends and importance can not be evaluated at present. Toward the end of the Paleozoic, widespread uplift, accompanied by faulting and volcanism, raised the whole of the country above sea-level. Subsequent erosion resulted in positive features of structural origin, such as the Central Goajira massif, the Maracaibo platform, and the El Baul swell, which had an effect on Late Mesozoic and Tertiary sedimentation.

Beginning in the Late Mesozoic, the Caribbean Sea began an extensive transgression of northern and western Venezuela. The east-west-trending Caribbean orthogeosyncline developed in the area now occupied by the Caribbean Mountains; shelf conditions prevailed elsewhere.

Volcanism and major deformation of the Caribbean geosyncline began about Middle Cretaceous time, leading to the folding, faulting, and metamorphism of the previously deposited Cretaceous rocks. However, sedimentation, volcanism, and deformation, although on decreasing scale, continued throughout Late Cretaceous and Paleocene time and perhaps into the early Eocene. Dominant structural features in the Coast Range trend N. 70°–80° E.; wrench (strike-slip) faulting with horizontal displacements of several kilometers is common. It has been suggested that the over-all deformation of the Coast Range resulted from an east-west shear couple related to the development of the Caribbean sea area. Renewed uplift and south-southeastward thrusting, with related N. 60° W. strike-slip faulting, which reached a maximum in the Late Tertiary have caused the crumpling, faulting, and over-riding of the northern edge of the Eastern Venezuela basin to the south. The northern oil fields of the Eastern Venezuela basin are controlled either directly or indirectly by the consequent structures.

The Eastern Venezuela basin is an east-plunging asymmetrical elongate feature which was initiated in the late Eocene with the downsinking of the area south of the Caribbean ranges and east of the El Baul swell. Greatest depths are in the north close to the mountains. In addition to the north flank structures related to Coast Range uplift, east-west faulting with minor cross-faulting on the south flank, probably associated with the sinking of the basin, is important in the localization of oil fields.

The Perija, Maracaibo, Andes, and Barinas-Apure provinces owe their character as distinct units to the Tertiary Andean deformation, with the basins sinking as the mountains rose. The Cretaceous and Eocene oil fields of western Venezuela owe their existence to the Andean orogeny; the Middle to Late Tertiary fields are also linked to it. There is some indication that movements began first in the northwest (Sierra de Perija) during the Eocene, progressed southeastward across the more-or-less stable Maracaibo platform, reached the Andes at the close of the Eocene, and culminated in the Mio-Pliocene. The mountains, with dominant trend of N. 30° E. for the Perija and N. 45° E. for the Andes, are essentially complexly folded and faulted structural arches with high-angle reverse, normal, and wrench faults. Mountainward-dipping reverse faults are thought to bound their flanks. Both the Maracaibo and Barinas-Apure basins have asymmetrical cross sections with deepest zones close to the flanks of the Andes.

The Falcon province shows some relation to the Maracaibo basin and the Andes both in its sedimentation and in its deformational history. Originally a narrow trough, it received great thicknesses of sediments during the Middle and Late Tertiary and was finally folded and uplifted in the Pliocene, as well as in earlier Tertiary time.

An outstanding tectonic feature of northern Venezuela is a series of long east-west-trending right-lateral wrench faults that are located close to and roughly parallel with the coast. Best known of these are the

Oca fault in the west and the Pilar fault in the east. It is possible that these faults are at least as old as Cretaceous, that they are related to the tectonic history of the general Caribbean area as suggested by Bucher and others, and that they have played a major role in the deformation of northern Venezuela.

The displacement on other large wrench faults, such as the northeast-trending Bocono fault in the Andes and the northwest-trending Urica and San Francisco faults in the eastern Serrania del Interior, must be taken into account in reconstructing past structural and sedimentological trends and relationships.

The two most prominent tectonic features of Venezuela, the Coast Range (northern Caribbean Mountains) and the Andes, differ rather markedly from each other in the following respects: (a) the Coast Range had its origin in a trough of more-or-less geosynclinal character; the Venezuelan Andes did not; (b) many of the Coast Range rocks were metamorphosed during deformation; no metamorphism took place during the Andean orogeny; (c) volcanism was common in the Coast Range area both somewhat before and during deformation; no post-Lower Mesozoic volcanism is known in the Andes; (d) the Coast Range has a belt of serpentinites; the Andes does not; (e) the major deformation of the Coast Range was Middle to Late Cretaceous; that of the Andes was latest Eocene to Miocene.

The contact between the Coast Range and Andean trends at the Barquisimeto Gap is abrupt and may be modified by later faulting. Genetic and structural continuity of the Venezuelan Andes and the Caribbean Ranges as suggested by many geologists is questionable.

