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 from the mainland through the Greater Antilles. This mobile belt separates the Gulf and Caribbean regions, and the forelands to the bordering basins were in the Gulf of Mexico and Atlantic Ocean. The initial and main period of geosynclinal subsidence and sedimentation is Mesozoic in age; however, thick deposits were laid down during the Tertiary in the Chapayal basin and eastward in various island areas.

In nuclear Central America the sediments were derived, primarily, from the south and from an important older Paleozoic mobile belt and its subsequent ancient Maya Mountains-Cayman Basin landmass lying on the northwest flank of the Caribbean. The partly foundered northwest Caribbean hinterland, and the arcing of the Late Paleozoic-Mesozoic and Late Mesozoic mobile belt (which incorrectly suggest a foundered craton and surrounding rim syncline in the Antillean-Caribbean region) provide the basic framework for the tectonic relationships betweeen North and South America. It is highly questionable that the Lesser Antilles is related in time with the earlier Late Paleozoic-Mesozoic mobile belt, but is more likely late Cretaceous and early Tertiary. The foundering of the Gulf craton occurred with the beginning of the Mesozoic, and the initial deposits of the Gulf Embayment are the red-bed clastics and associated sediments of Triassic-Jurassic age.

The older and partly metamorphosed sediments in nuclear Central America and its environs include undifferentiated Carboniferous and older Paleozoic, and possible Precambrian. Younger unmetamorphosed sedimentary rocks are Permian, Triassic (?), Jurassic, Cretaceous, lower Eocene, Oligocene, and Late Tertiary in age and include one of the thickest Mesozoic evaporite sequences known in the world. Important orogenies are reflected in the sediments during all the major diastrophic events and during the early Oligocene. Intended as a principal contribution to the geology of the region is the introduction here of a supporting stratigraphic chart showing those formation names and ages which are accepted in Guatemala by the local Stratigraphic Nomenclature Committee.

A late Tertiary and Quaternary volcanic belt follows the Sierra Madre axis for a short distance in eastern Mexico and Guatemala and diverges southeastward through the remainder of Central America, forming the physiographic Rocky Mountain backbone.

No more than two dozen wells have been drilled for oil or gas in all northern Central America. Although the results have been negative, numerous encouraging shows indicate a future petroleum province. Evaporitic deposits in the Cretaceous and Jurassic limit the potential section of reservoir porosity. This poses no insurmountable problem, however, for explorationists utilizing thorough regional stratigraphic and tectonic studies.

16. Outline of Tectonic History of Mexico: EDUARDO J. GUZMÁN and ZOLTÁN DE CSERNA, Petróleos Mexicanos and Instituto de Geologia, México, D.F., Mexico

The principal morphotectonic provinces of Mexico are: (1) Sierra Madre del Sur composed of middle Paleozoic metamorphics, (2) Sierra Madre Oriental made up of folded Mesozoic carbonates resting on folded Paleozoic sediments overlying Precambrian crystallines, (3) Gulf Coastal Plain and Yucatán Peninsula consisting of Tertiary marine sediments affected locally by salt tectonics and resting on folded Mesozoic sediments and Paleozoic metamorphics, (4) Sierra Madre Occidental consisting of flat-lying Tertiary lavas and pyroclastics which rest on folded Mesozoic sediments and Paleozoic metamorphics, (5) Trans-Mexico Volcanic Belt of late Tertiary and Quaternary age, (6) Sonoran Basin and Range Province comprising folded and faulted Paleozoic and Mesozoic sediments and volcanics, and (7) Baja California Peninsula composed of Cretaceous granitic batholiths and Mesozoic and Tertiary clastics and volcanics.

Present structure and resultant physiography developed from the consolidation of three orthogeosynclines into as many structural belts, two of which bordered the southern peninsular extension of the Precambrian hedreocraton of North America and underwent regional metamorphism and granitic emplacement during the middle Paleozoic orogeny at the end of the Paleozoic and block-faulting with accompanying volcanic activity during early Mesozoic time.

The third structural belt of Mesozoic-Tertiary age developed from an orthogeosyncline which covered the entire country from south to north and was affected by regional metamorphism and granitic emplacement in its western part toward the end of the Cretaceous and by orogeny mainly in its eastern part during early Tertiary time. This orogeny, which formed the Sierra Madre Oriental, was followed in the western two-thirds of the country by block-faulting and extensive volcanism during the remainder of the Tertiary, whereas east of the present Sierra Madre front deltaic deposits filled the molasse basins grading eastward into finer clastics of the Gulf Coast. During Pleistocene and Recent time a chain of basaltic volcanoes developed along a belt crossing the country from east to west at the latitude of Mexico City.

To date, commercial oil production has only been established in the Coastal Plain of the Gulf of Mexico; in the northern and southern districts, production is obtained from Tertiary clastics filling the molasse basins, whereas in the central district it comes from carbonates of the late Jurassic and Cretaceous miogeosyncline.

17. Tectonic Framework of Southwestern United States, and Possible Continental Rifting: CHAS. B. HUNT, U. S. Geological Survey, Denver, Colorado

Major structural features in southwestern United States mostly trend northerly, but a study of the seismic, gravity, and geologic maps of the region suggests there may be four or more southeast-trending structures obliquely crossing and largely obscured by the northerly ones. The most southwesterly of these is conspicuous enough, the San Andreas rift. Displacement on this fault system is right-lateral and has been estimated as great as 350 miles.

Another structure parallel with the San Andreas rift is 150 miles northeast. In part, it coincides with the front of the Sierra Nevada, but the gravity and seismic maps suggest it may continue northwestward across the center of northern California and southeastward across the southwest corner of Arizona.

A third parallel structure is about 100 miles farther northeast and in part coincides with the southwest edge of the Colorado Plateau. The seismic, gravity, and geologic maps show it extending northwestward across Nevada. It is lost in southwestern New Mexico, but the structurally disturbed Trans-Pecos Texas area is aligned with it as are a few scattered epicenters.

The fourth southeast-trending structure is represented by the well known late Paleozoic troughs and highlands that extend diagonally across the Rocky Mountains. This alignment extends southeastward across the Panhandle of Texas to the Wichita Mountains in southwestern Oklahoma. If these structures have right-lateral displacement comparable with that along the San Andreas rift, an aggregate displacement of 1,200–1,500 miles is indicated.