14. Tectonic History of South-Central American Orogen: Joel J. Lloyd, Union Oil Company of California, San Jose, Costa Rica

The Middle American channel connecting the primeval Atlantic and Pacific oceans was subjected to forces in Upper Jurassic time that folded the sea bed into a series of parallel ridges striking SE. to NW. The westward and most tenuous of the ridges was ruptured by extrusive material that grew from the channel floor and emerged to form a chain of volcanic islands, the Western Archipelago. Erosion of the islands and deposition to the northeast provided the sediments of the Nicoya complex now exposed along the west coast of Costa Rica and Panama.

Volcanic eruption and continuing erosion throughout the Cretaceous supplied sediment to the shallowing Channel area. Deposition during this period was mainly from the Archipelago although some material was derived from the northern nuclear Central American mass. By the end of Cretaceous most of the denuded islands had foundered and the Western Archipelago had disappeared.

Diastrophism accompanying the Laramide revolution rejuvenated and further upfolded one of the interior ridges. The Guanarivas Island emerged in northern Costa Rica and southern Nicaragua. Volcanoes on Guanarivas were the north end of a chain that continued as volcanic islands southward and eastward through Panama. Eastern Panama, belonging to the Choco borderland, which had been emergent throughout the Cretaceous, began to founder in lower Eocene and was submerged by the beginning of the middle Eocene. Volcanic detritus and submarine laval flows are predominant in the accumulating Eocene sediments of the channel.

Guanarivas Island and the volcanic islands had disappeared by lower Oligocene time which was an epoch of comparative quiescence. Renewed activity in the middle Oligocene resulted in the growth of the Talamanca ridge and the appearance of islands in southern Costa Rica and northeastern Panama.

Continued growth through early Miocene culminated in development of the West Talamanca fault and total emergence of the ridge by the end of the middle Miocene. The faulted upthrust block was tilted eastward, creating compressive forces that fractured the eastern front of the high area and initiated folding on the Atlantic foreland of southern Costa Rica and northeastern Panama. The Miocene diastrophism was accompanied by the growth of volcanoes on the ridge in Panama.

Total emergence of a narrow strip of land, bordered by the Pacific Ocean and the Nicaraguan depression opening to the Caribbean, resulted in the first uninterrupted connection of South America with nuclear Central America in Pliocene time. During the Pliocene, strike-slip faulting on the west side of the new Isthmus extended from Nicaragua to Panama bringing up the Jurassic Nicoya complex that is now exposed as the core of peninsulas from Santa Elena to Azuero. In what may have been the same adjustment that caused the faulting a new chain of volcanoes appeared along the Pacific coast from Nicaragua to the northern edge of the Talamanca ridge.

By Quaternary time the Talamanca ridge had become stabilized and adjusted, the Nicaraguan depression was filled in leaving only Lakes Nicaragua and Managua and the San Juan River to mark its former course, and the Isthmus had assumed the shape we know today.

This relatively simple tectonic history provokes questions concerning forces and crustal behavior, validity of fixed mobile continental theories, isthmian links, volcanic island arcs, and continental front folding that cannot be answered today. The scope of the problems are indicated, however, and direction of investigation indicated that may occupy geologists for many generations.

15. Nuclear Central America Hub of Antillean Transverse Belt: J. H. Brineman, Argus Petroleum Corporation, Guatemala, and G. L. Vinson, Esso Standard (Guatemala) Inc.

Nuclear Central America comprises the eastern part of the Sierra Madre del Sur geanticline and its flanking geosynclinal portion of the Gulf Coast and Caribbean embayments. Southeastern Mexico, Guatemala, British Honduras, Honduras, and Nicaragua make up the principal land area. Nuclear Central America disappears toward the east into the Caribbean Sea in easterly trending tectonic lineaments. The north flank of this geanticline is the crucial area for regional geologic interpretation.

The Mesozoic-Cenozoic Chapayal basin, or the eastern extension of the Chiapas foredeep, and the southern part of the Yucatan platform are the prime sedimentary areas involved. Chapayal basin, one of the local deep basins that ring and nearly surround the Gulf Embayment, is sharply asymmetric, having a steep and highly folded and faulted south limb and a gentle opposing limb which shelves northward over the Yucatan platform. The eastern part of the shelf area is interrupted by the Maya Mountain uplift in British Honduras which developed during the Paleozoic and was rejuvenated at the end of the Paleozoic. The Maya Mountains represent a remnant of an older Paleozoic hinterland that provided a source for later Paleozoic and Mesozoic sedimentation. It was a stable or slightly positive area during much of Mesozoic and Cenozoic time.

The Late Paleozoic-Mesozoic mobile belt, which sets the pattern for the geology of the nuclear Central America and the Antillean region, extends eastward